BORATE PHOSPHORS

Processing to Applications

Edited by
S. K. OMANWAR
R. P. SONEKAR
N. S. BAJAJ

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Preface

Borates also play important roles in the family of material science due to its simple structural and chemical properties. The borate-based phosphors have attracted much attention, due to their high optical stability, can be synthesized by using low-cost synthesis through conventional and non-conventional methods. The technology based on these materials are also environmentally friendly. Moreover, it allows to select the number of borates compounds with different structures. Hence, depending on their selection, they can be used in a variety of applications based on phosphor technology that can start from your daily utilities and end up at medical and radiological applications. However, the synthesis of borate phosphors with desired structures is at best tricky and hence the selection of proper technique is plays a vital role.

In this book, we have discussed the structural and chemical parameters of borates as phosphors, the suitable synthesis methods and way of proper characterization of materials. Also, we have made a tremendous literature survey on borate materials based on their applications. This book covers the entire electromagnetic spectra utilized for fetching luminescence from the prepared borate material through the globe. On the basis of that, the chapters were distributed and formulated; likewise the book starts with an introduction to borates, their properties and synthesis technique and ends on their modification in properties of borate functional groups when mixed up or substituted with other metallic functional groups.

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Editors' Biographies

Dr. S. K. Omanwar recently retired as a Sr. Professor (HAG) and Former Head, Department of Physics, on June 30, 2019, and since July 1, 2019, he has been working as a distinguished UGC-BSR Faculty Fellow at Sant Gadge Baba Amravati University, Amravati – 444602 (M.S.), India.

Dr. Omanwar has more than 32 years of teaching and administrative experience and a distinctive research career in developing inorganic luminescent materials for various applications such as mercury free lamps, SSL, display devices, LED-based photo-therapy devices, spectral matching phosphors for solar PV panels, PL-LCD panels, PDP panels, CFL bulbs and TLD and OSL materials for personnel radiation monitoring, as well as biomaterials. He has developed the commercially viable competitive products such as TLD, OSL and SSL devices. He has also developed a cost-effective method such as simple combustion method with little modification for the easy synthesis of these materials. Besides having sponsored research projects, he has received good citations with SCOPUS (163) and Thomson & Reuters (122). He has delivered several invited talks at many international events and is a life member of 11 national organizations. He has been a mentor for many Ph.D. scholars and PG students from 1986 till date. He has been the recipient of 26 awards and 178 recognitions.

Dr. R. P. Sonekar, Ph.D., Professor, Department of Physics, G. S. College Khamgaon (MH), India

Dr. R. P. Sonekar was awarded a master's degree from the RTM Nagpur Univesity, Nagpur, in 1989 and his Ph.D. (physics) on borates from SGB Amravati University in 2008. Looking at his excellence soon after his master's degree, he was appointed as assistant professor at G.S. Arts, Commerce and Science College, Khamgaon, affiliated with the SGB Amravati University, Amravati. During his career, he has achieved many milestones in the field of research. Ge has completed two minor and one major project on borates. He also obtained a FIP fellowship from UGC to complete his Ph.D. work in borates. Dr. Sonekar has expertise in borate phosphors till date and he has guided 5+ students strictly on synthesis and application of borates. He has excellent publications in indexed journals.

Dr. N. S. Bajaj, Ph.D., UGC- Fellow, Assistant Professor, Department of Physics, Toshniwal Arts, Commerce and Science College, Sengaon, Dist: Hingoli (MH), India.

Dr. N. S. Bajaj obtained his master's degree from the Vidhyabharti College, Amravati, affiliated with the SGB Amravati University, Amravati, in 2008 and his Ph.D. (physics) from the same university in 2014. He served from 2010–2015 as a UGC-Project Fellow at SGB Nagpur University, in a project sanctioned under the supervision of Dr. S. K. Omanwar. He also served various colleges under the same university as a visiting lecturer. In 2015, he became an assistant professor at the Toshniwal Arts, Commerce and Science College, Sengaon affiliated to SRTM University, Nanded. During his short career, he has achieved many milestones in the field of research and received a couple of international awards and recognitions. Recently, he was awarded the most precious award: Marathwad Bhushan Award. Dr. Bajaj has expertise in the synthesis of phosphors and phosphor application radiation dosimeter. He has excellent publications in indexed journals.

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1 Introduction to Borate Phosphors

P. K. Tawalare and A. B. Gawande

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1.1 INTRODUCTION

The varied aspects of luminescence and the complex processes involved in the origin of light emission, offer interesting challenges for researchers in this field. This is one of the research fields, wherein diverse application area exists, which range from radiation monitoring for health and safety, phosphors for lamps and display purposes to X-ray imaging and other means of medical diagnostics.

Luminescence is a well-established field of scientific research. In 1652, Zechi made an important contribution to the understanding of photoluminescence. It is the emission of light, which persists after the excitation agency, is removed (luminescence). Moreover; he proved experimentally that the color of the phosphorescence light in a material is independent of the color of the exciting light and also clearly distinguished the phenomenon from scattering. About 200 years later, Stoke showed that the incident and emitted light differed in color and enunciated his well-known Stoke's law regarding the increase in wavelength, which accompanies photoluminescence. In 1867, E. Bequerel distinguished two types of phosphorescence or after-glow, which were attributed respectively to monomolecular and to bimolecular decay mechanism.

The last few decades have witnessed dramatic changes in research on luminescence. There has been a phenomenal growth in the subject, and a significant progress has been made in the field of luminescence research. Recent research is characterized by strong interaction among other branches of solid-state physics and between different areas of luminescence using inorganic and organic materials. Both experimental as well as theoretical approaches have been made.

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Luminescent materials are called phosphors. The first systematic study of luminescent crystals was made by Lenard [1] and his school, at the beginning of the 20th century. The phosphors they studied are called 'Lenard Phosphors'. The practical interest in luminescent materials for use in efficient cathode ray screens, and eventually for luminescent lamps, which were then developed in 1930s, stimulated the study of crystal luminescence in a very substantial way.

1.2 PHOSPHORS

Phosphors are solid, luminescent materials that emit photons when excited by an external energy source, such as an electron beam (cathodoluminescence) or ultraviolet light (photoluminescence). Phosphors are composed of an inert host lattice, which is transparent to the excitation radiation and an activator, typically a 3d or 4f electron metal, which is excited under energy bombardment. The process of luminescence occurs by adsorption of energy at the activator site, relaxation, and subsequent emission of a photon and a return to the ground state. The efficiency of a phosphor depends on the amount of relaxation that occurs during the activation and emission. Relaxation is the process in which energy is lost to the lattice as heat; it needs to be minimized in order to extract the highest luminous efficiency. The luminous efficiency is defined as the ratio of the energy emitted to the energy absorbed.

1.3 APPLICATIONS OF PHOSPHORS

The substantial advances in understanding luminescent phenomena and the discoveries of unusual luminescent processes, for example, up-conversion and quantum splitting, present unusual opportunities for the applications of luminescence. In some instances, these possible applications depend on improvements in efficiencies and stabilities of inorganic luminescent materials; in other instances, on the problems of adapting the available scientific understanding of luminescent phenomena to established techniques. Luminescent materials find applications ranging from as commonplace as lighting to very sophisticated such as lasers. Some of the applications of luminescence are given in Table 1.1.

1.3.1 Luminescence Phenomenon

1.3.1.1 Principle

Luminescence is defined as the emission of light by bodies, which is in excess of that attributable to black body radiation, and persists considerably longer than the periods of electromagnetic radiations in the visible range after the excitation stops.

Important characteristics which distinguish luminescence from other light emitting phenomena are time lag between the excitation and emission, spectral distribution of emission and its temperature dependence. Thus, for black body radiation, the emission maximum shifts to shorter wavelengths with increasing temperature, while the reverse is true for photoluminescence (PL). Again, intensity of emission increases with temperature for black body radiation, while the photoluminescence intensity decreases with temperature due to thermal quenching.

The luminescent system generally consists of a host lattice and a luminescent centre, often called an 'activator'. In general, the host needs to be transparent to the radiation source used for the excitation process. The activator absorbs the exciting radiation and is raised to an excited state. The excited state returns to the ground state by emission of radiation or by non-radiative decay. It is necessary to suppress this non-radiative process. In some materials, the excitation radiation is not absorbed by the activator but the other ion may absorb the exciting radiation and subsequently transfer it to the activator. In this case, the absorbing ion is called a 'sensitizer'. In many cases, the host lattice transfers its excitation energy to the activator so that the host lattice acts as the sensitizer. High-energy excitation always excites the host lattice. Direct excitation of an activator is only possible with ultraviolet and visible radiation [2].

TABLE 1.1
Classification of luminescence with excitation source and applications

Luminescence type	Excitation source	Applications
Photoluminescence	Photons	Fluorescent lamps, PL-LCD, plasma display, LASERs, LSCs, paints, inks, upconversion material
Cathodoluminescence	Electrons	TV set, FED, oscilloscope, monitors, storage tubes, flying spot scanners, radars
Electroluminescence	Electric field	LEDs, EL displays, diode lasers
Radioluminescence	Ionizing radiations such as X-rays or gamma rays	X-ray imaging, scintilators, dosimetry
Optically stimulated luminescence	Visible Photons	X-ray radiography, dosimetry
Lyoluminescence	Chemical reaction	Detectors, analytical devices, lyoluminescence dosimetry
Chemiluminescence	Chemical reaction	Analytical chemistry
Bioluminescence	Biochemical reaction	Analytical chemistry
Thermoluminescence	Ionizing radiations	Radiation dosimetry, archeological and geological dating, forensic science
Triboluminescence	Mechanical energy	Mechanical engineering, energy, biological monitoring, and sensors as well as lighting, imaging, and displaying
Sonoluminescence	Ultrasound	Estimating the extreme temperatures generated in the bubbles during implosion

1.3.1.2 Excitation

In general, luminescence may be excited by a number of agents such as light, cathode rays or positive ion bombardment or X-rays, by contact with flame, or by friction. The region of wavelengths for which a given material can be excited by optical means with high efficiency usually consists of one or more broadbands, which are characteristic of both the host material and the activator. The position of the bands evidently is of much importance for practical purposes. For example, it is important that the given material possess a prominent excitation band at 253.7 nm, if it is to be excited by radiation from a low-pressure mercury discharge. It should be emphasized that not all crystals possessing a high efficiency for optical excitation, also posses a high efficiency for excitation by cathode rays. It has generally been observed that the efficiency of excitation of luminescence decreases, reversibly, as the temperature is raised sufficiently.

1.3.1.3 Emission

The emission spectra of luminescent material usually consists of one or more bands whose position is related to the activator. In general, peaks become narrower and narrower in the crystalline materials as the temperature of the specimen is lowered, and they approximate sharp lines near the absolute zero of the temperature. It is clear that if the electrons, which absorb energy and radiate light, are in the well-shielded inner shells of the atom (for example, rare earth ions), excitation may have relatively little effect upon the chemical binding, in which case the degradation of energy will be smaller than it would be if the electrons that are to be excited are in the outermost shell.

1.3.1.4 Decay Characteristics

An examination of the decay properties of the luminescent materials indicate that they fall in to two broad classifications [3]:

In the first type, the decay equation is given by:

$$I(t) = I_o \exp(-\alpha t)$$

where I_o is the initial intensity, I(t) is the intensity at time t and α is a constant.

This resembles closely the process governing the progress of monomolecular reaction. This behavior suggests that in these cases the luminescence takes place by simple excitation with subsequent optical emission in the active centre, the excitation energy remaining closely localized in the centre between excitation and emission. The decay constant is independent of temperature and is small.

Most of the luminescent materials, which are valued for their long decay characteristics, obey a decay equation of second type:

$$I(t) = I_o/(\beta t + 1)^n$$

where I_o is the initial intensity, I(t) is the intensity at time t and β and n are constants.

This equation is similar to the rate equation for the bimolecular reaction. The constant β is dependent on temperature. The atoms or clusters of atoms become ionized during the excitation and the luminescent radiation is emitted during recombination of the free electrons and the ionized centres. Johnson [4,5] has suggested that essentially all centres become ionized during excitation and that a majority of free electrons are recaptured into a state, which has a very long lifetime (of the order of milliseconds), because the optical transition to the ground state is forbidden. These electrons contribute an exponential component to the decay curve. The remaining electrons are captured at the trapping centres and are released over a period of time that is long compared to the lifetimes of the excited state of the fluorescing centre. The second class of electrons is responsible for the bimolecular component of the decay curve.

1.3.1.5 Mechanism

The configurational coordinate model describes the electronic transitions of absorption and emission [6]. It shows the potential energy curves of the absorbing centre as a function of configurational coordinates. In optical absorption, the centre is promoted from its ground state to the high vibrational level of the excited state. The centre returns first to the lowest vibrational level of the excited state, giving up excess energy to the surroundings. This is schematically shown in Figure 1.1.

The activator ions possess energy levels that can be populated by direct activation or indirectly by energy transfer, and are responsible for the luminescence. Generally, two types of activator ions can be distinguished. In the first type the energy levels of the activator ions involved in the emission process show only weak interactions with the host lattice (e.g. many of the lanthanide ions Ln^{3+}). The characteristic line emission spectra can be observed in this case. The second types of activator ions strongly interact with the

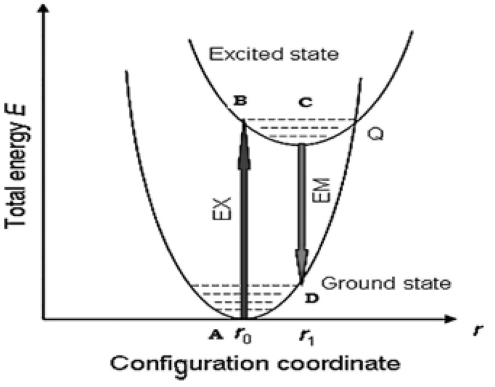

FIGURE 1.1 A schematic illustration of a configurational coordinate model.

host lattice (e.g. Mn^{2+}, Eu^{2+}, Ce^{3+}, Pb^{2+}, etc.). The strong couplings of the electronic states with vibrational modes of the lattice mainly lead to more or less broadbands in the spectrum. The half width (FWHM) is related to the Stokes shift S, which is the energy difference between absorption and emission maximum.

$$\text{FWHM} = \sqrt{8}\ \ln 2\ \sqrt{2kT}\ \sqrt{S}\,[\text{eV}]$$

$$S = S_e h\omega_e + S_g h\omega_g$$

S_e and S_g are Huang-Rhys parameters for the excited and ground state, respectively.

Phosphors that show an emission with a large Stokes shift usually exhibit a low quenching temperature, which is disadvantageous for many applications.

In general, the luminescent process can be divided into the steps of energy absorption, energy transfer and emission. Energy absorption need not take place at the activator ion itself but can occur at random places in the lattice. This implies that energy transfer of the absorbed energy to the luminescent centre takes place before emission can occur. The migration of energy absorbed by the lattice can take place through one of the following processes:

- Migration of electric charge (electrons, holes),
- Migration of excitons,
- Resonance between atoms with sufficient overlap integrals,
- Re-absorption of photons emitted by another activator ion or sensitizer.

The occurrence of energy transfer within a luminescent material has far-reaching consequences for its properties as a phosphor. On the other hand, the absorbed energy can migrate to the crystal surface or to the lattice defects, where it is lost by radiation-less deactivation. As a consequence, the quantum efficiency of the phosphor declines.

Besides the quantum yield, the quality of a phosphor material is further characterized by its colour points, the lumen equivalent, the reflection spectrum and the emission lifetime under given excitation conditions. The colour point is derived from the spectral energy distribution of the emission and is defined according to the convention of the *Commission Internationale d'Eclairage* (CIE) in a normalized two-dimensional coordinate system shown in Figure 1.2.

For lighting applications, the colour saturation of the phosphors is of less importance. In contrast, the luminescent materials should emit a spectrum with a high lumen equivalent. This value is calculated by multiplication of the spectral power distribution P(λ) of the phosphor

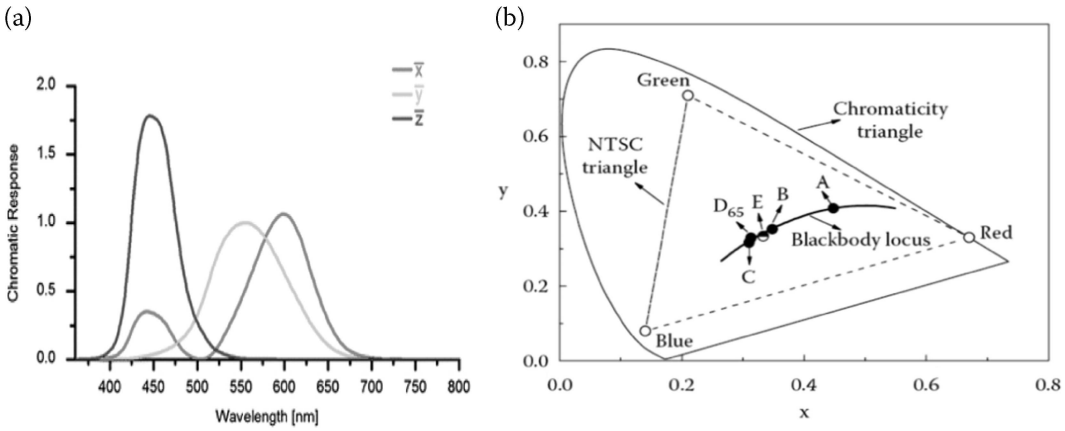

FIGURE 1.2 (a) 1931 CIE XYZ colour-matching. (b) 1931 CIE chromaticity diagram.

emission, which integral has been normalized with the spectral luminous efficiency (LE) for the human eye V(λ):

$$LE = \int_{380}^{780} V(\lambda)\ P(\lambda)\ d\lambda \quad [lm/W]$$

To obtain white light with a high lumen equivalent, it is important that the phosphors applied in a mixture display very sharp emission spectra or even better emission lines, rather than broad emission spectra; otherwise a light is generated in spectral areas where the eye sensitivity is too low. Naturally, also the emission maximum of line emitting phosphors should not be too far off the eye sensitivity curve maximum.

To determine just how efficient a phosphor is, the term 'quantum efficiency' (QE) is defined. It is the ratio between the number of photons emitted and the number of photons absorbed by the phosphor. Generally, the phosphors that have QEs of 80% or greater are considered to be efficient phosphors.

Besides the quantity, there is also a quality performance of light sources with one factor usually being traded off against the other. Light quality is mainly determined by the colour rendering of the light source, which is the ability to display the colours of an irradiated object in a natural way. A qualitative measure is the colour-rendering index (CRI), which by definition can adopt values between 0 and 100. This value is calculated by comparing the reflection spectra of selected test colours obtained by irradiation with the light source under investigation with the reflection spectra when irradiated in the same way with a black body radiator. By definition, a black body radiator has a colour-rendering index of 100. In contrast, a line emitter with a single emission line at any part of the visible spectral region has a CRI of zero, because colours cannot be displayed under such an irradiation source. While a combination of line emitters yields high light output but moderate CRI, broadband emitters enable higher CRI values to be obtained. In addition, colour rendering is dependant on the spectral position of the emission maximum and thus on the spectral power distribution of the phosphor. A compromise has to be found between colour rendering and high light output.

The luminescence efficiency of a phosphor falls at higher temperatures. This is called 'temperature quenching'. The activator concentration in excess may also cause reduction in the intensity of the phosphor, which is termed 'concentration quenching'. There are some impurities whose presence, even in very small amount, will reduce the intensity of the phosphor. Such impurities are called as 'killer impurities'.

Classification of Luminescence

'Luminescence' is the general term that covers both fluorescence and phosphorescence. The concept of fluorescence originated from the mineral fluorite because the phenomenon of light emission under ultraviolet radiation was first recognized in that mineral. Phosphorescence is named after the well-known optical property of the element phosphorous. In Greek, the term 'phosphor' means 'light bearer'. But the chemical element phosphorous is not phosphor. The difference between fluorescence and phosphorescence is to some extent arbitrary. Historically, the temperature independent decay is known as fluorescence while the temperature-dependent decay is phosphorescence. According to modern conventions, fluorescence refers to the emission, which persists for 10^{-3} s to 10^{-8} s while the phosphorescence persists for a considerably longer duration from 10^{-3} s to several seconds. The various types of luminescence are distinguished by a prefix, which denotes the mode of excitation, e.g. photoluminescence is caused by the absorption of photons of visible or near-visible radiation, electroluminescence is caused due to electric field etc. Thermoluminescence is rather a misnomer. Thermoluminescence is the thermally stimulated luminescence excited by other means and the thermal energy is not the source of excitation.

There are a variety of luminescence phenomena observed in nature or in man-made materials. The nomenclature given to these is invariably related to the exciting agent, which produce the luminescence. Following description summarizes the main types of the luminescence emission phenomena.

Photoluminescence

This is the emission produced by excitation with the light photons. The fluorescent lamp used in household and general lighting is the principal example of this. A 254 nm UV radiation from the mercury vapor discharge is absorbed by one of activator impurities in the phosphor coated on the inner side of the glass tube. Some of this energy is transferred by resonance to a second impurity. By adjusting the relative concentrations of these activator impurities, one can produce desired modification in the colour of the light. There are a large variety of organic and inorganic phosphors, which are used in the consumer items like in road and traffic signals, displays, laundry whiteners, etc. in addition to those used in industrial and scientific applications. An example of high technology is called LASER, a kind of photoluminescence in which emission is coherent.

Cathodoluminescence

When electron beams generated at the electrical cathodes do excite, the emission produced is called cathodoluminescent. The screens of cathode ray tubes and television tubes glow by this kind of emission. In cathode ray tubes, zinc and cadmium sulfide phosphors are used.

Radioluminescence

When X-rays or nuclear radiations provide the excitation energy, the resulting luminescence is called radioluminescence.

Scintillation

This phenomenon is the same as radio-luminescence. It is given this name because it is used as a technique to detect individual light pulses generated by the incidence of each X-ray, or gamma ray photon or a nuclear particle. Such light pulses are called scintillations, since like a spark they are very short lived. Thallium-activated sodium iodide is a well-known scintillation detector used for gamma ray spectrometry. The intensity of the scintillation (light pulse) is directly proportional to the energy of the incident gamma ray photon (when it is totally absorbed). The measurement of this pulse intensity, therefore, provided the means for knowing the gamma ray energy.

Electroluminescence

Application of electric fields can produce luminescence in many phosphors. There is another type of electroluminescence, known as injection luminescence. In this, electrons are injected from an external supply across a semiconductor p-n junction. On applying a DC voltage across the junction, such that the electrons flow to the p-region, luminescence is produced by the electron-hole recombination in that region. The light emitting diodes (LEDs), which are now commonly used as display devices in many scientific instruments, are based on this principle.

Chemiluminescence

Some chemical reactions are the source of luminescence. The oxidation of white phosphorous in air is the best-known example of this. All chemical molecules are not capable of luminescence. Lyo-luminescence, which is caused during the dissolution of certain compounds, which have been bombarded by X-rays beforehand, is a kind of chemiluminescence. A well-known example is the case of X-irradiated NaCl, which emits a flash of light when quickly dissolved in water.

Bioluminescence

Biochemical reactions inside the cell of living organisms can produce electronic excited states of the biomolecules. Fire flies, glowworms, some bacteria and fungi and many sea creatures, both near the surface and at great depths, are the striking examples of luminescence in living beings.

Triboluminescence

A large number of inorganic and organic materials subjected to mechanical stress emit light, which is called triboluminescence. It has also been named mechanoluminescence by some authors. The spectra of triboluminescence light are similar to those of photoluminescence in many substances.

Thermoluminescence

Unlike the various types of luminescence phenomena listed above, the prefix 'thermo' here does not mean the form of excitation energy, but to stimulation of luminescence, which was excited in a different way. The primary agent for the induction of TL in a material is the ionizing radiation (X-rays or gamma radiation) or sometimes even UV rays to which the material is exposed. The light produced by subsequent heating of material is called TL.

The most broadly investigated and utilized of all thermally stimulated phenomena is the emission of light during the heating of a solid sample, previously excited. The initial excitation (typically by irradiation) is the source of energy, whereas the heating serves only as a trigger, which helps in releasing this accumulated energy. The term thermally stimulated luminescence (TSL) is more descriptive; however, 'thermoluminescence' is traditionally more often utilized and popularly accepted.

As noted except for very unusual cases, the occurrence of the TL curve following a given irradiation is a 'one-shot' effect. Cooling the sample and re-heating it normally does not result in a second TL emission.

Luminescent Materials

The general materials used as phosphors may be classified according to their use in the application or according to the chemical forms. Considering the synthesis viewpoint they are classified here on the basis of their chemical forms. The main categories are as follows:

a. Inorganic materials: These are mainly solid-state compounds that consist of crystals 1–10 μm in size. The inorganic phosphor usually consists of a host lattice with activator ions doped into it in small concentrations, typically a few mole percent or less. The activator ions posses energy levels that can be populated by direct excitation or indirectly by energy transfer, and are responsible for the luminescence. Generally, two types of activator ions can be distinguished. In the first type, the energy levels of the activator ion involved in the emission process show only weak interaction with the host lattice. Typical examples are many of the lanthanide ions Ln^{3+}, where the optical transitions take place solely between 4f terms that are well shielded from their chemical environment by outer electrons. As a consequence, characteristic line emission spectra can be observed. The second type of activator ions strongly interact with the host lattice. This is the case when d electrons are involved. For example. in Mn^{2+}, Eu^{2+}, and Ce^{3+}, as well as for s2 ions like Pb^{2+} or Sb^{3+}, or for complex anions such as MoO42– or NbO42–. The strong coupling of the electronic states with vibrational modes of lattice mainly lead to more or less broadbands in the spectrum.
   Some of the host materials used for inorganic phosphors are aluminates, arsenates, borates, bromides, carbonates, chlorides, chromates, cuprates, fluorides, ferrites, germanates, gallates, indates, iodides, mangnates, nitrides, oxides, phosphates, selenides, silicates, sulphides, sulphates, tantalates, titanates, tungstates, uranates, vanadates, zirconates, halophosphates and apatite structures.
b. Organic materials: These are either polymers or low molecular weight materials applied as thin films or solid solutions. The most recent class of materials comprises main chain polymers with isolated chromophores and side chain polymers with linked chromophores. They are mainly used in organic light emitting diodes (OLEDs) [7].
c. Hybrid compounds: This class generally includes the organically modified silicates (ORMOSIL) [8] and hybrid organic-inorganic complexes such as Eu^{3+}, Tb^{3+}, or their complexes with β-diketones, aromatic carboxylic acids and heterocyclic ligands such as 2,2′-bipyridine and 1,10-phenanthroline, into various matrices [9].

1.4 BORATE-BASED PHOSPHORS

Borates are naturally occurring minerals containing boron, the fifth element on the periodic table. The element boron does not exist by itself in nature. Rather, boron combines with oxygen and other elements to form inorganic salts called borates. Boron has an ionic radius 0.11 Å and hence can occur in both triangular (BO_3) and tetrahedral (BO_4) coordination where bonded to oxygen [10]. BO_3 groups have an average B-O bond-valance approximately equal to 1 valence unit and BO_4 groups have an average B-O bond-valance approximately equal to 3/4 valence unit. Hence, both (BO_3) and (BO_4) groups can polymerize by sharing corners without violating the valance sum rule. Such polymerization is very common in both minerals and synthetic inorganic compounds. In general, a borate structure contains clusters of corner sharing (BO_3) and (BO_4) polyhedra, which occur as discrete polyanions to form larger clusters, chains, sheets or frameworks [11]. Since the boron atom is capable of coordination in either trigonal or tetragonal mode [12–14], borate anions exist in numerous structural types. There are hundreds of different structures with various borate anionic groups as basic structural units in the known borate crystals [15]. However, there are only a few types of basic structural units of borates of practical interest [12,16]:

i. $(BO_3)^{3-}$
ii. $(BO_4)^{5-}$
iii. $(B_2O_5)^{4-}$
iv. (iv) $(B_2O_7)^{8-}$
v. $(B_3O_6)^{3-}$
vi. $(B_3O_7)^{5-}$
vii. $(B_3O_8)^{7-}$
viii. $(B_3O_9)^{9-}$
ix. $(B_5O_{10})^{5-}$
x. $(B_4O_9)^{6-}$

A variety of pre-decided inorganic borate host materials attempted for successful synthesis and verifying the potential photoluminescence characteristics are listed in Table 1.2. In addition to the pre-decided list, a few new materials (hosts) are successfully synthesized.

1.4.1 Classification of Borates

Inorganic borate host compounds are classified into various groups on the basis of chemical composition and crystal structure.

1.4.1.1 Classification of Borates Based on Chemical Formula

1.4.1.2 Classification of Borates Based on Crystal Structure

Borate host inorganic compounds exist in numerous crystal structures. On the basis of crystal structure, borate compounds were classified as follows:

i. Aragonite-Type Borate

The aragonite-type borates crystallize in the structure of the mineral aragonite ACO_3, A = Ca, Ba, Pb, Sr. The structure of the aragonite borate is composed of the triangular borate ion group (BO_3), with a boron at the centre of the triangle and three oxygens at each corner. It has an orthorhombic symmetry.

Examples: $LaBO_3$ [10], $NdBO_3$ [11], $CeBO_3$ [12].

ii. Calcite-Type Borate

The calcite-type borates are the polymorphs of aragonite with trigonal symmetry.

Figure 1.3 represents the $InBO_3$ unit cell with (110) orientation.

Examples: $InBO_3$, $LuBO_3$, $ScBO_3$ [13].

TABLE 1.2
Inorganic borates are classified on the basis of a chemical formula

Sr no.	Borate type	Metal oxide	Examples
1	Metaborate	1 B_2O_3	$NaBO_2$ (Na_2O:B_2O_3), $LiBO_2$ (Li_2O: B_2O_3), CaB_2O_4 (CaO: B_2O_3), BaB_2O_4 (BaO: B_2O_3), SrB_2O_4 (SrO: B_2O_3), $CsBO_2$ (Cs_2O: B_2O_3)
2	Diborate	2 B_2O_3	$Li_2B_4O_7$ (Li_2O: 2 B_2O_3), $Na_2B_4O_7$ (Na_2O: 2 B_2O_3), ZnB_4O_7 (ZnO: 2 B_2O_3)
3	Triborate	3 B_2O_3	LiB_3O_5 (Li_2O: 3 B_2O_3), EuB_3O_6 (Eu_2O_3: 3 B_2O_3), CeB_3O_6 (Ce_2O_3:3 B_2O_3), BiB_3O_6 (Bi_2O_3: 3 B_2O_3)
4	Tetraborate	4 B_2O_3	AgB_4O_7 (Ag_2O: 4 B_2O_3), $Na_2B_8O_{13}$ (Na_2O: 4 B_2O_3)
5	Pentaborate	5 B_2O_3	CsB_5O_8 (Cs_2O: 5 B_2O_3), $Na_2B_{10}O_{16}$ (Na_2O: 5 B_2O_3)
6	Hexaborate	6 B_2O_3	SrB_6O_{10} (2 SrO: 6 B_2O_3)
7	Heptaborate	7 B_2O_3	$Li_3B_7O_{12}$ (3 Li_2O: B_2O_3)
8	Octaborate	8 B_2O_3	$Bi_2B_8O_{15}$ (2 Bi_2O_3: 8 B_2O_3), BaB_8O_{13} (2 BaO: 8 B_2O_3)
9	Nonaborate	9 B_2O_3	$NaBaB_9O_{15}$ (Na_2O:2BaO:9B_2O_3), $LiBaB_9O_{15}$ (Li_2O:2BaO:9B_2O_3), $LiSrB_9O_{15}$ (Li_2O:2SrO:9B_2O_3), $GdBaB_9O_{16}$ (Gd_2O_3:2BaO:9B_2O_3)
10	Deaborate	10 B_2O_3	$K_2B_{10}O_{16}$ (K_2O: 10 B_2O_3)

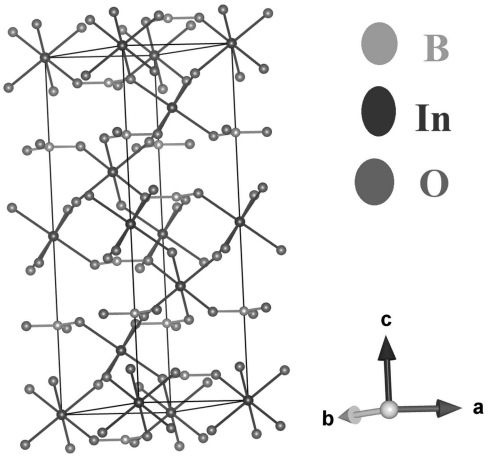

FIGURE 1.3 Ball-and-stick representation of $InBO_3$ unit cell with (110) orientation.

iii. Vaterite-Type Borate

The vaterite-type borates are the polymorphs of aragonite with hexagonal symmetry.
Examples: $SmBO_3$, $EuBO_3$ [14–16].

iv. Stillwelite-Type Borate

Mineral stillwelite is a family of trigonal borates with the general formula X [$BO(SiO_4)$] with X = Ce, La, Pr, Nd, Th. Stillwelite contains helical chains of (BO_4) tetrahedra polymerized by sharing corners [17]. These chains are decorated by SiO_4 tetrahedra that share two corners with adjacent (BO_4) tetrahedra. Boron is coordinated by four oxygen atoms in a tetrahedral arrangement. The (BO_4) tetrahedra polymerize by sharing corners to form a helical chain extending along the z-axis. The periphery of the chain is decorated by (SiO_4) tetrahedra that share two corners with an adjacent (BO_4) tetrahedral. The resultant [$BSiO_5$] chain is the fundamental building block of the structure that is repeated by the lattice translations to form a hexagonal columnar array.

The lanthanide borate-silicate materials $LnBSiO_5$ [18,19] (Ln = La, Gd, Y, Pr, Nd) exhibits stillwelite structure of $LaBSiO_5$, shown in Figure 1.4.

v. Melitite-Type Borates

Melitite represents a family of natural and synthetic compounds $A_2XZ_2O_7$, where A = Na, Ca, Sr, Ba, Cd, Pb, Y, Ln; X = Be, Mg, Co, Fe, Mn, Cu, Zn, Cd, Al, Ga; Z = Be, B, Al, Si, Ge. $Bi_2ZnB_2O_7$, $CaBiGaB_2O_7$ and $CdBiGaB_2O_7$ are the only examples of synthetic diborate members of the melitite family [20].

vi. Leucite-Type Borates

The leucite-type structure ($AlSi_2O_6$) exists over a wide range of alkali cations from Na to Cs [21]. Al atoms can be replaced by B [22–25]. The boron-substituted leucite is known as boro leucite [26]. The examples of boroleucite are $KBSiO_6$ [27] and $RbBSiO_6$ [28]. The structure of leucite [29] represents a continuous three- dimensional skeleton, formed by $(Si,Al)O_4$ tetrahedra, each of which shares all its oxygen with its neighbours [30,31].

vii. Warwickite-Type Borate

The warwickite is an orthorhombic oxyborate minerals [31] with the general formula M_2OBO_3 (M = Mg^{2+}, Mn^{2+}, Fe^{3+}, Ti^{4+}, Al^{3+}). Most transition metal oxyborates with the general formula $M^{2+}M^{3+}BO_4$ crystallizes in an orthorhombic structure of warwickite ($Mg_{1.5}Ti_{0.5}BO_4$), representing a system of linear, weakly interacting ribbons comprising two internal and external chains in which octahedrally coordinated divalent and trivalent transition metal atoms are randomly distributed over nonequivalent crystallographic positions of two types [32]. $MgGaBO_4$ is isostructural to the mineral warwickite $(Fe,Mg)Ti(BO_4)_2$ [33]. The structure of $MgGaBO_4$ along [001] contains ribbons of four edge-sharing octahedral formed from two pseudo-packed layers of oxygen atoms between which magnesium atoms occupy the octahedral interstices shown in Figure 1.5.

viii. Mineral Huntite Borate

These borate compounds crystallizes in the structure of the mineral huntite. These materials generally adopt a noncentrosymmetric structure, trigonal space group R32. The general formula of huntite borates is $LnM_3(BO_3)_4$ where Ln = Lanthanide and M = Al, Sc, Cr, Fe, Ga.

Examples: $CeSc_3(BO_3)_4$ [34], $TbAl_3(BO_3)_4$ [35].

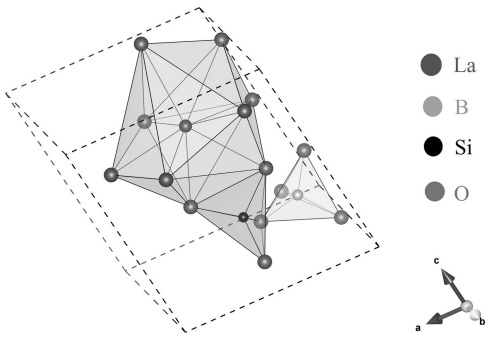

FIGURE 1.4 $LaBSiO_5$ with stillwellite structure.

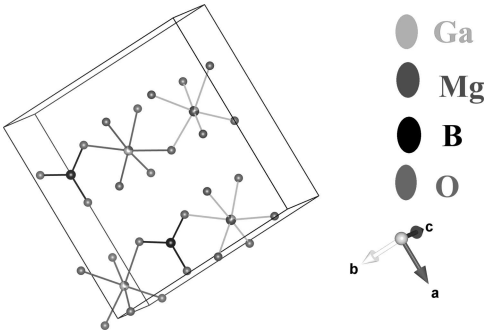

FIGURE 1.5 The structure of $MgGaBO_4$ along [001].

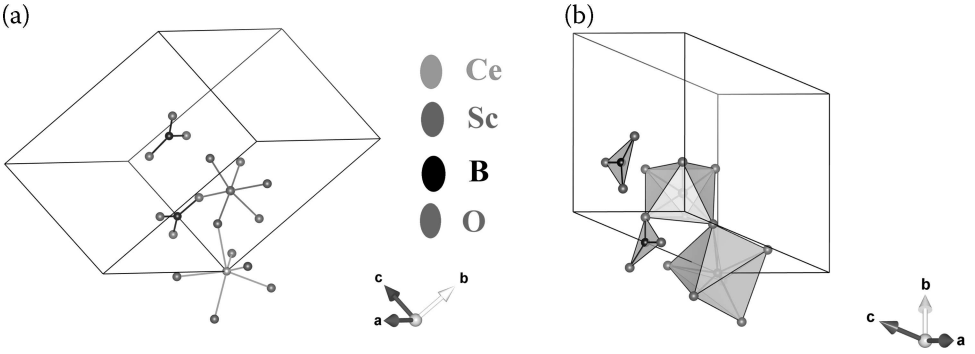

FIGURE 1.6 (a) Unit-cell contents of $CeSc_3(BO_3)_4$. (b) Sc_6O polyhedral connections in $CeSc_3(BO_3)_4$.

The compound $CeSc_3(BO_3)_4$ adopts the normal trigonal huntite structure shown by Figure 1.6 with Ce-centred distorted trigonal prisms and Sc-centred distorted octahedral dispersed between planes of BO_3 triangles that extend parallel to (001). Dissimilar polyhedra share only vertices, resulting in isolation of the CeO_6 prisms and BO_3 triangles; the ScO_6 octahedra share edges to form helices extending along (001).

ix. Mineral Boracite

The boracite represents a family of compounds having the general formula $M_3B_7O_{13}X$ where M = Mg, Cr, Mn, Fe, Co, Ni, Cu, Zn. Cd and X = Cl, Br, I. The term 'boracite' is due to the mineral $Mg_3B_7O_{13}Cl$ [36]. At present, more than 25 isomorphous boracite compounds exist. A complete structural investigation of high and low boracite $Mg_3B_7O_{13}Cl$ was reported by Ito et al. [37,38]. High boracite was described as cubic and low boracite as orthorhombic. Complete structural analysis was given for $Sr_2B_5O_9Cl$ is given in Figure 1.7.

1.4.2 Crystal Chemistry of Borates

In recent years, more and more research has been concentrated on borate crystals. Most of the obtained crystals contain independent orthoborate BO_3 groups in their structures. The structural chemistry of anhydrous borates is characterized by a variety of discrete and condensed BO_3 and BO_4 anions [39]. Predominant among these structures, especially binary and more complex borates are isolated BO_3 triangles (65%). Of the rest, almost one-half is represented by framework structures containing three-dimensional B_nO_m polyanions. In this case, BO_3 and BO_4 groups join by sharing common O atoms. Then, it is followed by insular (pyroborates and ring metaborates), network and chain-forming structures.

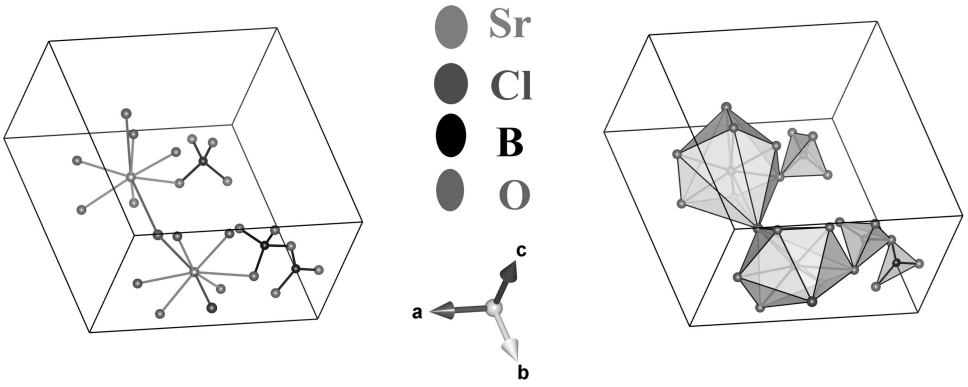

FIGURE 1.7 Unit cell of $Sr_2B_5O_9Cl$ showing coordination of Sr at various sites.

There are more than 50 types of boron-oxygen anions and polyanions in anhydrous borates [40]. However, all of them consist exclusively of three basic types of structural units of different composition. The first set of these basic types identify with BO_3 triangles (Δ) and BO_4 tetrahedra (□) as fundamental structural units (FSU), which are shown in Figure 1.8(a). They are isolated in orthoborates and can be merged in pyroborates, metaborates and polyborates.

The second basic type of structural units is usually built up of several FSU (from two to five) joined by sharing common O atoms. There is a rather limited number of these anionic groups. They are shown in Figure 1.8(b) and designated below as combined basic structural units (CSU). Only two of them, 2Δ and 3□, can be isolated in the structure of anhydrous pyroborates and some metaborates, respectively. The rest of the structural units of this type are components of various one-, two-, and three-dimensional B_nO_m polyanions by sharing their free O atoms.

Finally, in polyanions of anhydrous borates, it is expedient to distinguish one or more types of structural units. Structural elements of this category are, as a rule, more complex and characterize the borate structures on the whole. It is appropriate to designate these anionic groups as complete radicals of polyanions (CRP). Some of the typical CRP are demonstrated in Figure 1.8(c) and (d). The CRP may be visualized as one or more of the CSU and additional FSU (BO_3 triangles and/or BO_4 tetrahedra) joined by sharing common O atoms. Thus, it represents a full repeating fragment of a polyanion corresponding in composition aliquot to the B-O anion part in the structural formula of the borate. It is useful to note that the CRP identifies themselves with the CSU in the anhydrous orthoborate structures, and with the CSU in the pyroborates, metaborates and in some more complex borate compounds.

1.4.3 Applications of Borate Host Materials as Phosphors

Solid-state inorganic borates have become a focus of technological interest due to a variety of physical and chemical features exhibited by these compounds [41]. Owing to possible three-, or fourfold coordination of borate atoms, borates form a great number of compounds having diverse structures. Borates intrinsically possess characteristics that are advantageous for optical materials [42], which include wide transparency range, large electronic bandgap, good thermal and chemical stability, low preparative temperature, optical stability with good nonlinear characteristics and exceptionally high optical damage threshold [43–45]. The unique crystal structure of borates determines their enhanced UV transparency, good nonlinearity and relatively high resistance against laser-induced damage. Recent research on inorganic borates has been focused on the synthesis and characterization of compounds with potential application as optical material [46]. Borate compounds currently have been of considerable interest to the scientific community owing to their wide range of applications: Laser, NLO material, phosphor material and scintillator material, etc. Most of the borates are polyfunctional materials with nonlinear optical, piezo-electrical and

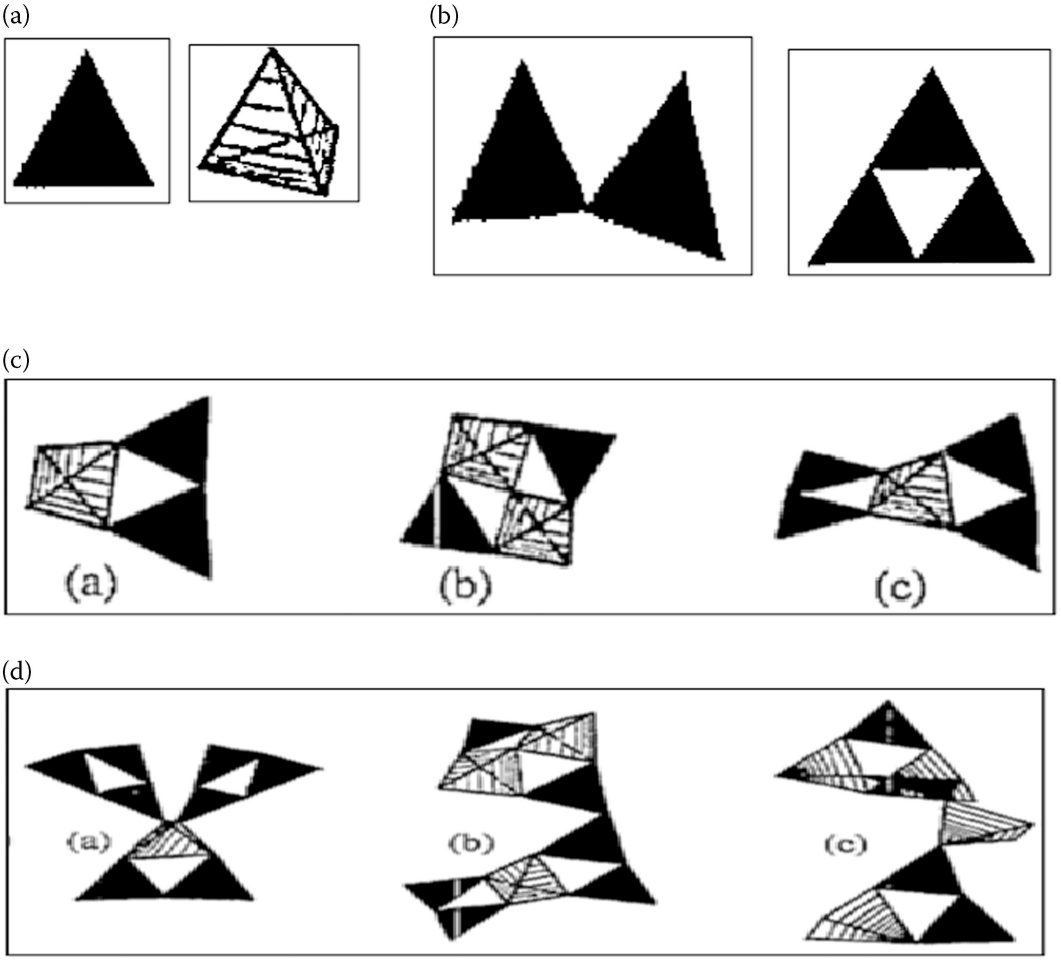

FIGURE 1.8 (a) Configuration of some basic B-O structural units in anhydrous borates: Fundamental structural units (Δ and □ isolated forms occur in orthoborate structure only). (b) Combined basic structural units as insular anions in pyroborate (a) and metaborate (b). (c) Combined basic structural units forming network and framework polyanions: (a) 2Δ + 1□ (b) 2Δ + 2□ (c) 4Δ + 1□. (d) Combined radicals of polyanions in network and framework polyborate structure: (a) (2Δ + 1□) + 2(3Δ) (b) (4Δ + 1□) + (2Δ + 2□) (c) (2Δ + 1□) + (2Δ+2□) + 1□.

acousto-electrical properties. Some borates are also suitable as a laser material for miniature laser [47]. Borate crystals with the structure of the naturally occurring mineral huntite $CaMg_3(CO_3)_4$ are widely known as polyfunctional materials having device potential due to their good thermal and chemical stabilities. The general formula of huntite borate is $LnM_3(BO_3)_4$, Ln = rare earth element and M = Al, Ga, Cr, Fe, Sc. Among them, rare earth aluminium borates $LnAl_3(BO_3)_4$ have attracted considerable attention for their luminescence properties and possible application as single crystal mini-laser [48]. In the following sections, the applications of inorganic borate compounds as LASER and NLO material and phosphor material are discussed.

1.4.3.1 Inorganic Borate as NLO and LASER Material

The NLO materials are materials used to generate new LASER sources of frequencies that cannot be obtained directly from available lasers. Efficient frequency conversion depends on crystal properties such as the effective nonlinear coefficient, refractive indices, phase-matching conditions and damage threshold. The borates with NLO properties form a large family of compounds.

The first NLO borate described was $KB_5O_8.4H_2O$ [49] in 1975, but intense research on NLO borate materials began with the advent of low-temperature BaB_2O_4 and LiB_3O_5 which are the most frequently used borate materials. A subsequent search for new borate compounds led to the continued discovery of new borate compounds with improved NLO properties.

Borate materials are also useful as a self-frequency doubling active laser sources. A commercial self-frequency doubling laser source is $YAl_3(BO_3)_4$: Nd^{3+}. Many new borates have been recently reported. Borophosphates which contain the borate group and the phosphate group as basic structural units has also drawn attention recently, as new functional materials for application in laser technologies [50]. Complex boron oxide materials attract considerable attention because they can be used as multifunctional optical materials in which the laser effect and nonlinear optical phenomena occur simultaneously. Borotungstate with the general formula Ln_3BWO_9, Ln = La, Pr, Nd, Sm – Ho are the promising complex borates [51]. Lanthanide calcium oxoborate $LnCa_4O(BO_3)_3$, Ln = La – Lu and Y, constitute a family of compounds intensively studied since 1997 due to their good NLO properties. These crystals could be doped with rare earth and can be used for self-frequency doubling and self-frequency mixing [52].

1.4.3.2 Inorganic Borate as Phosphor Material

During the past few years, a number of borate materials have been studied extensively due to their unique combinations of large electronic bandgaps, strong nonlinear optical properties, chemical and environmental stabilities and mechanical robustness. Due to their large electronic bandgaps, borate materials are excellent host lattices for luminescent ions. Rare earth borate compounds normally have high UV transparency and exceptional optical damage threshold, which makes them attractive for numerous practical applications such as in lamps and display applications. There are many excellent phosphors in the borate family, for example, YBO_3: Eu^{3+}, $GdBO_3$: Eu^{3+} and $LnMgB_5O_{10}$, etc. which have been applied in the region of UV-excited phosphors and integrated optics [53]. Rare earth borate compounds are an interesting class of luminescent materials. The rare earth borate phosphors were first introduced by R.I. Smirnova et al. [54] and have been of little or no interest for two decades. More recently, due to rising demand for new efficient phosphors for various applications such as lamp phosphor, FPD, PDP, etc. rare earth borates have attracted attention [55,56]. Rare earth orthoborates, RBO_3 (R = Y, La, Gd), doped with rare earth ions (Eu^{3+} and $Tb^{3+)}$ are interesting luminescent materials (56). Rare earth borates doped with Eu^{3+} are potential red-emitting phosphors. Gadolinium borate phosphors ranging from orthoborates to pentaborates have proved to be potential candidates for practical applications in fluorescent lamps due to their high efficiency [57–59].

Haloborates activated by Ce^{3+} ions have been recently shown to be a promising material for detecting thermal neutrons. Strontium haloborates doped with Eu^{2+} are well-known X- ray storage phosphors.

Plasma display panels (PDP) are regarded as the most promising candidate for large-sized flat panel displays (FPDs). Phosphors for the application in PDP are required to have high conversion efficiency by VUV radiation of 147 and/or 172 nm from the Xe gas plasma. The inorganic borate compounds have strong absorption in the VUV region [60] and therefore widely used as host lattices of phosphors for PDP applications. $LnBO_3$ doped with Eu^{3+} has been widely used as a luminescent material in plasma display panels (PDPs) due to the high quantum efficiency and good color coordinates under 147 nm VUV excitation [61]. At present, the most widely used red-emitting phosphor for PDP is $(YGd)BO_3$: Eu^{3+} [62]. The doped $YAl_3(BO_3)_4$ can be utilized as red PDP phosphor (Tables 1.3 and 1.4).

- Lamp Phosphors
- Led Phosphors
- UV-Based Photo Therapy Phosphors
- PDP Phosphors
- Radiation Dosimetery Phosphors
- Mechno or Layo-luminescent Phosphors
- Nir Quantum Cutting Phosphors
- Neutron Radiography

TABLE 1.3
Borate host inorganic NLO and LASER materials

Sr. no.	Inorganic borate	Applications	Ref.
1	CsB_3O_5	NLO material to generate deep UV	[63,64]
2	$CsLiB_6O_{10}$	NLO material for SHG and Higher order harmonic generation	[65–67]
3	$YAl_3(BO_3)_4:Nd^{3+}$	Self-frequency doubling LASER material	[68–77]
4	LiB_3O_5	NLO material for SHG	[78–82]
5	$NaBe_2BO_3F_2$ $KBe_2BO_3F_2$	VUV NLO material used in LASER chemistry and LASER medical science	[65,83–85]
6	$BaZn_2(BO_3)_2$	NLO material for SHG	[86]
7	β-BaB_2O_4	NLO material	[87–89]
8	$Ca_4GdO(BO_3)_3$	NLO material	[90]
9	$Ca_4YO(BO_3)_3$	NLO material for THG	[91]
10	$K_2Al_2B_2O_7$	New NLO material for THG	[92]
11	$YAl_3(BO_3)_4:Yb^{3+}$	Excellent self-frequency doubling (SFD) material	[93]
12	BiB_3O_6	NLO material for SHG and THG	[94]
13	$YAl_3(BO_3)_4:Cr^{3+}$	Tunable LASER gain medium	[95]
14	$Ca_4NdO(BO_3)_3$	Mini-laser material	[96]
15	$Sr_3Sc(BO_3)_3:Cr^{3+}$	LASER material	[97,98]
16	$LaBa_3(BO_3)_4:Nd^{3+}$	Miniature LASER material	[99]
17	$NdAl_3(BO_3)_4$	LASER material	[100–106]
18	$Ca_4GdO(BO_3)_3:Nd^{3+}$	Green-emitting micro-chip LASER	[107–110]
19	$Ca_4YO(BO_3)_3:Yb^{3+}$	Self-frequency doubling LASER material	[111]
20	$LaSC_3(BO_3)_4$	Tunable LASER material	[112]
21	$LaSC_3(BO_3)_4:Nd^{3+}$	Efficient LASER material	[113–115]
22	$LaB_3O_6:Pr^{3+}$	Micro-chip LASER material	[116]
23	$Ba_3Y(BO_3)_3:Nd^3$	LASER gain medium	[117]
24	$YbAl_3(BO_3)_4$	Stoicheometric NLO LASER material	[118]
25	$YAl_3(BO_3)_4:Pr^{3+}$	LASER material in UV region	[119]
26	$(Gd_{0.5}Y_{0.5})Ca_4O(BO_3)_4:Yb^{3+}$	Diode pumping LASER host material	[120]
27	$Sr_3Y(BO_3)_3:Yb^{3+}$	Femto-second and tunable LASER	[121]
28	$Sr_3La_2(BO_3)_4:Yb^{3+}$	LASER material	[122]
29	$Sr_3Gd(BO_3)_3:Nd^{3+}$	LASER material	[123]

Neutron radiography (NR) is a special application of neutron beams that developed neutron beam applications. The use of neutron beams for radiographic purposes is a relatively new method of non-destructive testing. Neutron imaging has expanded rapidly as a means of non-destructive testing (NDT) of materials. It is possible to develop scintillators, thermo-luminescent, optically stimulable, materials from the borates. These form the basis for the various methods developed for neutron radiography. Various neutron scintillators, phosphors for imaging plates, based on borates are reviewed in detail in chapter 10. Some important applications such as nuclear fuel inspection, bioimaging, dentistry and oral surgery, inspection of mechanical parts, etc. are discussed.

1.4.4 Mixed Borate Phosphors

Apart from these simple borates, several complex compositions exist involving mixed anions as well as double metal borates. Some of these complex borates show interesting luminescence

TABLE 1.4
Borate host inorganic luminescent materials

Sr. no.	Inorganic borate	Applications	Ref.
1	(Ce Gd)MgB_5O_{10}	Red-emitting phosphor in special deluxe lamps	[124]
2	(Ce Gd)MgB_5O_{10}: Tb^{3+}	Green-emitting phosphor in tricolor lamps	[124,125]
3	$Ca_4GdO(BO_3)_3$:Eu^{3+}	Potential red lamp phosphor	[126–128]
4	GdB_3O_6: Ce^{3+},Tb^{3+}	Potential green lamp phosphor	[129]
5	$SrBPO_5$: Eu^{3+}	Storage phosphor	[130,131]
6	$CaLaB_7O_{13}$: Ce^{3+},Tb^{3+}	Green-emitting phosphor in low-pressure Hg vapor lamps	[132]
7	$CaLaB_7O_{13}$: Eu^{3+}	Red-emitting phosphor in low-pressure Hg vapor lamps	[132]
8	SrB_4O_7: Sm^{2+}	Optical pressure gauge	[133]
9	$(Sr_{0.89}Na_{0.05})BPO_5$: $Ce_{0.05}$, $Tb_{0.01}$	Green-emitting phosphor in tricolor lamps	[134]
10	$Sr_2B_5O_9Br$: Ce^{3+}	Potential storage phosphor for thermal neutron	[135–137]
11	SrB_4O_7: Eu^{2+}	Commercial UV-emitting phosphor in medical lamps	[138,139]
12	$Sr_2B_5O_9Cl$: Eu^{2+}	Blue component of daylight phosphor	[140–144]
13	$Sr_2B_5O_9Cl$: Eu^{2+}**(Thin Film)**	Blue component in FED	[145–147]
14	$Ba_2B_5O_9Br$: Eu^{2+}	X-ray storage phosphor	[148]
15	$SrB_2Si_2O_8$: Eu^{2+}	Blue-emitting phosphor	[149]
16	$InBO_3$: Tb^{3+}	Green-emitting phosphor in CTV screens	[150]
17	La(BO_3,PO_4): Ce^{3+} Gd^{3+} Tb^{3+}	Green-emitting phosphor in high-quality tricolor lamps	[151]
18	$Ba_2B_5O_9Cl$:Tb^{3+}**(Thin Film)**	Green-emitting phosphor in FED	[152]
19	$Ba_2B_5O_9Cl$:Eu^{2+}**(Thin Film)**	Blue-emitting phosphor in flat panel display (FPD)	[153–155]
20	YBO_3: Eu^{3+}	Red-emitting VUV phosphor	[156–159]
21	$YAl_3(BO_3)_4$:Ho,Yb	Upconversion phosphor	[160]
22	$CaBPO_5$: Tb^{3+}	Green-emitting VUV phosphor	[161]
23	Y_3BO_6: Eu^{3+}	Red phosphor in vacuum discharge lamps or screens	[162]
24	(YGd)BO_3:Tb^{3+}	Green component in PDP	[163]
25	(YGd)BO_3:Eu^{3+}	Red component in PDP	[164–173]
26	$GdAl_3(BO_3)_4$:Eu^{3+}	Red component in PDP	[174,175]
27	(Y Gd)$Al_3(BO_3)_4$:Eu^{3+}	Red component in PDP	[176]
28	$GdAl_3(BO_3)_4$:Tb^{3+}	Green-emitting VUV phosphor	[177]
29	$BaZr(BO_3)_2$: Eu_{3+}	Red component in PDP	[178,179]

properties and are covered in this chapter. These include double borates containing rare earth $RM_3(BO_3)_4$, pentaborates $LaMgB_5O_{10}$, $M_3R_2(BO_3)_4$, where M is alkaline earth, mixed anion borates like aluminoborate $SrAl_2B_2O_7$, silicate-borates like pekovite, $SrB_2Si_2O_8$, haloborates, $M_2B_5O_9X$, where M is alkaline earth and X is halogen, phosphate borates, $MBPO_5$, where M is alkaline earth. Phosphors based on these compositions find use in various applications like fluorescent lamps, colour TV, plasma display panels, high-intensity discharge lamps based on xenon, optically pumped solid-state lasers, eye-safe lasers and X-ray imaging. This is briefly illustrated in chapter 11.

REFERENCES

[1] Seitz, F., Gorton, R., and Schulman, J. H. (1948). Luminescent Crystals. In: *Preparation and characteristics of Solid Luminescent Materials*. Pub: John Wiley & Sons, inc, NY, 1, 28. 10.1063/1.3066240

[2] Blasse, G., and Grabmaier, B. C. (1994). How Does a Luminescent Material Absorb Its Excitation Energy?. In: *Luminescent Materials*. Springer, Berlin, Heidelberg. 10.1007/978-3-642-79017-1_2
[3] Seitz, F., (1948). In: 'Luminescent Crystals', Preparation and characteristics of Solid Luminescent Materials, Symp. Cornell Univ., John Wiley & Sons, INC, NY, 9
[4] Johnson, R. P. (1939). Luminescence of sulphide and silicate phosphors. *J. Opt. Soc. Am.*, 29, 387–391. 10.1364/JOSA.29.000387
[5] Johnson, R. P. (1939). Decay of Willemite and zinc sulphide phosphors. *Phys. Rev.*, 55, 881. 10.1103/PhysRev.55.881
[6] Blasse G., and Grabmaier B. C. (1994) A General Introduction to Luminescent Materials. In: *Luminescent Materials*. Springer, Berlin, Heidelberg. 10.1007/978-3-642-79017-1_1
[7] Justel, T., Nikol, H., and Ronda, C. (1998). New developments in the field of luminescent materials for lighting and displays. *Angew. Chem. Int. Ed.*, 37, 3084–3103. 10.1002/(SICI)15213773(19981204)37:22 <3084::AID-ANIE3084>3.0.CO;2-W
[8] Mitschke, U., and Bauerle, P. (2000). The electroluminescence of organic materials. *J. Mater. Chem.*, 10, 1471–1507. 10.1039/A908713C
[9] Li, H., Inoue, S., Machida, K., and Adachi, G. (1999). Preparation and luminescence properties of organically modified silicate composite phosphors doped with an europium(III) β-diketonate complex. *Chem. Mater.*, 11, 3171–3176. 10.1021/cm990251a
[10] Antic-Fidance, E., Lemaitre-Blaise, M., Chaminade, J., and Porcher, P. (1992). Luminescence and crystal field calculation of aragonite-type $LaBO_3:Eu^{3+}$. *J. Alloys Compd.*, 180, 223–228. 10.1016/0925-8388(92)90384-L
[11] Levin, E. M., Roth, R. S., and Martin, J. B. (1961). Polymorphism of ABO_3 type rare earth borates. *Am. Mineral.*, 46 (9-10), 1030–1055.
[12] Weidelt, J., and Bambauer, H. U. (1968). Ein mit Aragonit isotypes Cerborat. Die Naturwissenschaften, 342–342. 10.1007/BF00600458
[13] Chadeyron, C., El- Ghozzi, M., Mahiou, R., Arbus, A., and Cousseins, J. C. (1997). Revised structure of the orthoborate YBO_3. *J. Solid State Chem.*, 128, 261–266. 10.1006/jssc.1996.7207
[14] Chaminade, J. P., Garcia, A., Pouchard, M., Fouassier, C., Jacquier, B., Perret-Gallix, D., and Gonzalez-Mestres, L. (1990). Crystal growth and characterization of $InBO_3$: Tb^{3+}. *J. Cryst. Growth*, 99, 799–804. 10.1016/S0022-0248(08)80029-2
[15] Cox, J. and Keszler, D. A. (1994). $InBO_3$. *Acta. Cryst.*, C50, 1857–1859. 10.1107/S0108270194003999
[16] Frondel, C., Biedl, A., and Ito, J. (1966). New type of ferric iron tourmaline1. *Am. Mineral.*, 51 (9–10), 1501–1505.
[17] Burns, P. C., Hawthorne, F. C., Macdonald, D. J., Dellaventura, G., and Parodi, G. C. (1993). The crystal structure of stillwellite. *Can. Mineral.*, 31, 147–152.
[18] Rulmant, A., and Tarte, P. (1988). Lanthanide borogermanates LnBGeO5: Synthesis and structural study by X-ray diffractometry and vibrational spectroscopy. *J. Solid State Chem.*, 75, 244–250. 10.1016/0022-4596(88)90163-6
[19] Chi, L., Chen, H., Zhuang, H., and Huang, J. (1997). Crystal structure of $LaBSiO_5$. *J. Alloys and Compd.*, 252 (1-2), L12–L15. 10.1016/S0925-8388(96)02625-4
[20] Barbier, J., Penin, N., and Cranswick, L. M. (2005). Melilite-type borates $Bi_2ZnB_2O_7$ and $CaBiGaB_2O_7$. *Chem. Mater.*, 17, 3130–3136. 10.1021/cm0503073
[21] Krzhizhanovskaya, M. G., Bubnova, R. S., Filatov, S. K., Meyer, D. C., and Paufler, P. (2006). Crystal structure and thermal behaviour of $(Rb,Cs)BSi_2O_6$ solid solutions. *Cryst. Res. Technol.*, 41, 285–292. 10.1002/crat.200510575
[22] Palaspagar, R. S., Gawande, A. B., Sonekar, R. P., Omanwar, S. K. (2015). $Eu^{3+} \rightarrow Eu^{2+}$ reduction in $BaAl_2B_2O_7$ phosphor in oxidizing environment, Optik, 126, 5030–5032. 10.1016/j.ijleo.2015.09.056
[23] Miclos, D., Smrcok, L., Durovic, S., Gypesova, D., and Handlovic, M. (1992). Refinement of the structure of boroleucite, $K(BSi_2O_6)$. *Acta. Cryst.*, C41, 1831–1832. 10.1107/S0108270192002270
[24] Mazza, D., and Lucco-Borlera, M. (1997). On the substitution of Fe and B for Al in the pollucite ($CsAlSi_2O_6$) structure. *J. Eur. Ceramic Soc.*, 17, 1767–1772. 10.1016/S0955-2219(96)00245-2
[25] Bubnova, R. S., Levin, A. A., Stepanov, N. K., Belger, A., Meyer, D. C., Polyakova, I. G., Filatov, S. K., and Paufler, P. (2002). Crystal structure of $K_{1-x}Cs_xBSi_2O_6$ (x = 0.12, 0.50) boroleucite solid solutions and thermal behaviour of $KBSi_2O_6$ and $K_{0.5}Cs_{0.5}BSi_2O_6$. *Zeitschrift fur Kristallographie Crystalline Materials*, 217 (2), 55–62.
[26] Voldan, J. (1979). Crystallization of a three-component compound in the system K_2O-SiO_2-B_2O_3. *Silikaty*, 23, 133–135.

[27] Voldan, J. (1981). Crystallization of $Rb_2O \cdot B_2O_3 \cdot {}_4SiO_2$. *Silikaty*, 25, 165–167.
[28] Satava, V., Klouzkova, A., Lezal, D., and Novotna, M. (2002). *Ceramics-Silikity*, 46, 37–40.
[29] Liebau, F. (1985). Crystal Chemical Classification of Silicates: Special Part. In: *Structural Chemistry of Silicates*. Springer, Berlin, Heidelberg. 10.1007/978-3-642-50076-3_7
[30] Palmer, D. C., Dove, M. T., Ibberson, R. M., and Powell, B. M. (1997). Structural behavior, crystal chemistry, and phase transitions in substituted leucite: High-resolution neutron powder diffraction studies. *Am. Mineral.*, 82 (1-2), 16–29. 10.2138/am-1997-1-203
[31] Bigi, S., Brigatti, M. F., and Capedri, S. (1991). Crystal chemistry of Fe- and Cr-rich warwickite. *Am. Mineral.*, 76 (7-8), 1380–1388.
[32] Balaev, A. D., Bayukov, O. A., Vasil′ev, A. D., and Ovchinnikov, S. G., Abd-Elmeguid, M., and Rudenko, V. V. (2003). *J. Exp. Theoretical Phys.*, 79, 989.
[33] Liang, J. K., Xu, T., Yang, Z., Chen, X. L., and Lan, Y. C. (2001). Phase relations in the MgO-Ga_2O_3-B_2O_3 system and crystal structure of $MgGaBO_4$. *J. Alloys Compd.*, 319, 247–252. 10.1016/S0925-8388(01)00871-4
[34] Reynolds, T. A., Peterson, G. A., and Keszler, D. A. (2000). Stoichiometric, trigonal huntite borate $CeSc_3(BO_3)_4$. *Int. J. Inorg. Mater.*, 2, 101–106. 10.1016/S1466-6049(00)00011-8
[35] Couwenberg, I., Binnemans, K., De Leebeeck, H., and Gorller- Walrand, C. (1998). Spectroscopic properties of the trivalent terbium ion in the huntite matrix $TbAl_3(BO_3)_4$. *J. Alloys Compd.*, 274, 157–163. 10.1016/S0925-8388(98)00549-0
[36] Peters, T. E., and Baglio, J. (1970). Luminescence and structural properties of alkaline earth chloroborates activated with divalent europium. *J. Inorg. Nuclear Chem.* 32, 1089–1095. 10.1016/0022-1902(70)80103-8
[37] Ito, T., Morimoto, N., and Sadanaga, R. (1951). The crystal structure of boracite. *Acta Crystallogr.*, 4, 310–316. 10.1107/S0365110X51001033
[38] Campa- Malina, J. Ulloa-Godinez, S., Barrera, A. Bucio, L., and Mata, J. (2006). Nano and micro reoriented domains and their relation with the crystal structure in the new ferroelectric boracite $Zn_3B_7O_{13}Br$. *J. Phys. Condens. Mater.*, 18, 4827. 10.1088/0953-8984/18/20/007
[39] Leonyuk, N. I. (1997). Structural aspects in crystal growth of anhydrous borates. *J. Crystal Growth*, 174, 301–307. 10.1016/S0022-0248(96)01164-5
[40] Leonyuk, N. I., and Leonyuk, L. I. (1983). *Crystal Chemistry of Anhydrous Borates*.
[41] Cheng, W. D., Zhang, H., Zheng, F. K., Chen, J. T., Zhang, Q. E., and Pandey, R. (2000). Electronic structures and linear optics of $A_2B_2O_5$ (A = Mg, Ca, Sr) pyroborates. *Chem. Mater.*, 12, 3591–3594. 10.1021/cm000188l
[42] Corbel, G., Rotoux, R., and Leblanc, M. (1998). Ab initio structure determination of new rare earth fluoride borates $Ln_3(BO_3)_2F_3$(Ln = Sm, Eu, and Gd). *J. Solid State Chem.*, 139, 52–56. 10.1006/jssc.1998.7800
[43] Chaminade, J. P., Gravereau, P., Jubera, V., and Fouassier, C. (1999). A new family of lithium rare-earth oxyborates, $LiLn_6O_5(BO_3)_3$ (Ln = Pr–Tm): Crystal structure of the gadolinium phase $LiGd_6O_5(BO_3)_3$. *J. Solid State Chem.*, 146, 189–196. 10.1006/jssc.1999.8331
[44] Keszler, D. A. (1996). Borates for optical frequency conversion. *Curr. Opin. Solid State Mater. Sci.*, 1, 204–211. 10.1016/S1359-0286(96)80085-4
[45] Becker, P. (1998). Borate materials in nonlinear optics. *Adv. Mater.*, 10, 979–992. 10.1002/(SICI)1521-4095(199809)10:13<979::AID-ADMA979>3.0.CO;2-N
[46] Park, H., and Barbier, J. (2000). Crystal structures of new gallo-borates $MGa_2B_2O_7$, M = Sr, Ba. *J. Solid State Chem.*, 154, 598–602. 10.1006/jssc.2000.8901
[47] Xia, H. R., Jiang, H. D., Gua, M., Wang, J. Y., Wei, J. Q., Hu, X. B., and Liu, Y. G. (2001). Absorption and emission properties of erbium calcium oxyborate crystals. *Opt. Commun.*, 188, 233–238. 10.1016/S0030-4018(00)01168-8
[48] Hinatsu, Y., dai, Y., Ito, K., Wakeshima, M., and Alemi, A. (2003). Magnetic and calorimetric studies on rare-earth iron borates $LnFe_3(BO_3)_4$ (Ln = Y, La–Nd, Sm–Ho). *J. Solid State Chem.*, 172, 438–445. 10.1016/S0022-4596(03)00028-8
[49] Dewey, C. F., Jr., Cook, W. R., Jr., Hodgson, R. T., and Wynne, J. J. (1975). Frequency doubling in $KB_5O_8{\cdot}4H_2O$ and $NH_4B_5O_8{\cdot}4H_2O$ to 217.3 nm. *Appl. Phys. Lett.*, 26, 714. 10.1063/1.88047
[50] Duan, C. J., Li, W. F., Wu, X. Y., Chen, H. H., Yang, X. X., and Zhao, J. T. (2006). Syntheses and X-ray excited luminescence properties of $Ba_3BP_3O_{12}$, $BaBPO_5$ and Ba_3BPO_7. *J. Lumin.*, 117, 83–89. 10.1016/j.jlumin.2005.03.016

[51] Maczka, M., Tomaszewski, P., Stepien Damm, J., Majchrowski, A., Macalik, L., and Hanuza, J. (2004). Crystal structure and vibrational properties of nonlinear Eu_3BWO_9 and Nd_3BWO_9 crystals. *J. Solid State Chem.*, 177, 3595–3602. 10.1016/j.jssc.2004.06.016

[52] Antic- Fidancev, E., Lupai, A., Caramanian, A., and Aka, G. (2004). Spectroscopic study of europium doped RCOB host lattices: Evidence of local perturbations. *J. Alloys Compd.*, 380, 141–145. 10.1016/j.jallcom.2004.03.041

[53] Zhang, Y., and Li, Y. D. (2004). Red photoluminescence properties and crystal structure of sodium rare earth oxyborate. *J. Alloys Compd.*, 370, 99–103. 10.1016/j.jallcom.2003.09.035

[54] Smirnova, R. I., Konopko, L. A., and Ivanenko, L. A. (1969). *Otkrytiya Izobreteniya Bulletin*, 46, 74.

[55] Mordkovich, V. (2000). Photo and cathodoluminescence in cerium-activated yttrium-aluminium borates. *MRS Proceedings*, 621, Q5.1.1. 10.1557/PROC-621-Q5.1.1

[56] Tukia, M., Holsa, J., Lastusaari, M., and Niittykoski, J. (2005). Eu^{3+} doped rare earth orthoborates, RBO_3 (R = Y, La and Gd), obtained by combustion synthesis. *Opt. Mater.*, 27, 1516–1522. 10.1016/j.optmat.2005.01.017

[57] Zhiran, H., and Blasse, G. (1985). Energy transfer phenomena in luminescent materials based on GdB_3O_6. *Mater. Chem. Phys.*, 12, 257–274. 10.1016/0254-0584(85)90096-3

[58] Hair, J. Th. de., and Canijnendijk, W. L. (1980). The intermediate role of Gd^{3+} in the energy transfer from a sensitizer to an activator (Especially Tb^{3+}). *J. Electrochem. Soc.*, 127, 161. 10.1149/1.2129608

[59] Jagannathan, R., Rao, R. P., and Kutty, T. N. R. (1989). Sensitized luminescence of Sm^{3+} in $GdBO_3$. *Mater. Chem. Phys.*, 23, 329–333. 10.1016/0254-0584(89)90075-8

[60] Lee, K. G., Yu, B. Y., Pyun, C. H., and Mho, S. I. (2002). Vacuum ultraviolet excitation and photoluminescence characteristics of $(Y,Gd)Al_3(BO_3)_4/Eu^{3+}$. *Solid State Commun.*, 122, 485–488. 10.1016/S0038-1098(02)00195-3

[61] Wen, F., Li, W., Liu, Z., Kim, T., Yoo, K., Shin, S., Moon, J. H., and Kim, J. H. (2005). Hydrothermal synthesis of Sb^{3+} doped and (Sb^{3+}, Eu^{3+}) co-doped YBO3 with nearly white light luminescence. *Solid State Commun.*, 133, 417–420. 10.1016/j.ssc.2004.12.013

[62] Wang, Y., Endo, T., He, L., and Wu, C. (2004). Synthesis and photoluminescence of Eu^{3+} doped $(Y,Gd)BO_3$ phosphors by a mild hydrothermal process. *J. Cryst. Growth*, 268, 568–574. 10.1016/j.jcrysgro.2004.04.093

[63] Wu, Y., Sasaki, T., Nakai, S., Yokoyani, A., Tang, H., and Chen, C. (1993). CsB_3O_5: A new nonlinear optical crystal. *Appl. Phys. Lett.*, 62, 2614. 10.1063/1.109262

[64] Kagebayashi, Y., Deki, K., Morimoto, Y., Miyazawa, S., and Sasaki, T. (2000). Development of new NLO borate crystals. *Japanese J. Appl. Phys.*, 39 L, 1093. 10.1142/S0218863501000589

[65] Mori, Y., Kuroda, I., Nakajima, S., and Nakai, S. (1995). New nonlinear optical crystal: Cesium lithium borate. *Appl. Phys. Lett.*, 67, 1818. 10.1063/1.115413

[66] Zhang, T., and Yonemura, M. (1997). Properties of $CsLiB_6O_{10}$ and $KBe_2BO_3F_2$ crystals for second-harmonic generation with ultrashort laser pulses. *Japanese J. Appl. Phys.*, 36, 6353. 10.1143/JJAP.36.6353

[67] Mori, Y., Kuroda, I., Nakajima, S., Sasaki, T., and Nakai, S. (1995). Growth of a nonlinear optical crystal: Cesium lithium borate. *Japanese J. Appl. Phys.*, 34, L 296–309. 10.1016/0022-0248(95)00309-6

[68] Nelmes, R. I., (1974). Structural studies of boracites. A review of the properties of boracites. *J. Phys. C: Solid State Phys.*, 7, 3840. 10.1088/0022-3719/7/21/008

[69] Pan, H. F., Liu, M. G., Xue, J., and Lu, B. S. (1990). The spectra and sensitisation of laser self-frequency-doubling $Nd_xY_{1-x}Al_3(BO_3)_4$ crystal. *J. Phys: Condens. Mater.*, 2, 4525. 10.1088/0953-8984/2/19/018

[70] Jaque, D., Capmany, J., and Sole, G. (1997). Optical bands and energy levels of Nd^{3+} ion in the $YAl_3(BO_3)_4$ nonlinear laser crystal. *J.Phys: Condens. Mater.*, 9, 9715. 10.1088/0953-8984/9/44/024

[71] Jaque, D., Capmany, J., Sole, G., DLuo, Z., and Jiang, A. D. (1998). Continuous-wave laser properties of the self-frequency-doubling $YAl_3(BO_3)_4$:Nd crystal. *J. Opt. Soc. Am. B*, 15, 1656–1662. 10.1364/JOSAB.15.001656

[72] Jaque, D., Capmany, J., and Garcia Sole, J. (1999). Red, green, and blue laser light from a single $Nd:YAl_3(BO_3)_4$ crystal based on laser oscillation at 1.3 μm. *Appl. Phys. Lett.*, 75, 325. 10.1063/1.124364

[73] Ji, Y., Liang, J., Xie, S., and Wu, X. (1994). Phase relations in the system BaO-Nd_2O_3-B_2O_3 ($B_2O_3 \geqslant 50$ mol%) and crystal growth of $NdBaB_9O_{16}$. *J. Cryst. Growth*, 137, 521–527. 10.1016/0022-0248(94)90993-8

[74] Luo, Z. D., Zhang, H., Huang, Y. D., Qiu, M. W., Huang, Y. C., Tu, C. Y., and Jiang, A. D. (1989). Study of $Li_6Y(BO_3)_3:Nd^{3+}$ crystal – A new laser crystal. *Chinese Phys. Lett.*, 6, 440. 10.1002/crat.2170260125

[75] Nikolov, V., and Peshev, P. (1994). A new solvent for the growth of $Y_{1-\chi}Nd_\chi Al_3(BO_3)_4$ single crystals from high-temperature solutions. *J. Cryst. Growth*, 144, 187–192. 10.1016/0022-0248(94)90454-5

[76] Jung, S. J., Choi, D., Kang, J. K., and Chung, S. J. (1995). Top-seeded growth of Nd: YAI3(BO3)4 from high temperature solution. *J. Cryst. Growth*, 148, 207–210. 10.1016/0022-0248(94)00873-6

[77] Jaque, D. (2001). Self-frequency-sum mixing in Nd doped nonlinear crystals for laser generation in the three fundamental colours: The NYAB case. *J. Alloys Compd.*, 323–324, 204–209. 10.1016/S0925-8388(01)01111-2

[78] Scripsick, M. P., Fang, X. H., Edwards, G. J., and Halliburton, L. E. (1993). Point defects in lithium triborate (LiB_3O_5) crystals. *J. Appl. Phys.*, 73, 1114. 10.1063/1.353275

[79] Gua, R., Markgraf, S. A., Furukawa, Y., Sato, M., and Bhalla, A. S. (1995). Pyroelectric, dielectric, and piezoelectric properties of LiB_3O_5, *J. Appl. Phys.*, 78, 7234. 10.1063/1.360435

[80] Yangyeng, J., Shuqing, Z., Yujing, H., Hongwu, Z., Ming, L., and Chaoen, H. (1991). Growth of lithium triborate (LBO) single crystal fiber by the laser-heated pedestal growth method. *J. Cryst. Growth*, 112, 283–286. 10.1016/0022-0248(91)90929-Y

[81] Katsumata, T., Ohshima, K., Oe, K., Hisamoto, M., Ohtaki, T., Konoura, H., Nakagawa, H., and Takahashi, K. (1992). Non-wetting container material for growing lithium and barium borate crystals. *J. Cryst. Growth*, 125, 270–280. 10.1016/0022-0248(92)90340-O

[82] Lim, A. R. (1993). Local structure of LiB_3O_5 single crystal from ^7Li nuclear magnetic resonance. *J. Appl. Phys.*, 94 (2003) 5095. 10.1063/1.1607512

[83] Mei, L., Wang, Y., Chen, C., and Wu, B. (1993). Nonlinear optical materials based on $MBe_2BO_3F_2$ (M = Na, K). *J. Appl. Phys.*, 74, 7014. 10.1063/1.355060

[84] Mei, L., Wang, Y., and Chen, C. (1994). Crystal structure of sodium beryllium borate fluoride. *Mater. Res. Bull.*, 29, 81–87. 10.1016/0025-5408(94)90108-2

[85] Keszler, D. A. (1996). Borates for optical frequency conversion. *Curr. Opin. Solid State Mater. Sci.*, 1, 204. 10.1016/S1359-0286(96)80085-4

[86] Smith, R. W., and Keszler, D. A. (1992). The noncentrosymmetric orthoborate $BaZn_2(BO_3)_2$. *J. Solid State Chem.*, 100, 325–330. 10.1016/0022-4596(92)90107-7

[87] Guaitieri, D. M., and Chai, B. H. T. (1989). Growth of β-barium borate from NaCl-Na2O solutions. *J. Cryst. Growth*, 97, 613–616. 10.1016/0022-0248(89)90562-9

[88] Bordui, P. F., Caivert, G. D., and Blachman, R. (1993). Immersion-seeded growth of large barium borate crystals from sodium chloride solution. *J. Cryst. Growth*, 129, 371–374. 10.1016/0022-0248(93)90469-D

[89] Polgar, K., and Peter, A. (1993). Etching study on beta barium metaborate (β-BaB_2O_4) single crystals. *J. Cryst. Growth*, 134, 219. 10.1016/0022-0248(93)90129-K

[90] Aka, G., Mougel, F., Auge, F., Kahn- Harari, A., Vivien, D., Benitez, J. M.., Salin, F., Pelenc, D., Balembois, F., Georges, P., Brun, A., Linain, N., and Jacquet, M. (2000). Overview of the laser and non-linear optical properties of calcium-gadolinium-oxo-borate $Ca_4GdO(BO_3)_3$, *J. Alloys Compd.*, 303–304, 401–408. 10.1016/S0925-8388(00)00648-4

[91] Iwai, M., Kuroda, I., Nakajima, S., Sasaki, T., and Nakai, S. (1997). Crystal growth and optical characterization of rare-Earth (Re) calcium oxyborate $ReCa_4O(BO_3)_3$ (Re = Y or Gd) as new nonlinear optical material. *Japanese J. Appl. Phys.*, 36, L276. 10.1143/JJAP.36.L276

[92] Hu, Z. G., Higashiyama, T., Yoshimura, M., Yap, Y. K., Mori, Y., and Sasaki, T. (1998). A new nonlinear optical borate crystal $K_2Al_2B_2O_7$ (KAB). *Japanese J. Appl. Phys.*, 37, L1093. 10.1143/JJAP.37.L1093

[93] Jiang, H., Li, J., Wang, J., Hu, X. B., Liu, H., Teng, B., Zhang, C. Q., Dekker, P., and Wang, P. (2001). Growth of Yb: $YAl_3(BO_3)_4$ crystals and their optical and self-frequency-doubling properties, *J. Cryst. Growth*, 233, 248–252. 10.1016/S0022-0248(01)01562-7

[94] Teng, B., Wang, J., Wang, Z., Jiang, H., Hu, X., Song, R., Liu, H., Liu, Y., Wei, J., and Shao, Z. (2001). Growth and investigation of a new nonlinear optical crystal: Bismuth borate BiB_3O_6, *J. Cryst. Growth*, 224, 280–283. 10.1016/S0022-0248(01)00975-7

[95] Wang, G., Hna, T. P. J., Gallagher, H. G., and Henderson, B. (1995). Novel laser gain media based on Cr^{3+} doped mixed borates $RX_3(BO_3)_4$. *Appl. Phys. Lett.*, 67, 3906. 10.1063/1.115313
[96] Norrestam, R., Nygren, M., and Bovin, J. O. (1992). Structural investigations of new calcium rare earth (R) oxyborates with the composition $Ca_4RO(BO_3)_3$, *Chem. Mater.*, 4, 737–743. 10.1021/cm00021a044
[97] Thompson, P. D., and Keszler, D. A. (1989). The new strontium scandium borate $Sr_3Sc(BO_3)_3$. *Chem. Mater.*, 1, 292–294. 10.1021/cm00003a004
[98] Thompson, P. D., and Keszler, D. A. (1994). Structure of $Sr_3Sc(BO_3)_3$. *Chem. Mater.*, 6, 2005–2007. 10.1021/cm00047a020
[99] Yan, J. F., and Yang, H. Y. P. (1987). Crystal structure of a new mini-laser material, $Nd_2Ba_3(BO_3)_4$. *Mater. Res. Bull.*, 22, 1347–1353. 10.1016/0025-5408(87)90299-6
[100] Ha, K., and Shi, S. (1988). Optical phonons and fluorescence quenching in new laser crystal nab. *J. Lumin.*, 40–41, 698–699. 10.1016/0022-2313(88)90396-1
[101] Sardar, D. K., and Powell, R. C. (1981). Time-resolved site-selection spectroscopy studies of $NdAl_3(BO_3)_4$ crystals. *J. Lumin.*, 22, 349–358. 10.1016/0022-2313(81)90012-0
[102] Hong, H. Y. P., and Dwight, K. (1974). Crystal structure and fluorescence lifetime of $NdAl_3(BO_3)_4$, a promising laser material. *Mater. Res. Bull.*, 9, 1661–1665. 10.1016/0025-5408(74)90158-5
[103] Wang, G., He, M., and Luo, Z. (1991). Structure of β-$NdAl_3(BO_3)_4$(NAB) crystal. *Mater. Res. Bull.*, 26, 1085–1089. 10.1016/0025-5408(91)90092-Z
[104] Jaque, D., Enguita, O., J., Garcia Sole., Jiang, A. D., and Luo, Z. D. (2000). Infrared continuous-wave laser gain in neodymium aluminum borate: A promising candidate for microchip diode-pumped solid state lasers. *Appl. Phys. Lett.*, 76, 2176. 10.1063/1.126289
[105] Luo, Z. D., Jiang, A. D., Huang, Y., and Qiu, M. (1991). Studies on the self-activated laser crystal:neodymium aluminium borate $NdAl_3(BO_3)_4$. *Sci. China A*, 34, 762–768. 10.1360/ya1991-34-6-762
[106] Chinn, S. R., and Hong, H. Y. P. (1975). CW laser action in acentric $NdAl_3(BO_3)_4$ and $KNdP_4O_{12}$. *Opt. Commun.*, 15, 345–350. 10.1016/0030-4018(75)90242-4
[107] Mougel, F., Auge, F., Aka, G., Kahn-Harari, A., Vivien, D., Balenbois, F., Georges, P., and Brun, A. (1998). New green self-frequency-doubling diode-pumped Nd:$Ca_4GdO(BO_3)_3$ laser. *Appl. Phys. B*, 67, 533–535. 10.1007/s003400050540
[108] Brenier, A., and Kityk, I. V. (2001). Spectroscopic properties of Pr^{3+} doped $Ca_4GdO(BO_3)_3$ (GdCOB). *J. Appl. Phys.*, 90, 232. 10.1063/1.1379779
[109] Aka, G., Reino, E., Loiseau, P., Vivien, D., Ferrand, B., Fulbert, L., Pelenc, D., Lucas-Leclin, G., and Georges, P. (2004). $Ca_4REO(BO_3)_3$ crystals for green and blue microchip laser generation: From crystal growth to laser and nonlinear optical properties. *Opt. Mater.*, 26, 431. 10.1016/j.optmat.2004.02.009
[110] Mougel, F., Aka, G., Kahn-Harari, A., and Vivien, D. (1999). CW blue laser generation by self-sum frequency mixing in Nd:$Ca_4GdO(BO_3)_3$ (Nd:GdCOB) single crystal. *Opt. Mater.*, 13, 293–297. 10.1016/S0925-3467(99)00081-6
[111] Jiang, H., wang, J., Zhang, H., Hu, X., Burns, P., and Piper, J. A. (2002). Spectral and luminescent properties of Yb^{3+} ions in $YCa_4O(BO_3)_3$ crystal. *Chem. Phys. Lett.*, 361, 499–503. 10.1016/S0009-2614(02)00989-2
[112] Long, X., Lin, Z., Hu, Z., Wang, G., and Van, T. P. J. (2002). Optical study of Cr^{3+} doped $LaSc_3(BO_3)_4$ crystal. *J. Alloys Compd.*, 347, 52–55. 10.1016/S0925-8388(02)00785-5
[113] Chen, W., Wang, G., Lin, Z., and Hu, Z. (1999). Spectral parameters of Nd^{3+} ion in β-Nd^{3+}:$LaSc_3(BO_3)_4$ crystal. *Opt. Commun.*, 162, 49–52. 10.1016/S0030-4018(99)00080-2
[114] Chen, W., Wang, G., Lin, Z., and Hu, Z. (1999). Optical transition probability of Nd^{3+} ions in a α-Nd^{3+}:$LaSc_3(BO_3)_4$ crystal. *Phys. Rev.*, B 60, 15469. 10.1103/PhysRevB.60.15469
[115] Meyn, J. P., Jensen, T., and Hubber, G. (1994). Spectroscopic properties and efficient diode-pumped laser operation of neodymium-doped lanthanum scandium borate. *IEEE J. Quantum Electron.*, 30, 913–917. 10.1109/3.291362
[116] Lin, X., Xiong, F., Chen, Y., Gong, X., Liao, J., and Huang, Y. (2005). Growth and spectral properties of Pr^{3+}:LaB_3O_6 single crystal. *J. Cryst. Growth*, 280, 113–117. 10.1016/j.jcrysgro.2005.03.007
[117] Pan, S., Hu, Z., Lin, Z., and Wang, G. (2003). Growth and X-ray diffraction of Nd^{3+} doped $Ba_3Y(BO_3)_3$ crystal. *J. Cryst. Growth*, 247, 452–456. 10.1016/S0022-0248(02)02052-3

[118] Xu, Y., Gong, X., Chen, Y., Huang, M., Luo, Z., and Huang, Y. (2003). Crystal growth and optical properties of YbAl3(BO3)4: A promising stoichiometric laser crystal, *J. Cryst. Growth*, 252, 241. 10.1016/S0022-0248(03)00863-7

[119] Leonyuk, N. I., Kaporulina, E. V., Maltsev, V. V., Pilipenko, O. V., Melekhova, M. D., and Mokhov, A. V. (2004). Crystal growth and characterization of $YAl_3(BO_3)_4$ doped with Sc, Ga, Pr, Ho, Tm, Yb. *Opt. Mater.*, 26, 443–447. 10.1016/j.optmat.2003.09.010

[120] Zhang, Y., Lin, Z., Hu, Z., and Wang, G. (2005). Growth and spectroscopic properties of Yb^{3+}:$Gd_{0.5}Y_{0.5}Ca_4O(BO_3)_3$ crystal. *J. Alloys Compd.*, 390, 194–196. 10.1016/j.jallcom.2004.07.058

[121] Zhao, D., Hu, Z., Hu, Z., Lin, Z., and Wang, G. (2005). Growth and spectral properties of Er^{3+}/Yb^{3+} codoped $Sr_3Y(BO_3)_3$ crystal. *J. Cryst. Growth*, 277, 401–405. 10.1016/j.jcrysgro.2005.01.081

[122] Pan, J., Lin, Z., Hu, Z., Zhang, L., and Wang, G. (2006). Crystal growth and spectral properties of Yb^{3+}:$Sr_3La_2(BO_3)_4$ crystal. *Opt. Mater.*, 28, 250–254. 10.1016/j.optmat.2004.12.019

[123] Pan, J., Wu, S., and Wang, G. (2006). Crystal growth and spectral properties of Nd^{3+}:$Sr_3Gd(BO_3)_3$ crystal. *Opt. Mater.*, 28, 391–394. 10.1016/j.optmat.2004.12.022

[124] Smet, B. M. J. (1987). Phosphors based on rare-earths, a new era in fluorescent lighting. *Mater. Chem. Phys.*, 16, 283–299. 10.1016/0254-0584(87)90103-9

[125] Ronda, C. R., Justel, T., and Nikol, H. (1998). Rare earth phosphors: Fundamentals and applications. *J. Alloys Compd.*, 275–277, 669–676. 10.1016/S0925-8388(98)00416-2

[126] Aron, A., Tigreat, P. Y., Caramanian, A., and Antic- Fidancev, E. (2000). Infrared and visible emission of Pr^{3+}, Eu^{3+}, Yb^{3+}/Er^{3+} in $Ca_4Gd(BO_3)_3O$ (GdCOB). *J. Lumin.*, 87–89, 611–613. 10.1016/S0022-2313(99)00328-2

[127] Duan, C. J., Chen, H. H., Yang, X. X., and Zhao, J. T. (2006). Luminescence properties of Eu^{3+}, Tb^{3+} or Tm^{3+} activated $Ca_4GdO(BO_3)_3$ under X-ray and UV excitation. *Opt. Mater.*, 28, 956–961. 10.1016/j.optmat.2005.05.005

[128] Zhang, Y., and Li, Y. (2005). Photo-luminescent properties of Eu^{3+} ion-doped $Ca_4REO(BO_3)_3$ (RE double bond La,Y,Gd). *J. Lumin.*, 113, 45–49. 10.1016/j.jlumin.2004.08.051

[129] Guo, F., and Peng, Y. (1988). Photoluminescence of terbium ion in the binary system of GdB_3O_6 – CeB_3O_6. *J. Lumin.*, 40–41, 175–176. 10.1016/0022-2313(88)90144-5

[130] Nakamura, T., Takeyama, T., Takahashi, N., Jagannathan, R., Karthikeyani, A., Smith, G. M., and Riedi, P. C. (2003). High-frequency EPR investigation of X-ray storage $SrBPO_5$:Eu phosphor. *J. Lumin.*, 102–103, 369–372. 10.1016/S0022-2313(02)00537-9

[131] Karthikeyani, A., and Jagannathan, R. (2000). Eu^{2+} luminescence in stillwellite-type $SrBPO_5$ – A new potential X-ray storage phosphor. *J. Lumin.*, 86, 79–85. 10.1016/S0022-2313(99)00171-4

[132] Risheng, C., Jinggen, H., Ling, L., and Yan, X. (1988). Study of the new boron-rich calcium rare earth borate $CaLnB_7O_{13}$. *Mater. Res. Bull.*, 23, 1699–1704. 10.1016/0025-5408(88)90178-X

[133] Datchi, F., Le Toyllec, R., and Loubeyre, P. (1997). Improved calibration of the SrB_4O_7:Sm^{2+} optical pressure gauge: Advantages at very high pressures and high temperatures. *J. Appl. Phys.*, 81, 3333. 10.1063/1.365025

[134] Lu, C. H., Godbole, S. V., and Natarajan, V. (2005). Luminescence characteristics of strontium borate phosphate phosphors. *Mater. Chem. Phys.*, 94, 73–77. 10.1016/j.matchemphys.2005.04.011

[135] Dotsenko, V. P. (2000). Rapid synthesis of nanoscale colloidal metal clusters by microwave irradiation. *J. Mater. Chem.*, 10, 9. 10.1039/B002232M

[136] Dotsenko, V. P., berezovskaya, I. V., Efryushina, N. P., Voloshinovskii, A. S., Dorenbos, P., and van Eijk, C. W. E. (2001). Luminescence of Ce^{3+} ions in strontium haloborates, *J. Lumin.*, 93, 137–145. 10.1016/S0022-2313(01)00179-X

[137] Sidorenko, A. V., Bos, A. J. J., Dorenbos, P., van Eijk, C. W. E., Rodnyi, P. A., berezovskaya, I. V., Dotsenko, V. P., Guillot- Noel, O., and Gourier, D. (2004). Radiation induced defects in $Sr_2B_5O_9Br$:Ce^{3+} storage phosphor, *J. Phys: Condens. Mater.*, 16, 4131. 10.1088/0953-8984/16/23/027

[138] Z., Pei, Zeng, Q., and Su, Q. (2000). The application and a substitution defect model for $Eu^{3+} \rightarrow Eu^{2+}$ reduction in non-reducing atmospheres in borates containing BO_4 anion groups. *J. Phys. Chem. Solids*, 61, 9–12. 10.1016/S0022-3697(99)00237-1

[139] Keszler, D. A. (1999). Synthesis, crystal chemistry, and optical properties of metal borates. *Curr. Opin. Solid State Mater. Sci.*, 4, 155–162. 10.1016/S1359-0286(99)00011-X

[140] Mc Carthy, G. J., and White, W. B. (1970). On the stabilities of the lower oxides of the rare earths. *J. Less Common Metals*, 22, 409–417. 10.1016/0022-5088(70)90128-1

[141] Machida, K., Adachi, G., and Shiokava, J. (1979). Luminescence properties of Eu(II)-borates and Eu^{2+} activated Sr-Borates. *J. Lumin.*, 21, 101–110. 10.1016/0022-2313(79)90038-3
[142] Peters, T. E., and Baglio, J. (1970). *Inog J. Nucl. Chem.*, 32, 1083.
[143] Diaz, A., and Keszler, D. A. (1996). Red, green, and blue Eu^{2+} luminescence in solid-state borates: A structure-property relationship. *Mater. Res. Bull.*, 31, 147–151. 10.1016/0025-5408(95)00182-4
[144] Pei, Z. Zeng, Q., and Su, Q. (1999). A study on the mechanism of the abnormal reduction of $Eu^{3+} \rightarrow Eu^{2+}$ in $Sr_2B_5O_9Cl$ prepared in air at high temperature. *J. Solid State Chem.*, 145, 212–215. 10.1006/jssc.1999.8246
[145] Zhao, J., and Cocivera, M. (2001). Luminescent characteristics of blue-emitting $Sr_2B_5O_9Cl$: Eu thin-film phosphors. *Appl. Phys. Lett.*, 79, 740. 10.1063/1.1391410
[146] Jiang, Y. D., Zhang, F., Summers, C. J., and Wang, Z. I. (1999). Synthesis and properties of Sr_2CeO_4 blue emission powder phosphor for field emission displays. *Appl. Phys. Lett*, 74, 1677. 10.1063/1.123652
[147] Kumar, D., Sankar, J., Cho, K. G., Cracium, V., and Singh, R. K. (2000). Enhancement of cathodoluminescent and photoluminescent properties of Eu:Y_2O_3 luminescent films by vacuum cooling. *Appl. Phys. Lett.*, 77, 2518. 10.1063/1.1318938
[148] Meijrink, A., and Blasse, G. (1991). Photostimulated luminescence and thermally stimulated luminescence of some new X-ray storage phosphors. *J. Phys. D: Appl. Phys.*, 24, 626. 10.1088/0022-3727/24/4/016
[149] Verstgen, J. M. P. J., Ter Vrugt, J. W., and Wanmaker, W. L. (1972). Luminescence of Eu^{2+}-activated $SrB_2Si_2O_8$. *J. Inorg. Nucl. Chem.*, 34, 3588.
[150] Welkar, T. (1991). Recent developments on phosphors for fluorescent lamps and cathode-ray tubes. *J. Lumin.*, 48–49, 49–56. 10.1016/0022-2313(91)90075-7
[151] Diang, S. J., Zhang, D. W., Wang, P. F., and Wang, J. J. (2001). Preparation and photoluminescence of the Ce, Tb and Gd-doped lanthanum borophosphate phosphor. *Mater. Chem. Phys.*, 68, 98–104. 10.1016/S0254-0584(00)00300-X
[152] Hao, J., Gao, J., and Cocivera, M. (2015). Stimuli responsive upconversion luminescence nanomaterials and films for various applications. *Appl. Phys. Lett.*, 44, 1585–1607. 10.1039/C4CS00171K
[153] Hao, J., Gao, J., and Cocivera, M. (2003). *Appl. Phys. Lett.*, 82, 2778.
[154] Hao, J., and Cocivera, M. (2001). *Appl. Phys. Lett.*, 79, 740.
[155] Hao, J., and Cocivera, M. (2001). *Appl. Phys. Lett.*, 81, 4154.
[156] Wei, Z. G., Sun, L. D., Jiang, X. C., Liao, C. S., and Yan, C. H. (2003). Correlation between size-dependent luminescent properties and local structure around Eu^{3+} ions in YBO_3:Eu nanocrystals: An XAFS study. *Chem. Mater.*, 15, 3011–3017. 10.1021/cm0341888
[157] Yang, Z., Ren, M., Lin, J. H., Su, M. Z., Tao, T., and Wang, W. (2004). Ordered Nanosheet-based YBO_3:Eu^{3+} assemblies: Synthesis and tunable luminescent properties. *J. Phys. Chem. B*, 108, 11, 3387–3390. 10.1021/jp037301q
[158] Wei, Z. G., Sun, L. D., Liao, C. S., Jiang, X. C., and Yan, C. H. (2003). Size dependence of luminescent properties for hexagonal YBO_3:Eu nanocrystals in the vacuum ultraviolet region. *J. Appl. Phys.*, 93, 9783. 10.1063/1.1575496
[159] Jiang, C., Yan, C. H., Sun, L. D., Wei, Z. G., and Liao, C. S. Hydrothermal homogeneous urea precipitation of hexagonal YBO_3:Eu^{3+} nanocrystals with improved luminescent properties. *J. Solid State Chem.*, 175 (2003) 245-151. 10.1016/S0022-4596(03)00276-7
[160] Li, J., Wang, J., Tan, H., Cheng, X., Song, F., Zhang, H., and Zhao, S. (2003). Growth and optical properties of Ho,Yb:$YAl_3(BO_3)_4$ crystal. *J. Cryst. Growth*, 256, 324–327. 10.1016/S0022-0248(03)01370-8
[161] Liang, H., Zeng, Q., Tao, Y., Wang, S., and Su, Q. (2003). VUV-UV excited luminescent properties of calcium borophosphate doped with rare earth ions. *Mater. Sci. Eng.*, B98, 213–219. 10.1016/S0921-5107(03)00034-5
[162] Boyer, D., Bertrand-Chadeyran, G., Mahiou, R., Brioude, A., and Mugnier, J. (2003). Synthesis and characterization of sol–gel derived Y_3BO_6:Eu^{3+} powders and films. *Opt. Mater.*, 24, 35–41. 10.1016/S0925-3467(03)00102-2
[163] Kwon, I. E., Yu, B. Y., Bae, H., Hwang, Y. J., Kwon, T. W., Kim, C. H., Pyun, C. H., and Kim, S. J. (2000). Luminescence properties of borate phosphors in the UV/VUV region. *J. Lumin.*, 87–89, 1039–1041. 10.1016/S0022-2313(99)00532-3

[164] Kang, Y. C., and Park, S. B. (1999). Morphology of $(Y_xGd_{1-x})BO_3$:Eu phosphor particles prepared by spray pyrolysis from aqueous and colloidal solutions. *Japanese J.Appl. Phys.*, 38, L 1541. 10.1143/JJAP.38.L1541

[165] Ronda, C. R. (1997). Recent achievements in research on phosphors for lamps and displays. *J. Lumin.*, 72-74, 49–54. 10.1016/S0022-2313(96)00374-2

[166] Kim, D. S., and Lee, R. Y. (2000). Synthesis and photoluminescence properties of $(Y,Gd)BO_3$: Eu phosphor prepared by ultrasonic spray. *J. Mater. Sci.*, 35, 4777–4782. 10.1023/A:1004864426980

[167] Justel, T., Krupa, J. C., and Wiechert, D. U. (2001). VUV spectroscopy of luminescent materials for plasma display panels and Xe discharge lamps. *J. Lumin.*, 93, 179–189. 10.1016/S0022-2313(01)00199-5

[168] Yu, Z., Huang, X., Zhung, W., Cui, X., and Li, H. (2005). Crystal structure transformation and luminescent behavior of the red phosphor for plasma display panels. *J. Alloys Compd.*, 390, 220–222. 10.1016/j.jallcom.2004.07.065

[169] Sohn, J. R., Kang, Y. C., Park, H. D., and Yoon, S. G. (2002). $(YGd)BO_3$:Eu phosphor particles prepared from the solution of polymeric precursors by spray pyrolysis. *Japanese J. Appl. Phys.*, 41, 6007. 10.1143/JJAP.41.6007

[170] Wei, Z. G., Sun, L. D., Liao, C. S., Cheng Jiang, X. C., and Yan, C. H. (2002). Synthesis and size dependent luminescent properties of hexagonal $(Y,Gd)BO_3$:Eu nanocrystals. *J. Mater. Chem.*, 12, 3665–3670. 10.1039/B207103G

[171] Jeoung, B. W., Hong, G. Y., Yoo, W. T., and Yoo, J. S. (2004). Preparation of spherical phosphor $(Y,Gd)BO_3$:Eu by polymeric-aerosol pyrolysis. *J. Electrochem. Soc.*, 151, H213. 10.1149/1.1790513

[172] Gupta, S. K., Agrawal, D. C., and Mahapatra, Y. N. (2004). Photoluminescence and morphological studies of $(Y_{0.5}Gd_{0.5})BO_3$:Eu phosphor powders prepared by the urea hydrolysis route. *J. Electrochem. Soc.*, 151, H239. 10.1149/1.1804814

[173] Sano, H., Matsumoto, T., Matsumoto, Y., and Koinuma, H. (2005). *Appl. Phys. Lett.*, 86, 21124.

[174] Park, W., Lee, R. Y., Summer, C. J., Do, Y. R., and Yang, H. G. Photoluminescence properties of $Al_3GdB_4O_{12}$:Eu phosphors, *Mater. Sci. Eng.*, B78, 28–31. 10.1016/S0921-5107(00)00509-2

[175] Wang, Y., Uheda, K., Takizawa, H., Mizumoto, U., and Endo, T. (2001). Synthesis of $Gd_{1-x}Eu_xAl_3(BO_3)_4$ $(0 < x \leq 1)$ and its photoluminescence properties under UV and vacuum ultraviolet regions. *J. Electrochem. Soc.*, 148, G430. 10.1149/1.1383778

[176] Lee, K. G., Yu, B. Y., Pyun, C. H., and Mho, Sun-II. (2002). Vacuum ultraviolet excitation and photoluminescence characteristics of $(Y,Gd)Al_3(BO_3)_4/Eu^{3+}$. *Solid State Commun.*, 22, 485–488. 10.1016/S0038-1098(02)00195-3

[177] Hongpeng, Y., Hong, G., Zeng, X., Pyun, C. H., Yu, B. Y., and Bae, H. S. (2000). VUV excitation properties of $LnAl_3B_4O_{12}$:Re (Ln = Y, Gd; Re = Eu, Tb). *J. Phys. Chem. Solids*, 61, 1985–1988. 10.1016/S0022-3697(00)00192-X

[178] Tian, L., You, B. Y., Pyun, C. H., Park, H. L., and Mho, Sun-il. (2004). New red phosphors $BaZr(BO_3)_2$ and $SrAl_2B_2O_7$ doped with Eu^{3+} for PDP applications. *Solid State Commun.*, 129, 43–46. 10.1016/j.ssc.2003.09.012

[179] Tian, L., Kim, S. J., Park, H. L., and Mho, S. I. (2006). Variation of the photoluminescence and vacuum ultraviolet excitation characteristics of $BaZr(BO_3)_2:Eu^{3+}$ by the incorporation of Al^{3+}, La^{3+}, or Y^{3+} into the lattice. *Mater. Res. Bull.*, 41, 29–37. 10.1016/j.materresbull.2005.07.039

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Seitz, F. , Gorton, R. , and Schulman, J. H. (1948). Luminescent Crystals. In: Preparation and characteristics of Solid Luminescent Materials. Pub: John Wiley & Sons, inc, NY, 1, 28. 10.1063/1.3066240

Blasse, G. , and Grabmaier, B. C. (1994). How Does a Luminescent Material Absorb Its Excitation Energy?. In: Luminescent Materials. Springer, Berlin, Heidelberg. 10.1007/978-3-642-79017-1_2

Seitz, F. , (1948). In: 'Luminescent Crystals', Preparation and characteristics of Solid Luminescent Materials, Symp. Cornell Univ., John Wiley & Sons, INC, NY, 9

Johnson, R. P. (1939). Luminescence of sulphide and silicate phosphors. J. Opt. Soc. Am., 29, 387–391. 10.1364/JOSA.29.000387

Johnson, R. P. (1939). Decay of Willemite and zinc sulphide phosphors. Phys. Rev., 55, 881. 10.1103/PhysRev.55.881

Blasse G. , and Grabmaier B. C. (1994) A General Introduction to Luminescent Materials. In: Luminescent Materials. Springer, Berlin, Heidelberg. 10.1007/978-3-642-79017-1_1

Justel, T. , Nikol, H. , and Ronda, C. (1998). New developments in the field of luminescent materials for lighting and displays. Angew. Chem. Int. Ed., 37, 3084–3103. 10.1002/(SICI)15213773(19981204)37:22 <3084::AID-ANIE3084>3.0.CO;2-W

Mitschke, U. , and Bauerle, P. (2000). The electroluminescence of organic materials. J. Mater. Chem., 10, 1471–1507. 10.1039/A908713C

Li, H. , Inoue, S. , Machida, K. , and Adachi, G. (1999). Preparation and luminescence properties of organically modified silicate composite phosphors doped with an europium(III) β-diketonate complex. Chem. Mater., 11, 3171–3176. 10.1021/cm990251a

Antic-Fidance, E. , Lemaitre-Blaise, M. , Chaminade, J. , and Porcher, P. (1992). Luminescence and crystal field calculation of aragonite-type LaBO3:Eu3+ . J. Alloys Compd., 180, 223–228. 10.1016/0925-8388(92)90384-L

Levin, E. M. , Roth, R. S. , and Martin, J. B. (1961). Polymorphism of ABO3 type rare earth borates. Am. Mineral., 46 (9-10), 1030–1055.

Weidelt, J. , and Bambauer, H. U. (1968). Ein mit Aragonit isotypes Cerborat. Die Naturwissenschaften, 342–342. 10.1007/BF00600458

Chadeyron, C. , El- Ghozzi, M. , Mahiou, R. , Arbus, A. , and Cousseins, J. C. (1997). Revised structure of the orthoborate YBO3 . J. Solid State Chem., 128, 261–266. 10.1006/jssc.1996.7207

Chaminade, J. P. , Garcia, A. , Pouchard, M. , Fouassier, C. , Jacquier, B. , Perret-Gallix, D. , and Gonzalez-Mestres, L. (1990). Crystal growth and characterization of InBO3: Tb3+ . J. Cryst. Growth, 99, 799–804. 10.1016/S0022-0248(08)80029-2

Cox, J. and Keszler, D. A. (1994). InBO3 . Acta. Cryst., C50, 1857–1859. 10.1107/S0108270194003999

Frondel, C. , Biedl, A. , and Ito, J. (1966). New type of ferric iron tourmaline1. Am. Mineral., 51 (9–10), 1501–1505.

Burns, P. C. , Hawthorne, F. C. , Macdonald, D. J. , Dellaventura, G. , and Parodi, G. C. (1993). The crystal structure of stillwellite. Can. Mineral., 31, 147–152.

Rulmant, A. , and Tarte, P. (1988). Lanthanide borogermanates LnBGeO5: Synthesis and structural study by X-ray diffractometry and vibrational spectroscopy. J. Solid State Chem., 75, 244–250. 10.1016/0022-4596(88)90163-6

Chi, L. , Chen, H. , Zhuang, H. , and Huang, J. (1997). Crystal structure of LaBSiO5 . J. Alloys and Compd., 252 (1-2), L12–L15. 10.1016/S0925-8388(96)02625-4

Barbier, J. , Penin, N. , and Cranswick, L. M. (2005). Melilite-type borates Bi2ZnB2O7 and CaBiGaB2O7 . Chem. Mater., 17, 3130–3136. 10.1021/cm0503073

Krzhizhanovskaya, M. G. , Bubnova, R. S. , Filatov, S. K. , Meyer, D. C. , and Paufler, P. (2006). Crystal structure and thermal behaviour of (Rb,Cs)BSi2O6 solid solutions. Cryst. Res. Technol., 41, 285–292. 10.1002/crat.200510575

Palaspagar, R. S. , Gawande, A. B. , Sonekar, R. P. , Omanwar, S. K. (2015). Eu3+→Eu2+ reduction in BaAl2B2O7 phosphor in oxidizing environment, Optik, 126, 5030–5032. 10.1016/j.ijleo.2015.09.056

Miclos, D. , Smrcok, L. , Durovic, S. , Gypesova, D. , and Handlovic, M. (1992). Refinement of the structure of boroleucite, K(BSi2O6). Acta. Cryst., C41, 1831–1832. 10.1107/S0108270192002270

Mazza, D. , and Lucco-Borlera, M. (1997). On the substitution of Fe and B for Al in the pollucite (CsAlSi2O6) structure. J. Eur. Ceramic Soc., 17, 1767–1772. 10.1016/S0955-2219(96)00245-2

Bubnova, R. S. , Levin, A. A. , Stepanov, N. K. , Belger, A. , Meyer, D. C. , Polyakova, I. G. , Filatov, S. K. , and Paufler, P. (2002). Crystal structure of K1-xCsxBSi2O6 (x = 0.12, 0.50) boroleucite solid solutions and thermal behaviour of KBSi2O6 and K0.5Cs0.5BSi2O6 . Zeitschrift fur Kristallographie Crystalline Materials, 217 (2), 55–62.

Voldan, J. (1979). Crystallization of a three-component compound in the system K2O-SiO2-B2O3 . Silikaty, 23, 133–135.

Voldan, J. (1981). Crystallization of Rb2O · B2O3 · 4SiO2 . Silikaty, 25, 165–167.

Satava, V. , Klouzkova, A. , Lezal, D. , and Novotna, M. (2002). Ceramics-Silikity, 46, 37–40.

Liebau, F. (1985). Crystal Chemical Classification of Silicates: Special Part. In: Structural Chemistry of Silicates. Springer, Berlin, Heidelberg. 10.1007/978-3-642-50076-3_7
Palmer, D. C. , Dove, M. T. , Ibberson, R. M. , and Powell, B. M. (1997). Structural behavior, crystal chemistry, and phase transitions in substituted leucite: High-resolution neutron powder diffraction studies. Am. Mineral., 82 (1-2), 16–29. 10.2138/am-1997-1-203
Bigi, S. , Brigatti, M. F. , and Capedri, S. (1991). Crystal chemistry of Fe- and Cr-rich warwickite. Am. Mineral., 76 (7-8), 1380–1388.
Balaev, A. D. , Bayukov, O. A. , Vasil′ev, A. D. , and Ovchinnikov, S. G. , Abd-Elmeguid, M. , and Rudenko, V. V. (2003). J. Exp. Theoretical Phys., 79, 989.
Liang, J. K. , Xu, T. , Yang, Z. , Chen, X. L. , and Lan, Y. C. (2001). Phase relations in the MgO-Ga2O3-B2O3 system and crystal structure of MgGaBO4 . J. Alloys Compd., 319, 247–252. 10.1016/S0925-8388(01)00871-4
Reynolds, T. A. , Peterson, G. A. , and Keszler, D. A. (2000). Stoichiometric, trigonal huntite borate CeSc3(BO3)4 . Int. J. Inorg. Mater., 2, 101–106. 10.1016/S1466-6049(00)00011-8
Couwenberg, I. , Binnemans, K. , De Leebeeck, H. , and Gorller- Walrand, C. (1998). Spectroscopic properties of the trivalent terbium ion in the huntite matrix TbAl3(BO3)4 . J. Alloys Compd., 274, 157–163. 10.1016/S0925-8388(98)00549-0
Peters, T. E. , and Baglio, J. (1970). Luminescence and structural properties of alkaline earth chloroborates activated with divalent europium. J. Inorg. Nuclear Chem. 32, 1089–1095. 10.1016/0022-1902(70)80103-8
Ito, T. , Morimoto, N. , and Sadanaga, R. (1951). The crystal structure of boracite. Acta Crystallogr., 4, 310–316. 10.1107/S0365110X51001033
Campa- Malina, J. Ulloa-Godinez, S. , Barrera, A. Bucio, L. , and Mata, J. (2006). Nano and micro reoriented domains and their relation with the crystal structure in the new ferroelectric boracite Zn3B7O13Br. J. Phys. Condens. Mater., 18, 4827. 10.1088/0953-8984/18/20/007
Leonyuk, N. I. (1997). Structural aspects in crystal growth of anhydrous borates. J. Crystal Growth, 174, 301–307. 10.1016/S0022-0248(96)01164-5
Leonyuk, N. I. , and Leonyuk, L. I. (1983). Crystal Chemistry of Anhydrous Borates.
Cheng, W. D. , Zhang, H. , Zheng, F. K. , Chen, J. T. , Zhang, Q. E. , and Pandey, R. (2000). Electronic structures and linear optics of A2B2O5 (A = Mg, Ca, Sr) pyroborates. Chem. Mater., 12, 3591–3594. 10.1021/cm000188l
Corbel, G. , Rotoux, R. , and Leblanc, M. (1998). Ab initio structure determination of new rare earth fluoride borates Ln3(BO3)2F3(Ln = Sm, Eu, and Gd). J. Solid State Chem., 139, 52–56. 10.1006/jssc.1998.7800
Chaminade, J. P. , Gravereau, P. , Jubera, V. , and Fouassier, C. (1999). A new family of lithium rare-earth oxyborates, LiLn6O5(BO3)3 (Ln = Pr–Tm): Crystal structure of the gadolinium phase LiGd6O5(BO3)3 . J. Solid State Chem., 146, 189–196. 10.1006/jssc.1999.8331
Keszler, D. A. (1996). Borates for optical frequency conversion. Curr. Opin. Solid State Mater. Sci., 1, 204–211. 10.1016/S1359-0286(96)80085-4
Becker, P. (1998). Borate materials in nonlinear optics. Adv. Mater., 10, 979–992. 10.1002/(SICI)1521-4095(199809)10:13<979::AID-ADMA979>3.0.CO;2-N
Park, H. , and Barbier, J. (2000). Crystal structures of new gallo-borates MGa2B2O7, M = Sr, Ba. J. Solid State Chem., 154, 598–602. 10.1006/jssc.2000.8901
Xia, H. R. , Jiang, H. D. , Gua, M. , Wang, J. Y. , Wei, J. Q. , Hu, X. B. , and Liu, Y. G. (2001). Absorption and emission properties of erbium calcium oxyborate crystals. Opt. Commun., 188, 233–238. 10.1016/S0030-4018(00)01168-8
Hinatsu, Y. , dai, Y. , Ito, K. , Wakeshima, M. , and Alemi, A. (2003). Magnetic and calorimetric studies on rare-earth iron borates LnFe3(BO3)4 (Ln = Y, La–Nd, Sm–Ho). J. Solid State Chem., 172, 438–445. 10.1016/S0022-4596(03)00028-8
Dewey, C. F., Jr. , Cook, W. R., Jr. , Hodgson, R. T. , and Wynne, J. J. (1975). Frequency doubling in KB5O84H2O and NH4B5O84H2O to 217.3 nm. Appl. Phys. Lett., 26, 714. 10.1063/1.88047
Duan, C. J. , Li, W. F. , Wu, X. Y. , Chen, H. H. , Yang, X. X. , and Zhao, J. T. (2006). Syntheses and X-ray excited luminescence properties of Ba3BP3O12, BaBPO5 and Ba3BPO7 . J. Lumin., 117, 83–89. 10.1016/j.jlumin.2005.03.016
Maczka, M. , Tomaszewski, P. , Stepien Damm, J. , Majchrowski, A. , Macalik, L. , and Hanuza, J. (2004). Crystal structure and vibrational properties of nonlinear Eu3BWO9 and Nd3BWO9 crystals. J. Solid State Chem., 177, 3595–3602. 10.1016/j.jssc.2004.06.016
Antic- Fidancev, E. , Lupai, A. , Caramanian, A. , and Aka, G. (2004). Spectroscopic study of europium doped RCOB host lattices: Evidence of local perturbations. J. Alloys Compd., 380, 141–145. 10.1016/j.jallcom.2004.03.041
Zhang, Y. , and Li, Y. D. (2004). Red photoluminescence properties and crystal structure of sodium rare earth oxyborate. J. Alloys Compd., 370, 99–103. 10.1016/j.jallcom.2003.09.035
Smirnova, R. I. , Konopko, L. A. , and Ivanenko, L. A. (1969). Otkrytiya Izobreteniya Bulletin, 46, 74.
Mordkovich, V. (2000). Photo and cathodoluminescence in cerium-activated yttrium-aluminium borates. MRS Proceedings, 621, Q5.1.1. 10.1557/PROC-621-Q5.1.1

Tukia, M. , Holsa, J. , Lastusaari, M. , and Niittykoski, J. (2005). Eu3+ doped rare earth orthoborates, RBO3 (R = Y, La and Gd), obtained by combustion synthesis. Opt. Mater., 27, 1516–1522. 10.1016/j.optmat.2005.01.017

Zhiran, H. , and Blasse, G. (1985). Energy transfer phenomena in luminescent materials based on GdB3O6 . Mater. Chem. Phys., 12, 257–274. 10.1016/0254-0584(85)90096-3

Hair, J. Th. de. , and Canijnendijk, W. L. (1980). The intermediate role of Gd3+ in the energy transfer from a sensitizer to an activator (Especially Tb3+). J. Electrochem. Soc., 127, 161. 10.1149/1.2129608

Jagannathan, R. , Rao, R. P. , and Kutty, T. N. R. (1989). Sensitized luminescence of Sm3+ in GdBO3 . Mater. Chem. Phys., 23, 329–333. 10.1016/0254-0584(89)90075-8

Lee, K. G. , Yu, B. Y. , Pyun, C. H. , and Mho, S. I. (2002). Vacuum ultraviolet excitation and photoluminescence characteristics of (Y,Gd)Al3(BO3)4/Eu3+ . Solid State Commun., 122, 485–488. 10.1016/S0038-1098(02)00195-3

Wen, F. , Li, W. , Liu, Z. , Kim, T. , Yoo, K. , Shin, S. , Moon, J. H. , and Kim, J. H. (2005). Hydrothermal synthesis of Sb3+ doped and (Sb3+, Eu3+) co-doped YBO3 with nearly white light luminescence. Solid State Commun., 133, 417–420. 10.1016/j.ssc.2004.12.013

Wang, Y. , Endo, T. , He, L. , and Wu, C. (2004). Synthesis and photoluminescence of Eu3+ doped (Y,Gd)BO3 phosphors by a mild hydrothermal process. J. Cryst. Growth, 268, 568–574. 10.1016/j.jcrysgro.2004.04.093

Wu, Y. , Sasaki, T. , Nakai, S. , Yokoyani, A. , Tang, H. , and Chen, C. (1993). CsB3O5: A new nonlinear optical crystal. Appl. Phys. Lett., 62, 2614. 10.1063/1.109262

Kagebayashi, Y. , Deki, K. , Morimoto, Y. , Miyazawa, S. , and Sasaki, T. (2000). Development of new NLO borate crystals. Japanese J. Appl. Phys., 39 L, 1093. 10.1142/S0218863501000589

Mori, Y. , Kuroda, I. , Nakajima, S. , and Nakai, S. (1995). New nonlinear optical crystal: Cesium lithium borate. Appl. Phys. Lett., 67, 1818. 10.1063/1.115413

Zhang, T. , and Yonemura, M. (1997). Properties of CsLiB6O10 and KBe2BO3F2 crystals for second-harmonic generation with ultrashort laser pulses. Japanese J. Appl. Phys., 36, 6353. 10.1143/JJAP.36.6353

Mori, Y. , Kuroda, I. , Nakajima, S. , Sasaki, T. , and Nakai, S. (1995). Growth of a nonlinear optical crystal: Cesium lithium borate. Japanese J. Appl. Phys., 34, L 296–309. 10.1016/0022-0248(95)00309-6

Nelmes, R. I. , (1974). Structural studies of boracites. A review of the properties of boracites. J. Phys. C: Solid State Phys., 7, 3840. 10.1088/0022-3719/7/21/008

Pan, H. F. , Liu, M. G. , Xue, J. , and Lu, B. S. (1990). The spectra and sensitisation of laser self-frequency-doubling NdxY1-xAl3(BO3)4 crystal. J. Phys: Condens. Mater., 2, 4525. 10.1088/0953-8984/2/19/018

Jaque, D. , Capmany, J. , and Sole, G. (1997). Optical bands and energy levels of Nd3+ ion in the YAl3(BO3)4 nonlinear laser crystal. J.Phys: Condens. Mater., 9, 9715. 10.1088/0953-8984/9/44/024

Jaque, D. , Capmany, J. , Sole, G. , DLuo, Z. , and Jiang, A. D. (1998). Continuous-wave laser properties of the self-frequency-doubling YAl3(BO3)4:Nd crystal. J. Opt. Soc. Am. B, 15, 1656–1662. 10.1364/JOSAB.15.001656

Jaque, D. , Capmany, J. , and Garcia Sole, J. (1999). Red, green, and blue laser light from a single Nd:YAl3(BO3)4 crystal based on laser oscillation at 1.3 μm. Appl. Phys. Lett., 75, 325. 10.1063/1.124364

Ji, Y. , Liang, J. , Xie, S. , and Wu, X. (1994). Phase relations in the system BaO-Nd2O3-B2O3 (B2O350 mol%) and crystal growth of NdBaB9O16 . J. Cryst. Growth, 137, 521–527. 10.1016/0022-0248(94)90993-8

Luo, Z. D. , Zhang, H. , Huang, Y. D. , Qiu, M. W. , Huang, Y. C. , Tu, C. Y. , and Jiang, A. D. (1989). Study of Li6Y(BO3)3:Nd3+ crystal – A new laser crystal. Chinese Phys. Lett., 6, 440. 10.1002/crat.2170260125

Nikolov, V. , and Peshev, P. (1994). A new solvent for the growth of Y1−χNdχAl3(BO3)4 single crystals from high-temperature solutions. J. Cryst. Growth, 144, 187–192. 10.1016/0022-0248(94)90454-5

Jung, S. J. , Choi, D. , Kang, J. K. , and Chung, S. J. (1995). Top-seeded growth of Nd: YAl3(BO3)4 from high temperature solution. J. Cryst. Growth, 148, 207–210. 10.1016/0022-0248(94)00873-6

Jaque, D. (2001). Self-frequency-sum mixing in Nd doped nonlinear crystals for laser generation in the three fundamental colours: The NYAB case. J. Alloys Compd., 323–324, 204–209. 10.1016/S0925-8388(01)01111-2

Scripsick, M. P. , Fang, X. H. , Edwards, G. J. , and Halliburton, L. E. (1993). Point defects in lithium triborate (LiB3O5) crystals. J. Appl. Phys., 73, 1114. 10.1063/1.353275

Gua, R. , Markgraf, S. A. , Furukawa, Y. , Sato, M. , and Bhalla, A. S. (1995). Pyroelectric, dielectric, and piezoelectric properties of LiB3O5 , J. Appl. Phys., 78, 7234. 10.1063/1.360435

Yangyeng, J. , Shuqing, Z. , Yujing, H. , Hongwu, Z. , Ming, L. , and Chaoen, H. (1991). Growth of lithium triborate (LBO) single crystal fiber by the laser-heated pedestal growth method. J. Cryst. Growth, 112, 283–286. 10.1016/0022-0248(91)90929-Y

Katsumata, T. , Ohshima, K. , Oe, K. , Hisamoto, M. , Ohtaki, T. , Konoura, H. , Nakagawa, H. , and Takahashi, K. (1992). Non-wetting container material for growing lithium and barium borate crystals. J. Cryst. Growth, 125, 270–280. 10.1016/0022-0248(92)90340-O

Lim, A. R. (1993). Local structure of LiB3O5 single crystal from 7Li nuclear magnetic resonance. J. Appl. Phys., 94 (2003) 5095. 10.1063/1.1607512

Mei, L. , Wang, Y. , Chen, C. , and Wu, B. (1993). Nonlinear optical materials based on MBe2BO3F2 (M = Na, K). J. Appl. Phys., 74, 7014. 10.1063/1.355060

Mei, L. , Wang, Y. , and Chen, C. (1994). Crystal structure of sodium beryllium borate fluoride. Mater. Res. Bull., 29, 81–87. 10.1016/0025-5408(94)90108-2

Keszler, D. A. (1996). Borates for optical frequency conversion. Curr. Opin. Solid State Mater. Sci., 1, 204. 10.1016/S1359-0286(96)80085-4
Smith, R. W. , and Keszler, D. A. (1992). The noncentrosymmetric orthoborate BaZn2(BO3)2 . J. Solid State Chem., 100, 325–330. 10.1016/0022-4596(92)90107-7
Guaitieri, D. M. , and Chai, B. H. T. (1989). Growth of β-barium borate from NaCl-Na2O solutions. J. Cryst. Growth, 97, 613–616. 10.1016/0022-0248(89)90562-9
Bordui, P. F. , Caivert, G. D. , and Blachman, R. (1993). Immersion-seeded growth of large barium borate crystals from sodium chloride solution. J. Cryst. Growth, 129, 371–374. 10.1016/0022-0248(93)90469-D
Polgar, K. , and Peter, A. (1993). Etching study on beta barium metaborate (β-BaB2O4) single crystals. J. Cryst. Growth, 134, 219. 10.1016/0022-0248(93)90129-K
Aka, G. , Mougel, F. , Auge, F. , Kahn- Harari, A. , Vivien, D. , Benitez, J. M.., Salin, F. , Pelenc, D. , Balembois, F. , Georges, P. , Brun, A. , Linain, N. , and Jacquet, M. (2000). Overview of the laser and non-linear optical properties of calcium-gadolinium-oxo-borate Ca4GdO(BO3)3 , J. Alloys Compd., 303–304, 401–408. 10.1016/S0925-8388(00)00648-4
Iwai, M. , Kuroda, I. , Nakajima, S. , Sasaki, T. , and Nakai, S. (1997). Crystal growth and optical characterization of rare-Earth (Re) calcium oxyborate ReCa4O(BO3)3 (Re = Y or Gd) as new nonlinear optical material. Japanese J. Appl. Phys., 36, L276. 10.1143/JJAP.36.L276
Hu, Z. G. , Higashiyama, T. , Yoshimura, M. , Yap, Y. K. , Mori, Y. , and Sasaki, T. (1998). A new nonlinear optical borate crystal K2Al2B2O7 (KAB). Japanese J. Appl. Phys., 37, L1093. 10.1143/JJAP.37.L1093
Jiang, H. , Li, J. , Wang, J. , Hu, X. B. , Liu, H. , Teng, B. , Zhang, C. Q. , Dekker, P. , and Wang, P. (2001). Growth of Yb: YAl3(BO3)4 crystals and their optical and self-frequency-doubling properties, J. Cryst. Growth, 233, 248–252. 10.1016/S0022-0248(01)01562-7
Teng, B. , Wang, J. , Wang, Z. , Jiang, H. , Hu, X. , Song, R. , Liu, H. , Liu, Y. , Wei, J. , and Shao, Z. (2001). Growth and investigation of a new nonlinear optical crystal: Bismuth borate BiB3O6 , J. Cryst. Growth, 224, 280–283. 10.1016/S0022-0248(01)00975-7
Wang, G. , Hna, T. P. J. , Gallagher, H. G. , and Henderson, B. (1995). Novel laser gain media based on Cr3+ doped mixed borates RX3(BO3)4 . Appl. Phys. Lett., 67, 3906. 10.1063/1.115313
Norrestam, R. , Nygren, M. , and Bovin, J. O. (1992). Structural investigations of new calcium rare earth (R) oxyborates with the composition Ca4RO(BO3)3 , Chem. Mater., 4, 737–743. 10.1021/cm00021a044
Thompson, P. D. , and Keszler, D. A. (1989). The new strontium scandium borate Sr3Sc(BO3)3 . Chem. Mater., 1, 292–294. 10.1021/cm00003a004
Thompson, P. D. , and Keszler, D. A. (1994). Structure of Sr3Sc(BO3)3 . Chem. Mater., 6, 2005–2007. 10.1021/cm00047a020
Yan, J. F. , and Yang, H. Y. P. (1987). Crystal structure of a new mini-laser material, Nd2Ba3(BO3)4 . Mater. Res. Bull., 22, 1347–1353. 10.1016/0025-5408(87)90299-6
Ha, K. , and Shi, S. (1988). Optical phonons and fluorescence quenching in new laser crystal nab. J. Lumin., 40–41, 698–699. 10.1016/0022-2313(88)90396-1
Sardar, D. K. , and Powell, R. C. (1981). Time-resolved site-selection spectroscopy studies of NdAl3(BO3)4 crystals. J. Lumin., 22, 349–358. 10.1016/0022-2313(81)90012-0
Hong, H. Y. P. , and Dwight, K. (1974). Crystal structure and fluorescence lifetime of NdAl3(BO3)4, a promising laser material. Mater. Res. Bull., 9, 1661–1665. 10.1016/0025-5408(74)90158-5
Wang, G. , He, M. , and Luo, Z. (1991). Structure of β-NdAl3(BO3)4(NAB) crystal. Mater. Res. Bull., 26, 1085–1089. 10.1016/0025-5408(91)90092-Z
Jaque, D. , Enguita, O. , J., Garcia Sole ., Jiang, A. D. , and Luo, Z. D. (2000). Infrared continuous-wave laser gain in neodymium aluminum borate: A promising candidate for microchip diode-pumped solid state lasers. Appl. Phys. Lett., 76, 2176. 10.1063/1.126289
Luo, Z. D. , Jiang, A. D. , Huang, Y. , and Qiu, M. (1991). Studies on the self-activated laser crystal:neodymium aluminium borate NdAl3(BO3)4 . Sci. China A, 34, 762–768. 10.1360/ya1991-34-6-762
Chinn, S. R. , and Hong, H. Y. P. (1975). CW laser action in acentric NdAl3(BO3)4 and KNdP4O12 . Opt. Commun., 15, 345–350. 10.1016/0030-4018(75)90242-4
Mougel, F. , Auge, F. , Aka, G. , Kahn-Harari, A. , Vivien, D. , Balenbois, F. , Georges, P. , and Brun, A. (1998). New green self-frequency-doubling diode-pumped Nd:Ca4GdO(BO3)3 laser. Appl. Phys. B, 67, 533–535. 10.1007/s003400050540
Brenier, A. , and Kityk, I. V. (2001). Spectroscopic properties of Pr3+ doped Ca4GdO(BO3)3 (GdCOB). J. Appl. Phys., 90, 232. 10.1063/1.1379779
Aka, G. , Reino, E. , Loiseau, P. , Vivien, D. , Ferrand, B. , Fulbert, L. , Pelenc, D. , Lucas-Leclin, G. , and Georges, P. (2004). Ca4REO(BO3)3 crystals for green and blue microchip laser generation: From crystal growth to laser and nonlinear optical properties. Opt. Mater., 26, 431. 10.1016/j.optmat.2004.02.009
Mougel, F. , Aka, G. , Kahn-Harari, A. , and Vivien, D. (1999). CW blue laser generation by self-sum frequency mixing in Nd:Ca4GdO(BO3)3 (Nd:GdCOB) single crystal. Opt. Mater., 13, 293–297. 10.1016/S0925-3467(99)00081-6
Jiang, H. , wang, J. , Zhang, H. , Hu, X. , Burns, P. , and Piper, J. A. (2002). Spectral and luminescent properties of Yb3+ ions in YCa4O(BO3)3 crystal. Chem. Phys. Lett., 361, 499–503. 10.1016/S0009-2614(02)00989-2

Long, X. , Lin, Z. , Hu, Z. , Wang, G. , and Van, T. P. J. (2002). Optical study of Cr3+ doped LaSc3(BO3)4 crystal. J. Alloys Compd., 347, 52–55. 10.1016/S0925-8388(02)00785-5
Chen, W. , Wang, G. , Lin, Z. , and Hu, Z. (1999). Spectral parameters of Nd3+ ion in β-Nd3+:LaSc3(BO3)4 crystal. Opt. Commun., 162, 49–52. 10.1016/S0030-4018(99)00080-2
Chen, W. , Wang, G. , Lin, Z. , and Hu, Z. (1999). Optical transition probability of Nd3+ ions in a α-Nd3+:LaSc3(BO3)4 crystal. Phys. Rev., B 60, 15469. 10.1103/PhysRevB.60.15469
Meyn, J. P. , Jensen, T. , and Hubber, G. (1994). Spectroscopic properties and efficient diode-pumped laser operation of neodymium-doped lanthanum scandium borate. IEEE J. Quantum Electron., 30, 913–917. 10.1109/3.291362
Lin, X. , Xiong, F. , Chen, Y. , Gong, X. , Liao, J. , and Huang, Y. (2005). Growth and spectral properties of Pr3+:LaB3O6 single crystal. J. Cryst. Growth, 280, 113–117. 10.1016/j.jcrysgro.2005.03.007
Pan, S. , Hu, Z. , Lin, Z. , and Wang, G. (2003). Growth and X-ray diffraction of Nd3+ doped Ba3Y(BO3)3 crystal. J. Cryst. Growth, 247, 452–456. 10.1016/S0022-0248(02)02052-3
Xu, Y. , Gong, X. , Chen, Y. , Huang, M. , Luo, Z. , and Huang, Y. (2003). Crystal growth and optical properties of YbAl3(BO3)4: A promising stoichiometric laser crystal, J. Cryst. Growth, 252, 241. 10.1016/S0022-0248(03)00863-7
Leonyuk, N. I. , Kaporulina, E. V. , Maltsev, V. V. , Pilipenko, O. V. , Melekhova, M. D. , and Mokhov, A. V. (2004). Crystal growth and characterization of YAl3(BO3)4 doped with Sc, Ga, Pr, Ho, Tm, Yb. Opt. Mater., 26, 443–447. 10.1016/j.optmat.2003.09.010
Zhang, Y. , Lin, Z. , Hu, Z. , and Wang, G. (2005). Growth and spectroscopic properties of Yb3+:Gd0.5Y0.5Ca4O(BO3)3 crystal. J. Alloys Compd., 390, 194–196. 10.1016/j.jallcom.2004.07.058
Zhao, D. , Hu, Z. , Hu, Z. , Lin, Z. , and Wang, G. (2005). Growth and spectral properties of Er3+/Yb3+ codoped Sr3Y(BO3)3 crystal. J. Cryst. Growth, 277, 401–405. 10.1016/j.jcrysgro.2005.01.081
Pan, J. , Lin, Z. , Hu, Z. , Zhang, L. , and Wang, G. (2006). Crystal growth and spectral properties of Yb3+:Sr3La2(BO3)4 crystal. Opt. Mater., 28, 250–254. 10.1016/j.optmat.2004.12.019
Pan, J. , Wu, S. , and Wang, G. (2006). Crystal growth and spectral properties of Nd3+:Sr3Gd(BO3)3 crystal. Opt. Mater., 28, 391–394. 10.1016/j.optmat.2004.12.022
Smet, B. M. J. (1987). Phosphors based on rare-earths, a new era in fluorescent lighting. Mater. Chem. Phys., 16, 283–299. 10.1016/0254-0584(87)90103-9
Ronda, C. R. , Justel, T. , and Nikol, H. (1998). Rare earth phosphors: Fundamentals and applications. J. Alloys Compd., 275–277, 669–676. 10.1016/S0925-8388(98)00416-2
Aron, A. , Tigreat, P. Y. , Caramanian, A. , and Antic- Fidancev, E. (2000). Infrared and visible emission of Pr3+, Eu3+, Yb3+/Er3+ in Ca4Gd(BO3)3O (GdCOB). J. Lumin., 87–89, 611–613. 10.1016/S0022-2313(99)00328-2
Duan, C. J. , Chen, H. H. , Yang, X. X. , and Zhao, J. T. (2006). Luminescence properties of Eu3+, Tb3+ or Tm3+ activated Ca4GdO(BO3)3 under X-ray and UV excitation. Opt. Mater., 28, 956–961. 10.1016/j.optmat.2005.05.005
Zhang, Y. , and Li, Y. (2005). Photo-luminescent properties of Eu3+ ion-doped Ca4REO(BO3)3 (RE double bond La,Y,Gd). J. Lumin., 113, 45–49. 10.1016/j.jlumin.2004.08.051
Guo, F. , and Peng, Y. (1988). Photoluminescence of terbium ion in the binary system of GdB3O6 – CeB3O6 . J. Lumin., 40–41, 175–176. 10.1016/0022-2313(88)90144-5
Nakamura, T. , Takeyama, T. , Takahashi, N. , Jagannathan, R. , Karthikeyani, A. , Smith, G. M. , and Riedi, P. C. (2003). High-frequency EPR investigation of X-ray storage SrBPO5:Eu phosphor. J. Lumin., 102–103, 369–372. 10.1016/S0022-2313(02)00537-9
Karthikeyani, A. , and Jagannathan, R. (2000). Eu2+ luminescence in stillwellite-type SrBPO5 − A new potential X-ray storage phosphor. J. Lumin., 86, 79–85. 10.1016/S0022-2313(99)00171-4
Risheng, C. , Jinggen, H. , Ling, L. , and Yan, X. (1988). Study of the new boron-rich calcium rare earth borate CaLnB7O13 . Mater. Res. Bull., 23, 1699–1704. 10.1016/0025-5408(88)90178-X
Datchi, F. , Le Toyllec, R. , and Loubeyre, P. (1997). Improved calibration of the SrB4O7:Sm2+ optical pressure gauge: Advantages at very high pressures and high temperatures. J. Appl. Phys., 81, 3333. 10.1063/1.365025
Lu, C. H. , Godbole, S. V. , and Natarajan, V. (2005). Luminescence characteristics of strontium borate phosphate phosphors. Mater. Chem. Phys., 94, 73–77. 10.1016/j.matchemphys.2005.04.011
Dotsenko, V. P. (2000). Rapid synthesis of nanoscale colloidal metal clusters by microwave irradiation. J. Mater. Chem., 10, 9. 10.1039/B002232M
Dotsenko, V. P. , berezovskaya, I. V. , Efryushina, N. P. , Voloshinovskii, A. S. , Dorenbos, P. , and van Eijk, C. W. E. (2001). Luminescence of Ce3+ ions in strontium haloborates, J. Lumin., 93, 137–145. 10.1016/S0022-2313(01)00179-X
Sidorenko, A. V. , Bos, A. J. J. , Dorenbos, P. , van Eijk, C. W. E. , Rodnyi, P. A. , berezovskaya, I. V. , Dotsenko, V. P. , Guillot- Noel, O. , and Gourier, D. (2004). Radiation induced defects in Sr2B5O9Br:Ce3+ storage phosphor, J. Phys: Condens. Mater., 16, 4131. 10.1088/0953-8984/16/23/027
Z., Pei , Zeng, Q. , and Su, Q. (2000). The application and a substitution defect model for Eu3+ → Eu2+ reduction in non-reducing atmospheres in borates containing BO4 anion groups. J. Phys. Chem. Solids, 61, 9–12. 10.1016/S0022-3697(99)00237-1

Keszler, D. A. (1999). Synthesis, crystal chemistry, and optical properties of metal borates. Curr. Opin. Solid State Mater. Sci., 4, 155–162. 10.1016/S1359-0286(99)00011-X
Mc Carthy, G. J. , and White, W. B. (1970). On the stabilities of the lower oxides of the rare earths. J. Less Common Metals, 22, 409–417. 10.1016/0022-5088(70)90128-1
Machida, K. , Adachi, G. , and Shiokava, J. (1979). Luminescence properties of Eu(II)-borates and Eu2+ activated Sr-Borates. J. Lumin., 21, 101–110. 10.1016/0022-2313(79)90038-3
Peters, T. E. , and Baglio, J. (1970). Inog J. Nucl. Chem., 32, 1083.
Diaz, A. , and Keszler, D. A. (1996). Red, green, and blue Eu2+ luminescence in solid-state borates: A structure-property relationship. Mater. Res. Bull., 31, 147–151. 10.1016/0025-5408(95)00182-4
Pei, Z. Zeng, Q. , and Su, Q. (1999). A study on the mechanism of the abnormal reduction of Eu3+ → Eu2+ in Sr2B5O9Cl prepared in air at high temperature. J. Solid State Chem., 145, 212–215. 10.1006/jssc.1999.8246
Zhao, J. , and Cocivera, M. (2001). Luminescent characteristics of blue-emitting Sr2B5O9Cl:Eu thin-film phosphors. Appl. Phys. Lett., 79, 740. 10.1063/1.1391410
Jiang, Y. D. , Zhang, F. , Summers, C. J. , and Wang, Z. I. (1999). Synthesis and properties of Sr2CeO4 blue emission powder phosphor for field emission displays. Appl. Phys. Lett, 74, 1677. 10.1063/1.123652
Kumar, D. , Sankar, J. , Cho, K. G. , Cracium, V. , and Singh, R. K. (2000). Enhancement of cathodoluminescent and photoluminescent properties of Eu:Y2O3 luminescent films by vacuum cooling. Appl. Phys. Lett., 77, 2518. 10.1063/1.1318938
Meijrink, A. , and Blasse, G. (1991). Photostimulated luminescence and thermally stimulated luminescence of some new X-ray storage phosphors. J. Phys. D: Appl. Phys., 24, 626. 10.1088/0022-3727/24/4/016
Verstgen, J. M. P. J. , Ter Vrugt, J. W. , and Wanmaker, W. L. (1972). Luminescence of Eu2+-activated SrB2Si2O8 . J. Inorg. Nucl. Chem., 34, 3588.
Welkar, T. (1991). Recent developments on phosphors for fluorescent lamps and cathode-ray tubes. J. Lumin., 48–49, 49–56. 10.1016/0022-2313(91)90075-7
Diang, S. J. , Zhang, D. W. , Wang, P. F. , and Wang, J. J. (2001). Preparation and photoluminescence of the Ce, Tb and Gd-doped lanthanum borophosphate phosphor. Mater. Chem. Phys., 68, 98–104. 10.1016/S0254-0584(00)00300-X
Hao, J. , Gao, J. , and Cocivera, M. (2015). Stimuli responsive upconversion luminescence nanomaterials and films for various applications. Appl. Phys. Lett., 44, 1585–1607. 10.1039/C4CS00171K
Hao, J. , Gao, J. , and Cocivera, M. (2003). Appl. Phys. Lett., 82, 2778.
Hao, J. , and Cocivera, M. (2001). Appl. Phys. Lett., 79, 740.
Hao, J. , and Cocivera, M. (2001). Appl. Phys. Lett., 81, 4154.
Wei, Z. G. , Sun, L. D. , Jiang, X. C. , Liao, C. S. , and Yan, C. H. (2003). Correlation between size-dependent luminescent properties and local structure around Eu3+ ions in YBO3:Eu nanocrystals: An XAFS study. Chem. Mater., 15, 3011–3017. 10.1021/cm0341888
Yang, Z. , Ren, M. , Lin, J. H. , Su, M. Z. , Tao, T. , and Wang, W. (2004). Ordered Nanosheet-based YBO3:Eu3+ assemblies: Synthesis and tunable luminescent properties. J. Phys. Chem. B, 108, 11, 3387–3390. 10.1021/jp037301q
Wei, Z. G. , Sun, L. D. , Liao, C. S. , Jiang, X. C. , and Yan, C. H. (2003). Size dependence of luminescent properties for hexagonal YBO3:Eu nanocrystals in the vacuum ultraviolet region. J. Appl. Phys., 93, 9783. 10.1063/1.1575496
Jiang, C. , Yan, C. H. , Sun, L. D. , Wei, Z. G. , and Liao, C. S. Hydrothermal homogeneous urea precipitation of hexagonal YBO3:Eu3+ nanocrystals with improved luminescent properties. J. Solid State Chem., 175 (2003) 245-151. 10.1016/S0022-4596(03)00276-7
Li, J. , Wang, J. , Tan, H. , Cheng, X. , Song, F. , Zhang, H. , and Zhao, S. (2003). Growth and optical properties of Ho,Yb:YAl3(BO3)4 crystal. J. Cryst. Growth, 256, 324–327. 10.1016/S0022-0248(03)01370-8
Liang, H. , Zeng, Q. , Tao, Y. , Wang, S. , and Su, Q. (2003). VUV-UV excited luminescent properties of calcium borophosphate doped with rare earth ions. Mater. Sci. Eng., B98, 213–219. 10.1016/S0921-5107(03)00034-5
Boyer, D. , Bertrand-Chadeyran, G. , Mahiou, R. , Brioude, A. , and Mugnier, J. (2003). Synthesis and characterization of sol–gel derived Y3BO6:Eu3+ powders and films. Opt. Mater., 24, 35–41. 10.1016/S0925-3467(03)00102-2
Kwon, I. E. , Yu, B. Y. , Bae, H. , Hwang, Y. J. , Kwon, T. W. , Kim, C. H. , Pyun, C. H. , and Kim, S. J. (2000). Luminescence properties of borate phosphors in the UV/VUV region. J. Lumin., 87–89, 1039–1041. 10.1016/S0022-2313(99)00532-3
Kang, Y. C. , and Park, S. B. (1999). Morphology of (YxGd1-x)BO3:Eu phosphor particles prepared by spray pyrolysis from aqueous and colloidal solutions. Japanese J.Appl. Phys., 38, L 1541. 10.1143/JJAP.38.L1541
Ronda, C. R. (1997). Recent achievements in research on phosphors for lamps and displays. J. Lumin., 72-74, 49–54. 10.1016/S0022-2313(96)00374-2
Kim, D. S. , and Lee, R. Y. (2000). Synthesis and photoluminescence properties of (Y,Gd)BO3: Eu phosphor prepared by ultrasonic spray. J. Mater. Sci., 35, 4777–4782. 10.1023/A:1004864426980
Justel, T. , Krupa, J. C. , and Wiechert, D. U. (2001). VUV spectroscopy of luminescent materials for plasma display panels and Xe discharge lamps. J. Lumin., 93, 179–189. 10.1016/S0022-2313(01)00199-5

Yu, Z. , Huang, X. , Zhung, W. , Cui, X. , and Li, H. (2005). Crystal structure transformation and luminescent behavior of the red phosphor for plasma display panels. J. Alloys Compd., 390, 220–222. 10.1016/j.jallcom.2004.07.065
Sohn, J. R. , Kang, Y. C. , Park, H. D. , and Yoon, S. G. (2002). (YGd)BO3:Eu phosphor particles prepared from the solution of polymeric precursors by spray pyrolysis. Japanese J. Appl. Phys., 41, 6007. 10.1143/JJAP.41.6007
Wei, Z. G. , Sun, L. D. , Liao, C. S. , Cheng Jiang, X. C. , and Yan, C. H. (2002). Synthesis and size dependent luminescent properties of hexagonal (Y,Gd)BO3Eu nanocrystals. J. Mater. Chem., 12, 3665–3670. 10.1039/B207103G
Jeoung, B. W. , Hong, G. Y. , Yoo, W. T. , and Yoo, J. S. (2004). Preparation of spherical phosphor (Y,Gd)BO3:Eu by polymeric-aerosol pyrolysis. J. Electrochem. Soc., 151, H213. 10.1149/1.1790513
Gupta, S. K. , Agrawal, D. C. , and Mahapatra, Y. N. (2004). Photoluminescence and morphological studies of (Y0.5Gd0.5)BO3: Eu phosphor powders prepared by the urea hydrolysis route. J. Electrochem. Soc., 151, H239. 10.1149/1.1804814
Sano, H. , Matsumoto, T. , Matsumoto, Y. , and Koinuma, H. (2005). Appl. Phys. Lett., 86, 21124.
Park, W. , Lee, R. Y. , Summer, C. J. , Do, Y. R. , and Yang, H. G. Photoluminescence properties of Al3GdB4O12:Eu phosphors, Mater. Sci. Eng., B78, 28–31. 10.1016/S0921-5107(00)00509-2
Wang, Y. , Uheda, K. , Takizawa, H. , Mizumoto, U. , and Endo, T. (2001). Synthesis of Gd1 − xEuxAl3(BO3)4 (0 < x ≤ 1) and its photoluminescence properties under UV and vacuum ultraviolet regions. J. Electrochem. Soc., 148, G430. 10.1149/1.1383778
Lee, K. G. , Yu, B. Y. , Pyun, C. H. , and Mho, Sun-Il . (2002). Vacuum ultraviolet excitation and photoluminescence characteristics of (Y,Gd)Al3(BO3)4/Eu3+ . Solid State Commun., 22, 485–488. 10.1016/S0038-1098(02)00195-3
Hongpeng, Y. , Hong, G. , Zeng, X. , Pyun, C. H. , Yu, B. Y. , and Bae, H. S. (2000). VUV excitation properties of LnAl3B4O12:Re (Ln = Y, Gd; Re = Eu, Tb). J. Phys. Chem. Solids, 61, 1985–1988. 10.1016/S0022-3697(00)00192-X
Tian, L. , You, B. Y. , Pyun, C. H. , Park, H. L. , and Mho, Sun-il . (2004). New red phosphors BaZr(BO3)2 and SrAl2B2O7 doped with Eu3+ for PDP applications. Solid State Commun., 129, 43–46. 10.1016/j.ssc.2003.09.012
Tian, L. , Kim, S. J. , Park, H. L. , and Mho, S. I. (2006). Variation of the photoluminescence and vacuum ultraviolet excitation characteristics of BaZr(BO3)2:Eu3+ by the incorporation of Al3+, La3+, or Y3+ into the lattice. Mater. Res. Bull., 41, 29–37. 10.1016/j.materresbull.2005.07.039

Borate Phosphor

Kingsley, J. J. , and Patil, K. C. (1988). A novel combustion process for the synthesis of fine particle α-alumina and related oxide materials. Mater. Lett., 6, 427–432. 10.1016/0167-577X(88)90045-6
Westesen, K. , and Wehler, T. (1993). Investigation of the particle size distribution of a model intravenous emulsion. J. Pharm Sci., 82, 12, 1237–1244. 10.1002/jps.2600821211
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2015). Aldo-keto synthesis effect on Eu3+ fluorescence in YBO3 compared with solid state diffusion. J. Rare Earths, 33, 5, 486–490. 10.1016/S1002-0721(14)60445-2
Li, C. M. , Lambert, N. , Chen, Y. N. , Chen, G. Y. , and Nori, F. (2012). Witnessing Quantum Coherence: From solid-state to biological systems. Sci. Rep., 2012, 2, 885. 10.1038/srep00885
Bu, J. , Wang, P. , Ai, L. , Sang, X. , and Li, Y. (2011). A new method for preparation and luminescence of YBO3:Eu3+ phosphor. Adv. Mater. Res., 287, 1460. 10.4028/www.scientific.net/AMR.287-290.1460
Wei, Z. , Sun, L. , Liao, C. , Yan, C. , and Huang, S. (2002). Fluorescence intensity and color purity improvement in nanosized YBO3:Eu. Appl. Phys. Lett., 80, 1447. 10.1063/1.1452787
Wanga, L. , and Wang, Y. (2007). Enhanced photoluminescence of YBO3:Eu3+ with the incorporation of Sc3+ Bi3+ and La3+ for plasma display panel application. J. Lumin., 122, 921. 10.1016/j.jlumin.2006.01.327
Chen, L. , Luo, A. , Deng, X. , Xue, S. , Zhang, Y. , Liu, F. , Zhu, J. , Yao, Z. , Jiang, Y. , and Chen, S. (2013). Luminescence and energy transfer in the Sb3+ and Gd3+ activated YBO3 phosphor. J. Lumin., 143, 670. 10.1016/j.jlumin.2013.06.014
Dubey, V. , Kaur, J. , Agrawal, S. , and Suryanarayana, N. S. (2013). Synthesis and characterization of Eu3+ doped YBO3 phosphor. Int. J. Lumin. Appl., 3, 98.
Dubey, V. , Kaur, J. , Agrawal, S. , Suryanarayana, N. S. , and Murthy, K. V. R. (2014). Effect of Eu3+ concentration on photoluminescence and thermoluminescence behavior of YBO3:Eu3+ phosphor. Superlattices Microstruct., 67, 156. 10.1016/j.spmi.2013.12.026
Zhang, W. , Liu, S. , Hu, Z. , Liang, Y. , Feng, Z. , and Sheng, X. (2014). Preparation of YBO3:Dy3+, Bi3+ phosphors and enhanced photoluminescence. Mater. Sci. Eng. B, 187, 108. 10.1016/j.mseb.2014.05.006
Vijayakumar, R. , Devakumar, B. , and Huang, X. (2021). Energy transfer induced color-tunable emissions from Ba2Gd5B5O17:Ce3+/Tb3+ borate phosphors for white LEDs. J. Lumin., 229, 117685.

10.1016/j.jlumin.2020.117685
Huang, D. , Zhu, H. , Deng, Z. , Yang, H. , Hu, J. , Liang, S. , Chen, D. , Ma, E. , and Guo, W. (2021). A highly efficient and thermally stable broadband Cr3+-activated double borate phosphor for near-infrared light-emitting diodes. J. Mater. Chem. C, 9, 1, 164–172. 10.1039/D0TC04803H
Chauhan, A. O. , Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2016). Synthesis and photoluminescence properties of Pb2+ doped inorganic borate phosphor NaSr4(BO3)3 . AIP Conference Proceedings, 1728, 020470. 10.1063/1.4946521
Chauhan, A. O. , Sawala, N. S. , Palan, C. B. , and Omanwar, S. K. (2015). Synthesis and PL study of UV emitting phosphor LiSr4(BO3)3:Pb2+ . Int. J. Lumin. Appl., 5, 4, 465–467.
Das, S. , Reddy, A. A. , Babu, S. S. , and Prakash, G. G. (2011). Controllable white light emission from Dy3+–Eu3+ co-doped KCaBO3 phosphor. J. Mater. Sci., 46, 77707775. 10.1007/s10853-011-5756-5
Tamboli, S. , Nair, G. B. , Dhoble, S. J. , and Burghate, D. K. (2018). Energy transfer from Pr3+ to Gd3+ ions in BaB8O13 phosphor for phototherapy lamps. Phys. B: Condens. Matter, 535, 232–236. 10.1016/j.physb.2017.07.042
Gavhane, K. H. , Bhadane, M. S. , Bhoir, A. S. , Kulkarni, P. P. , Patil, B. J. , Bhoraskar, V. N. , Dhole, S. D. , and Dahiwale, S. S. (2020). Tm-Tstop analysis and dosimetric properties of Ce doped BaB4O7 phosphor. J. Alloys Compd., 817, 152805. 10.1016/j.jallcom.2019.152805
Sahare, P. D. , Singh, M. , and Kumar, P. (2015). Synthesis and TL characteristics of MgB4O7:Mn,Tb phosphor. J. Lumin., 160, 158–164. 10.1016/j.jlumin.2014.11.042
Anishia, S. R. , Jose, M. T. , Annalakshmi, O. , Ponnusamy, V. , and Ramasamy, V. (2010). Dosimetric properties of rare earth doped LiCaBO3 thermoluminescence phosphors. J. Lumin., 130, 10, 1834–1840. 10.1016/j.jlumin.2010.04.019
Ali, A. , Zafar, H. , Zia, M. , Ul Haq, I. , Phull, A. R. , Ali, J. S. , and Hussain, A. (2016). Synthesis, characterization, applications, and challenges of iron oxide nanoparticles. Nanotechnol. Sci. Appl., 9, 49–67. 10.2147/NSA.S99986
Shao, Z. , Zhou, W. , and Zhu, Z. (2012). Advanced synthesis of materials for intermediate-temperature solid oxide fuel cells. Prog. Mater. Sci., 57, 804. 10.1016/j.pmatsci.2011.08.002
Chen J. , Shi Y. , and Shi J. (2004). Synthesis of (Y,Gd)2O3:Eu nanopowder by a novel co-precipitation processing. J. Mater. Res. 19, 3586–3591. 10.1557/JMR.2004.0477
Jadhav A. P. , Pawar A. , Kim C. W. , Cha H. G. , Pal U. , and Kang Y. S. (2009). Effect of different additives on the size control and emission properties of Y2O3:Eu3+ nanoparticles prepared through the coprecipitation method. J. Phys. Chem. C, 113, 16652. 10.1021/jp9059399
Yadav, S. R. , Dutta, R. K. , Kumar, M. , and Pandey, A. C. (2009). Improved color purity in nano-size Eu3+-doped YBO3 red phosphor. J. Lumin., 129, 1078. 10.1016/j.jlumin.2009.04.032
Hu, Y. , Tao, Y. , Huang, Y. , Yu, X. , Zhang, C. , Liang, T. , and Yu, J. (2011). Luminescent properties of (Y, Gd)BO3:Eu3+ under VUV excitation for PDP prepared by co-precipitation method. Adv. Mater. Rapid Commun., 5, 348.
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. Effect of partially replacement of Gd3+ ions on fluorescence properties of YBO3:Eu3+ phosphor synthesized via precipitation method. Opt. Mater., 39, 74–80. 10.1016/j.optmat.2014.11.001
Jadhav, A. P. , Kim, C. W. , Cha, H. G. , Pawar, A. U. , Jadhav, N. , A.Pal, U. , and Kang, Y. S. (2009). Effect of different surfactants on the size control and optical properties of Y2O3:Eu3+ nanoparticles prepared by coprecipitation method. J. Phys. Chem. C., 113, 31, 1932–7447. 10.1021/jp903067j
Qiao, X. , Cheng, Y. , Qin, L. , Qin, C. , Cai, P. , Kim, S. I. , and Seo, H. J. (2014). Coprecipitation synthesis, structure and photoluminescence properties of Eu3+-doped sodium barium borate. J. Alloys Compd., 617, 946–951. 10.1016/j.jallcom.2014.08.050
Lu, H. Y. , and Chen, Y. S. (2015). The influence of codopant aluminum ions (Al3+) on the optical characteristics of YBO3: Sm3+ phosphors. J. Nanomater., 16, 1, 1. 10.1155/2015/615863
Haghiri, M. E. , Saion, E. , Abdullah, W. S. W. , Soltani, N. , Hashim, M. , Navasery, M. , and Shafaei, M. A. (2013). Thermoluminescence studies of manganese doped calcium tetraborate (CaB4O7:Mn) nanocrystal synthesized by co-precipitation method. Radiat. Phys. Chem., 90, 1–5. 10.1016/j.radphyschem.2013.05.009
Singh, V. , Mahamuda, S. , Rao, A. S. , Rao, J. L. , and Irfan, M. (2020). Luminescence and EPR properties of UVB emitting Gd doped NaBaPO4 phosphor prepared by co-precipitation method. Optik, 206, 164086. 10.1016/j.ijleo.2019.164086
Zheng, Y. , Qu, Y. , Tian, Y. , Rong, C. , Wang, Z. , Li, S. , Chen, X. , and Ma, Y. (2009). Effect of Eu3+-doped on the luminescence properties of zinc borate nanoparticles. Colloids Surf. A Physicochem. Eng. Asp., 349, 19–22.
Lu, C. H. , and Saha, S. K. (2000). Synthesis of ferroelectric nanocrystalline SrBi2Ta2O9 powder by colloid-gel process. Mater. Res. Bull., 35, 13, 2135–2143. 10.1016/S0025-5408(00)00422-0
Kahoul, A. , Nkeng, P. , Hammouche, A. , Naamoune, F. , and Poillerat, G. (2001). A sol+gel route for the synthesis of Bi2Ru2O7 pyrochlore oxide for oxygen reaction in alkaline medium. J. Solid State Chem., 161(2001), 379. 10.1006/jssc.2001.9346
Campero, A. , Cardoso, J. , and Pacheco, S. (1997). Ethylene glycol-citric acid-silica hybrid organic-inorganic materials obtained by the sol-gel method. J. Sol-Gel Sci. Technol., 8, 535–539. 10.1007/BF02436895

Xue, J. , Wu, T. , Dai, Y. , and Xia, Y. (2019). Electrospinning and electrospun nanofibers: Methods, materials, and applications. Chem. Rev., 119, 8, 5298–5415. 10.1021/acs.chemrev.8b00593
Hsu, W. T. , Wu, W. H. , and Lu, C. H. (2003). Synthesis and luminescent properties of nano-sized Y3Al5O12:Eu3+ phosphors. Mater. Sci. and Eng. B, 104, 40. 10.1016/S0921-5107(03)00268-X
Yan, B. , and Wang, C. (2008). Synthesis and luminescence properties of REAl3(BO3)4:Eu3+/Tb3+ (RE=Y, Gd) phosphors from sol–gel composition of hybrid precursors. Solid State Sci., 10, 1, 82–89.
Santiago, M. , Marcazzó, J. , Grasselli, C. , Lavat, A. , Molina, P. , Spano, F. , and Caselli, E. (2011). Thermo- and radioluminescence of undoped and Dy-doped strontium borates prepared by sol-gel method. Radiat. Meas., 46, 12, 1488–1491. 10.1016/j.radmeas.2011.01.006
Shyichuk, A. , and Lis, S. (2013). Green-emitting nanoscaled borate phosphors Sr3RE2(BO3)4:Tb3+ . Mater. Chem. Phys., 140, 2–3, 447–452. 10.1016/j.matchemphys.2013.03.019
Rao, R. P. (2003). Tb3+ activated green phosphors for plasma display panel applications. J. Electrochem. Soc., 150, 8, H165. 10.1149/1.1583718
Bengisu, M. , Yilmaz, E. , Farzad, H. , and Reis, S. T. (2008). Borate, lithium borate, and borophosphate powders by sol–gel precipitation. J. Sol-Gel Sci. Technol., 45, 3, 237–243. 10.1007/s10971-008-1681-8
Shyichuk, A. A. , and Lis, S. (2011). Photoluminescence properties of nanosized strontium-yttrium borate phosphor Sr3Y2(BO3)4:Eu3+ obtained by the sol-gel Pechini method. J. Rare Earths, 29, 12, 1161–1165. 10.1016/S1002-0721(10)60617-5
Seraiche, M. , Guerbous, L. , Kechouane, M. , Potdevin, A. , Chadeyron, G. , and Mahiou, R. (2017). VUV excited luminescence of Gd0.9Eu0.1BO3 nanophosphor prepared by aqueous sol-gel method. J. Lumin., 192, 404–409. 10.1016/j.jlumin.2017.07.012
Wang, C. , and Yan, B. , Sol–gel synthesis and photoluminescence of RE3BO6:Eu3+/Tb3+ (RE=Y, Gd) microcrystalline phosphors from hybrid precursors, J. Non-Cryst. Solids., 354 (10–11,) 962–969. 10.1016/j.jnoncrysol.2007.08.029
Yang, R. , Sun, X. , Jiang, P. , Gao, W. , Cong, R. , and Yang, T. (2018). Sol-gel syntheses of pentaborate β-LaB5O9 and the photoluminescence by doping with Eu3+, Tb3+, Ce3+, Sm3+, and Dy3+ . J. Solid State Chem., 258, 212–219. 10.1016/j.jssc.2017.10.022
Zhang, Y. , Li, Y. , and Yin, Y. (2005). Red photoluminescence and morphology of Eu3+ doped Ca3La3(BO3)5 phosphors. J. Alloys Compd., 400, 1–2, 222–226. 10.1016/j.jallcom.2005.04.001
Patil, K. C. , Aruna, S. T. , and Ekambaram, S. (1997). Combustion synthesis. Curr. Opin. Solid State Mater. Sci., 2, 158–165. 10.1016/S1359-0286(97)80060-5
Philpot, K. A. , Munir, Z. A. , and Holt, J. B. (1987). An investigation of the synthesis of nickel aluminides through gasless combustion. J. Mater. Sci., 22, 159–169. 10.1007/BF01160566
Booth, F. (1953). The theory of self-propagating exothermic reactions in solid systems. Trans. Faraday Soc., 49, 1953, 272–281. 10.1039/TF9534900272
Moore, J. J. , and Feng, H. J. (1995). Combustion synthesis of advanced materials, Part I. Reaction parameters. Prog. Mater. Sci., 39, 243–273. 10.1016/0079-6425(94)00011-5
Ekambaram, S. , Patil, K. C. , and Maaza, M. J. (2005). Synthesis of lamp phosphors: Facile combustion approach. J. Alloys Compd., 393, 81–92. 10.1016/j.jallcom.2004.10.015
Merzhanov, A. G. , and Borovinskaya, I. P. (1993). Historical retrospective of SHS: An autoreview. Int. J. Self-Propagating High-Temp. Synth., 6, 1993, 119.
Subrahmanyam, J. , and Vijaykumar, M. (1992). Self-propagating high-temperature synthesis. J. Mater. Sci., 27, 6249–6273. 10.1007/BF00576271
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2014). Synthesis and characterization of MgY2B2O7:Eu(III) phosphors. Int. J. Chem Tech Res., 6, 3287–3290.
Li, X. , Liu, H. , Wang, J. , Zhang, X. , and Cui, H. (2004). Preparation and properties of YAG nano-sized powder from different precipitating agent. Opt. Mater., 25, 4, 407–412.
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2015). Combustion synthesis and photoluminescence properties of Eu3+ activated Y2Zr2O7 nano phosphor. Indian J. Phys., 89, 295–298. 10.1007/s12648-014-0554-y
Onani, M. O. , Okil, J. O. , and Dejene, F. B. (2014). Solution–combustion synthesis and photoluminescence properties of YBO3:Tb3+ phosphor powders. Physica B, 439, 133–136. 10.1016/j.physb.2013.10.056
Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2014). Combustion synthesis and energy transfer mechanism of Bi3+ → Gd3+ and Pr3+ → Gd3+ in YBO3 . Combust. Sci. Technol., 186, 785–791. 10.1080/00102202.2013.878708
Hargunani, S. P. , Sonekar, R. P. , Singh, A. , Khosla, A. , and Arya, S. , (2020) Structural and spectral studies of Ce3+ doped Sr3Y(BO3)3 nano phosphors prepared by combustion synthesis, Materials Technology, 1–12. 10.1080/10667857.2020.1859052
Ingle, J. , Sonekar, R. , Omanwar, S. , Wang, Y. , and Zhao, L. (2014). Combustion synthesis and luminescent properties of metal yttrium borates M3Y2 (BO3)4:Eu3+ (M=Ba, Sr) for PDPs applications. Solid State Sci., 33, 19–24. 10.1016/j.solidstatesciences.2014.04.007
Ingle, J. , Gawande, A. , Sonekar, R. , Omanwar, S. , Wangd, Y. , and Zhao, L. (2013). Combustion synthesis and optical properties of oxy-borate phosphors YCa4O(BO3)3:RE3+ (RE = Eu3+, Tb3+) under UV, VUV excitation. J. Alloys Compd., 585, 633–636. 10.1016/j.jallcom.2013.09.178

Bajaj, N. , and Omanwar, S. (2013). Combustion synthesis and characterization of phosphor KSr4(BO3)3:Dy3+ . Opt. Mater., 35, 1222–1225. 10.1016/j.optmat.2013.01.025
Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2014). Synthesis and PL study of UV emitting phosphor KCa4(BO3)3:Pb2+ . J. Lumin., 149, 200–203. 10.1016/j.jlumin.2014.01.044
Bhagat, S. P. , Gawande, A. B. , and Omanwar, S. K. (2015). Photoluminescence study of a novel UV emitting phosphor Sr2Mg(BO3)2:Pb2+,Gd3+ . Opt. Mater., 40, 36–40. 10.1016/j.optmat.2014.11.043
Singh, V. , Chakradhar, R. P. S. , Rao, J. L. , and Zhu, J.-J. (2008). Studies on red-emitting Cr3+ doped barium aluminate phosphor obtained by combustion process. Mater. Chem. Phys., 111, 1, 143–148.
Pekgözlü, İ. (2013). Photoluminescence properties of M2Mg(BO3)2:Sm3+ (M:Sr and Ba). J. Lumin., 134, 813. 10.1016/j.jlumin.2012.09.031
Dawson, W. J. (1988). Hydrothermal synthesis of advanced ceramic powder. Am. Ceram. Soc. Bull., 67, 1673–1678.
Kim, T. , and Kang, S. (2005). Hydrothermal synthesis and photoluminescence properties of nano-crystalline GdBO3:Eu3+ phosphor. Mater. Res. Bull., 40(11), 1945–1954. 10.1016/j.materresbull.2005.06.001
Wang, Y. , Endo, T. , He, L. , and Wu, C. (2004). Synthesis and photoluminescence of Eu3+-doped (Y,Gd)BO3 phosphors by a mild hydrothermal process. J. Crystal Growth, 268, 568–574. 10.1016/j.jcrysgro.2004.04.093
Szczeszak, A. , Grzyb, T. , Barszcz, B. , Nagirnyi, V. , Aleksei, K. , and Lis, S. (2013). Hydrothermal synthesis and structural and spectroscopic properties of the new triclinic form of GdBO3:Eu3+ nanocrystals. Inorg. Chem., 52(9), 4934–4940. 10.1021/ic302525k
Zheng, J. , Wu, X. , Ren, Q. , Bai, W. , Ren, Y. , Wang, M. , and Hai, O. (2020). Investigation of luminescence properties and energy transfer in Sm3+ and Eu3+ co-doped Sr3Y(BO3)3 red phosphors. Optics Laser Technol., 122, 105857. 10.1016/j.optlastec.2019.105857
Liang, P. , Liu, J. W. , and Liu, Z. H. (2016). Controllable hydrothermal synthesis of Eu3+/Tb3+/Dy3+ activated Zn8[(BO3)3O2(OH)3] micro/nanostructured phosphors, energy transfer and tunable emissions. RSC Adv., 6 (92) 89113–89123. 10.1039/C6RA19101K
Wang, Y. , Endo, T. , He, L. , and Wu, C. Synthesis and photoluminescence of Eu3+-doped (Y,Gd)BO3 phosphors by a mild hydrothermal process. J. Crystal Growth, 268, 3–4, 568–574. 10.1016/j.jcrysgro.2004.04.093
He, L. , and Wang, Y. H. (2005). Control of morphology of YBO3:Eu by a mild hydrothermal process. Mater. Sci. Forum, 475, 1829–1832. 10.4028/www.scientific.net/MSF.475-479.1829
Wang, Y. H. , Wu, C. F. , and Zhang, J. C. (2006). Hydrothermal synthesis and photoluminescence of novel green-emitting phosphor Y1−xBO3:xTb3+ . Mater. Res. Bull., 41, 8, 1571–1577. 10.1016/j.materresbull.2005.05.031
Wen, F. , Li, W. , Liu, Z. , Kim, T. , Yoo, K. , Shin, S. , Moon, J.-H. , and Kim, J. H. (2005). Hydrothermal synthesis of Sb3+ doped and (Sb3+, Eu3+) co-doped YBO3 with nearly white light luminescence. Solid State Commun., 133, 7, 417–420. 10.1016/j.ssc.2004.12.013
Shmurak, S. Z. , Kedrov, V. V. , Kiselev, A. P. , Fursova, T. , and Shmytko, I. (2017). Spectral and structural characteristics of Lu1-x-yCexTbyBO3 orthoborates prepared by the hydrothermal synthesis method. Phys. Solid State, 59, 2017, 1171–1182. 10.1134/S1063783415080326
Wang, Y. , Wu, C. , and Wei, J. (2007). Hydrothermal synthesis and luminescent properties of LnPO4:Tb,Bi (Ln=La,Gd) phosphors under UV/VUV excitation. J. Lumin., 126, 2, 503–507. 10.1016/j.jlumin.2006.09.006
https://serc.carleton.edu/research_education/geochemsheets/techniques/SXD.html
Ma, T. , Kapustin, E. A. , Yin, S. X. , Liang, L. , Zhou, Z. , Niu, J. , Li , Hua, L. , Wang, Y. , Su, J. , Li, J. , Wang, X. , Wang, W. D. , Wang, W. , Sun, J. , and Yaghi, O. M. (2018). Single-crystal x-ray diraction structures of covalent organic frameworks. Science, 361, 48–52. 10.1126/science.aat7679
Nazarov, M. , and Noh, D. Y. , (2011) . New Generation of Europium- and Terbium-Activated Phosphors, From Syntheses to Applications, CRC Press, 02-Sep-2011 - Science - 300 pages 10.4032/9789814364058
Patil, A. , (2010). Study of electrical, structural and gas sensing characteristics of ZnO thick solid films with different dopants. August, 2010 http://hdl.handle.net/10603/2233
Daniel, R. , and Musil, J. , (2014). Novel Nanocomposite Coatings, Advances and Industrial Applications, ISBN 9789814411172, CRC Press, 16-Dec-2014 - Science - 344 pages).
X-Ray and Neutron Diffraction, Materials Characterization (2019). SN 978-1-62708-213-6.
Rice, S. A. (1956). Small angle scattering of X-rays. A. Guinier and G. Fournet. Translated by C. B. Wilson and with a bibliographical appendix by K. L. Yudowitch. Wiley, New York, 1955. 268 pp. J. Polym. Sci., 19, 594–594. 10.1002/pol.1956.120199326
Bauer, P. S. , Amenitsch, H. , Baumgartner, B. , Köberl, G. , Rentenberger, C. , and Winkler, P. M. (2019). In-situ aerosol nanoparticle characterization by small angle X-ray scattering at ultra-low volume fraction. Nat. Commun., 10, 2041–1723. 10.1038/s41467-019-09066-4
Tanner, B. , Hase, T. , Lafford, T. , and Goorsky, M. (2004). Grazing incidence in-plane X-ray diffraction in the laboratory. Powder Diffr., 19, 1, 45–48. 10.1154/1.1649319
Cowley, J. M. , (1992) . Electron Diffraction Techniques, International Union of Crystallography Science – 2, 423 pages. ISBN 0-19-855733-7 10.1002/crat.2170290319

Fuller, W. , and Mahendrasingam, A. (2017). X-Ray Diffraction, Studies of Fibres and Films. Editor(s): John C. Lindon , George E. Tranter , David W. Koppenaal , Encyclopedia of Spectroscopy and Spectrometry. 3rd ed., Academic Press, 667–675. ISBN 9780128032244.
Arnott, S. , and Wonacott, A. J. (1966). The refinement of the molecular & crystal structures of polymers using X-ray data and stereochemical constraints. Polymer, 7, 157–166. 10.1016/0032-3861(66)90009-7
von Ardenne, M. (1938). Das Elektronen-Rastermikroskop. Theoretische Grundlagen. Zeitschrift für Physik (in German), 109(9-10), 553–572, Bibcode:1938ZPhy.109.553V. 10.1007/BF01341584
Pendse, D. R. , and Chin. A. K. (2001). Cathodoluminescence and Transmission Cathodoluminescence, Editor(s): K. H. Jürgen Buschow , Robert W. Cahn , Merton C. Flemings , Bernhard Ilschner , Edward J. Kramer , Subhash Mahajan , Patrick Veyssière , Encyclopedia of Materials: Science and Technology, Elsevier, 2001, 1–7, ISBN 9780080431529, 10.1016/B0-08-043152-6/00190-X
Xu, R. (2015). Light scattering, a review of particle characterization applications. Particuology, 18, 11–21. 10.1016/j.partic.2014.05.002
https://www.vcbio.science.ru.nl/en/fesem/info/principe/
The Nobel Prize in Physics 1986, Perspectives – Life through a Lens. nobelprize.org.
Su, D. (2017). Advanced electron microscopy characterization of nanomaterials for catalysis. Green Energy Environ., 2, 2, 70–83. 10.1016/j.gee.2017.02.001
Kumar, P. S. , Pavithra, K. G. , and Naushad, M. (2019). Chapter 4 - Characterization Techniques for Nanomaterials, Editor(s): Sabu Thomas , El Hadji Mamour Sakho , Nandakumar Kalarikkal , Samuel Oluwatobi Oluwafemi , Jihuai Wu , Nanomaterials for Solar Cell Applications, Elsevier, 2019, 97–124.
http://getdrawings.com/drawing-tag/microscope
Pentassuglia, S. , Agostino, V. , Tommasi, T. , (2018). Electroactive Biofilm, A Biotechnological Resource, Editor(s): Klaus Wandelt , Encyclopedia of Interfacial Chemistry, Elsevier, 2018, 110–123, ISBN 9780128098943. https://doi.org/10.1016/B978-0-12-409547-2.13461-4
Egger, M. D. , and Petran, M. (1967). New reflected-light microscope for viewing unstained brain and ganglion cells. Science, 157, 305–307. 10.1126/science.157.3786.305
Davidovits, P. , and Egger, M. D. (1973). Photomicrography of Corneal Endothelial Cells in vivo. Nature, 244, 366–367. 10.1038/244366a0
Amos, W. B. , and White, J. G. (2003). How the confocal laser scanning microscope entered biological research. Biol. Cell, 95, 335–342. 10.1016/s0248-4900(03)00078-9
https://bitesizebio.com/19958/what-is-confocal-laser-scanning-microscopy/
Ohnesorge, F. (1993). True atomic resolution by atomic force microscopy through repulsive and attractive forces. Science, 260, 5113, 1451–1456. 10.1126/science.260.5113.1451PMID 17739801. S2CID 27528518 Bibcode:1993Sci.260.1451O
Binnig, G. , Quate, C. F. , and Gerber, C. H. (1986). Atomic force microscope. Phys. Rev. Lett., 56, 930–933. 10.1103/PhysRevLett.56.930
Adams, J. , Hector, L. , Siegel, D. , Yuand, H. , and Zhong, J. (2001). Adhesion, lubrication and wear on the atomic scale. Surf. Interface Anal., 31, 619–626. 10.1002/sia.1089
Bhushan, B. , Israelachvili, J. N. , and Landman, U. (1995). Nanotribology: Friction, wear and lubrication at the atomic scale. Nature, 374, 607–616. 10.1038/374607a0
Sanz-Medel, A. , and Costa-Fernandez, J. M. (2005). PHOSPHORESCENCE | Principles and Instrumentation, Editor(s): Paul Worsfold , Alan Townshend , Colin, Pool . Encyclopedia of Analytical Science. 2nd ed., Elsevier, 149–157, ISBN 9780123693976.
Gooijer, C. , Ariese, F. , and Velthorst, N. H. (2005). FLUORESCENCE | High-Resolution Techniques, Editor(s): Paul Worsfold , Alan Townshend , Colin Poole . Encyclopedia of Analytical Science. 2nd ed., Elsevier, 119–128, ISBN 9780123693976.
Koparkar, K. A. , Bajaj, N. , and Omanwar, S. , (2014) A potential candidate for lamp phosphor, Eu3+ activated K2Y2B2O7 . Adv. Opt. Technol., 1–5. 10.1155/2014/706459
Blasse, G. , and Grabmaier, B. C. (1994). Luminescent materials, Springer-Verlag, Berlin, Heidelberg, 11, ISBN: 978-3-540-58019-5.
Lakowicz, J. R. (2006). Principles of Fluorescence Spectroscopy. 3rd ed., Springer, London, UK.
Seitz, F. (1948). ‘Luminescent Crystals’, Preparation and characteristics of Solid Luminescent Materials, Symp. Cornell Univ., John Wiley & Sons, INC, NY p 9.
Johnson, R. P. (1939). Luminescence during intermittent optical excitation. J. Opt. Soc. Amer., 29, 7, 283–290. 10.1364/JOSA.29.000283
Lakowicz, J. R. , Laczko, G. , Cherek, H. , Gratton, E. , and Limkeman, M. (1984). Analysis of fluorescence decay kinetics from variable-frequency phase shift and modulation data. Biophys. J., 46, 463–477. 10.1016/S0006-3495(84)84043-6
Wagnieres, G. A. , Star, W. M. , and Wilson, B. C. (1998). In vivo fluorescence spectroscopy and imaging for oncological applications. Photochem. Photobiol., 68, 5, 603–632. 10.1111/j.1751-1097.1998.tb02521.x
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2015). Effect of partially replacement of Gd3+ ions on fluorescence properties of YBO3:Eu3+ phosphor synthesized via precipitation method. Opt. Mater., 39, 7480. 10.1016/j.optmat.2014.11.001

Solgi, S. , Tafreshi, M. J. , and Ghamsari, M. S. (2019). A facile route for synthesis of highly pure α-CaB4O7 compound. Mater. Res. Express, 6, 026205–026209. 10.1088/2053-1591/aaeec5
Raman, C. V. , and Krishnan, K. S. (1928). A new type of secondary radiation. Nature, 121, 501–502. 10.1038/121501c0
Raman, C. V. (1928). A new radiation. Indian J. Phys., 2, 387–398. http://www.jstor.org/stable/24101519
Smith, E. , and Dent, G. (2005). Modern Raman Spectroscopy, A Practical Approach. 1st ed. Wiley, ISBN 0-471-49668-5
Bumbrah, G. , and Sharma, R. (2015). Raman spectroscopy – Basic principle, instrumentation and selected applications for the characterization of drugs of abuse. Egypt. J. Forensic Sci., 6, 209–215. 10.1016/j.ejfs.2015.06.001
Raman, C. V. , and Krishnan, K. S. (1928). A new type of secondary radiation. Nature, 121, 501–502. 10.1038/121501c0
Briggs, D. , and Seah, M. P. (1990). Practical Surface Analysis. Angewandte Chemie, John Wiley, Chichester. 10.1002/ange.19951071133
Siegbahn, K. (1966). Alpha- beta- and gamma-ray spectroscopy. Am. J. Phys., 34, 1966, 275. 10.1119/1.1972911
Siegbahn, K. (1982). Electron-spectroscopy for atoms, molecules, and condensed matter. Science, 217, 111–121. 10.1126/science.217.4555.111
Moulder, J. F. , Chastain, J. , and King, R. C. (1995). Handbook of X-ray photoelectron spectroscopy: A reference book of standard spectra for identification and interpretation of XPS data, Physical Electronics, Eden Prairie, MN (1995).
Zhu, H. , Zhang, L. , Zuo, T. , Gu, X. , Wang, Z. , Zhu, L. , and Yao, K. (2008). Sol–gel preparation and photoluminescence property of YBO3:Eu3+/Tb3+ nanocrystalline thin films. Applied Surf. Sci., 254(20), 6362–6365. 10.1016/j.apsusc.2008.03.183
Baer, D. R. , and Thevuthasan, S. (2010). Chapter 16 - Characterization of Thin Films and Coatings, Editor(s): Peter M. Martin , Handbook of Deposition Technologies for Films and Coatings. 3rd ed., William Andrew Publishing, NY, 13815 United States,749–864.
Kohli, R. (2019). Developments in Surface Contamination and Cleaning, Chapter 3 - Methods for Assessing Surface Cleanliness, Editor(s): Rajiv Kohli , K. L. Mittal , 12, Elsevier, 23–105.
Skoog, D. , Holler, F. , and Crouch, S. (2007). Principles of Instrumental Analysis. 6th ed. Thomson Brooks/Cole, Belmont, CA, 169–173. ISBN 978-0-495-01201-6.
Metha, A. (13 December 2011). “Principle”. PharmaXChange.info.
Lewis, M. J. , (1996). Sensible and latent heat changes: Physical Properties of Foods and Food Processing Systems, Pages 220–245, ISBN 9781855732728. 10.1533/9781845698423.220
Paulik, J. , Paulik, F. , and Arnold, M. (1983). Thermogravimetric examination of the dehydration of calcium nitrate tetrahydrate under quasiisothermal and quasi-isobaric conditions. J. Thermal Anal., 27, 409418. 10.1007/BF01914678

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Gribben, J. (2004). The scientists; a history of science told through the lives of its greatest inventors. Random House, New York, 424–432.
Harrison, G. R. , and Forbes, G. S. (1925). Spectral energy characteristics of the mercury vapor lamp. J. Opt. Soc. Am., 10, 1–17.
Blasse, G. , and Grabmaier, B. C. (1994). Luminescent materials, Springer-Verlag, Berlin, Heidelberg, 10–11.
Gaster, L. , and Dow, J. S. (1915). Modern illuminants and illuminating engineering, Whittaker & Co, SY16 2AB UK,, 107–111.
Edison, T. A. (1880). Electric-Lamp. No. 223,898. Patented Jan. 27, U. S. patent 865367 Fluorescent Electric Lamp.
Moore's Etheric Light . 1896. The Young Newark Electrician's New And Successful Device. New York Times, Retrieved 2008-05-26.
Justel, T. , Nikol, H. , and Ronda, C. (1998). Angew. Chem. Int. Ed., 37, 3084–3103.
Claude, G. (1913). The development of neon tubes. Eng. Mag., 271–274.
Van Dulken, S. (2002). Inventing the 20th century: 100 inventions that shaped the world: from the airplane to the zipper, New York University Press, New York, 42.
Cao, L. M. , Bu, W. B. , Ren, C. A. , Xu, X. , and Li, Q. (2008). Preparation and luminescent properties of Zn2SiO4:Mn2+ . Key Eng. Mater., 368–372, 375–377.
Lojpur, V. , Nikolić, M. G. , Jovanović, D. , Medić, M. , Antić, Ž. , and Dramićanin, M. D. (2013). Luminescence thermometry with Zn2SiO4:Mn2+ powder. Appl. Phys. Lett., 103, 141912, 1–5.
Srivastava, A. M. , and Soules, T. F. (2000). Phosphors, John Wiley & Sons, Inc., Hoboken, New Jersey.

Stevels, A. L. N. (1976). Recent developments in the application of phosphors. J. Lumin., 12/13, 97.
Josephine, S. , MaxWei, S. , and Sohn, M. D. (2016). A retrospective analysis of compact fluorescent lamp experience curves and their correlations to deployment programs. Energy Policy, 98, 505–512.
Blasse, G. , Bril, A. , and Nieuwpoort, W. C. (1966). On the Eu3+ fluorescence in mixed metal oxides: Part I- The crystal structure sensitivity of thr intensity ratio of electric and magnetic dipole emission. J. Phys. Chem. Solids, 27, 1587–1592.
Adam, J. , Metzger, W. , Koch, M. , Rogin, P. , Coenen, T. , Atchison, J. S. , and König, P. (2017). Light emission intensities of luminescent Y2O3:Eu and Gd2O3:Eu particles of various sizes. Nanomaterials, 7, 26–30.
Sommerdijk, J. L. , and Verstegen, J. M. P. J. (1974). Concentration dependence of the Ce3+ and Tb3+ luminescence of Ce1-xTbxMgAl11O19 . J. Lumin., 9, 415–419.
Kim, K.-B. , Kim, Y.-I. , Chun, H.-G. , Cho, T.-Y. , Jung, J.-S. , and Kang, J.-G. (2002). Structural and optical properties of BaMgAl10O17 Eu2+ phosphor. Chem. Mater., 14, 5045–5052.
Chandar Rao, P. , Ravinder, G. , Anusha, S. , and Sreelatha, C. J. (2021). Synthesis and characterization of BaMgAl10O17: Eu2+ phosphor for efficient displays. AIP Conf. Proc., 2317, 030017, 1–6.
Ekambaram, S. , and Patil, K. C. (1995). Synthesis and properties of rare earth doped lamp phosphors. Bull. Mater. Sci., 18, 921–930.
Welkar, T. (1991). An Interdisciplinary Journal of Research on Excited State Processes in Condensed Matter. J. Lumin., 48, 49, 49 and 50.
Ya, Z. , and Brgoch, J. (2021). Opportunities for next-generation luminescent materials through artificial intelligence. J. Phys. Chem. Letters, 12, 764–772.
Allen, J. W. (1991). Impact processes in electroluminescence. J. Lumin., 48–49, 49–50.
Matossi, F. , and Nudelman, S. (1959). Luminescence. Methods Exp. Phys., 6, 293–334.
Kim, D. , Kim, H.-E. , and Kim, C.-H. (2020). Enhancement of long-persistent phosphorescence by solid-state reaction and mixing of spectrally different phosphors. ACS Omega, 5, 10909–10918.
Illuminating Engineering Society (2020). ANSI/IES LM-86-20, approved method: Measuring luminous flux and color maintenance of remote phosphor components, IES, New York.
M. S. Ibrahim , W. K. C. Yung and J. Fan (2018). Lumen Maintenance Lifetime Prediction for Phosphor-converted White LEDs with a Wiener Process based Model *IEEE Xplore* 20th International Conference on Electronic Materials and Packaging 1–4.
Lakowicz, J. R. (2006). Mechanisms and dynamics of fluorescence quenching. Principles of Fluorescence Spectroscopy, 331–351.
Tian, B. , Chen, B. , Tian, Y. , Sun, J. , Li, X. , Zhang, J. , Zhong, H. , Cheng, L. , and Hua, R. (2012). Concentration and temperature quenching mechanisms of Dy3+ luminescence in BaGd2ZnO5 phosphors. J. Phys. Chem. Solids, 73, 1314–1319.
Meza, O. , Villabona-Leal, E. G. , Diaz-Torres, L. A. , Desirena, H. , Rodríguez-López, J. L. , and Pérez, E. (2014). Luminescence concentration quenching mechanism in Gd2O3:Eu3+ . J. Phys. Chem. A, 118, 1390–1396.
Wei-Ning, W. , Widiyastuti, W. , Ogi, T. , Lenggoro, I. W. , and Okuyama, K. (2007). Correlations between crystallite/particle size and photoluminescence properties of sub micrometer phosphors. Chem. Mater., 19, 1723–1730.
Park, H. K. , Oh, J. H. , and Do, Y. R. (2012). Toward scatter-free phosphors in white phosphor-converted light-emitting diodes. Opt. Express, 20, 10218–10228.
Thompson, P. D. , Huang, J. F. , Smith, R. W. , and Keszler, D. A. (1991). The mixed orthoborate pyroborates Sr2Sc2B4O11 and Ba2Sc2B4O11: pyroborate geometry. J. Solid State Chem., 95, 126–135.
He, M. , Kienle, L. , Simon, A. , Chen, X. L. , and Duppel, V. (2004). Re-examination of the crystal structure of Na2Al2B2O7: stacking faults and twinning. J. Solid State Chem., 177, 3212–3218.
Wu, L. , Chen, X. L. , Li, H. , He, M. , Xu, Y. P. , and Li, X. Z. (2005). Structure determination and relative properties of novel cubic borates MM'4(BO3)3 (M = Li, M′ = Sr; M = Na, M′ = Sr, Ba). Inorg. Chem., 44, 6409–6414.
Cai, G. M. , Sun, Yu , Li, H. K. , Fan, X. , Chen, X. L. , Zheng, F. , and Jin, Z. P. (2011). Crystal structure and photoluminescence of Tb3+-activated Ba3InB3O9 . Mater. Chem. Phys., 129, 761–768.
Das, K. , Marathe, A. , Zhang, X. , Zhao, Z. , and Chaudhuri, J. (2016). Superior white light emission and color tunability of tri-doped YBO3:Tb3+, Eu3+ and Dy3+ for white light emitting diodes. RSC Adv., 6, 95055–95061.
Murthy, K. V. R. , Sai Prasad, A. S. , and Rao, M. R. (2012). Luminescence characteristics of Eu and Tb doped YGdBO3 phosphor. Phys. Procedia, 29, 70–75.
Zhang, J. , Yang, M. , Jin, H. , Wang, X. , Zhao, X. , Liu, X. , and Peng, L. (2012). Self-assembly of LaBO3:Eu twin microspheres synthesized by a facile hydrothermal process and their tunable luminescence properties. Mater. Res. Bull., 47, 247–252.
Ingle, J. T. , Gawande, A. B. , Sonekar, R. P. , Nagpure, P. A. , and Omanwar, S. K. (2013). Synthesis and photoluminescence of inorganic borate host red emitting VUV phosphor YCaBO4:Eu3+ . AIP Conf. Proc., 1536, 895–899.

Lin, H. , Hou, D. , Li, L. , Tao, Y. , and Liang, H. (2013). Luminescence and site occupancies of Eu3+ in La2CaB10O19 . Dalton Trans., 42, 12891–12897.
Pązik, R. , Zawisza, K. , Watras, A. , Maleszka-Bagińska, K. , Boutinaud, P. , Mahiou, R. , and Dereń, P. J. (2012). Temperature induced emission quenching processes in Eu3+-doped La2CaB10O19 . J. Mater. Chem., 22, 22651–22657.
Koparkar, K. A. , Bajaj, N. S. , and Omanwar, S. K. (2015). Effect of Eu3+ doping on fluorescence properties of novelphosphor Li2Y2B2O7 . Optoelectr. Adv. Mater. – Rapid Comm., 9, 7–8, 915–918.
Zeng, H. , You, F. , Peng, H. , and Huang, S. (2015). Energy transfer from Ce3+ to Tb3+, Dy3+ and Eu3+ in Na3Y(BO3)2 . J. Rare Earth, 33, 1051–1055.
Saubat, B. , Vlasse, M. , and Foussier, C. (1980). Synthesis and structural study of the new rare earth magnesium borates LnMgB5O10 (Ln = La, …, Er). J. Solid State Chem., 34, 271.
Leskel, M. , Saakes, M. , and Blasse, G. (1984). Energy transfer phenomena in GdMgB5O10 . Mater. Res. Bull., 19, 151–159.
Lin, C. K. , Yu, M. , Pang, M. L. , and Lin, J. (2006). Photoluminescent properties of sol-gel derived (La,Gd)MgB5O10:Ce3+/Tb3+ nanocrystalline thin films. Opt. Mater., 28, 913–918.
Johan de Hair , and Johan Van Kemenade (1983). New Tb3+ and Mn2+ activated phosphors and their applications in “Deluxe” lamps Conference: 3rd Int. Conf. Science and Technology of Light Sources, At: Toulouse.
Sonekar, R. P. , Omanwar, S. K. , Moharil, S. V. , Muthal, P. L. , Dhopte, S. M. , and Kondawar, V. K. (2009). Luminescence in LaBaB9O16 prepared by combustion synthesis . J. Lumin., 129, 624–628.
Andrii, S. , and Lis, S. (2013). Green-emitting nanoscaled borate phosphors Sr3RE2(BO3)4:Tb3+ . Mater. Chem. Phys., 140, 447–452.
Sankar, R. (2008). Efficient green luminescence in Tb3+ activated borates, A6MM′(BO3)6 . Opt. Mater., 31, 268–275.
Zhang, X. , Zhang, J. , Xu, J. , and Su, Q. (2005). Luminescent properties of Eu2+-activated SrLaGa3S6O phosphor. J. Alloys Compd., 389, 247252.
Jiang, Y. , Ning, L. , Xia, S. , Yin, M. , and Tanner, P. A. (2004). Third-order contributions to the 8S7/2 → 6P7/2, 6P5/2 two-photon transitions of Eu2+ in KMgF3. J. Phys: Condens Matter, 16, 2773–2778.
Lucas, F. , Jaulmes, S. , Quarton, M. , Le Mercier, T. , Guillen, F. , and Fouassier, C. (2000). Crystal structure of SrAl2B2O7 and Eu2+ luminescence. J Solid State Chem., 150, 404–409.
Jee, S. D. , Park, J. K. , and Lee, S. H. (2006). Photoluminescence properties of Eu2+ activated Sr3SiO5 phosphors. J. Mater. Sci., 41, 3139–3141.
Sonekar, R. P. , Omanwar, S. K. , and Moharil, S. V. (2009). Combustion synthesis and photoluminescence of Eu2+ doped BaB8O13 . Ind. J. Pure Appl. Phys., 47, 441–443.
Meza-Rochaa, A. N. , Camarillob, I. , Moralesc, R. L. , and Caldiño, U. (2017). Reddish-orange and neutral/warm white light emitting phosphors: Eu3+, Dy3+ and Dy3+/Eu3+ in potassium mzinc phosphate glasses. J. Lumin., 183, 341–347.
Caldino, U. , Speghini, A. , and Bettinelli, M. (2006). Optical spectroscopy of zinc metaphosphate glasses activated by Ce3+ and Tb3+ ions . J. Phys: Condens. Matter, 18, 3499–3505.
Yury Yu, D. , Deyneko, D. V. , Spassky, D. A. , Lazoryak, B. I. , and Stefanovich, S. Yu . (2021). A novel high color purity blue-emitting Tm3+ doped β-Ca3(PO4)2 type phosphor for WLED application. Optik, 227, 166027–166032.
Sha Chen , and Jiaxing Zhang . 2016. Environmental Impacts of Compact Fluorescent Lamps and Linear Fluorescent Lamps in China, International Conference on Civil, Transportation and Environment (ICCTE 2016) ISBN 978-94-6252-185-8.
Lim, S. R. , Kang, D. , Ogunseitan, O. A. , and Schoenung, J. M. (2013). Potential environmental impacts from the metals in incandescent, compact fluorescent lamp (CFL) and light - emitting diode (LED) bulbs. Environ. Sci. Technol., 47, 1040–1047.
Weber, L. F. (2000). Colour plasma displays, the electrical engineering handbook, edited by Richard C. Dorf , CRC Press, Boca Raton, Florida, 1997.
Kenji, T. (2006). Recent research and development of VUV phosphors for a mercury free lamp. J. Alloys Compd., 408–412, 665–668.
Kenji, T. , Yu Ichiro, I. , Takashi, N. , Kazuyoshi, U. , and Mineo, S. (2003). New VUV phosphor, NaLnGeO4:Eu3+ (Ln = Rare Earth). Chem. Lett., 32, 346–347.
Ronda, C. R. (1995). Phosphors for lamps and displays: an application view. J. Alloys Compd., 225, 534–538.
Mildren, R. P. , and Carman, R. J. (2001). Enhanced performance of a dielectric barrier discharge lamp using short pulsed excitation. J. Phys. D: Appl. Phys., 34, L1–L3.
Sommerdijk, J. L. , Bril, A. , and Jager, A. W. (1974). Two photon luminescence with ultraviolet excitation of trivalent praseodymium. J. Lumin., 8, 341–343.
Srivastava, A. M. , and Doughty, D. A. (1996). Photon cascade luminescence of Pr3+ in LaMgB5O10 . J. Electrochem. Soc., 143, 4113–4116.
Chen, Y. , Shi, C. , Yan, W. , Qi, Z. , and Fu, Y. (2006). Energy transfer between Pr3+ and Mn2+ in SrB4O7: Pr, Mn. Appl. Phy. Lett., 88, 061906, 1–3.

Depp, S. W. , and Howard, W. E. (1993). Flat-panel displays: recent advances in microelectronics and liquid crystals make possible video screens that can be hung on a wall or worn on a wrist. Sci. Am., 268, 90–97.
Pappalardo, R. (1976). Calculated quantum yields for photon-cascade emission (PCE) for Pr3+ and Tm3+ in fluoride hosts. J. Lumin., 14, 159–193.

Borate Phosphors for Solid-State Lighting

Shur, M. S. , and Zukauskas, R. (2005). Solid-state lighting: toward superior illumination. Proceedings of the IEEE, 93(10), 1691–1703. 10.1109/JPROC.2005.853537
Žukauskas, A. , Vaicekauskas, R. , Ivanauskas, F. , Vaitkevičius, H. , and Shur, M. S. (2008). Spectral optimization of phosphor-conversion light-emitting diodes for ultimate colour rendering. Applied Physics Letters, 93(5), 051115. 10.1063/1.2966150
A. Katelnikovas , A. Kareiva , H. Winkler , T. Jüstel , ICL'11 – 16th International Conference on Luminescence, Ann Arbor, MI, USA, June 26–July 1 (2011) 60.
Johnstone, B. (2007). Brilliant!: Shuji Nakamura and the Revolution in Lighting Technology. Prometheus Books, Amherst, New York, USA.
T.A. Edison , U.S. patent No. 223, (1879) 898.
Thayer, R. N. , and Barnes, B. T. (1939). The basis for high efficiency in fluorescent lamps. Journal of the Optical Society of America, 29(3), 131–134. https://www.osapublishing.org/josa/abstract.cfm?URI=josa-29-3-131
F. Meyer , H. Spanner , and E. Germet , US 2 182(1939) 732.
Tarashioon, S. , Baiano, A. , Van Zeijl, H. , Guo, C. , Koh, S. W. , Van Driel, W. D. , and Zhang, G. Q. (2012 May 1). An approach to "Design for Reliability" in solid state lighting systems at high temperatures. Microelectronics Reliability, 52(5), 783–793. 10.1016/j.microrel.2011.06.029
Nakamura, S. (1991). GaN growth using GaN buffer layer. Japanese Journal of Applied Physics, 30(10A), L1705. 10.1143/jjap.30.l1705
Nakamura, S. , Mukai, T. , and Senoh, M. (1994). Candelaclass highbrightness InGaN/AlGaN double heterostructure bluelightemitting diodes. Applied Physics Letters, 64(13), 1687–1689. 10.1063/1.111832
Wierer, J. J. , Steigerwald, D. A. , Krames, M. R. , O'Shea, J. J. , Ludowise, M. J. , Christenson, G. , ... and Stockman, S. A. (2001). High-power AlGaInN flip-chip light-emitting diodes. Applied Physics Letters, 78(22), 3379–3381. 10.1063/1.1374499
Zakheim, D. A. , Smirnova, I. P. , Roznanskii, I. V. , Gurevich, S. A. , Kulagina, M. M. , Arakcheeva, E. M. , ... and Itkinson, G. V. (2005). High-power flip-chip blue light-emitting diodes based on AlGaInN. Semiconductors, 39(7), 851–855. 10.1134/1.1992647
Narukawa, Y. , Ichikawa, M. , Sanga, D. , Sano, M. , and Mukai, T. (2010). White light emitting diodes with super-high luminous efficacy. Journal of Physics D: Applied Physics, 43(35), 354002. 10.1088/0022-3727/43/35/354002
Mueller-Mach, R. , Mueller, G. O. , Krames, M. R. , and Trottier, T. (2002). High-power phosphor-converted light-emitting diodes based on III-nitrides. IEEE Journal of Selected Topics in Quantum Electronics, 8(2), 339–345. 10.1109/2944.999189
Mueller-Mach, R. , Mueller, G. O. , and Krames, M. R. (2004, January). Phosphor materials and combinations for illumination-grade white PCLEDs. In Third International Conference on Solid State Lighting (Vol. 5187, pp. 115–122). International Society for Optics and Photonics.10.1117/12.514074
Nakamura, S. , and Fasol, G. (2013). The Blue Laser Diode: GaN Based Light Emitters and Lasers. Springer Science & Business Media,Berlin, Germany.
Jüstel, T. , Möller, S. , Winkler, H. , and Adam, W. (2012). Luminescent Materials in Ullmann's Encyclopedia of Industrial Chemistry, Vol. A1-28. 1–75
https://www.lrc.rpi.edu/programs/solidstate/sslwhat.asp
https://www.energy.gov/sites/default/files/2020/02/f72/2019_ssl-energy-savings-forecast.pdf
https://www.idtechex.com/en/research-report/oled-lighting-opportunities-2017-2027-forecasts-technologies-players/526
Xie, R. J. , Li, Y. Q. , Hirosaki, N. , and Yamamoto, H. (2011). Nitride Phosphors and Solid-state Lighting. Boca Raton, FL: Taylor & Francis. 10.1201/b10939
https://www.stouchlighting.com/blog/top-15-advantages-of-led-lighting
https://innovationtoronto.com/2017/03/flexible-led-displays-containing-printed-electronics-ready-for-roll-to-roll-manufacturing/
https://www.ledsmagazine.com/architectural-lighting/retail-hospitality/article/16696265/benefits-and-drawbacks-of-leds
https://worldwidescience.org/topicpages/l/led+accent+lighting.html
https://www.thelightbulb.co.uk/resources/ultimate-guide-led-lights-advantages-leds/

Khan, Q. , Khan, S. A. , and Bao, Q. (2020 Jan 1). Light-emitting devices. In 2D Materials for Photonic and Optoelectronic Applications (pp. 175–197). Woodhead Publishing, Sawston, Cambridge, 10.1016/B978-0-08-102637-3.00007-3

Humphreys, C. J. (2008). Solid-state lighting. MRS Bulletin, 33(4), 459–470. 10.1557/mrs2008.91

https://www.doitpoms.ac.uk/tlplib/semiconductors/direct.php

Fu, H. , and Zhao, Y. 2018). Efficiency Droop in GaInN/GaN LEDs. In Nitride Semiconductor Light-Emitting Diodes (LEDs), Jan 1 (pp. 299–325). Woodhead Publishing, Sawston, Cambridge.

Huang, J. J. , Kuo, H. C. , and Shen, S. C. (2017 Oct 24). Nitride Semiconductor Light-Emitting Diodes (LEDs): Materials, Technologies, and Applications. Woodhead Publishing, Sawston, Cambridge,10.1016/C2016-0-01551-6

https://www.led-professional.com/technology/light-generation/successful-extraction-of-light-from-semiconductors-with-the-highest-efficiency

Steigerwald, D. A. , Bhat, J. C. , Collins, D. , Fletcher, R. M. , Holcomb, M. O. , Ludowise, M. J. , ... and Rudaz, S. L. (2002). Illumination with solid state lighting technology. IEEE Journal of Selected Topics in Quantum Electronics, 8(2), 310–320. 10.1109/2944.999186

Ye, S. , Xiao, F. , Pan, Y. X. , Ma, Y. Y. , and Zhang, Q. Y. (2010 Dec 1). Phosphors in phosphor-converted white light-emitting diodes: recent advances in materials, techniques and properties. Materials Science and Engineering: R: Reports, 71(1), 1–34. 10.1016/j.mser.2010.07.001

Chen, L. , Lin, C. C. , Yeh, C. W. , and Liu, R. S. (2010). Light converting inorganic phosphors for white light-emitting diodes. Materials, 3(3), 2172–2195. 10.3390/ma3032172

Blasse, G. , and Bril, A. (1967). A new phosphor for flyingspot cathoderay tubes for colour television: yellow emitting Y3Al5O12–Ce3+. Applied Physics Letters, 11(2), 53–55. 10.1063/1.1755025

Hirayama, H. , Tsukada, Y. , Maeda, T. , and Kamata, N. (2010). Marked enhancement in the efficiency of deep-ultraviolet AlGaN light-emitting diodes by using a multiquantum-barrier electron blocking layer. Applied Physics Express, 3(3), 031002 10.1016/j.jcrysgro.2003.12.030

Wang, H. X. , Li, H. D. , Lee, Y. B. , Sato, H. , Yamashita, K. , Sugahara, T. , and Sakai, S. (2004). Fabrication of high-performance 370 nm ultraviolet light-emitting diodes. Journal of Crystal Growth, 264(1–3), 48–52. 10.1016/j.jcrysgro.2003.12.030

Lee, S. N. , Paek, H. S. , Kim, H. , Kim, K. K. , Cho, Y. H. , Jang, T. , and Park, Y. (2008). Growth and characterization of the AlInGaN quaternary protective layer to suppress the thermal damage of InGaN multiple quantum wells. Journal of Crystal Growth, 310(16), 3881–3883. 10.1016/j.jcrysgro.2008.05.056

Liu, Y. , Egawa, T. , Ishikawa, H. , and Jimbo, T. (2003). Growth and characterization of high-quality quaternary AlInGaN epilayers on sapphire. Journal of Crystal Growth, 259(3), 245–251. 10.1016/j.jcrysgro.2003.07.014

McIntosh, F. G. , Boutros, K. S. , Roberts, J. C. , Bedair, S. M. , Piner, E. L. , and ElMasry, N. A. (1996). Growth and characterization of AlInGaN quaternary alloys. Applied Physics Letters, 68(1), 40–42. 10.1063/1.116749

Park, B. K. , Park, H. K. , Oh, J. H. , Oh, J. R. , and Do, Y. R. (2012). Selecting morphology of Y3Al5O12: Ce3+ phosphors for minimizing scattering loss in the pc-LED package. Journal of the Electrochemical Society, 159(4), J96. 10.1149/2.031204jes

Kottaisamy, M. , Thiyagarajan, P. , Mishra, J. , and Rao, M. R. (2008). Color tuning of Y3Al5O12: Ce phosphor and their blend for white LEDs. Materials Research Bulletin, 43(7), 1657–1663. 10.1016/j.materresbull.2007.09.005

Shen, C. Y. , Li, K. , Hou, Q. L. , Feng, H. J. , and Dong, X. Y. (2010). White LED based on YAG: Ce, Gd phosphor and CdSe–ZnS core/shell quantum dots. IEEE Photonics Technology Letters, 22(12), 884–886. 10.1109/LPT.2010.2046724

Uchida, Y. , Setomoto, T. , Taguchi, T. , Nakagawa, Y. , and Miyazaki, K. (2000, June). Characteristics of high-efficiency InGaN-based white LED lighting. In Display Technologies Iii (Vol. 4079, pp. 120–126). International Society for Optics and Photonics. 10.1117/12.389397

Adachi, S. , Abe, H. , Kasa, R. , and Arai, T. (2012). Synthesis and Properties of Hetero-Dialkaline Hexafluorosilicate Red Phosphor KNaSiF6:Mn4+. Journal of the Electrochemical Society, 159, J34– J37.

Adachi, S. , Abe, H. , Kasa, R. , and Arai, T. (2011). Synthesis and properties of hetero-dialkaline hexafluorosilicate red phosphor KNaSiF6: Mn4+. Journal of the Electrochemical Society, 159(2), J34. 10.1149/2.064202jes

Arai, Y. , and Adachi, S. (2011). Optical properties of Mn4+-activated Na2SnF6 and Cs2SnF6 red phosphors. Journal of Luminescence, 131(12), 2652–2660. 10.1016/j.jlumin.2011.06.042

Kasa, R. , and Adachi, S. (2012). Red and Deep Red Emissions from Cubic K2SiF6:Mn4+ and Hexagonal K2MnF6 Synthesized in HF/KMnO4/KHF2/Si Solutions,Journal of the Electrochemical Society, 159, J89–J95.

Kasa, R. , and Adachi, S. (2012). Red and deep red emissions from cubic K2SiF6: Mn4+ and hexagonal K2MnF6 synthesized in HF/KMnO4/KHF2/Si solutions. Journal of the Electrochemical Society, 159(4), J89. 10.1149/2.005204jes

Arai, Y. , and Adachi, S. (2011). Optical Transitions and Internal Vibronic Frequencies of MnF_6^{2-} Ions in Cs_2SiF_6 and Cs_2GeF_6 Red Phosphors,Journal of the Electrochemical Society, 158, J179–J183.

Arai, Y. , and Adachi, S. (2011). Optical Transitions and Internal Vibronic Frequencies of MnF_6^{2-} Ions in Cs_2SiF_6 and Cs_2GeF_6 Red Phosphors. Journal of the Electrochemical Society, 158(6), J179. 10.1149/1.3576124

Wang, J. , Jing, X. , Yan, C. , Lin, J. , and Liao, F. (2006). Influence of fluoride on f–f transitions of Eu3+ in LiEuM2O8 (M = Mo, W). Journal of Luminescence, 121(1), 57–61. 10.1016/j.jlumin.2005.10.003

Guo, C. , Gao, F. , Xu, Y. , Liang, L. , Shi, F. G. , and Yan, B. (2009). Efficient red phosphors Na5Ln (MoO4) 4: Eu3+ (Ln = La, Gd and Y) for white LEDs. Journal of Physics D: Applied Physics, 42(9), 095407. 10.1088/0022-3727/42/9/095407

Qi, X. , Liu, C. M. , and Kuo, C. C. (2010). Pr3+ doped LaTiNbO6 as a single phosphor for white LEDs. Journal of Alloys and Compounds, 492(1–2), L61–L63. 10.1016/j.jallcom.2009.11.188

Ju, G. , Hu, Y. , Wu, H. , Yang, Z. , Fu, C. , Mu, Z. , and Kang, F. (2011). A red-emitting heavy doped phosphor Li6Y (BO3) 3: Eu3+ for white light-emitting diodes. Optical Materials, 33(8), 1297–1301.10.1016/j.optmat.2011.03.002

Sakirzanovas, S. , Dutczak, D. , Kareiva, A. , and Jüstel, T. (2012). Concentration influence on temperature-dependent luminescence properties of samarium substituted strontium tetraborate. Journal of Luminescence, 132(1), 141–146. 10.1016/j.jlumin.2011.08.011

Chikte, D. , Omanwar, S. K. , and Moharil, S. V. (2014). Blue emitting KSCN: xCe phosphor for solid state lighting. Journal of Luminescence, 145, 729–732. 10.1016/j.jlumin.2013.08.057

Chikte, D. , and Omanwar, S. K. (2019). Synthesis and luminescence properties of novel NaSCN: xCe3+ phosphor. Journal of Asian Ceramic Societies, 7(3), 350–354. 10.1080/21870764.2019.1641885

Liu, W. R. , Chiu, Y. C. , Yeh, Y. T. , Jang, S. M. , and Chen, T. M. (2009). Luminescence and energy transfer mechanism in Ca10K (PO4) 7: Eu2+, Mn2+ phosphor. Journal of The Electrochemical Society, 156(7), J165–J169. 10.1149/1.3121531

Huang, C. H. , Chen, T. M. , Liu, W. R. , Chiu, Y. C. , Yeh, Y. T. , and Jang, S. M. (2010). A single-phased emission-tunable phosphor Ca9Y (PO4) 7: Eu2+, Mn2+ with efficient energy transfer for white-light-emitting diodes. ACS Applied Materials & Interfaces, 2(1), 259–264. 10.1021/am900668r

Kim, T. G. , Kim, Y. S. , and Im, S. J. (2009). Energy transfer and brightness saturation in (Sr, Ca) 2P2O7: Eu2+, Mn2+ phosphor for UV-LED lighting. Journal of the Electrochemical Society, 156(7), J203. 10.1149/1.3131324

Guo, N. , Zheng, Y. , Jia, Y. , Qiao, H. , and You, H. (2012). A tunable warm-white-light Sr 3 Gd (PO 4) 3: Eu 2+, Mn 2+ phosphor system for LED-based solid-state lighting. New Journal of Chemistry, 36(1), 168–172. 10.1039/C1NJ20532C

Lü, W. , Luo, Y. , Hao, Z. , Zhang, X. , Wang, X. , and Zhang, J. (2012). A new dual-emission phosphor Ca4Si2O7F2: Ce3+, Mn2+ with energy transfer for near-UV LEDs. Materials Letters, 77, 45–47. 10.1016/j.matlet.2012.02.095

Smet, P. F. , Parmentier, A. B. , and Poelman, D. (2011). Selecting conversion phosphors for white light-emitting diodes. Journal of the Electrochemical Society, 158(6), R37–R54 10.1149/1.3568524

Amachraa, M. , Wang, Z , Chen, C. , Hariyani, S. , Tang, H. , Brgoch, J. , and Ong, S. P. (2020 Jul 6). Predicting thermal quenching in inorganic phosphors. Chemistry of Materials, 32(14), 6256–6265. 10.1021/acs.chemmater.0c02231

https://en.wikibooks.org/wiki/File:Human_photopic_response.jpg#metadata

Chhajed, S. , Xi, Y. , Li, Y.-L. , Gessmann, Th. , and Schubert, E. F. (2005). Influence of junction temperature on chromaticity and colour-rendering properties of trichromatic white-light sources based on light-emitting diodes. Journal of Applied Physics, 97. 10.1063/1.1852073

Mirhosseini, R. , Schubert, M. F. , Chhajed, S. , Cho, J. , Kim, J. K. , and Schubert, E. F. (2009). Improved colour rendering and luminous efficacy in phosphor-converted white light-emitting diodes by use of dual-blue emitting active regions. Optics Express, 17 (13) 10805–10813. 10.1364/OE.17.010806

https://upload.wikimedia.org/wikipedia/commons/thumb/8/8f/CIE_<underline>1931</underline>_XYZ_Color_Matching_Functions.svg/325px-CIE_1931_XYZ_Color_Matching_Functions.svg.png

Ohno, Y. (2004, October). Color rendering and luminous efficacy of white LED spectra. In Fourth International Conference on Solid State Lighting (Vol. 5530, pp. 88-98). International Society for Optics and Photonics. 10.1117/12.565757

Tian Y. (2014 Dec). Development of phosphors with high thermal stability and efficiency for phosphor-converted LEDs. Journal of Solid State Lighting, 1(1), 1–5. 10.1186/s40539-014-0011-8

Dexter, D. L. , and Schulman, J. H. (1954 Jun). Theory of concentration quenching in inorganic phosphors. The Journal of Chemical Physics, 22(6), 1063–1070. 10.1063/1.1740265

Park, H. K. , Oh, J. H. , Do, Y. R. (2012 Apr 23). Toward scatter-free phosphors in white phosphor-converted light-emitting diodes. Optics Express, 20(9), 10218–10228. 10.1364%2FOE.20.010218

Chen, R. , and Lockwood, D. J. (2002). Developments in luminescence and display materials over the last 100 years as reflected in electrochemical society publications. Journal of the Electrochemical Society, 149(9), S69. 10.1149/1.1502258

Blasse, G. (1967). Concentration quenching of Eu3+ fluorescence. The Journal of Chemical Physics, 46(7), 2583–2585. 10.1063/1.1841087

Velchuri, R. , Kumar, B. V. , Devi, V. R. , Prasad, G. , Prakash, D. J. , and Vithal, M. (2011). Preparation and characterization of rare earth orthoborates, LnBO3 (Ln= Tb, La, Pr, Nd, Sm, Eu, Gd, Dy, Y) and LaBO3: Gd, Tb, Eu by metathesis reaction: ESR of LaBO3: Gd and luminescence of LaBO3: Tb, Eu. Materials Research Bulletin, 46(8), 1219–1226. 10.1016/j.materresbull.2011.04.006

Kim, K. , Moon, Y. M. , Choi, S. , Jung, H. K. , and Nahm, S. (2008). Luminescent properties of a novel green-emitting gallium borate phosphor under vacuum ultraviolet excitation. Materials Letters, 62(24), 3925–3927. 10.1016/j.matlet.2008.04.085

Shahare, D. I. , Deshmukh, B. T. , Moharil, S. V. , Dhopte, S. M. , Muthal, P. L. , and Kondawar, V. K. (1994). Synthesis of Li2B4O7: Cu phosphor. Physica Status Solidi (A), 141(2), 329–334. 10.1002/pssa.2211410210

Bessière, A. , Jacquart, S. , Priolkar, K. , Lecointre, A. , Viana, B. , and Gourier, D. (2011). ZnGa 2 O 4: Cr 3+: a new red long-lasting phosphor with high brightness. Optics Express, 19(11), 10131–10137. 10.1364/OE.19.010131

Huang, Y. , Nakai, Y. , Tsuboi, T. , and Seo, H. J. (2011). The new red-emitting phosphor of oxyfluoride Ca 2 RF 4 PO 4: Eu 3+(R = Gd, Y) for solid state lighting applications. Optics Express, 19(7), 6303–6311. 10.1364/OE.19.006303

Yuan, S. , Yang, Y. , Zhang, X. , Tessier, F. , Cheviré, F. , Adam, J. L. , ... and Chen, G. (2008). Eu2+ and Mn2+ codoped Ba2Mg (BO3)2—new red phosphor for white LEDs. Optics Letters, 33(23), 2865–2867. 10.1364/OL.33.002865

Bandi, V. R. , Nien, Y. T. , Lu, T. H. , and Chen, I. G. (2009). Effect of calcination temperature and concentration on luminescence properties of novel Ca3Y2Si3O12: Eu phosphors. Journal of the American Ceramic Society, 92(12), 2953–2956. 10.1111/j.1551-2916.2009.03308.x

Huang, C. H. , and Chen, T. M. (2010). Ca 9 La (PO 4) 7: Eu 2+, Mn 2+: an emission-tunable phosphor through efficient energy transfer for white light-emitting diodes. Optics Express, 18(5), 5089–5099. 10.1364/OE.18.005089

Kodaira, C. A. , Brito, H. F. , and Felinto, M. C. F. (2003). Luminescence investigation of Eu3+ ion in the RE2 (WO4) 3 matrix (RE = La and Gd) produced using the Pechini method. Journal of Solid State Chemistry, 171(1–2), 401–407. 10.1016/S0022-4596(02)00221-9

Kuo, T. W. , Huang, C. H. , and Chen, T. M. (2010). Novel yellowish-orange Sr8 Al12O24S2: Eu2+ phosphor for application in blue light-emitting diode based white LED. Optics Express, 18(102), A231–A236. 10.1364/OE.18.00A231

Duan, C. J. , Delsing, A. C. A. , and Hintzen, H. T. (2009). Photoluminescence properties of novel red-emitting Mn2+-activated MZnOS (M–= Ca, Ba) phosphors. Chemistry of Materials, 21(6), 1010–1016. 10.1021/cm801990r

Ando, M. , and Ono, Y. A. (1990). Role of Eu2+ luminescent centers in the electrooptical characteristics of red emitting CaS: Eu thinfilm electroluminescent devices with memory. Journal of Applied Physics, 68(7), 3578–3583. 10.1063/1.346317#

Kumar, V. , Pitale, S. S. , Mishra, V. , Nagpure, I. M. , Biggs, M. M. , Ntwaeaborwa, O. M. , and Swart, H. C. (2010). Luminescence investigations of Ce3+ doped CaS nanophosphors. Journal of Alloys and Compounds, 492(1–2), L8–L12. 10.1016/j.jallcom.2009.11.076

Xie, R. J. , Hirosaki, N. , Mitomo, M. , Takahashi, K. , and Sakuma, K. (2006). Highly efficient white-light-emitting diodes fabricated with short-wavelength yellow oxynitride phosphors. Applied Physics Letters, 88(10), 101104. 10.1063/1.2182067

Liu, T. C. , Cheng, B. M. , Hu, S. F. , and Liu, R. S. (2011). Highly stable red oxynitride β-SiAlON: Pr3+ phosphor for light-emitting diodes. Chemistry of Materials, 23(16), 3698–3705. 10.1021/cm201289s

Hecht, C. , Stadler, F. , Schmidt, P. J. , auf der Günne, J. S. , Baumann, V. , and Schnick, W. (2009). SrAlSi4N7: Eu2+− A nitridoalumosilicate phosphor for warm white light (pc) LEDs with edge-sharing tetrahedra. Chemistry of Materials, 21(8), 1595–1601. 10.1021/cm803231h

Wu, L. , Sun, J. C. , Zhang, Y. , Jin, S. F. , Kong, Y. F. , and Xu, J. J. (2010). Structure determination and relative properties of novel chiral orthoborate KMgBO3. Inorganic Chemistry, 49(6), 2715–2720. 10.1021/ic901963t

Wu, L. , Zhang, Y. , Kong, Y. F. , Sun, T. Q. , Xu, J. J. , and Chen, X. L. (2007). Structure determination of novel orthoborate NaMgBO3: a promising birefringent crystal. Inorganic Chemistry, 46(13), 5207–5211. 10.1021/ic062429i

Wu, L. , Zhang, Y. , Chen, X. L. , Kong, Y. F. , Sun, T. Q. , Xu, J. J. , and Xu, Y. P. (2007). The Na2O–SrO–B2O3 diagram in the B-rich part and the crystal structure of NaSrB5O9. Journal of Solid State Chemistry, 180(4), 1470–1475. 10.1016/j.jssc.2007.02.014

Wu, L. , Chen, X. L. , Zhang, Y. , Kong, Y. F. , Xu, J. J. , and Xu, Y. P. (2006). Ab initio structure determination of novel borate NaSrBO3. Journal of Solid State Chemistry, 179(4), 1219–1224.10.1016/j.jssc.2006.01.003

Wu, L. , Chen, X. L. , Li, H. , He, M. , Xu, Y. P. , and Li, X. Z. (2005). Structure Determination and Relative Properties of Novel Cubic Borates MM ‘4 (BO3) 3 (M = Li, M ‘= Sr; M = Na, M ‘= Sr, Ba). Inorganic Chemistry, 44(18), 6409–6414. 10.1021/ic050299s

Yuan, S. , Yang, Y. , Zhang, X. , Tessier, F. , Cheviré, F. , Adam, J. L. , ... and Chen, G. (2008). Eu 2+ and Mn 2+ codoped Ba 2 Mg (BO 3) 2—new red phosphor for white LEDs. Optics Letters, 33(23), 2865–2867. 10.1364/OL.33.002865

Liu, W. R. , Lin, C. C. , Chiu, Y. C. , Yeh, Y. T. , Jang, S. M. , and Liu, R. S. (2010). ZnB 2 O 4: Bi 3+, Eu 3+: a highly efficient, red-emitting phosphor. Optics Express, 18(3), 2946–2951. 10.1364/OE.18.002946

Zhang, Y. , Wu, L. , Ji, M. , Wang, B. , Kong, Y. , and Xu, J. (2012). Structure and photoluminescence properties of KSr 4 (BO 3) 3: Eu 3+ red-emitting phosphor. Optical Materials Express, 2(1), 92–102.

10.1364/OME.2.000092
Yang, F. , Liang, Y. , Liu, M. , Li, X. , Zhang, M. , and Wang, N. (2013). Photoluminescence properties of novel red-emitting NaSrBO3: Eu3+ phosphor for near-UV light-emitting diodes. Optics & Laser Technology, 46, 14–19. 10.1016/j.optlastec.2012.04.015
Chikte, D. , Omanwar, S. K. , and Moharil, S. V. (2013). Luminescence properties of red emitting phosphor NaSrBO3: Eu3+ prepared with novel combustion synthesis method. Journal of Luminescence, 142, 180–183. 10.1016/j.jlumin.2013.03.045
Li, J. , Yan, H. , and Yan, F. (2016). A novel orange-red emitting borate based phosphor for NUV pumped LEDs. Optik, 127(15), 5984–5989. 10.1016/j.ijleo.2016.04.022
Bajaj, N. S. , Koparkar, K. A. , Nagpure, P. A. , and Omanwar, S. K. (2017). Red and blue emitting borate phosphor excited by near Ultraviolet Light. Journal of Optics, 46(2), 91–94. 10.1007/s12596-016-0344-3
Yuan, S. , Yang, Y. , Zhang, X. , Tessier, F. , Cheviré, F. , Adam, J. L. , ... and Chen, G. (2008). Eu 2+ and Mn 2+ codoped Ba 2 Mg (BO 3) 2—new red phosphor for white LEDs. Optics Letters, 33(23), 2865–2867. 10.1364/OL.33.002865
Majling, J. , Figusch, V. , Čorba, J. , and Hanic, F. (1974). Crystal data on calcium borate chloride, Ca2BO3Cl. Journal of Applied Crystallography, 7(3), 402-402. 10.1107/S0021889874009927
Chikte, D. , Omanwar, S. K. , and Moharil, S. V. (2014). Yellow emitting phosphor for solid state lighting Ca2BO3Cl:Eu2+. International Journal of Basic and Applied Research-Special issue, 4161–4164.
Song, W. S. , Kim, Y. S. , and Yang, H. (2009). Yellow-emitting phosphor of Sr3B2O6: Eu2+ for application to white light-emitting diodes. Materials Chemistry and Physics, 117(2-3), 500–503. 10.1016/j.matchemphys.2009.06.042
Xue, Y. , Xu, X. , Hu, L. , Fan, Y. , Li, X. , Li, J. , ... and Tang, C. (2011). Synthesis and photoluminescence characteristics of (Sr, Ca) 3B2O6: Eu for application in white light-emitting diodes. Journal of Luminescence, 131(9), 2016–2020. 10.1016/j.jlumin.2011.04.032
Wang, R. , Xu, J. , and Chen, C. (2012). Luminescent characteristics of Sr2B2O5: Tb3+, Li+ green phosphor. Materials Letters, 68, 307–309. 10.1016/j.matlet.2011.10.005
Zhijun, W. A. N. G. , Zhiping, Y. , Panlai, L. I. , Qinglin, G. , and Yanmin, Y. A. N. G. (2010). Luminescence characteristics of LiCaBO3: Tb3+ phosphor for white LEDs. Journal of Rare Earths, 28(1), 30–33. 10.1016/S1002-0721(09)60044-2
Cai, G. M. , Sun, Y. , Li, H. K. , Fan, X. , Chen, X. L. , Zheng, F. , and Jin, Z. P. (2011). Crystal structure and photoluminescence of Tb3+-activated Ba3InB3O9. Materials Chemistry and Physics, 129(3), 761–768. 10.1016/j.matchemphys.2011.04.071
Geng, W. , Zhou, X. , Ding, J. , and Wang, Y. (2018). NaBaY (BO3) 2: Ce3+, Tb3+: A novel sharp green emitting phosphor used for WLED and FEDs. Journal of the American Ceramic Society, 101(10), 4560–4571. 10.1111/jace.15693
Guo, C. , Jing, H. , and Li, T. (2012). Green-emitting phosphor Na 2 Gd 2 B 2 O 7: Ce 3+, Tb 3+ for near-UV LEDs. RSC Advances, 2(5), 2119–2122. 10.1039/C2RA00808D
Panse, V. R. , Kokode, N. S. , Yerpude, A. N. , and Dhoble, S. J. (2016). Combustion synthesis of Sr2B2O5: Tb3+ green emitting phosphor for solid state lighting. Optik, 127(4), 1603–1606. 10.1016/j.ijleo.2015.11.030
Singh, V. , Shinde, K. N. , Singh, N. , Pathak, M. S. , Singh, P. K. , and Dubey, V. (2018). Green emitting Tb doped LiBaB9O15 phosphors. Optik, 156, 677–683.10.1016/j.ijleo.2017.11.145
Zhuo, Y. , Zhong, J. , and Brgoch, J. (2019). Controlling Eu2+ substitution towards a narrow-band green-emitting borate phosphor NaBaB9O15: Eu2+. 10.26434/chemrxiv.10110773.v1 1-13
Zhen, L. I. , Zheng, S. , Xing, Y. A. N. G. , Bin, L. U. O. , Shuai, L. I. , Yong, S. U. N. , and Cheng, Q. (2017). Luminescence properties of Sr2MgB2O6: Tb3+, Li+ green-emitting phosphor. Journal of Rare Earths, 35(3), 211–216. 10.1016/S1002-0721(17)60901-3
Liu, W. R. , Huang, C. H. , Wu, C. P. , Chiu, Y. C. , Yeh, Y. T. , and Chen, T. M. (2011). High efficiency and high colour purity blue-emitting NaSrBO 3: Ce 3+ phosphor for near-UV light-emitting diodes. Journal of Materials Chemistry, 21(19), 6869–6874. 10.1039/C1JM10765H
Li, X. , Liu, C. , Guan, L. , Wei, W. , Yang, Z. , Guo, Q. , and Fu, G. (2012). An ideal blue Sr3B2O6: Ce3+ phosphor prepared by sol-combustion method. Materials Letters, 87, 121–123. 10.1016/j.matlet.2012.07.094
Reddy, A. A. , Das, S. , Ahmad, S. , Babu, S. S. , Ferreira, J. M. , and Prakash, G. V. (2012). Influence of the annealing temperatures on the photoluminescence of KCaBO3: Eu3+ phosphor. RSC Advances, 2(23), 8768–8776. 10.1039/C2RA20866K
Chikte, D. , Omanwar, S. K. , and Moharil, S. V. (2014) Blue Emitting Phosphor for Solid State Lighting Application by combustion synthesis: KCaBO3:Ce3+. International Journal of Researches in Biosciences, Agriculture & Technology, 1(2), 173–183.
Nakamura, S. , Inabe, K. , and Takeuchi, N. (1992). Luminescence of sintered Ca2B5O9Cl: Eu2+ excited by UV-light or X-rays. Japanese Journal of Applied Physics, 31(6R), 1823. 10.1143/jjap.31.1823
Guo, C. , Xu, Y. , Ding, X. , Li, M. , Yu, J. , Ren, Z. , and Bai, J. (2011). Blue-emitting phosphor M2B5O9Cl: Eu2+ (MSr, Ca) for white LEDs. Journal of Alloys and Compounds, 509(4), L38–L41. 10.1016/j.jallcom.2010.10.032
Chikte, D. , Omanwar, S. K. , and Moharil, S. V. (2018) Synthesis and photoluminescence properties of Blue emitting Europium doped calcium chloro-borate phosphor suitable for solid state lighting application.

International Journal of Review of Research, 10, 10–14.
Wang, Q. , Deng, D. , Hua, Y. , Huang, L. , Wang, H. , Zhao, S. , ... and Xu, S. (2012). Potential tunable white-emitting phosphor LiSr4 (BO3) 3: Ce3+, Eu2+ for ultraviolet light-emitting diodes. Journal of Luminescence, 132(2), 434–438. 10.1016/j.jlumin.2011.09.003
Panlai, L. , Zhijun, W. , Zhiping, Y. , and Qinglin, G. (2010). A potential single-phased white-emitting LiBaBO3: Ce3+, Eu2+ phosphor for white LEDs. Journal of Rare Earths, 28(4), 523–525. 10.1016/S1002-0721(09)60145-9
Das, S. , Reddy, A. A. , Babu, S. S. , and Prakash, G. V. (2011). Controllable white light emission from Dy 3+–Eu 3+ co-doped KCaBO 3 phosphor. Journal of Materials Science, 46(24), 7770–7775. 10.1007/s10853-011-5756-5
Li, P. , Yang, Z. , Wang, Z. , and Guo, Q. (2008). White-light-emitting diodes of UV-based Sr3Y2 (BO3) 4: Dy3+ and luminescent properties. Materials Letters, 62(10-11), 1455–1457. 10.1016/j.matlet.2007.08.085
Zhang, Q. Y. , Yang, C. H. , and Pan, Y. X. (2007). Enhanced white light emission from GdAl3 (BO3) 4: Dy3+, Ce3+ nanorods. Nanotechnology, 18(14), 145602. 10.1088/0957-4484/18/14/145602
Chang, C. K. , and Chen, T. M. (2007). Sr 3 B 2 O 6: Ce 3+, Eu 2+: a potential single-phased white-emitting borate phosphor for ultraviolet light-emitting diodes. Applied Physics Letters, 91(8), 081902. 10.1063/1.2772195
Guo, C. , Luan, L. , Xu, Y. , Gao, F. , and Liang, L. (2008). White light–generation phosphor Ba2Ca (BO3) 2: Ce3+, Mn2+ for light-emitting diodes. Journal of the Electrochemical Society, 155(11), J310. 10.1149/1.2976215
Xiao, F. , Xue, Y. N. , Ma, Y. Y. , and Zhang, Q. Y. (2010). Ba2Ca (B3O6) 2: Eu2+, Mn2+: A potential tunable blue–white–red phosphors for white light-emitting diodes. Physica B: Condensed Matter, 405(3), 891–895. 10.1016/j.physb.2009.10.009
Guo, C. , Luan, L. , Shi, F. G. , and Ding, X. (2009). White-emitting phosphor Ca2BO3Cl: Ce3+, Eu2+ for UV light-emitting diodes. Journal of the Electrochemical Society, 156(6), J125. 10.1149/1.3106039
Xiao, F. , Xue, Y. N. , and Zhang, Q. Y. (2009). Ca2BO3Cl: Ce3+, Eu2+: a potential tunable yellow–white–blue-emitting phosphors for white light-emitting diodes. Physica B: Condensed Matter, 404(20), 3743–3747. 10.1016/j.physb.2009.06.122
Li, B. , Huang, X. , and Lin, J. (2018). Single-phased white-emitting Ca3Y (GaO) 3 (BO3) 4: Ce3+, Tb3+, Sm3+ phosphors with high-efficiency: photoluminescence, energy transfer and application in near-UV-pumped white LEDs. Journal of Luminescence, 204, 410–418. 10.1016/j.jlumin.2018.08.044
Cai, G. M. , Yang, N. , Liu, H. X. , Si, J. Y. , and Zhang, Y. Q. (2017). Single-phased and colour tunable LiSrBO3: Dy3+, Tm3+, Eu3+ phosphors for white-light-emitting application. Journal of Luminescence, 187, 211–220. 10.1016/j.jlumin.2017.03.017
Gaffuri, P. , Salaün, M. , Gautier-Luneau, I. , Chadeyron, G. , Potdevin, A. , Rapenne, L. , ... and Ibanez, A. (2020). Rare-earth-free zinc aluminium borate white phosphors for LED lighting. Journal of Materials Chemistry C, 8(34), 11839–11849. 10.1039/D0TC02196B
https://www.gtvinc.com/latest-led-technology-trends-in-led-industry/
https://www.earthled.com/blogs/light-2-0-the-earthled-blog-led-lighting-news-tips-reviews/37176324-how-to-choose-the-best-led-light-bulb-for-any-room-in-your-home
https://www.standardpro.com/3-basic-types-of-lighting/
https://www.hgtv.com/design/remodel/mechanical-systems/lighting-tips-for-every-room
https://www.havells.com/en/consumer/lighting.html#gref
https://5.imimg.com/data5/SELLER/Default/2020/11/FI/EN/ON/8313991/wipro-wifi-enabled-smart-led-bulb-b22-9-watt-125x125.jpg
https://www.electrical4u.com/road-lighting-design/
https://www.wiprolighting.com/products/outdoor/streetlights
https://www.ledil.com/product-landing/
https://innovationtoronto.com/<underline>2017/03</underline>/flexible-led-displays-containing-printed-electronics-ready-for-roll-to-roll-manufacturing/
https://www.persistencemarketresearch.com/market-research/led-lighting-market.asp#:~:text=At%20present%2C%20LED%20based%20automotive,LEDs%20nearly%20achieve%20daylight%20quality
https://www.ledsmagazine.com/manufacturing-services-testing/assembly-contract-manufacturing/article/16695370/implementing-led-flash-in-camera-phones
https://www.osram.com/am/light-for/led-lighting/index.jsp
https://soundcertified.com/how-to-install-led-light-strips-car/
Graydon, O. , Jenkins, A. , Pei Chin Won, R. , and Gevaux, D. (2007). Haitz's law. Nature Photonics, 1(1). 10.1038/nphoton.2006.78
https://www.lifitn.com/im-new
https://www.techadvisor.com/feature/small-business/what-is-li-fi-everything-you-need-know-3788560/#:~:text=With%20Li%2DFi%2C%20your%20light,a%20TED%20Talk%20in%202011
https://www.communicationstoday.co.in/two-gujarat-villages-first-in-india-to-get-lifi/

https://www.theglobeandmail.com/drive/culture/article-how-to-automatic-high-beam-systems-work/
https://medium.com/acmvit/li-fi-the-future-of-internet-e573eab6bd0d
https://www.ledsmagazine.com/architectural-lighting/retail-hospitality/article/16696265/benefits-and-drawbacks-of-leds

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Soehnge, H. , Ouhtit, A. , and Ananthaswamy, H. N. (1997). Front. Biosci., 2, 1, d538.
Hardy K. , Meltz M. , and Glickman R. (1997). Medical Physics Publishing. Madison.
Gawande, A. B. (2015). Ultra Violet light Emitting Borate Phosphors. ISBN-978-3-659-71157-2.
Diffey, B. L. (1984). Photodermatology, 1, 103.
McKinlay, A. F. , and Diffey, B. L. (1987). CIE-Journal, 6, 17.
Diffey, B. L. , Janseen, C. T. , Urbach, F. , and Wulf, H. C. (1997). Photodermatol. Photoimmunol. Photomed., 13, 64.
CIE Standard . (1998). Commission Internationale de l" Eclairage, Vienna.
Gordon, P. M. , Saunders, P. J. , Diffey, B. L. , and Farr, P. M. (1998). Br. J. Dermatol., 139, 811.
Diffey, B. L. (1994). Photochem. Photobiol., 60, 380.
Webb, A. R. , Slaper, H. , Koepke, P. , and Schmalwieser, A. W. (2011). Photochem. Photobiol., 87, 483.
Farr, P. M. , and Diffey, B. L. (1985). Br. J. Dermatol., 113, 65.
Parrish., J. A. , and Jaenicke, K. F. (1981). J. Invest. Dermatol., 76, 359.
Dare, R. A. S. , Goodfield, M. J. , and Rowell, N. R. (1989). Br. J. Dermatol, 65, 121.
Krutmann, J. , Czech, W. , and Diepgen, T. (1992). J. Am. Acad. Dermatol., 225, 26.
Kroft, E. B. , Berkhof, N. J. , and Van de Kerkhof, P. C. (2008). J. Am. Acad. Dermatol., 59, 1017.
Cates, E. L. H. (May, 2013). Ph.D. Thesis. Georgia.
Berneburg, M. , Cken, M. R. , and Benedix, F. (2005). Acta. Derm. Venereol., 85, 98.
Honigsmann, H. (2001). Clin. Exp. Dermatol., 26, 343.
Hemne, P. S. , Kunghatkar, R. G. , Dhoble, S. J. , Moharil, S. V. , and Singh, V. (2017). Luminescence, 32, 260.
Fitzpatric, T. B. , and Pathak, M. A. (1959). J. Invest. Dermatol., 32, 229.
Honigsmann, H. (2013). Photochem. Photobiol. Sci., 12, 16.
Mofty A. M. E. (1968). Vitiligo and Psoralens, Pergamon Press, Oxford, 1.
Parrish, J. A. , Fitzpatrick, T. B. , Tanenbaum, L. , and Pathak, M. A. (1974). New Engl. J. Med., 291, 1207.
Hemne, P. S. , Kunghatkar, R. G. , Dhoble, S. J. , Moharil, S. V. , and Singh, V. (2017). Luminescence, 32, 260–270.
Pathak, M. A. , and Daniels, F. (1962). J. Invssr. Dermnrol, 39, 225.
Berneburg, M. , Rocken, M. , and Benedix, F. (2005). Acta Derm Venereol, 85, 98.
Green, C. , Ferguson, J. , Lakshmipathi, T. , and Johnson, B. E. (1988). Br. J. Dermatol., 119, 691.
Mysore, V. (2009). Indian J. Dermatol. Venereol. Leprol., 75, 119.
Fritz, K. (2008). Med. Laser. Appl., 23, 87.
Lucroy, M. D. (2002). Vet. Clin. Small. Anim., 32, 693.
Wiegell, S. R. , Wulf, H. C. , Szeimies, R. M. , Seguin, N. B. , Bissonnette, R. , Gerritsen, M. J. , Gilaberte, Y. , Pinton, P. C. , Morton, C. A. , Sidoroff, A. , and Braathen, L. R. (2012). J. Eur. Acad. Dermatol. Venereol., 26, 673.
Kalisiak, M. S. , and Rao, J. (2007). P. Dermatol. Clin., 25, 15.
Sotiriou, E. , Apalla, Z. , Maliamani, F. , Zaparas, N. , Panagiotidou, D. , and Ioannides, D. (2009). J. Eur. Acad. Dermatol. Venereol., 23, 1061.
Chamberlain, A. J. , and Kurwa, H. A. (2003). Am. J. Clin. Dermatol., 4, 149.
Langan, S. M. , and Collins, P. (2006). Br. J. Dermatol., 154, 146.
Szeimies, R. M. , Karrer, S. , and Fijan, S. R. (2002). J. Am. Acad. Dermatol., 47, 258.
Carlson S. , and Bordeaux J. (2011). Evidence Based Dermatology. 2nd ed. People’s Medical Publishing House, Shelton, CT.
Adam, R. , Schmitt, B. A. , and Jeremy, S. (2013). Clin. Dermatol., 31, 712.
Jennifer, D. , Bahner, M. D. , and Jeremy, S. (2013). Clin. Dermatol., 31, 792.
Leggett, C. L. , Gorospe, E. C. , Murad, M. H. , Montori, V. M. , Barona, T. H. , and Wang, K. K. (2012). Photodiag. Photod. Ther., 9, 189.
Julia Buchholz, D. V. M. , and Walt, H. (2013). Photodiag. Photod. Ther., 10, 342.
Fischer, T. (1976) UV-light treatment of psoriasis. Acta Derm Venereol, 56, 473.
Parrish, J. A. , and Jaenicke, K. F. (1981) Action spectrum for phototherapy of psoriasis. J. Invest. Dermatol., 76, 359.

Chauhan, A. O. , Gawande, A. B. , and Omanwar, S. K. (2016). J. Inorg. Organ. Poly. Mater., 26, 1023.
Weelden, H. V. , Faille, H. B. , Young, E. , and Leun, J. C. V. (1988). Br. J. Dermatol, 119, 119.
Karvonen, J. , Kokkonen, E. , and Ruotsalainen, E. (1989). Acta. Derm. Venereol., 69.
Johnson, B. , Green, C. , and Lakshmipathi, T. (1988). J. Ferguson Proc. 2nd Eur. Photobiol. Congr., Padua, Italy.
Rose, R. F. , Batchelor, R. J. , Turner, D. , and Goulden, V. (2009). J. Am. Acad. Dermatol., 61, 259.
Haykal, K. A. , Groseilliers, J. P. D. (2006). J. Cutan. Med. Surg., 10, 234.
de Vries, A. J. , and Blasse, G. (1986). Mat. Res. Bull., 21, 683.
Folkerts, H. F. , Ghianni, F. , Blasse, G. (1996). J. Phys. Chem. Solids, 57, 1659.
Dijken, V. , Folkerts, H. F. , and Blasse, G. (1997). J. Lumin., 72, 660.
Dieke G. H. (1968). Spectra and Energy Levels of Rare Earth Ions in Crystals. Interscience, New York.
Zhang, Q. Y. , and Huang, X. Y. (2010). Prog. Mater. Sci., 55, 353.
Sun, H. T. , Zhou, J. , and Qiu, J. (2014). Prog. Mater. Sci., 64, 1.
De Jong, M. , Meijerink, A. , Barandiaran, Z. , and Seijo, L. (2014). J. Phys. Chem. C, 118, 17932.
Mohan, R. (2010) Green bismuth. Nat. Chem., 2, 336.
Xia, Z. , Chen, D. , Yang, M. , and Ying, T. (2010). J. Phys. Chem. Solids, 71, 175.
Kang, F. , Peng, M. , Xu, S. , Ma, Z. , Dong, G. , and Qiu, J. (2014). Eur. J. Inorg. Chem., 2014, 1373.
Zeng, X. , Im, S. J. , Jang, S. H. , Kim, Y. M. , Bin Park, H. , Son, S. H. , Hatanaka, H. , Kim, G. Y. , and Kim, S. G. (2006). J. Lumin., 121, 1.
Chen, L. , Jiang, Y. , Zhang, G. , Wu, C. , Yang, G. , Wang, C. , and Li, G. (2008). Chinese Physic Lett., 25, 1884.
Ju, G. , Hu, Y. , Chen, L. , Wang, X. , Mu, Z. , Wu, H. , and Kang, F. (2012). J. Lumin., 132, 1853.
Blasse, G. , and Bril, A. (1967). J. Chem. Phys., 47, 5139.
Forster, V. T. (1948). Ann. Phys., 437, 55.
Dexter, D. L. (1953). J. Chem. Phys., 21, 836.
Xu, C. , Sheng, Y. , Yuan, B. , Guan, H. , Ma, P. , Song, Y. , Zou, H. , and Zheng, K. (2016). RSC Adv., 6, 89984.
Zhu, J. , Cheng, W. D. , Wu, D. S. , Zhang, H. , Gong, Y. J. , Tong, H. N. , and Zhao, D. (2008). J. Alloys Compd., 454, 419.
Ternane, R. , Adad, M. T. C. , Panczer, G. , Goutaudier, C. , Dujardin, C. , Boulon, G. , Ariguib, N. K. , and Ayedi, M. T. (2002). Solid State Sci., 4, 53.
Blasse, G. , Grabmaier, B. C. (1994). Lumin. Mater. Springer, Berlin, Heidelberg.
Caldino, U. , Speghini, A. , and Bettinelli, M. (2006). J. Phys. Condens. Matter, 18, 3499.
Wang, T. , Xia, Z. , Xiang, Q. , and Qin, S. (2015). Q. Liu. J. Lumin., 166, 106.
Wu, L. , Chen, X. L. , Tu, Q. Y. , He, M. , Zhang, Y. , and Xu, Y. P. (2003). J. Alloys Compd., 358, 23.
Wu, L. , Chen, X. L. , Zhang, Y. , Kong, Y. F. , Xu, J. J. , and Xu, Y. P. (2006). J. Solid State Chem., 179, 1219.
Wu, L. , Chen, X. L. , Li, H. , He, M. , Xu, Y. P. , and Li, X. Z. (2005). Inorg. Chem., 44, 6409.
Gravereau, P. , Chaminade, J. P. , Pechev, S. , Nikolov, V. , Ivanova, D. , and Peshev, P. (2002). Solid State Sci., 4, 993.
Nagpure, P. A. , Bajaj, N. S. , Sonekar, R. P. , and Omanwar, S. K. (2011). Indian J. Pure. Appl. Phys., 49, 799.
Nagpure, P. A. , and Omanwar, S. K. (2012). J. Lumin., 132, 2088.
Tamboli, S. , Rajeswari, B. , and Dhoble, S. J. (2016). Luminescence, 31, 551–556.
Singh, V. , Sivaramaiah, G. , Singh, N. , Pathak, M. S. , Rao, J. L. , Singh, Pramod K , and Nagpure, A. S. (2019). Bull. Mater. Sci., 42, 19.
Nagpure, P. A. , and Omanwar, S. K. (2015). Indian J. Pure. Appl. Phys., 53, 77.
Deng, T. , Yan, S. , and Hu, J. (Feb 2016). J. Rare Earths, 34, 2, 137.
Kunghatkar, R. G. , Hemne, P. S. , and Dhoble, S. J. (2018). AIP Conf. Proc., 1953, 080038, doi: 10.1063/1.5032844
Bhagat, S. P. , Gawande, A. B. , and Omanwar, S. K. , 10.1016/j.optmat.2014.11.043
Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2014). Mater. Res. Bull., 60, e285–e291.
Ramteke, D. D. , and Gedam, R. S. (May 2014). J. Rare Earths, 32, 5, 389.
Kunghatkar, R. G. , Dhoble, S. J. , and Hemne, P. S. (2016). Luminescence, 31, 1503, doi: 10.1002/bio.3136
Pekgozlu, I. , and Karabulut, H. (2009). Inorg. Mater., 45, 1, 61.
Sankar, R. , and Rao, G. V. S. (1998). J. Alloys Compd., 281, 126.
Tascıoglu, S. , Pekgozlu, I. , and Mergen, A. (2008). Mater. Chem. Phys., 112, 78.
Pekgozlu, I. , et al. (2008). J. Lumin., 128, 9, 1541.
Pekgozlu, I. , Tascıoglu, S. , and Menger, A. (2008). Inorg. Mater., 44, 10, 1151.
Blasse, G. , Sas, S. J. M. , Smit, W. M. A. , and Konijnendijk, W. L. (1986). Mater. Chem. Phys., 14, 253.
Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2013). AIP Conf. Proc., 1536, 601.
Pekgozlu, I. , Erdogmus, E. , Demirel, B. , Gok, M. S. , Karabulut, H. , and Basak, A. S. (2011). J. Lumin., 131, 2290–2293.

Kunghatkar, R. G. , Dhoble, S. J. , and Hemne, P. S. (2016). Luminescence. 10.1002/bio.3136
Nicholas, G. (Jan-Feb 2010). Reed, Public Health Rep., 125, 1, 15–27.
https://www.lighting.philips.com/main/products/uv-disinfection/air
Kneiss, M. III-Nitride Ultraviolet Emitters Technology and Applications. Springer Series in Materials Science, ISBN 978-3-319-24098-5 10.1007/978-3-319-24100-5

Borate Phosphor

Holonyak, N. , and Bevacqua, S. F. (1962). Coherent (Visible) light emission from Ga (As1-xPx). Junctions, 4 (1), 82–83. 10.1063/1.1753706
Nakamura, S. , Senoh, N. , Iwasa, N. , and Nagahama, S. (1995). High-brightness ingan blue, green and yellow light-emitting diodes with quantum well structures. Japanese Journal of Applied Physics, 34 (2), L797–L799. 10.1143/JJAP.34.L797
Nakamura, S. (1997). III–V nitride-based light-emitting devices. Solid State Communications, 102 (2–3), 237–248. 10.1016/S0038-1098(96)00722-3
Bommel, W. V. (2015). Interior lighting fundamentals. Technology and Application. Springer, Cham
Lin, M. , Ho, W. , Shih, F. , Chen, D. , and Wu, Y. (1998). A cold-cathode fluorescent lamp driver circuit with synchronous primary-side dimming control. IEEE Transactions on Industrial Electronics, 45 (2), 249–255. 10.1109/41.681223
Lin, D. , and Yan, W. (2010). Modeling of cold cathode fluorescent lamps (CCFLs) with realistic electrode profile. IEEE Transactions on Power Electronics, 25(3), 699–709. 10.1109/TPEL.2009.2035359
Alberts, I. , Barratt, D. , Ray, A. , Disp, J. (2010). Hollow cathode effect in cold cathode fluorescent lamps: A review. Journal of Display Technology, 6(2), 52–59. 10.1109/JDT.2009.2031924
LEECL , U.S. patent No. 2005057143 (2005) 11 08.
Guangsup, C. , Lee, J. Y. , Lee, D. H. , Kim, S. B. , Song, H. S. , Jehuan, K. , Kim, B. S. , Kang, J. G. , Choi, E. H. , Lee, U. W. , Yang, S. C. , and Verboncoeur, J. P. (2005). Glow discharge in the external electrode fluorescent lamp. IEEE Transactions on Plasma Science, 33 (4), 1410–1415. 10.1109/TPS.2005.852434
Cho, K. , Oh, W. , Moon, G. , Park, M. , and Lee, S. (2007). A study on the equivalent model of an external electrode fluorescent lamp based on equivalent resistance and capacitance variation. Journal of Power Electronics, 7(1), 38–43. 10.6113/JPE.2007.7.1.38
D. S. Lim , U. S. Patent No. 2006126332 (2006) 6 15.
I. Hironori , Japanese Patent No. 2004079270 (2004) 0311.
Jinno, M. , Okamoto, M. , Takeda, M. , and Motomura, H. (2007). Luminance and efficacy improvement of low-pressure xenon pulsed fluorescent lamps by using an auxiliary external electrode. Journal of Physics D: Applied Physics, 40 (13), 3889–3895. 10.1088/0022-3727/40/13/S08
Park, J. , and Lim, S. (2007). LCD backlights, light sources, and flat fluorescent lamps. Journal of the Society for Information Display, 15(12), 1109–1114. 10.1889/1.2825100
Hu, W. , Liu, Z. , and Yang, M. (2010). Luminescence characteristics of mercury-free flat fluorescent lamp with arc-shape anodes. IEEE Transactions on Consumer Electronics, 56(4), 2631–2635. 10.1109/TCE.2010.5681150
Jung, J. C. , Lee, J. K. , Seo, I. W. , Oh, B. J. , and Whang, K. W. (2009). Electro-optic characteristics and areal selective dimming method for a new highly efficient mercury-free flat fluorescent lamp (MFFL). Journal of Physics D: Applied Physics, 42(12), 125205. 10.1088/0022-3727/42/12/125205
Winsor, M. , and Flynn, J. (2007). SID Symposium Digest of Technical Paper, 38, 979–982.
Shur, M. , and Zukauskas, A. (2005). Solid-state lighting: Toward superior illumination. Proceedings of the IEEE, 93(10), 1691–1703. 10.1109/JPROC.2005.853537
Lin, H. , Liang, H. , Han, B. , Zhong, J. , Su, Q. , Dorenbos, P. , Birowosuto, M. D. , Zhang, G. , Fu, Y. , and Wu, W. (2007). Luminescence and site occupancy of Ce3+ in Ba2Ca(BO3)2 . Physical Review B, 76(3), 035117. 10.1103/PhysRevB.76.035117
Komeno, A. , Uematsu, K. , Toda, K. , and Sato, M. (2006). VUV properties of Eu-doped alkaline earth magnesium silicate. Journal of Alloys and Compounds, 408–412, 871–874. 10.1016/j.jallcom.2005.01.070
Zhang, Z. , Yuan, J. , Chen, S. , Chen, H. , Yang, X. , Zhao, J. , Zhang, G. , and Shi, C. (2008). Investigation on the luminescence of RE3+ (RE = Ce, Tb, Eu and Tm) in KMGd(PO4)2 (M = Ca, Sr) phosphates. Optical Materials, 30(12), 1848 - 1853. 10.1016/j.optmat.2007.12.002
Lee, K. , Yu, B. , Pyun, C. , and Mho, S. (2002). Vacuum ultraviolet excitation and photoluminescence characteristics of (Y,Gd)Al3(BO3)4/Eu3+ . Solid State Communications, 122 (9), 485–488. 10.1016/S0038-1098(02)00195-3
Shinoya, S. , and Yen, W. M. (1998). Phosphor Handbook. CRC Press, Boca Raton, FL, 623.
Weston, G. F. (1975). Plasma panel displays. Journal of Physics E: Scientific Instruments, 8(12), 981. 10.1088/0022-3735/8/12/001

Boeuf, J. P. (2003). Plasma display panels: Physics, recent developments and key issues. Journal of Physics D: Applied Physics, 36(6), R53. 10.1088/0022-3727/36/6/201

Nagpure, P. A. (2012). Thesis submitted to Sant Gadge Baba Amravati University, Amravati.

http://www.plasmacoalition.org © 2004 Coalition for Plasma Science.

Jüstel, T. , Nikol, H. , (2000). Optimization of luminescent materials for plasma display panels. Advanced Materials, 12(7), 527–530. 10.1002/(SICI)1521-4095(200004)12:7<527::AID-ADMA527>3.0.CO;2-8

Weber L.F. (1997). “Color Plasma Displays,” The Electrical Engineering Handbook, edited by Richard C. Dorf , CRC Press, Boca Raton, Florida.

Ishii, M. , Takeda, Y. , Shiga, T. , Igarashi, K. , and Mikoshiba, S. (2000). Data-pulse-voltage reduction of AC-PDPs by using metastable-particle priming.Journal of the Society for Information Display, 8(3), 217–221.

Lakshamanan, A. (2008). Luminescence and Display Phosphors Phenomena and Applications. Nova Science Publishers, Inc, New York, NY, USA.

Ronda, C. R. (1995). Phosphors for lamps and displays: An applicational view. Journal of Alloys and Compounds, (1995) 534–538. 10.1016/0925-8388(94)07065-2

Justel, T. , Krupa, J.-C. , and Wiechert, D. U. (2001). VUV spectroscopy of luminescent materials for plasma display panels and Xe discharge lamps. Journal of Luminescence, 93(3), 179–189. 10.1016/S0022-2313(01)00199-5

McCauley, R. A. , Hummel, F. A. , and Hoffman, M. V. (1971). Phase equilibria and Eu2+, Tb3+, and Mn2+ activated luminescent phases in the CaOMgOP2O5 system. Journal of the Electrochemical Society, 118 (5), 755–759. 10.1149/1.2408158

B. L. Clark (2001)., Ph.D. Thesis, Oregon State, University.

Ingle, J. T. (2015). Thesis submitted to Sant Gadge Baba Amravati University, Amravati.

F. Meyer , H. Spanner , and E. Germet , US 2 182(1939) 732.

Jung, K.Y. , Lee, H. W. , Kang, Y. C. , Park, S. B. , and Yang, Y. S. (2005). Luminescent properties of (Ba,Sr)MgAl10O17:Mn,Eu green phosphor prepared by spray pyrolysis under VUV excitation. Chemistry of Materials, 17(10), 2729–2734. 10.1021/cm050074f

Ingle, J. T. , Sonekar, R. P. , Nagpure, P. A. , and Omanwar, S. K. (2013). Synthesis and UV, VUV photoluminescence of red emitting borate host PDP phosphors YCaBO4: Eu3+ and YBO3:Eu3+ . International Journal of Current Research, 5(03), 529–531. http://www.journalcra.com

Kim, C. H. , Kwon, I. E. , Park, C. H. , Wang, Y. J. , Bae, H. , Yu, B.Y. , Pyun, C. H. , and Hong, G.Y. (2000). Phosphors for plasma display panels. Journal of Alloys and Compounds, 311(1), 33–39. 10.1016/S0925-8388(00)00856-2

Wang, L. , and Wang, Y. (2007). Enhanced photoluminescence of YBO3:Eu3+ with the incorporation of Sc3+ Bi3+ and La3+ for plasma display panel application. Journal of Luminescence, 122–123, 921–923. 10.1016/j.jlumin.2006.01.327

Tian, L. H. , Yu, B.Y. , Pyun, C. H. , Park, H. L. , and Mho, S. I. (2004). New red phosphors BaZr(BO3)2 and SrAl2B2O7 doped with Eu3+ for PDP applications. Solid State Communications, 129(1), 43–46. 10.1016/j.ssc.2003.09.012

Tian, L.H. , Kim, S.J. , Park, H.L. , and Mho, S.I. , (2006). Variation of the photoluminescence and vacuum ultraviolet excitation characteristics of BaZr(BO3)2:Eu3+ by the incorporation of Al3+, La3+, or Y3+ into the lattice. Materials Research Bulletin, 41(1), 29–37. 10.1016/j.materresbull.2005.07.039

Park, W. , Summers, C. J. , Do, Y. R. , and Yang, H.G. (2002). Photoluminescence properties of red emitting BaGdB9O16:Eu phosphor. Journal of Materials Science, 37, (2002), 4041–4045. 10.1023/A:1019652832744

He, L. , and Wang, Y. (2007). Synthesis of Sr3Y2(BO3)4:Eu3+ and its photoluminescence under UV and VUV excitation. Journal of Alloys and Compounds, 431(1–2), 226–229. 10.1016/j.jallcom.2006.05.047

Tian, L. , and Mho, S. I. (2005). Luminescence and VUV excitation characteristics of Eu3+- or Tb3+- activated Ca4YO(BO3)3 . Journal of the Korean Physical Society, 47(6), 1070–1073. https://www.researchgate.net/profile/Sun-il_Mho/publication/282368805__

Chen, Z. , and Yan, Y. , (2006). Nano-sized PDP phosphors prepared by solution combustion method. Journal of Materials Science, 41, 5793–5796. 10.1007/s10853-006-0129-1

Sohn, K. S. , Kim, C. H. , Park, J. T. , and Park, H. D. (2002). Optimization of red phosphor for plasma display panel by the combinatorial chemistry method. Journal of Materials Research, 17, 3201–3205. 10.1557/JMR.2002.0463

Bechtel, H. , Justel, T. , Glaser, H. , and Wiechert, D. U. , (2012). Phosphors for plasma-display panels: Demands and achieved performance. Journal of the Society for Information Display, 10(1), 63–67. 10.1889/1.1827845

Recent Developments in Display Phosphors, Ravi P Rao, Proc. of ASID ’06, 8-12 Oct, New Delhi.

Hu, Y. , Tao, Y. , Huang, Y. , Yu, X. , Zhang, C. , Liang,T. , and Yu, J. (2011). Luminescent properties of (Y, Gd) BO3: Eu3+ under VUV excitation for PDP prepared by co-precipitation method. Optoelectronics and Advanced Materials – Rapid Communications, 5(4), 348–352. https://oam-rc.inoe.ro/articles/luminescent-properties-of-y-gdbo3eu3-under-vuv-excitation-for-pdp-prepared-by-co-precipitation-method/

He, L. , and Wang, Y. (2007). Synthesis of Sr3Y2(BO3)4: Eu3+ and its photoluminescence under UV and VUV excitation. Journal of Alloys and Compounds, 431(1-2), 226–229. 10.1016/j.jallcom.2006.05.047

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zhao, L. (2014). Solution combustion synthesis and optimization of phosphors for plasma display panels. Optical Materials, 36(8), 1299–1304. 10.1016/j.optmat.2014.03.015

Xinmin, Z. , Hong, C. , and Jongsu, K. (2009). Photoluminescence properties of (Gd1–*x* Eu *x*)Ba3B9O18 red emitting phosphors. Journal of Rare Earths, 27(1), 50–53. 10.1016/S1002-0721(08)60189-1

Park, W. , Lee, R. Y. , Summers, C. J. , Do, Y. R. , Yang, H. G. (2000). Photoluminescence properties of Al3GdB4O12:Eu phosphors. Materials Science and Engineering: B, 78(1), 28–31. 10.1016/S0921-5107(00)00509-2

Guo, R. , Tang, S. , Cheng, B. , and Tan, D. (2013). A new red emitting phosphor: La2SrB10O19:Eu3+ . Journal of Luminescence, 138, 170–173. 10.1016/j.jlumin.2013.02.008

Wang, Y. , Endo, T. , Xie, E. , He, D. , and Liu, B. (2004). Luminescence properties of Ca4GdO(BO3)3:Eu in ultraviolet and vacuum ultraviolet regions. Microelectronics Journal, 35(4), 357–361. 10.1016/S0026-2692(03)00245-3

Yanga, H. C. , Lia, C. Y. , Hea, H. , Tao, Y. , Xu, J. H. , and Sua, Q. (2006). VUV–UV excited luminescent properties of LnCa4O(BO3)3:RE3+ (Ln = Y, La, Gd; Re = Eu, Tb, Dy, Ce). Journal of Luminescence, 118(1), 61–69. 10.1016/j.jlumin.2005.06.007

Guifang, L. , Quanxi, C. , Zhimin, L. , Yunxia, H. , and Jiang, H. (2010). Solution combustion synthesis and luminescence properties of (Y,Gd)Al3(BO3)4:Eu3+ phosphors. Journal of Rare Earths, 28 (5), 709–712. 10.1016/S1002-0721(09)60185-X

Nagpure, P. A. , and Omanwar, S. K. (2013). Combustion synthesis of borate phosphors for use in plasma display panels and mercury-free fluorescent lamps. International Journal of Self-Propagating High-Temperature Synthesis, 22(1), 32–36. 10.3103/S106138621301007X

Chen, L. , Fu, Y. , Zhang, G. , Bao, J. , and Gao, C. (2008). Optimization of Pr3+, Tb3+, and Sm3+ co-doped (Y0.65Gd0.35)BO3:Eu0.05 3+ VUV phosphors through combinatorial approach. Journal of Combinational Chemistry, 10 (3), 401–404. 10.1021/cc700172e

Wei, Z. , Sun, L. , Liao, C. , Yan, C. , and Huang, S. (2002). Fluorescence intensity and colour purity improvement in nanosized YBO3:Eu. Applied Physics Letters, 80(8), 1447–1449. 10.1063/1.1452787

Wanga, L. , and Wang, Y. (2007). Enhanced photoluminescence of YBO3:Eu3+ with the incorporation of Sc3+ Bi3+ and La3+ for plasma display panel application. Journal of Luminescence, 122–123, 921–923. 10.1016/j.jlumin.2006.01.327

Dubey, V. , Kaur, J. , Agrawal, S. , and Suryanarayana, N. S. (2013). Synthesis and characterization of Eu3+ doped YBO3 phosphor. International Journal of Luminescence and Applications, 3, 98–101.

Dubey, V. , Kaur, J. , Agrawal, S. , Suryanarayana, N.S. (2014). Effect of Eu3+ concentration on photoluminescence and thermoluminescence behavior of YBO3:Eu3+ phosphor. Superlattices and Microstructures, 67, 156–171. 10.1016/j.spmi.2013.12.026

Yadav, S. R. , Dutta, R. K. , Kumar, M. , Pandey, A. C. (2009). Improved color purity in nanosize Eu3+doped YBO3 red phosphor. Journal of Luminescence, 129, 1078–1082.

Zhu, H. , Zhang, L. , Zuo, T. , Gu, X. , Wang, Z. , Zhu, L. , and Yao, K. (2008). Sol–gel preparation and photoluminescence property of YBO3:Eu3+/Tb3+ nanocrystalline thin films. Applied Surface Science, 254(20), 6362–6365. 10.1016/j.apsusc.2008.03.183

Zhang, X. , Marathe, A. , Sohal, S. , Holtz, M. , Davis, M. , Hope-Weeks, L. J. , and Chaudhuri, J. (2012). Synthesis and photoluminescence properties of hierarchical architectures of YBO3:Eu3+ . Journal of Materials Chemistry, 22(13), 6485–6490. 10.1039/C2JM30255A

Dexpert-Ghys, J. , Mauricot, R. , Caillier, B. , Guillot, P. , Beaudette, T. , Jia, G. , Tanner P. A. , and Cheng, B. M. (2010). VUV excitation of YBO3 and (Y,Gd)BO3 phosphors doped with Eu3+ or Tb3+: Comparison of efficiencies and effect of site-selectivity. Journal of Physical Chemistry C, 114(14), 6681–6689. 10.1021/jp909197t

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , and Wang, Y. (2014). Modified route of combustion synthesis and photoluminescence of (Y,Gd)Al3(BO3)4:Eu3+ phosphors for PDPs applications. International Journal of Chemical and Physical Sciences, 3, 37–42.
https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.679.8744&rep=rep1&type=pdf

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zhao, L. (2014). Combustion synthesis and VUV photoluminescence studies of borate host phosphors YBO3:RE3+ (RE = Eu3+, Tb3+) for PDPs applications. Combustion Science and Technology, 186(1), 83–89. 10.1080/00102202.2013.846332

Ingle, J. T. , Gawande, A. B. , Sonekar, R. P. , Nagpure, P. A. , and Omanwar, S. K. (2013). Synthesis and photoluminescence of inorganic borate host red emitting VUV phosphor YCaBO4: Eu3+ . Proceeding of International Conference on Recent Trends in Applied Physics and Material Science AIP Conference Proceedings 1536, 895–896. 10.1063/1.4810517

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zhao, L. (2014). Combustion synthesis and photoluminescence study of novel red phosphor (Y1xy, Gdx)BaB9O16:Eu3+y for display and lighting. Journal of Alloys and Compounds, 608, 235–240. 10.1016/j.jallcom.2014.04.079

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zhao, L. (2014). Combustion synthesis and luminescent properties of metal yttrium borates M3Y2 (BO3)4: Eu3+ (M = Ba, Sr) for PDPs applications. Solid State Sciences, 33, 19–24. 10.1016/j.solidstatesciences.2014.04.007

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zhao, L. (2014). Solution combustion synthesis and optimization of phosphors for plasma display panels. Optical Materials, 36(8), 1299–1304. 10.1016/j.optmat.2014.03.015

Ingle, J. T. , Gawande, A. B. , Sonekar, R. P. , Omanwar, S. K. Wang, Y. , and Zhao, L. (2014). Combustion synthesis and optical properties of Oxy-borate phosphors YCa4O(BO3)3:RE3+ (RE = Eu3+, Tb3+) under UV, VUV excitation. Journal of Alloys and Compounds, 585 (5), 633–636. 10.1016/j.jallcom.2013.09.178

Ingle, J. T. , Sonekar, R. P. , and Omanwar, S. K. (2016). Combustion synthesis and superior photo-luminescence from rare earth doped (Eu, Tb) lanthanum borates phosphors for display. Journal of Materials Science: Materials in Electronics, 27, 10735–10741. 10.1007/s10854-016-5175-0

Zhang, Z. , Zhang, S. , Zhang, W. , and Yang, W. (2016). VUV spectroscopic properties of rare-earth (RE3+, Sm3+, Eu3+, Tb3+, Dy3+) -Activated Layered Borate Ba6Gd9B79O138. Solid State Sciences, 64, 69–75. 10.1016/j.solidstatesciences.2016.12.014

Huibing, X. , Weidong, Z. , Xiaofan , Ronghui, W. , Yunsheng, L. H. , and Tian. X. , (2010). Effect of Li+ ions doping on structure and luminescence of (Y,Gd)BO3:Tb3+ . Journal of Rare Earths, 28 (5), 701–704. 10.1016/S1002-0721(09)60183-6

Park, K. , Kim, J. , and Kim, K. Y. (2012). Enhancement of green emission for Al3+-doped YBO3:Tb3+ . Materials Chemistry and Physics, 136 (1), 264–267. 10.1016/j.matchemphys.2012.06.067

Li, X. , and Wang, Y. (2010). VUV-excited luminescence properties of Tb3+ activated BaGdB9O16 . Journal of Rare Earths, 28 (3), 361–364. 10.1016/S1002-0721(09)60112-5

Zang, D. S. , Song, J. H. , Park, D. H. , Kim, Y. C. , and Yoon, D. H. (2009). New fast-decaying green and red phosphors for 3D application of plasma display panels. Journal of Luminescence, 129 (9), 1088–1093. 10.1016/j.jlumin.2009.05.004

Chawla, S. , Ravishanker , Khan, A. F. , Yadav, A. , Chander, H. , and Shanker, V. (2011). Enhanced luminescence and degradation resistance in Tb modified Yttrium Borate core–nano silica shell phosphor under UV and VUV excitation. Applied Surface Science, 257 (16), 7167–7171. 10.1016/j.apsusc.2011.03.082

Kim, C. , Kwon, I. , Park, C. , Hwang, Y. , Bae, H. , Yu, B. , Pyun, C. , and Hong, G. (2000). Phosphors for plasma display panels. Journal of Alloys and Compounds, 311 (1), 33–39. 10.1016/S0925-8388(00)00856-2

Rao, R. P. (2003). Tb3+ activated green phosphors for plasma display panel applications. Journal of The Electrochemical Society, 150 (8), H165–H171. 10.1149/1.1583718

Kwon, E. , Yu, B. Y. , Bae, H. , Hwang, Y. , Kwon, T. , Kim, C. , Pyun, C. , and Kim, S. (2000). Luminescence properties of borate phosphors in the UV/VUV region. Journal of Luminescence, 87–89, 1039–1041. 10.1016/S0022-2313(99)00532-3

Nagpure, P. A. , Sonekar, R. P. , Omanwar, S. K. , Pande, A. C. (2011). Photoluminescence study of green PDP phosphor LaBaB9O16:Tb/CeTb. International Journal of Advanced Engineering Sciences And Technologies, 8 (2), 311–315.

Yang, Y. , Bao, A. , Lai, H. , Tao, Y. , and Yang, H. (2009). Luminescent properties of SrAl2B2O7: Ce3+, Tb3+ . Journal of Physics and Chemistry of Solids, 70 (10), 1317–1321. 10.1016/j.jpcs.2009.06.012

Cheng, S. D. , Kam, C. H. , and Buddhudu, S. (2001). Enhancement of green emission from Tb3+:GdOBr phosphors with Ce3+ ion co-doping. Materials Research Bulletin, 36 (5–6), 1131–1137. 10.1016/S0025-5408(01)00587-6

Henderson, E.W. , and Meehan, J. P. (1974). Optical properties of divalent rare earth ions in SrAlF5 . Journal of Luminescence, 8 (5), 415–427. 10.1016/0022-2313(74)90082-9

Tian, L. , Mho, S. , Yu, B. , and Park, H. (2005). Luminescence and VUV excitation characteristics of Eu3+- or Tb3+- activated Ca4YO(BO3)3. Journal of the Korean Physical Society, 47 (6), 1070 –1073.

Justel, T. , and Nikol, H. (2000). Optimization of luminescent materials for plasma display panels. Advanced Materials, 12 (7), 527–530. 10.1002/(SICI)1521-4095(200004)12:7<527::AID-ADMA527>3.0.CO;2-8

Dawson, B. , Ferguson, M. , Marking, G. , and Diaz, A. (2004). Mechanisms of VUV damage in BaMgAl10O17:Eu2+ . Chemistry of Materials, 16 (25), 5311–5317. 10.1021/cm0489284

Rao, R. , and Devine, D. (2000). RE-activated lanthanide phosphate phosphors for PDP applications. Journal of Luminescence, 87–89, 1260–1263. 10.1016/S0022-2313(99)00551-7

Kim, K. , Koo, K. , Cho, T. , and Chun, H. (2003). Effect of heat treatment on photoluminescence behavior of BaMgAl10O17:Eu phosphors. Materials Chemistry and Physics, 80 (3), 682–689. 10.1016/S0254-0584(03)00110-X

Zhang, S. , Kono, T. , Ito. A. , Yasaka, T. , and Uchiike, H. (2004). Degradation mechanisms of the blue-emitting phosphor BaMgAl10O17:Eu2+ under baking and VUV-irradiating treatments. Journal of Luminescence, 106 (1), 39–46. 10.1016/S0022-2313(03)00132-7

Hata, E. , Kunimoto, T. , Tanaka, M. , Yamaguchi, S. , Ohmi, K. , Tanaka, S. , and Kobayashi, H. (2003). Proceedings of the IDW’03 (Fukuoka, Japan), pp. 853.

Tanamachi, N. , Egoshi, K. , Tanno, H. , Zeng, Q. , and Zhang, S. (2004). Proceedings of the IDW’04 (Niigata, Japan), pp. 1085.

Liang, H. , Zeng, Q. , Tao, Y. , Wang, S. , and Su, Q. (2003). VUV-UV excited luminescent properties of calcium borophosphate doped with rare earth ions. Materials Science and Engineering: B, 98 (3), 213–219. 10.1016/S0921-5107(03)00034-5

Justel, T. , Bechtel, H. , Mayr, W. , and Wiechert, D. (2003). Blue emitting BaMgAl10O17:Eu with a blue body colour. Journal of Luminescence, 104 (1–2), 137–143. 10.1016/S0022-2313(03)00010-3

Saubat, B. , Fouassier, C. , Hagenmuller, P. , and Bourcet, J. C. (1981). Luminescent efficiency of Eu3+ and Tb3+ in LaMgB5O10 – Type borates under excitation from 100 to 400 nm. Materials Research Bulletin, 16(2), 193–198. 10.1016/0025-5408(81)90081-7

Lin, H. , Liang, H. , Tian, Z. , Su, Q. , Xie, H. and Ding, J. (2006). Vacuum-ultraviolet–vis luminescence of dibarium magnesium orthoborate Ba2Mg(BO3)2 doped with Ce3+ and Eu2+ ions. Journal of Materials Research, 21, 864–869. 10.1557/jmr.2006.0123

Sivakumar, V. , Hong, G. Y. , Kim, J. S. , and Jeon, D. Y. (2009). Novel blue-emitting phosphor Sr2.979Eu0.021Al10−xBxSiO20 (x = 0, 0.25, 0.5, 0.75 and 1) for PDP applications. Journal of Luminescence, 29 (12), 1632–1636. 10.1016/j.jlumin.2008.12.021

Ling, H. E. , Yuhua, W. , and Weimin, S. (2009). Luminescence properties of BaB8O13:Eu under UV and VUV excitation. Journal of Rare Earths, 27 (3), 385–389. 10.1016/S1002-0721(08)60256-2

Park, C. H. , and Bluhm, K. (1996). Pb6(AsO4)[B(AsO4)4] – A new crystal structure type in the system PbO/B2O3/As2O3 with remarks about Pb(BAsO5). Z. Naturforsch, 51b, 313–318. 10.1515/znb-1996-0303

Hasegawa, Y. , Murakoshi, K. , Wada, Y. , Yanagida, S. , Kim, J. H. , Nakashima, N. , and Yamanaka, T. (1996). Enhancement of luminescence of Nd3+ complexes with deuterated hexafluoroacetylacetonato ligands in organic solvent. Chemical Physics Letters, 248 (1–2), 8–12. 10.1016/0009-2614(95)01279-6

Toda, K. (2006). Recent research and development of VUV phosphors for a mercury-free lamp. Journal of Alloys and Compounds, 408–412, 665–668. 10.1016/j.jallcom.2005.01.080

Blasse, G. , and Grabmaier, B. C. (1994). Luminescent Materials. Springer-Verlag, Berlin. 10.1007/978-3-642-79017-1

Henderson, B. , and Imbusch, G. F. (1989). Optical Spectroscopy in Inorganic Solids. Clarendon, Oxford.

Ronda, C. R. (1995). Phosphors for lamps and displays: An applicational view. Journal of Alloys and Compounds, 225 (1–2), 534–538. 10.1016/0925-8388(94)07065-2

Depp, S. W. , and Howard, W. E. (1993). Flat-Panel Displays. Scientific American, 268 (3), 90–97.

Vollkommer, F. , and Hitzschke, L. (2013). Beratender Ausschuß der Industriephysiker: Durchbruch bei der effizienten Erzeugung von ExcimerStrahlung: Hohe Erwartungen an die Leuchtstofforschung. Physikalische Blätter, 53 (9), 887–889. 10.1002/phbl.19970530912

Sommerdijk, J. L. , Bril, A. , and Jager, A. W. (1974). Two photon luminescence with ultraviolet excitation of trivalent praseodymium. Journal of Luminescence, 8 (4), 341–343. 10.1016/0022-2313(74)90006-4

Pappalardo, R. (1976). Calculated quantum yields for photon-cascade emission (PCE) for Pr3+ and Tm3+ in fluoride hosts. Journal of Luminescence, 14 (3), 159–193. 10.1016/S0022-2313(76)90592-5

Auzel, F. , and Acad, C. R. (1966). Science (Paris), 262, 1016. (In French).

Srivastava, A. M. , and Doughty, D. A. (1996). Photon cascade luminescence of Pr3+ in LaMgB5O10 . Journal of The Electrochemical Society, 143 (12), 4113–4116. 10.1149/1.1837346

Chen, Y. , Shi, C. , Yan, W. , Qi, Z. , and Fu, Y. (2006). Energy transfer between Pr3+ and Mn2+ in SrB4O7: Pr, Mn. Applied Physics Letters, 88 (6), 061906-1-061906-3. 10.1063/1.2172731

Han, B. , Liang, H. , Huang, Y. Tao, Y. , and Su, Q. (2010). Vacuum ultraviolet−visible spectroscopic properties of Tb3+ in Li(Y, Gd)(PO3)4: Tunable emission, quantum cutting, and energy transfer. Journal of Physical Chemistry, 114 (14), 6770–6777. 10.1021/jp100755d

Hou, D. , Liang, H. , Xie, M. , Ding, X. , Zhong, J. , Su, Q. , Tao, Y. , Huang, Y. , and Gao, Z. (2011). Bright green-emitting, energy transfer and quantum cutting of Ba3Ln(PO4)3: Tb3+ (Ln = La, Gd) under VUV-UV excitation. Optics Express, 19 (12), 11071–11083. 10.1364/OE.19.011071

Song, J. H. , Song, Y. , Kim, J. , Kim, M. , Kwon, S. , Park, D. , Kim, Y. , and Zang, D. , (2008). IMID/IDMC/ASIA Display'08 Digest, 34 (3), 1255.

Moon, T. , Hong, G. Y. , Lee, H. C. , Moon, E. A. , Jeoung, B. W. , Hwang, S. T. , Kim, J. S. , and Ryu, B. G. (2009). Effects of Eu2+ co-doping on VUV photoluminescence properties of BaMgAl10O17:Mn2+ phosphors for plasma display panels. Electrochemical and Solid-State Letters, 12 (7), J61–J63. 10.1149/1.3126528

Oskam, K. D. , Wegh, R. T. , Donker, H. , Dvan , Loef, E.V. D van , and Meijerink, A. (2000). Downconversion: A new route to visible quantum cutting. Journal of Alloys and Compounds, 300–301, 421–425. 10.1016/S0925-8388(99)00755-0

Wang, D. , and Kodama, N. (2009). Visible quantum cutting through downconversion in GdPO4:Tb3+ and Sr3Gd(PO4)3:Tb3+ . Journal of Solid-State Chemistry, 182 (8), 2219–2224. 10.1016/j.jssc.2009.05.026

Liang, W. , and Wang, Y. (2010). Visible quantum cutting through downconversion in Eu3+-doped K2GdZr(PO4)3 phosphor. Materials Chemistry and Physics, 119 (1–2), 214–217. 10.1016/j.matchemphys.2009.08.058

Zhang, J. , Wang, Y. , Chen, G. , and Huang, Y. (2014). Investigation on visible quantum cutting of Tb3+ in oxide hosts. Journal of Applied Physics, 115 (9), 093108–1-093108-7. 10.1063/1.4867612

Maarten, L. , Heerdt, H. , Kolk, Evan der , Yen, W. M. , Srivastava, A. M. (2002). Vacuum ultraviolet spectroscopy of Pr3+ in CaAl4O7, LaMgAl11O19 and SrLaAlO4 . Journal of Luminescence, 100 (1–4), 107–113. 10.1016/S0022-2313(02)00454-4

Wegh, R. T. , Donker, H. , Loef, E. V. D. , Oskam, K. D. , and Meijerink, A. (2000). Quantum cutting through downconversion in rare-earth compounds. Journal of Luminescence, 87–89, 1017–1019. 10.1016/S0022-2313(99)00514-1
Moine, B. , and Bizarri, G. (2003). Rare-earth doped phosphors: Oldies or goldies? Materials Science and Engineering: B, 105 (1–3), 2–7. 10.1016/j.mseb.2003.08.004

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Cameron, J. (1991). Radiation dosimetry. Environ. Health Perspect., 91, 45–48.
Li, J. , Hao, J. Q. , Li, C. Y. , Zhang, C. X. , Tang, Q. , Zhang, Y. L. , Sua, Q. , and Wang, S. B. (2005). Thermally stimulated luminescence studies for dysprosium doped strontium tetraborate. Radia. Meas., 39, (2005), 229–233.
McKeever, S. W. S. , and Moscovitch, M. (2003). On the advantages and disadvantages of optically stimulated luminescence dosimetry and thermoluminescence dosimetry. Radiat. Prot. Dosim., 104, 263270.
McKeever, S. W. S. , Moscovitch, M. , and Townsend, P. D. (1995). Thermoluminescence Dosimetry Materials: Properties and Use. Nuclear Technology Publishing, Ashford, 28, 210.
McKeever, S. W. S. (2002). New millennium frontiers of luminescence dosimetry. Radiat. Prot. Dosim., 100, 27–32.
McKeever, S. W. S. , Blair, M. W. , Bulur, E. , Gaza, R. , Gaza, R. , Kalchgruber, R. , Klein, D. M. , and Yukihara, E. G. (2004). Recent advances in dosimetry using the optically stimulated luminescence of Al2O3:C. Radiat. Prot. Dosim., 109, 269–274.
Bhatt, B. C. , and Kulkarni, M. S. (2014). Thermoluminescent phosphors for radiation dosimetry. Defect Diffus. Forum, 347, 179–227.
Markey, B. G. , Colyott, L. E. , and McKeever, S. W. S. (1995). Time-resolved optically stimulated luminescence from α-Al2O3:C. Radiat. Meas., 24, 457–463.
McKeever, S. W. S. (2001). Optically stimulated luminescence dosimetry. Nucl. Instrum. Methods Phys. Res. Sect. B, 184, 29–54.
Pradhan, A. S. , Lee, J. I. , and Kim, J. L. (2008). Recent developments of optically stimulated luminescence materials and techniques for radiation dosimetry and clinical applications. J. Med. Phys., 33, 85–99.
Bhatt, B. C. (2011). Thermoluminescence, optically stimulated luminescence and radiophotoluminescence dosimetry: aA perspective, 34, 6–16.
Pradhan, A. S. , Lee, J. I. , and Kim, J. L. (2008). Recent developments of optically stimulated luminescence materials and techniques for radiation dosimetry and clinical applications. J. Med. Phys., 33, 85–99.
Akselrod, M. S. , Bøtter-Jensen, L. , and McKeever, S. W. S. (2006). Optically stimulated luminescence and its use in medical dosimetry. Radiat. Meas., 41, S78.
Guide to the Riso TL/OSL reader, RISO, DTU, Denmark (2010).
McKeever, S. W. S. , and Moscovitch, M. (2003). On the advantages and disadvantages of optically stimulated luminescence dosimetry and thermoluminescence dosimetry. Radiat. Prot. Dosim., 104, 263–270.
Yukihara, E. G. , Milliken, E. D. , and Doull, B. A. (2014). Thermally stimulated and recombination processes in MgB4O7 investigated by systematic lanthanide doping. J. Lumin., 154, 251–259.
Sahare P. D. , Singh M. , and Kumar P. (2015). A new high sensitivity Na2LiPO4:Eu OSL phosphor. RSC. Adv., 5 3474–3481.
Barve, R. , Patil, R. R. , Gaikwad, N. P. , Kulkarni, M. S. , Mishra, D. R. , Soni, A. , Bhatt, B. C. , and Moharil, S. V. (2013). Optically stimulated luminescence and thermoluminescence in some Cu+ doped alkali fluoro-silicates. Radiat. Meas., 59, (2013), 73–80.
Bulur, E. (1996). An alternative technique for optically stimulated luminescence (OSL) experiment. Radiat. Meas., 26, 701–709.
Kuhns, C. K. , Larsen, N. A. , and McKeever, S. W. S. (2000). Characteristics of LM-OSL from several different types of quartz. Radiat. Meas., 32, 413–418.
Bulur, E. (2000). A simple transformation for converting CW-OSL curves to LM-OSL curves. Radiat. Meas., 32, 141–145.
McKeever, S. W. S. (2001). Optically stimulated luminescence dosimetry. Nucl. Instrum. Methods Phys. Res. B, 184, 29–54.
Yukihara, E. G. , Whitley, V. H. , McKeever, S. W. S. , Akselrod, A. E. , and Akselrod, M. S. (2004). Effect of high-dose irradiation on the optically stimulated luminescence of Al2O3:C. Radiat. Meas., 38, 317–330.
Yukihara, E. G. , and McKeever, S. W. S. (2006). Ionisation density dependence of the optically and thermally stimulated luminescence from Al2O3:C. Radiat. Prot. Dosim., 119, 206–217.
Yukihara, E. G. , Whitley, V. H. , Polf, J. C. , Klein, D. M. , McKeever, S. W. S. , Akselrod, A. E. , and Akselrod, M. S. (2003). The effects of deep trap population on the thermoluminescence of Al2O3:C. Radiat. Meas., 37, 627–638.

Yukihara, E. G. , Whitley, V. H. , McKeever, S. W. S. , Akselrod, A. E. , and Akselrod, M. S. (2004). Effect of high-dose irradiation on the optically stimulated luminescence of Al2O3:C. Radiat. Meas., 38, 317.
Akselrod, M. S. , and Gorelova, E. A. (1993). Deep traps in highly sensitive α-Al2O3:C TLD crystals. Radiat. Meas., 21, 143–146.
Polf, J. C. , Yukihara, E. G. , Akselrodand, M. S. , and McKeever, S. W. S. (2004). Real-time luminescence from Al2O3 fiber dosimeters. Radiat. Meas., 38, 227–240.
Evans, B. D. , Pogatshnik, G. J. , and Chen, Y. (1994). Optical properties of lattice defects in α-Al2O3 . Nucl. Instrum. Methods Phys. Res. B, 91, (1994), 258–262.
Akselrod, M. S. , and McKeever, S. W. S. (1999). Radiation dosimetry method using pulsed optically stimulated luminescence. Radiat. Prot. Dosim., 81, 167–175.
Piesch, E. , Burgkhardt, B. , Fischer, M. , Rrber, H. G. , and Ugi, S. (1986). Properties of radiophotoluminescent glass dosemeter systems using pulsed laser UV excitation. Radiat. Prot. Dosim., 17, 293–297.
Piesch, E. , Burgkhardt, B. , and Vilgis, M. (1990). Photoluminescence dosimetry: Progress and present state of art. Radiat. Prot. Dosim., 33, 215–226.
Piesch, E. , Burgkhardt, B. , and Vilgis, M. (1993). Progress in phosphate glass dosimetry: Experiences and routine monitoring with a modern dosimetry system. Radiat. Prot. Dosim., 47, 409–414.
Chen, C. T. , Wu, Y. C. , and Li, R. K. (1990). The development of new NLO crystals in the borate series. J. of Cryst. Growth, 99, 790–798.
Lu, C. H. , Godbole, S. V. , and Natarajan, V. (2005). Luminescence characteristics of strontium borate phosphate phosphors. Mater. Chem. Phys., 93, 73–77.
Wu, L. , Chen, X. L. , Li, H. , He, M. , Dai, L. , Li, X. Z. , and Xu, Y. P. (2004). Structure determination of a new compound LiCaBO3 . J. Solid State Chem, 177, 1111–1116.
Bajaj, N. S. , and Omanwar, S. K. (2012). Combustion synthesis and luminescence characteristic of rare earth activated LiCaBO3 . J. Rare Earths, 30, 1005–1008.
Jose, M. T. , Anishia, S. R. , Annalakshmi, O. , and Ramasamy, V. (2011). Determination of thermoluminescence kinetic parameters of thulium doped lithium calcium borate. Radiat. Meas., 46, 1026–1032.
Nagpure, P. A. , Bajaj, N. S. , Sonekar, R. P. , and Omanwar, S. K. (2011). Synthesis and luminescence studies of novel rare earth activated lanthanum pentaborate. Indian J. Pure Appl. Phys., 49, 799–802.
Wu, L. , Chen, X. L. , Li, H. , He, M. , Dai, L. , Li, X. Z. , and Xu, Y. P. (2004). Structure determination of a new compound LiCaBO3 . J. Solid State Chem., 177, 1111–1116.
Chen, C. T. , Wu, B. , Jiang, A. , and You, G. (1985). A new-type ultraviolet shg crystal—β-BaB2O4 . Sci. Sin. B, 18, 235–243.
Chen, C. T. , Wu, Y. , Jiang, A. , Wu, B. , You, G. , Li, R. , and Lin, S. (1989). New nonlinear-optical crystal: LiB3O5 . J. Opt. Soc. Am. B, 6, 616–621.
Chen, C. T. , Wang, Y. , Wu, B. , Wu, K. , Zeng, W. , and Yu, L. (1995). Design and synthesis of an ultraviolet-transparent nonlinear optical crystal Sr2Be2B2O7 . Nature, 373, 322–324.
Takenaga, M. , Yamamota , and Yamashita, T. (1980). Preparation and characteristics of Li2B4O7:Cu phosphor. Nucl. Instrum. Methods B, 175, 77–78.
Shahare, D. I. , Deshmukh, B. T. , Moharil, S. V. , Dhopte, S. M. , Muthal, P. L. , and Kondawar, V. K. (1994). Synthesis of Li2B4O7:Cu phosphor. Phys. Status Solidi (A), 141, 329–334.
Palan, C. B. , Chauhan, A. O. , Sawala, N. S. , Bajaj, N. S. , and Omanwar, S. K. (2016). Synthesis and preliminary TL/OSL properties of Li2B4O7: Cu-Ag phosphor for radiation dosimetry. Optik, 127, 6419–6423.
Shahare, D. I. , Dhoble, S. J. , and Moharil, S. V. (1993). Preparation and characterization of magnesium-borate phosphor. J. Mater. Sci. Lett., 12, 1873–1874.
Palan, C. B. , Chauhan, A. O. , Sawala, N. S. , Bajaj, N. S. , and Omanwar, S. K. (2015). Thermoluminescence and optically stimulated luminescence properties of MgB4O7: Ag phosphor. Int. J. Lumin. Appl., 5, 408–410.
Yamashita, T. , Nada, N. , Onishi, H. , and Kitamura, S. (1971). Proc. 2nd Int. Conf. On Lum. Dosim., Gathilinburg, CONF-680920, 1968, PP 4; Health Phys. 21:295.
Palan, C. B. , Koparkar, K. A. , Bajaj, N. S. , Soni, A. , and Omanwar, S. K. (2016). Synthesis and thermoluminescence/optically stimulated luminescence properties of CaB4O7:Ce phosphor. J. Mater. Sci: Mater. Electron, 27, 5600–5606.
Fukuda Y. , Mizuguchi K. M. , and Takeuchi N. (1986). Thermoluminescence in Sintered CaB4O7:Dy and CaB4O7:Eu. Radiat. Prot. Dosim., 19, 397–401.
Fukuda, Y. , Tomita, A. , and Takeuchi, N. (1990). Electron affinity of CaB4O7:PbO ceramic obtained by a simultaneous measurement of TL and TSEE. J. Mater. Sci. Lett., 9, 867–868.
He, M. , Chen, X. L. , Hu, B. Q. , Zhou, T. , Xu, Y. P. , and Xu, T. (2002). The ternary system Li2O–Al2O3–B2O3: Compounds and phase relations. J. Solid State Chem., 165, 187–192.
He, M. , Chen, X. L. , Gramlich, V. , Baerlocher, Ch , Zhou, T. , and Hu, B. Q. (2002). Synthesis, structure, and thermal stability of Li3AlB2O6 . J. Solid State Chem., 163, 369–376.
Wu, L. , Chen, X. L. , Tu, Q. Y. , He, M. , Zhang, Y. , and Xu, Y. P. (2002). Phase relations in the system Li2O–MgO–B2O3 . J. Alloys Compd., 333, 154–158.

Wu, L. , Chen, X. L. , Tu, Q. Y. , He, M. , Zhang, Y. , and Xu, Y. P. (2003). Phase relations in the system Li2O–CaO–B2O3 . J. Alloys Compd., 358, 23–28.
Norrestam, R. (1989). The crystal structure of monoclinic LiMgBO3 . Z. Kristallogr. Cryst. Mater., 187, 103–110.
Schla¨ eger, M. , Hoppe, R. , and Anorg., Z. (1993). Darstellung und Aufbau von BaLi [BO3]. Allg. Chem., 619, 976–982.
Wu, L. , Chen, X. L. , Xu, Y. P. , and Sun, Y. P. (2005). Inorg. Chem., 44, 2005, 6409–6414.
Jiang, L. H. , Zhang, Y. L. , Li, C. Y. , Hao, J. Q. , and Su, Q. (2007). Phase relations in the system Li2O–CaO–B2O3 thermoluminescence properties of Ce3+-doped LiSr4(BO3)3 phosphor. Mater. Lett., 61, 5107–5109.
Jiang, L. , Zange, Y. , Li, C. , Pang, R. , Shi, L. , Zhang, S. , Hao, J. , and Su, Q. (2009). Thermoluminescence characteristics of NaSr4(BO3)3:Ce3+ under β-ray irradiation. J. Rare Earths, 27, 320–322.
Jiang, L. H. , Zhang, Y. L. , Li, C. Y. , Hao, J. Q. , and Su, Q. (2009). Synthesis, photoluminescence, thermoluminescence and dosimetry properties of novel phosphor KSr4(BO3)3:Ce. J. Alloys Compd., 482, 313–316.
Annalakshmi, O. , Jose, M. T. , Madhusoodanan, U. , Venkatraman, B. , and Amarendra, G. (2013). Kinetic parameters of lithium tetraborate based TL materials. J. Lumin., 141, 60–66.
Rawat, N. S. , Kulkarni, M. S. , Tyagi, M. , Ratna, P. , Mishra, D. R. , Singh, S. G. , Tiwari, B. , Soni, A. , Gadkari, S. C. , and Gupta, S. K. (2012). TL and OSL studies on lithium borate single crystals doped with Cu and Ag. J. Lumin., 132, 1969–1975.
Schulman, J. H. , Kirk, R. D. , and West, E. J. (1967). Luminescence dosimetry, U.S. Atomic Energy Commission Symposium Series 8, CONF-650637, 113.
Takenaga, M. , Yamamato, O. , Yamashita, T. (1983). A new phosphor Li2B4O7: Cu for TLD. Health Phys., 44, 1983, 387–393.
Shahare, D. I. , Deshmukh, B. T. , Moharil, S. V. , Dhopte, S. M. , Muthal, P. L. , and Kondawar, V. K. (1994). Phys. Status Solidi A, 141, 329.
Prokic, M. (2002). Dosimetric characteristics of Li2B4O7:Cu,Ag,P solid TL detectors. Radiat. Prot. Dosim., 2002, 265–268.
Rawat, N. S. , Kulkarni, M. S. , Tyagi, M. , Ratna, P. , Mishra, D. R. , Singh, S. G. , Tiwari, B. , Soni, A. , Gadkari, S. C. , and Gupta, S. K. (2012). TL and OSL studies on lithium borate single crystals doped with Cu and Ag. J. Lumin., 132, 1969–1975.
Kerikmäe, M. , Danilkin, M. , Lust, A. , Nagirnyi, V. , Pung, L. , Ratas, A. , Romet, I. , and Seeman, V. (2013). Hole traps and thermoluminescence in Li2B4O7:Be. Radiat. Meas., 56, 147–149.
Özdemir, A. , Z. Yeğingil , N. Nur , K. Kurt , T. Tüken , T. Depçi , G. Tansuğ , V. Altunal , V. Güçkan , G. Sığırcık , Yu, Yan ; Karataşlı , Muhammet , and Dolek, Y. , 2016. Thermoluminescence study of Mn doped lithium tetraborate powder and pellet samples synthesised by solution combustion synthesis. Department of Radiation Oncology Faculty Papers. Paper 78. https://jdc.jefferson.edu/radoncfp/78
Brant, A. T. , Kananan, B. E. , Murari, M. K. , McClory, J. W. , Petrosky, J. C. , Adamiv, V. T. , Burak, Y. V. , Dowben, P. A. , and Halliburton, L. E. (2011). Electron and hole traps in Ag-doped lithium tetraborate (Li2B4O7) crystals. J. Appl. Phys, 110, 093719.
Danilkin, M. I. , Koksharov, Yu. A. , Romet, I. , Seeman, V. O. , Vereschagina, N. Yu. , Zubova, A. I. , and Selyukova, A. S. (2019). Manganese agglomeration and radiation damage in doped Li2B4O7 . Radiat. Meas., 126, 106134–106137.
Horowitz, Y. S. (1981). The theoretical and microdosimetric basis of thermoluminescence and applications to dosimetry. Phys. Med. Biol., 26, 765–824.
Tiwari, B. , Rawat, N. S. , Desai, D. G. , Singh, S. G. , Tyagi, M. , Ratna, P. , Gadkari, S. C. , and Kulkarni, M. S. (2010). Thermoluminescence studies on Cu-doped Li2B4O7 single crystals. J. Lumin., 130, 2076–2083.
Drozdowski, W. , Brylew, K. , Kaczmarek, S. M. , Piwowarska, D. , Nakai, Y. , Tsuboi, T. , and Huang, W. (2014). Effect of doping with cobalt on radioluminescence and low temperature thermoluminescence of Li2B4O7 crystals. Radiat. Meas., 63 (2014), 26–31.
Holovey, V. M. , Sidey, V. I. , Lyamayev, V. I. , and Puga, P. P. (2007). Influence of reducing annealing on the luminescent properties of Li2B4O7:Cu single crystals. J. Lumin., 126, 408–412.
Kar, S. , Bairagi, S. , Debnath, C. , Verma, S. , and Bartwal, K. S. (2012). Thermoluminescence studies on γ-irradiated Mn:Li2B4O7 single crystals. Appl. Phys. Lett., 101, 071904–071904-4.
Laxamanan, A. R. , Chandra, B. , and Bhatt, R. C. (1982). Further studies on the radiation dosimetry characteristics of thermoluminescent Li2B4O7:Cu phosphor. Radiat. Meas., 2, 231–239.
Patra, G. D. , Singh, S. G. , Tiwari, B. , Singh, A. K. , Desai, D. G. , Tyagi, M. , Sen, S. , and Gadkari, S. C. (2016). Optically stimulated luminescence in Ag doped Li2B4O7 single crystal and its sensitivity to neutron detection and dosimetry in OSL mode. Radiat. Meas., 88, 14–19.
Ratasa, A. , Danilkina, M. , Kerikmäea, M. , Lusta, A. , Mändarb, H. , Seemanb, V. , and Slavin, G. (2012). Proceedings of the Estonian Academy of Sciences, 61, 279–295.
McKeever S. W. S. , Moscovitch M. , and Townsend P. D. (1995). Thermoluminescence Dosimetry Materials: Properties and Uses. Nuclear Technology Publishing, Ashford, 1995.

Prokić, M. (1980). Development of highly sensitive CaSO4: Dy/Tm and MgB4O7: Dy/Tm sintered thermoluminescent dosimeters. Nucl. Instrum. Methods B., 175, 83–86.
McKeever S. W. S. , Moscovitch M. , and Townsend P. D. (1995). Thermoluminescence Dosimetry Materials: Properties and Uses. Nuclear Technology Publishing, Ashford.
Yukihara, E. G. , Coleman, A. C. , and Doull, B. A. (2014). Passive temperature sensing using thermoluminescence: Laboratory tests using Li{sub 2}B{sub 4}O{sub 7}:Cu,Ag, MgB{sub 4}O{sub 7}:Dy,Li and CaSO{sub 4}:Ce,Tb. J. Lumin., 146, 515–526.
Gustafson, T. D. , Milliken, E. D. , Jacobsohnc, L. G. , and Yukiharaa, E. G. (2019). Progress and challenges towards the development of a new optically stimulated luminescence (OSL) material based on MgB4O7:Ce,Li. J. Lumin., 212, 242–249.
Yukihara, E. G. , Doull, B. A. , Gustafson, T. , Oliveira, L. C. , Kurt, K. , and Milliken, E. D. (2017). Optically stimulated luminescence of MgB4O7:Ce,Li for gamma and neutron dosimetry. J. Lumin., 183, 525–532.
Takenago, M. , Yamanoto, O. , and Yamashita, T. (1977). In Proceedings of the 5th International Conference on Lum Dosimetry (P. 148). Sao Paulo, Brazil.
Prokic, M. (1980). Development of highly sensitive CaSO4:Dy and MgB4O7:Dy/Tm sintered thermoluminescent dosimeters. Nucl. Instrum. Methods B, 175, 83–86.
Prokic, M. (1986). Magnesium borate in TL dosimetry. Radiat. Prot. Dosim., 17, 393–396.
Lochab, S. , Pandey, A. , and Sahare, P. (2007). Nanocrystalline MgB4O7:Dy for high dose measurement of gamma radiation. Phys. Status Solidi A-Appl. Mater., 204, 2416–2425.
Souza, L. F. , Vidal, R. M. , and Souza, S. O. (2014). Thermoluminescent dosimetric comparison for two different MgB4O7:Dy production routes. Radiat. Phys. Chem., 104, 100–103.
Paluch-Ferszt, M. , Kozłowska, B. , de Souza, S. O. , de Souza, L. F. , and Nukleonika, D. N. S. (2016). Analysis of dosimetric peaks of MgB4O7:Dy (40% Tefl on) versus LiF:Mg,Ti TL detectors. Nukleonika, 61(1), 49−52.
T. L. D. Poland . (2015). LiF:Mg,Ti thermoluminescent phosphor & pellets. Retrieved from http://www.tld.com.pl/tld/mts.html. 2001–2005.
Furetta . (2003). Handbook of Thermoluminescence. World Scientific Publishing, Italy.
Palan, C. B. , and Omanwar, S. K. (2017). Synthesis and preliminary TL/OSL properties of MgB4O7:Tb3+ phosphor for radiation dosimetry. IJRITCC, 5, 53–54.
Souza, L. F. , Silva, A. M. B. , Antonio, P. L. , Caldas, L. V. E. , Souza, S. O. , d'Errico, F. , and Souza, D. N. (2017). Dosimetric properties of MgB4O7: Dy, Li and MgB4O7: Ce, Li for optically stimulated luminescence applications. Radiat. Meas., 106, 2017, 196–199.
Gustafsona, T. D. , Millikenb, E. D. , Jacobsohn, L. G. , and Yukihara, E. G. (2019). Progress and challenges towards the development of a new optically stimulated luminescence (OSL) material based on MgB4O7:Ce,Li. J. Lumin., 212, 242–249.
Kitagawa, Y. , Yukihara, E. G. , and Tanabe, S. (2021). Development of Ce3+ and Li+ co-doped magnesium borate glass ceramics for optically stimulated luminescence dosimetry. J. Lumin., 232, 117847–117855.
Atuchin, V. V. , Kesler, V. G. , Zaitsev, A. I. , Molokeev, M. S. , Aleksandrovsky, A. S. , Kuzubov, A. A. , and Ignatova, N. Y. (2013). Electronic structure of α-SrB4O7: experiment and theory. J. Phys. Condens. Matter., 25, 085503.
Wang L. , Wang Y. , Wang D. , and Zhang J. (2008). Electronic structure calculations of SrB4O7 and SrB4O7:Eu crystals. Solid State Commun., 148 331–335.
Meijerink, A. , Nuyten, J. , and Blasse, G. (1989). Luminescence and energy migration in (Sr,Eu)B4O7, a system with a 4f7-4f65d crossover in the excited state. J. Lumin., 44, 19–31.
Stefani, R. , Maia, A. D. , Teotonio, E. E. S. , Monteiro, M. A. F. , Felinto, M. C. F. C. , and Brito, H. F. (2006). Photoluminescent behaviour of SrB4O7:RE2+ (RE=Sm and Eu) prepared by Pechini, combustion and ceramic methods. J. Solid State Chem., 179, 1086–1092.
Pei, Z. , Su, Q. , and Zhang, J. (1993). The valence change from RE3+ to RE2+ (RE=Eu, Sm, Yb) in SrB4O7: RE prepared in air and the spectral properties of RE2 . J. Alloys Compd., 198, 51–53.
Jiao, Z. , Li, S. , Yan, Q. , Wang, X. , and Shen, D. (2011). J. Phys. Chem. Solids, 72, 252–255.
Sakirzanovas, S. , Katelnikovas, A. , Dutczak, D. , Kareiva, A. , and Jüstel, T. (2012). Concentration influence on temperature-dependent luminescence properties of samarium substituted strontium tetraborate. J. Lumin., 132, 141–146.
Iwamoto, C. , and Fujihara, S. (2009). Fabrication and optical properties of NUV-emitting SiO2–SrB4O7:Eu2+ glass–ceramic thin films. Opt. Mater., 31, 1614–1619.
Stefani, R. , Maia, A. S. , Kodaira, C. A. , Teotonio, E. E.S. , Felinto, M. C. F. C. , and Brito, H. F. (2007). Highly enhanced luminescence of SrB4O7:Eu2+ phosphor prepared by the combustion method using glycine as fuel. Opt. Mater., 29, 1852–1855.
RodnyÏ, P. A. , Berezovskaya, I. V. , VoloshinovskiÏ, A. S. , Stryganyuk, G. B. , and Potapov, A. S. (2003). Translated from Optika i Spektroskopiya. Opt. Spectrosc., 94, 603–608.
Meijerink, A. , Van Hjxk, M. M. E. , and Blasse, G. (1993). Luminescence of Ag+ in crystalline and glassy SrB4O7 . J. Phys. Chem. Solids, 54, 90–906.

Blasé, G. , Meijerink, A. , Noms, M. , and Zuidema, J. (1994). Unusual bismuth luminescence in strontium tetraborate (SrB4O7: Bi). J. Phys. Chem. Solid, 55, 171–174.
Sun, Jiayue , Jicheng, Z. , Xiaotang, L. , and Haiyan, D. U. (2012). Luminescence properties of SrB4O7:Sm2+ for light conversion agent. J. Rare Earths, 30, 10841087.
Yavetskiy, R. P. , Dolzhenkova, E. F. , Tolmachev, A. V. , Parkhomenko, S. V. , Baumer, V. N. , and Prosvirnin, A. L. (2007). Radiation defects in SrB4O7:Eu2+ crystals. J. Alloys Compd., 441 202–205.
Schipper, W. J. , Meijerink, A. , and Blasse, G. (1994). The luminescence of Tm2+ in strontium tetraborate. J. Lumin., 62, 55–59.
Gou, J. , Wang, Y. , and Li, F. (2008). The luminescence properties of Dy3+-activated SrB4O7 under VUV excitation. J. Lumin., 128, 728–731.
Lia, J. , Hao, J. Q. , Li, C. Y. , Zhang, C. X. , Tang, Q. , Zhang, Y. L. , Su, Q. , and Wang, S. B. (2005). Radiat. Meas., 39, 229–233.
Bajaj, N. S. , and Omanwar, S. K. 2013. Thermo Luminescence Study of Srb4 O7: Cu Phosphor Prepared by Combustion Synthesis International Journal of Modern Physics: *Conference Series* 22:404–407.
Mishra, G. C. , Upadhyay, A. K. , Kher, R. S. , and Dhoble, S. J. (2011). Thermoluminescence and mechanoluminescence of gamma-ray-irradiated SrB4O7:Dy phosphors. Micro Nano Lett., 6, 978–981.
Kadam, R. M. , Rajeswari, B. , Mohapatra, M. , Porwal, N. K. , Hon, N. S. , Seshagiri, T. K. , and Natarajan, V. (2015). Radiation induced centres in irradiated SrB4O7 doped europium and their role in thermally stimulated reactions: Thermally stimulated luminescence, fluorescence and electron paramagnetic resonance studies. J. Lumin., 158, 475–483.
Santiago, M. , Lavat, A. , Caselli, E. , Lester, M. , Perisinotti, L. J. , Perisinotti, L. J. , de Figuereido, A. K. , Spano, F. , and Ortego, F. (1998). Thermoluminescence of strontium tetraborate. Phys. Status Solids A, 167, 233–236.
Schulman, J. H. , Kirk, R. D. , and West, E. J. (1967). Use of lithium borate for thermoluminescence dosimetry. In: Proc. Int. Conf. on Luminescence Dosimetry, US AEC Symposium series CONF-650637, Stanford University, USA: 113–117.
Takenaga, M. , Yamamoto, O. , and Yamashita, T. (1980). Preparation and characteristics of Li2B4O7:Cu phosphor. Nucl. Instrum. Methods, 175, 77–78.
Santiago, M. , Graseli, C. , Caseli, E. , Lester, M. , Lavat, A. , and Spano, F. (2001). Thermoluminescence of SrB4O7:Dy. Phys. Status Solidi (A), 185, 285–289.
Sabharwal, S. C. , and Sangeeta (1998). Effect of sodium doping on thermoluminescence and optical properties of barium borate (BaB2O4) single crystals. J. Crystal Growth, 187, 253–258.
Bajaj, N. S. , and Omanwar, S. K. (2012). Combustion synthesis and luminescence characteristic of rare earth activated LiCaBO3 . J. Rare Earths, 30, 1005–1008.
Yang, F. , Liang, Y. , Liu, M. , Li, X. , Zhang, M. , and Wang, N. (2013). Photoluminescence properties of novel red-emitting NaSrBO3:Eu3+ phosphor for near-UV light-emitting diodes. Opt. Laser Technol., 46, 14–19.
Kumar, V. A. K. , Bedyal, S. S. , Pitale, O. M. , Ntwaeaborwa , and Swart, H. C. (2013). Synthesis, spectral and surface investigation of NaSrBO3: Sm3+ phosphor for full colour down conversion in LEDs. J. Alloys Compd., 554, 214–220.
Bajaj, N. S. , and Omanwar, S. K. (2014). Advances in synthesis and characterization of LiMgBO3:Dy3+ . Int. J. Light Electron Opt., 125, 4077–4088.
Bajaj, N. S. , and Omanwar, S. K. (2014). Combustion synthesis and luminescence characteristics of NaSr4(BO3)3:Tb3+ . J. Lumin., 148, 169–173.
Fukuda, Y. , Tomita, A. , and Takeuchi, N. (1987). Thermoluminescence and thermally stimulated exoelectron emission of sintered CaB4O7 doped with Pb, Eu, or Dy. Phys. Status Solidi A, 99, K135–K138.
Fukuda, Y. , Tomita, A. , and Takeuchi, N. (1990). Electron affinity of CaB4O7:Pb ceramic obtained by a simultaneous measurement of TL and TSEE. J. Mater. Sci. Lett., 867, 867–868.
Fukuda Y. , Mizugchi K. , and Takeuchi N. (1986). Thermoluminescence in Sintered CaB4O7:Dy and CaB4O7:Eu. Radiat. Prot. Dosim., 17 397–401.
Tekin, D. , Ege, A. , Karali, T. , Townsend, P. D. , and Proki, M. (2010). Thermoluminescence studies of thermally treated CaB4O7:Dy. Radiat. Meas., 45, 764–767.
Haghiri, M. E. , Saion, E. , Soltani, N. , Abdullah, W. S. W. , Navasery, M. , Saraee, K. R. E. , and Deyhimi, N. (2014). Thermoluminescent dosimetry properties of double doped calcium tetraborate (CaB4O7:Cu–Mn) nanophosphor exposed to gamma radiation. J. Alloys Compd., 582, 392–397.
Akın, A. , Ekdal, E. , Arslanlar, Y. T. , Ayvacıklı, M. , Karal, T. , and Can, N. (2015). Thermally stimulated luminescence glow curve structure of β-irradiated CaB4O7:Dy. Luminescence, 30, 830–834.
Palan, C. B. , Koparkar, K. A. , Bajaj, N. S. , Soni, A. , and Omanwar, S. K. (2016). Synthesis and thermoluminescence/optically stimulated luminescence properties of CaB4O7:Ce phosphor. J. Mater. Sci.: Mater. Electron, 27, 5600–5606.
Aydın, T. , Demirtas, H. , and Aydın, S. (2013). TL/OSL studies of Li2B4O7:Cu dosimetric phosphors. Radiat. Meas., 58, 24–32.
Rawat, N. S. , Kulkarni, M. S. , Tyagi, M. , Ratna, P. , Mishra, D. R. , Singh, S. G. , Tiwari, B. , Soni, A. , Gadkari, S. C. , and Gupta, S. K. (2012). J. Lumin., 132, (8), 1969–1975.

Palan, C. B. , Bajaj, N. S. , and Omanwar, S. K. (2016). Luminescence properties of Eu2+ doped SrB4O7 phosphor for radiation dosimetry. Mater Res. Bull., 76, 216221.
Annalakshmi, O. , Jose, M. T. , Madhusoodanan, U. , Venkatraman, B. , and Amarendra, G. (2013). Kinetic parameters of lithium tetraborate based TL materials. J. Lumin., 141, 60–66.
Palan, C. B. , Koparkar, K. A. , Bajaj, N. S. , Soni, A. , and Omanwar, S. K. (2016). Synthesis and thermoluminescence/ optically stimulated luminescence properties of CaB4O7:Ce phosphor. J. Mater. Sci.: Mater. Electron., 27, 5600–5606.
Ravikumara, N. , ArunKumara, R. , Panigrahic, B. S. , Madhusoodananc, U. , Palan, C. B. , and Omanwar, S. K. (2018). Spectral and thermoluminescence characteristics of high gamma dose irradiated Dy:LiKB4O7 single crystals. Nucl. Instrum. Method B, 436, 203–210.
Ravikumar, N. , Kumar, R. A. , Madhusoodanan, U. , Panigrahi, B. S. , Palan, C. B. , and Omanwar, S. K. (2018). Luminescence properties of europium doped lithium potassium tetraborate (Eu:LiKB4O7) single crystal for dosimetry applications. J. Mater. Sci.: Mater. Electron., 29, 18511–18518.
Palan, C. B. , Chauhan, A. O. , Sawala, N. S. , Bajaj, N. S. , and Omanwar, S. K. (2016). Synthesis and preliminary TL/OSL properties of Li2B4O7: Cu-Ag phosphor for radiation dosimetry. Optik, 127, 6419–6423.
Palan, C. B. , Chauhan, A. O. , Sawala, N. S. , Bajaj, N. S. , and Omanwar, S. K. (2015). Thermoluminescence and optically stimulated luminescence properties of MgB4O7: Ag Phosphor. Int. J. Lumin. Appl., 5, 408–410.
Yukihara, E. G. , Doull, B. A. , Gustafson, T. , Oliveira, L. C. , Kurt, K. , and Milliken, E. D. (2017). Optically stimulated luminescence of MgB4O7:Ce,Li for gamma and neutron dosimetry. J. Lumin., 183, 525–532.
Souza, L. F. , Silva, A. M. B. , Antonio, P. L. , Caldas, L. V. E. , Souza, S. O. , d'Erricoc, F. , and Souza, D. N. (2017). Dosimetric properties of MgB4O7:Dy,Li and MgB4O7:Ce,Li for optically stimulated luminescence applications. Radiat. Meas., 106, 196–199.
Palan, C. B. , and Omanwar, S. K. (2017). Synthesis and preliminary TL/OSL properties of MgB4O7:Tb3+ phosphorfor radiation dosimetry. IJRITCC, 5, 53–54.
González, P. R. , Ávila, O. , Mendoza-Anaya, D. , and Escobar-Alarcón, L. (2021). Effect of sintering temperature on sensitivity of MgB4O7:Tm,Ag obtained by the solution combustion method. Appl. Radiat. Isot., 167, 109459.
Aydın, Talat , Demirtas, H. , and Aydın, S. (2013). TL/OSL studies of Li2B4O7:Cu dosimetric phosphors. Radiat. Meas., 58, 24–32.
Li, J. , Zhang, C. X. , Tang, Q. , Zhang, Y. L. , Hao, J. Q. , Su, Q. , and Wang, S. B. (2007). Synthesis, photoluminescence, thermoluminescence and dosimetry properties of novel phosphor Zn(BO2)2:Tb. J. Phys. Chem., 68, 143–147.
Liyan, L. , Jingquan, H. , Chengyu, Li , Qiang, T. , Chunxiang, Z. , Su, Q. , and Shubin, W. (2006). Thermoluminescence characteristics of SrB6O10:Tb. J. Rare Earths, 24, 276.
Blasse, G. (1983). Rev. Inorg. Chem., 15, 319–381.
Ternane, R. , Adad, M. T. C. , Panczer, G. , Goutaudier, C. , Dujardin, C. , Boulon, G. , Ariguib, N. K. , and Ayedi, M. T. (2002). Structural and luminescent properties of new Ce3+ doped calcium borophosphate with apatite structure. Solid State Sci., 4, 53–59.
Blasse, G. , and Grabmaier, B. C. (1994). A general introduction to luminescent materials luminescent materials. Lumin. Mater., 1–9. Springer, Berlin, Heidelberg. 10.1007/978-3-642-79017-1_1
Caldino, U. , Speghini, A. , and Bettinelli, M. (2006). Optical spectroscopy of zinc metaphosphate glasses activated by Ce3+ and Tb3+ ions. J. Phys. Condens. Matter, 18, 3499.
Leskela, M. , and Niinitso, L. (1992). Applications of rare earths in full-colour EL displays. Mater. Chem. Phys., 31, 7–11.
Raue, R. , Vink, A. T. , and Welkar, T. (1998). Phil. Tech. Rev., 44, 335.
Smets, B. M. (1987). Phosphors based on rare-earths, a new era in fluorescent lighting. J. Mater. Chem. Phys., 16, 283–299.
Dhoble, S. J. , Moharil, S. V. , Dhopte, S. M. , Muthal, P. L. , and Kondawar, V. K. (1993). Preparation and characterization of the K3Na(SO4)2: Eu phosphor. Phys. Status Solidi (A), 135, 289–297.
Gahane, D. H. , Kokode, N. S. , Muthal, P. L. , Dhopte, S. M. , and Moharil, S. V. (2009). Luminescence of Eu2+ in some iodides. Opt. Mater., 32, 18–21.
Hoffman, M. V. (1971). Alkaline earth aluminum fluoride compounds with Eu+2 activation. J. Electrochem. Soc., 118, 933.
United Nations Sources and Effects of Ionizing Radiation. Volume I: Report to the General Assembly, Scientific Annexes A and B, UNSCEAR Report (2008).
Czarwinski, R. , and Crick, M. J. (2011). Occupational exposures worldwide and revision of international standards for protection. Radiat. Prot. Dosim., 144, 2–11.
Bhatt, B. C. , and Kulkarni, M. S. (2013). Worldwide status of personnel monitoring using thermoluminescent (TL), optically stimulated luminescent (OSL) and radiophotoluminescent (RPL) dosimeters. Int. J. Lumin. Appl., 3, 6–10.
Bhatt, B. C. , and Kulkarni, M. S. (2014). Thermoluminescent phosphors for radiation dosimetry. Defect Diffus. Forum, 347, 179–227.

Patra, G. D. , Singh, S. G. , Tiwari, B. , Singh, A. K. , Desai, D. G. , Tyagi, M. , Sen, S. , and Gadkari, S. C. (2016). Optically stimulated luminescence in Ag doped Li2B4O7 single crystal and its sensitivity to neutron detection and dosimetry in OSL mode. Radiat. Meas., 88, 14–19.
Jensen, L. B. , and Thompson, I. M. G. (1995). An international intercomparison of passive dosemeters, electronic dosemeters and dose rate meters used for environmental radiation measurements. Radiat. Prot. Dosim., 60, 201.
Bajaj, N. S. , and Omanwar, S. K. (2013). Combustion synthesis and characterization of phosphor KSr4 (BO3)3:Dy3+ . Opt. Mater., 35, 1222–1225.
Akselrod, M. S. , Jensen, L. B. , and McKeever, S. W. S. (2007). Optically stimulated luminescence and its use in medical dosimetry. Radiat. Meas., 41, S78–S99.
Pradhan, A. S. , Lee, J. I. , and Kim, J. L. (2008). Recent developments of optically stimulated luminescence materials and techniques for radiation dosimetry and clinical applications. J. Med. Phys., 33, 85–99.
Yukihara E. G. , and McKeever S. W. S. (Eds.) (2011). Optically Stimulated Luminescence: Fundamentals and Applications. Wiley, Oklahoma, USA.
Huston, A. L. , Justus, B. L. , Falkenstein, P. L. , Miller, R. W. , Ning, H. , and Altemus, R. (2001). Remote optical fibre dosimetry. Nucl. Instrum. Methods B, 184, 55–67.
Prokic, M. (2002). Nuclear technology publishing dosimetric characteristics of Li2B4O7:Cu,Ag,P solid TL detectors. Radiat. Prot. Dosim., 100, 265–268.
Jensen, L. B. , Banerjee, D. , Jungner, H. , and Murray, A. S. (1999). Retrospective assessment of environmental dose rates using optically stimulated luminescence from Al2O3:C and quartz. Radiat. Prot. Dosim., 84, 537–542.

Borate

http://www.PV Lighthouse hosts Altermatt's lectures on the solar spectrum
Honsberg, C.B. , and Bowden, S.G. Atmospheric effects on solar radiation. page on www.pveducation.org
Sekuler R. , and Blake R. (1985). Perception, Alfred A. Knopf Inc, New York.
Honsberg, C.B. , and Bowden, S.G. PV array on a sunny and a cloudy. page on www.pveducation.org
Honsberg, C.B. , and Bowden, S.G. Photovoltaic education website. www.pveducation.org
Honsberg, C.B. , and Bowden, S.G. Standard solar spectra for space and terrestrial applications. page on www.pveducation.org
Powell, D.M. , Winkler, M.T. , Choi, H.J. , Simmons, C.B. , Needleman, D.B. , and Buonassisi, T. (2012). Crystalline silicon photovoltaic: a cost analysis framework for determining technology pathways to reach base load electricity costs. Energy Environ. Sci., 5, 5874–5883.
Green, M.A. , Emery, K. , Hishikawa, Y. , and Warta, W. (2011). Solar cell efficiency tables (version 37). Prog. Photovoltaics, 19, 84–92.
Honsberg, C.B. , and Bowden S.G. Normalized spectral response of a C-Si solar cell. page on www.pveducation.org
Zhang, X.D. , Jin, X. , Wang, D.F. , Xiong, S.Z. , Geng, X.H. , and Zhao, Y. (2010). Synthesis of NaYF4: Yb, Er nanocrystals and its application in silicon thin film solar cells. Phys. Status Solidi C, 7, 1128–1131.
de Wild, J. , Meijerink, A. , Rath, J.K. , van Sark, W.G.J.H.M. , and Schropp, R.E.I. (2010). Towards upconversion for amorphous silicon solar cells. Sol. Energy Mater. Sol. Cells, 94, 1919–1922.
de Wild, J. , Rath, J.K. , Meijerink, A. , van Sark, W.G.J.H.M. , and Schropp, R.E.I. (2010). Enhanced near-infrared response of a-Si:H solar cells with β-NaYF4: Yb3+ (18%), Er3+ (2%) upconversion phosphors. Sol. Energy Mater. Sol. Cells, 94, 2395–2398.
Honsberg, C.B. , and Bowden, S.G. Solar cell parameter. page on www.pveducation.org
Honsberg, C.B. , and Bowden, S.G. I-V characteristics of solar cell. page on www.pveducation.org
Honsberg, C.B. , and Bowden, S.G. The spectral response of a silicon solar cell. page on www.pveducation.org
Auzel, F. (2004). Upconversion and anti-stokes processes with f and d ions in solids. Chem. Rev., 104, 139–173.
Trupke, T. , Green, M.A. , and Wurfel, P. (2002). Improving solar cell efficiencies by up-conversion of sub-band-gap light. J. Appl. Phys., 92, 4117–4122.
Wegh, R.T. , Donker, H. , Oskam, K.D. , and Meijerink, A. (1999). Visible quantum cutting in LiGdF4: Eu3+ through downconversion. Sci., 283, 663–666.
Lian, H. , Shang, Z.H.M. , Geng, D. , Zhang, Y. , and Lin, J. (2013). Rare earth ions doped phosphors for improving efficiencies of solar cells. Energy, 57, 270–283.
Gibart, P. , Auzel, F. , Guillaume, J.C. , and Zahraman, K. (1996). Below band-gap IR response of substrate-free GaAs solar cells using two-photon up-conversion. Jpn. J. Appl. Phys., Part 135, 4401–4402.
Zhang, Q.Y. , and Huang, X.Y. (2010). Recent progress in quantum cutting phosphors. Prog. Mater. Sci., 55, 353–427.

Dexter, D.L. (1957). Possibility of luminescent quantum yields greater than unity. Phys. Rev., 108, 630–633.
Piper, W.W. , DeLuca, J.A. , and Ham, F.S. (1974). Cascade fluorescent decay in Pr3+-doped fluorides: achievement of a quantum yield greater than unity for emission of visible light. J. Lumin., 8, 344–348.
Sommerdijk, J.L. , Bril, A. , and de Jager, A.W. (1974). Two photon luminescence with ultraviolet excitation of trivalent praseodymium. J. Lumin., 8, 341–343.
Niranjana, V. , Janani, K. , and Venkata Ravikumar Darba Ramasubramanian, S. (2019). Investigations on the synthesis dependent luminescence property of LiGdF4: Eu3+ microcrystals. Optik., 198, 163233, 1–5.
Liu, B. , Chen, Y. , Shi, C. , Tang, H. , and Tao, Y. (2003). Visible quantum cutting in BaF2: Gd, Eu via downconversion. J. Lumin., 101, 155–159.
Strumpel, C. , McCann, M. , Beaucarne, G. , Arkhipov, V. , Slaoui, A. , Svrcek, V. , del Canizo, C. , and Tobias, I. (2007). Modifying the solar spectrum to enhance silicon solar cell efficiency—an overview of available materials. Sol. Energy Mater. Sol. Cells, 91, 238–249.
Xie, L.C. , Wang, Y.H. , and Zhang, H.J. (2009). Applications of rare earth Tb3+ − Yb3+ co-doped down-conversion materials for solar cells. Appl. Phys. Lett., 94, 061905, 1–3.
Zheng, W. , Zhu, H. , Li, R. , Tu, D. , Liu, Y. , Luo, W. , and Chen, X. (2012). Visible-to-infrared quantum cutting by phonon-assisted energy transfer in YPO4: Tm3+, Yb3+ phosphors. Phys. Chem. Chem. Phys., 14, 6974–6980.
van der Ende, B.M. , Aarts, L. , and Meijerink, A. (2009). Nearinfrared quantum cutting for photovoltaics. Adv. Mater., 21, 3073–3077.
van Wijngaarden, J.T. , Scheidelaar, S. , Vlugt, T.J.H. , Reid, M.F. , and Meijerink, A. (2010). Energy transfer mechanism for downconversion in the (Pr3+, Yb3+) couple. Phys. Rev. B: Condens. Matter., 81, 1551121.
Eilers, J.J. , Biner, D. , van Wijngaarden, J.T. , Kraemer, K. , Guedel, H.U. , and Meijerink, A. (2010). Efficient visible to infrared quantum cutting through downconversion with the Er3+-Yb3+ couple in Cs3Y2Br9 . Appl. Phys. Lett., 96, 1511061.
Lin, H. , Chen, D. , Yu, Y. , Yang, A. , and Wang, Y. (2011). Near-infrared quantum cutting in Ho3+/Yb3+ co-doped nanostructured glass ceramic. Opt. Lett., 36, 876878.
Bai, Z. , Fujii, M. , Hasegawa, T. , Imakita, K. , Mizuhata, M. , and Hayashi, S. (2011). Efficient ultraviolet-blue to near-infrared downconversion in Bi–Dy–Yb-doped zeolites. J. Phys. D: Appl. Phys., 44, 455301, 1–3.
Chen, D. , Wang, Y. , Yu, Y. , Huang, P. , and Weng, F. (2008). Quantum cutting downconversion by cooperative energy transfer from Ce3+ to Yb3+ in borate glasses. J. Appl. Phys., 104, 116105, 1–3.
Cheng, X. , Su, L. , Wang, Y. , Zhu, X. , Wei, X. , and Wang, Y. (2012). Near-infrared quantum cutting in YVO4:Yb3+ thin-films via downconversion. Opt. Mater., 34, 1102–1106.
Shestakov, M.V. , Tikhomirov, V.K. , Kirilenko, D. , Kuznetsov, A.S. , Chibotaru, L.F. , Baranov, A.N. , Van Tendeloo, G. , and Moshchalkov, V.V. (2011). Quantum cutting in Li (770 nm) and Yb (1000 nm) co-dopant emission bands by energy transfer from the ZnO nano-crystalline host. Opt. Express, 19, 15955–15964.
Wei, X. , Huang, S. , Chen, Y. , Guo, C. , Yin, M. , and Xu, W. (2010). Energy transfer mechanisms in doped near-infrared downconversion phosphor. J. Appl. Phys., 107, 103107, 1–3.
Rowan, B.C. , Wilson, L.R. , and Richards, B.S. (2008). Advanced material concepts for luminescent solar concentrators. IEEE J. Sel. Top. Quantum Electron., 14, 1312–1322.
Yamada, N. , Anh, L.N. , and Kambayashi, T. (2010). Escaping losses of diffuse light emitted by luminescent dyes doped in micro/nanostructured solar cell systems. Sol. Energy Mater. Sol. Cells, 94, 413–419.
de Boer, D.K.G. , Broer, D.J. , Debije, M.G. , Keur, W. , Meijerink, A. , Ronda, C.R. , and Verbunt, P.P.C. (2012). Progress in phosphors and filters for luminescent solar concentrators. Opt. Express, 20, A395–A405.
Debije, M.G. , and Verbunt, P.P.C. (2012). Thirty years of luminescent solar concentrator research: solar energy for the built environment. Adv. Energy Mater., 2, 12–35.
Klampaftis, E. , Ross, D. , McIntosh, K.R. , and Richards, B.S. (2009). Enhancing the performance of solar cells via luminescent down-shifting of the incident spectrum: a review. Sol. Energy Mater. Sol. Cells, 93, 1182–1194.
Stouwdam, J.W. , and van Veggel, F.C.J.M. (2002). Near-infrared emission of redispersible Er3+, Nd3+, and Ho3+ doped LaF3 nanoparticles. Nano Lett., 2, 733–737.
Hebbink, G.A. , Stouwdam, J.W. , Reinhoudt, D.N. , and vanVeggel, F.C.J.M. (2002). Lanthanide(III) doped nanoparticles that emit in the nearinfrared. Adv. Mater., 14, 1147–1150.
Zhang, M.F. , Shi, S.G. , Meng, J.X. , Wang, X.Q. , Fan, H. , Zhu, Y.C. , Wang, X.Y. , and Qian, Y.T. (2008). Preparation and characterization of near-infrared luminescent bifunctional core/shell nanocomposites. J. Phys. Chem. C, 112, 2825–2830.
Meng, J.X. , Li, J.Q. , Shi, Z.P. , and Cheah, K.W. (2008). Efficient energy transfer for Ce to Nd in Nd∕Ce codoped yttrium aluminum garnet. Appl. Phys. Lett., 93, 221908, 1–3.
Fu, H. , Cui, S. , Luo, Q. , Qiao, X. , Fan, X. , and Zhang, X. (2012). Broadband downshifting luminescence of Cr3+/Yb3+-codoped fluorosilicate glass. J. Non-Cryst. Solids, 358, 1217–1220.
Ye, S. , Jiang, N. , Zhou, J. , and Wang, D. (2012). Optical property and energy transfer in the ZnO-LiYbO2 hybrid phosphors under the indirect near-UV excitation. J. Qiu, J. Electrochem. Soc., 159, H11–H15.
Tikhomirov, V.K. , Vosch, T. , Fron, E. , Rodriguez, V.D. , Velazquez, J.J. , Kirilenko, D. , van Tendeloo, G. , Hofkens, J. , Van der Auweraer, M. , and Moshchalkov, V.V. (2012). Luminescence of oxyfluoride glasses co-doped with Ag nanoclusters and Yb3+ ions. RSC Adv, 2, 1496–1501.

Liu, G.X. , Zhang, R. , Xiao, Q.L. , Zou, S.Y. , Peng, W.F. , Cao, L.W. , and Meng, J.X. (2011). Efficient Bi3+→ Nd3+ energy transfer in Gd2O3:Bi3+, Nd3+ . Opt. Mater., 34, 313–316.
Zhang, G.G. , Liu, C.M. , Wang, J. , Kuang, X.J. , and Su, Q. (2011). An intense charge transfer broadband sensitized near-infrared emitting CaLaGa3S6O:Yb3+ phosphor suitable for solar spectral convertor. Opt. Express, 19, 24314-24319.
Luo, Q. , Qiao, X.S. , Fan, X.P. , and Zhang, X.H. (2011). Near-infrared emission of Yb3+ through energy transfer from ZnO to Yb3+ in glass ceramic containing ZnO nanocrystals. Opt. Lett., 36, 2767–2769.
Ye, S. , Jiang, N. , Zhou, J. , Wang, D. , and Qiu, J. (2012). Optical property and energy transfer in the ZnO-LiYbO2 hybrid phosphors under the indirect near-UV excitation. J. Electrochem. Soc., 159, H11–H13.
Luo, W.Q. , Li, R.F. , and Chen, X.Y. (2009). Host-sensitized luminescence of Nd3+ and Sm3+ ions incorporated in anatase titania nanocrystals. J. Phys. Chem. C, 113, 87728777.
Stouwdam, J.W. , and van Veggel, F.C.J.M. (2004). Sensitized emission in Ln3+doped TiO2 semiconductor nanoparticles. Chem. Phys. Chem., 5, 743–746.
Sawala, N.S. , Koparkar, K.A. , Bajaj, N.S. , and Omanwar, S.K. (2016). Near-Infrared down-conversion in Y(1-x)YbxVO4 for sensitization of c-Si solar cell. Optik, 127, 4375–4378.
Sawala, N.S. , Bajaj, N.S. , and Omanwar, S.K. (2016). Near-infrared quantum cutting in Yb3+ ion doped strontium vanadate . Infrared Phys. Technol., 76, 271–275.
Chen, D.Q. , Lei, L. , Yang, A.P. , Wang, Z.X. , and Wang, Y.S. (2012). Ultra-broadband near-infrared excitable upconversion core/shell nanocrystals. Chem. Commun., 48, 5898–5900.
Pathak, A.A. , Talewar, R.A. , Joshi, C.P. , and Moharil, S.V. (2017). Sensitization of Yb3+ emission in CaYAl3O7 host. Opt. Mater., 64, 217–223.
vanderEnde, B.M. , Aarts, L. , and Meijerink, A. (2009). Lanthanide ions as spectral converters for solar cells. Phys. Chem. Chem. Phys., 11, 11081–11095.
Zhou, J. , Teng, Y. , Lin, G. , and Qiu, J. (2011). Ultraviolet to near-infrared spectral modification in Ce3+ and Yb3+ co-doped phosphate glasses. J. Non-Cryst. Solids, 357, 2336–2340.
Zhou, W. , Yang, J. , Wang, J. , Li, Y. , Kuang, X. , Tang, J. , and Liang, H. (2012). Study on the effects of 5d energy locations of Ce3+ ions on NIR quantum cutting process in Y2SiO5: Ce3+, Yb3+ . Opt. Express, 20, A510–A518.
Ueda, J. , and Tanabe, S. (2009). Visible to near infrared conversion in Ce3+-Yb3+ co-doped YAG ceramics. J. Appl. Phys., 106, 0431011–0431015.
van der Kolk, E. , Ten Kate, O.M. , Wiegman, J.W. , Biner, D. , and Kramer, K.W. (2011). Enhanced 1G4 emission in NaLaF4: Pr3+, Yb3+ and charge transfer in NaLaF4: Ce3+, Yb3+ studied by Fourier transform luminescence spectroscopy. Opt. Mater., 33, 1024–1027.
Zhang, Q. , Wang, J. , Zhang, G. , and Su, Q. (2009). UV photon harvesting and enhanced near-infrared emission in novel quantum cutting Ca2BO3Cl: Ce3+, Tb3+, Yb3+ phosphor. J. Mater. Chem., 19, 7088–7092.
Zhou, J. , Teng, Y. , Ye, S. , Zhuang, Y. , and Qiu, J. (2010). Enhanced downconversion luminescence by co-doping Ce3+ in Tb3+-Yb3+ doped borate glasses. Chem. Phys. Lett., 486, 116–118.
Blasse, G. , and Bril, A. (1968). Investigations on Bi3+-activated phosphors. J. Chem. Phys., 48, 217–222.
Zhou, R. , Kou, Y. , Wei, X. , Duan, C. , Chen, Y. , and Yin, M. (2012). Broadband downconversion based near-infrared quantum cutting via cooperative energy transfer in YNbO4: Bi3+, Yb3+ phosphor. Appl. Phys. B, 107, 483–487.
Huang, X.Y. , Wang, J.X. , Yu, D.C. , Ye, S. , Zhang, Q.Y. , and Sun, X.W. (2011). Spectral conversion for solar cell efficiency enhancement using YVO4:Bi3+, Ln3+ (Ln = Dy, Er, Ho, Eu, Sm, and Yb) phosphors. J. Appl. Phys., 109, 113526, 1–7.
Lahoz, F. (2008). Ho3+ doped nanophase glass ceramics for efficiency enhancement in silicon solar cells. Opt. Lett., 33, 2982–2984.
Das, S. , Amarnath Reddy, A. , and Vijaya Prakash, G. (2011). Strong green upconversion emission from Er3+-Yb3+ co-doped KCaBO3 phosphor. Chem. Phys. Lett., 504, 206–210.
Yawalkar, M.M. , Zade, G.D. , Dabre, K.V. , and Dhoble, S.J. (2016). Luminescence study of Eu3+ doped Li6Y(BO3)3 phosphor for solid-state lighting. J. Bio. Chem. Sci., 31, 1037–1042.
Hargunani, S.P. (2016). Synthesis and upconversion properties of Er3+-Yb3+ co-doped LiBaBO3 phosphor engineering and technology. Int. Adv. Res. J. Sci., 3, 216–218.
Palan, C.B. , Chauhan, A.O. , Sawala, N.S. , Bajaj, N.S. , and Omanwar, S.K. (2016). Synthesis and preliminary TL/OSL properties of Li2B4O7: Cu-Ag phosphor for radiation dosimetry. Optik Int. J. Light Electron. Opt., 127, 6419–6423.
Palaspagar, R.S. , Gawande, A.B. , Sonekar, R.P. , and Omanwar, S.K. (2015). Synthesis and luminescent properties of Tb3+ activated novel magnesium alumino-borate phosphor. J. Chin. Adv. Mater. Soc., 3, 170–176.
Chauhan, A.O. , Palan, C.B. , Sawala, N.S. , and Omanwar, S.K. (2017). Combustion synthesis and photoluminescence study of UV emitting LaBaB9O16 phosphors. J. Mater. Sci. Mater. Electron., 28, 7643–7649.
Chauhan, A.O. , Koparkar, K.A. , Bajaj, N.S. , and Omanwar, S.K. (2016). Synthesis and photoluminescence properties of Pb2+ doped inorganic borate phosphor NaSr4(BO3)3 . AIP Conf. Proc., 1728, 0204701–0204704.

Zhao, J. , Wang, X. , Pang, Q. , and Zhang, A. (2021). Enhanced near-infrared luminescence in Ba3Y(BO3)3: Nd3+ by co-doping with Ce3+ . ECS J. Solid State Sci. Technol., 10, 016004, 1–3.
Krut'ko, V.A. , Komova, M.G. , Pominova, D.V. , and Nikiforova, G.E. (2019). Enhanced red up-conversion luminescence in La4−x−yGd10Ge2B6O34:Ybx,Ery synthesized by the liquid-phase homogenization with tartaric acid. J. Sol-Gel Sci. Tech., 92, 442–448.
Lia, H. , Lu, Y. , Lia, C. , Dengb, D. , Rong, K. , Jing, X. , Wang, L. , and Xu, S. (2019). Near-infrared down-conversion luminescence in Yb3+ doped self-activated TbZn(B5O10) phosphor. J. Optoelectr. Adv. Mater., 21, 373–384.
Hou, D. , Li, J. , Lin, H. , and Zhang, J. (2016). Energy transfer and downconversion near-infrared material of Tb3+ and Yb3+ doped Ca5(BO3)3F. Physica B: Condensed Matter, 500, 44–47.
Sontakke, A.D. , Ueda, J. , Katayama, Y. , Zhuang, Y. , Dorenbos, P. , and Tanabe, S. (2015). Role of electron transfer in Ce3+ sensitized Yb3+ luminescence in borate glass. J. Appl. Phys., 117, 013105, 1–7.
Chen, J.D. , Zhang, H. , Li, F. , and Guo, H. (2011). High efficient near-infrared quantum cutting in Ce3+-Yb3+ co-doped LuBO3 phosphors. Mater. Chem. Phys., 128, 191–194.
Zhang, J. , Wang, Y. , Chen, G. , and Huang, Y. (2014). Investigation on visible quantum cutting of Tb3+ in oxide hosts. J. Appl. Phys., 115, 093108, 1–7.
Hao, Z. , Jindeng, C. , and Hai, G. (2011). Efficient near-infrared quantum cutting by Ce-Yb couple in GdBO3 phosphors. J. Rare Earths, 29, 822–825.
Song, P. , and Jiang, C. (2013). Broadband solar spectral conversion in near-infrared quantum cutting. IEEE Photonic J., 5, 8400110, 1–10.
Liu, P. , Liu, J. , Zheng, X. , Luo, H. , Li, X. , Yao, Z. , Yu, X. , Shi, X. , Houa, B. , and Xi, Y. (2014). An efficient light converter YAB:Cr3+,Yb3+/Nd3+ with broadband excitation and strong NIR emission for harvesting c-Si-based solar cells. J. Mater. Chem. C, 2, 5769–5777.
Omanwar, S.K. , and Sawala, N.S. (2017). Spectral downshifting in MBO3:Nd3+ (M = Y, La) phosphor. Appl. Phys. A, 123, 673, 1–5.
Sawala, N.S. , Chauhan, A.O. , Palan, C.B. , and Omanwar, S.K. (2015). Spectral downshifting in Ce3+- Yb3+ co-doped YBO3 phosphor. Int. J. Lumin. Appl., 5, 456–459.
Guerbous, L. , Seraiche, M. , and Krachni, O. (2013). Photoluminescence and electron-vibrational interaction in 4fn-15d states of Ce3+ or Pr3+ ions doped LnBO3 (Ln = Lu, Y, La) orthoborates materials. J. Lumin., 134, 165–173.
Chen, L. , Luo, A. , Deng, X. , Xue, S. , Zhang, Y. , Zhu, J. , Yao, Z. , Jiang, Y. , Chen, S. , and Liu, F. (2013). Luminescence and energy transfer in the Sb3+ and Gd3+ activated YBO3 phosphor. J. Lumin., 143, 670–673.
Guo, H. , Sun, L. , Liang, J. , Li, B. , and Huang, X. (2019). High-efficiency and thermal-stable Eu3+-activated Ca3Y(AlO)3(BO3)4:Eu3+ red emitting phosphors for near-UV-excited white LEDs. J. Lumin, 205, 115–121.
Shyichuk, A. , and Lis, S. (2013). Green-emitting nanoscaled borate phosphors Sr3RE2(BO3)4:Tb3+ . Mater. Chem. Phys., 140, 447–452.
Shyichuk, A.A. , and Lis, S. (2011). Photoluminescence properties of nanosized strontium-yttrium borate phosphor obtained by the sol-gel Pechini method. J. Rare Earths, 29, 1161–1165.
Kruopyte, A. , Giraitis, R. , Juskenas, R. , Enseling, D. , Jüstel, T. , and Katelnikovas, A. (2017). Luminescence and luminescence quenching of efficient GdB5O9:Eu3+ red phosphors. J. Lumin., 192, 520–526.
Sun, Y. , An, X. , Chen, L. , Gao, Q. , Zhang, X. , Duan, L. , and Lü, W. (2018). Upconverting nanophosphor incorporated photoanodes for improved photoelectric performances of quantum dot sensitized solar cells. Mater. Res. Lett., 6, 314–320.
He, Y. , Liu, J. , Sung, S. , and Chang, C. (2021). Downshifting and antireflective thin films for solar module power enhancement. Mater. Design, 201, 109454, 1–14.
Xie, C. , Xie, S. , Yi, R. , Cao, R. , Yuan, H. , and Xiao, F. (2020). Site-selective occupation for broadband upconversion luminescence in Ca3Y(GaO)3(BO3)4:Yb3+, Mn2+ phosphors. J. Phys. Chem. C, 124, 6845–6852.
Zhao, D. , Xue, Y. , Fan, Y. , Zhang, R. , and Zhanga, S. (2021). A new series of rare-earth borate-phosphate family CsNa2Ln2(BO3)(PO4)2 (Ln = Ho, Er, Tm, Yb): Tunnel structure, upconversion luminescence and optical thermometry properties. J. Alloys Compd., 866, 158801, 1–5.
Maurya, A. , Bahadur, A. , and Bahadur Rai, S. (2019). Enhanced upconversion and downshifting emissions from Tb3+, Yb3+ co-doped CaZrO3 phosphor in presence of Li+ ions. Methods *Appl. Fluoresc.*, 7, 015002, 1–7.
Talewar, R.A. , S.K. Mahamuda , Swapna, K. , and Rao, A.S. (2018). Sensitization of Yb3+ by Nd3+ emission in alkaline-earth chloro borate glasses for laser and fiber amplifier applications. J. Alloys Compd., https://www.sciencedirect.com/science/article/abs/pii/S0925838818331591, 10.1016/j.jallcom.2018.08.270
Kim, H.T. , Lee, K. , Jin, W. , Um, H.D. , Lee, M. , Hwang, E. , Kwon, T.H. , and Seo, K. (2018). Phosphorescent energy downshifting for diminishing surface recombination in silicon nanowire solar cells. Sci. Rep., 8, 16974.
Soni, A. , Rai, V. , and Mahata, M. (2017). Yb3+ sensitized Na2Y2B2O7:Er3+ phosphors in enhanced frequency upconversion, temperature sensing and field emission display. Mater. Res. Bull., 89, 116–124.
Hao, Y. , Wang, Y. , Hu, X. , Liua, X. , Liu, E. , Fan, J. , Sun, Q. , and Miao, H. (2016). YBO3:Ce3+,Yb3+ based near-infrared quantum cutting phosphors: synthesis and application to solar cells. Ceramics Int., 42,

9396–9401.
Keshavamurthy, K. , and Eraiah, B. (2017). Silver lead borate glasses doped with europium ions for phosphors applications. Bull. Mater. Sci., 40, 859–863.
Hovel, H.J. , Hodgson, R.T. , and Woodall, J.M. (1979). The effect of fluorescent wavelength shifting on solar cell spectral response. Solar Energy Mater., 2, 19–29.
Loos, S. , Steudel, F. , Ahrens, B. , and Schweizer, S. (2014). Optical properties of down-shifting barium borate glass for CdTe solar cells. Opt. Mater., 41, 143–145.
Steudel, F. , Loos, S. , Ahrens, B. , and Schweizer, S. (2015). Luminescent borate glass for efficiency enhancement of CdTe solar cells. J. Lumin., 164, 76–80.
Thomas, S. , George, R. , Qamhieha, N. , Gopchandran, K.G. , Mahmoud, S.T. , and Quatela, A. (2021). Sm3+ doped strontium barium borate phosphor for white light emission: spectroscopic properties and Judd–Ofelt analysis. Spectrochim. Acta Part A: Mol. Biomol. Spectrosc, 248, 119187.
Borisov, S.M. , Gatterer, K. , Bitschnau, B. , and Klimant, I. (2010). Preparation and characterization of chromium(III)-activated yttrium aluminum borate: a new thermographic phosphor for optical sensing and imaging at ambient temperatures. J. Phys. Chem. C, 114, 9118–9124.
Chang, W. , Li, L. , Doub, M. , Yana, Y. , Jiang, S. , Pan, Y. , Wu, Z. , Zhou, X. , and Cui, M. (2019). Dual-mode downconversion luminescence with broad near-ultraviolet and blue light excitation in Tm3+/Yb3+ co-doped oxy-fluoride glasses for c-Si solar cells. Mater. Res. Bull., 112, 109–114.
Chinna, B. , Jamalaiah , and Rasool, S.N. (2015). Fluorescence properties of Sm3+ ions in yttrium aluminum borate phosphors for optical applications. J. Mol. Struct., 1097, 161–165.
Boyer, J.C. , and van veggel, F.C.J.M. (2010). Absolute quantum yield measurements of colloidal NaYF4: Er3+, Yb3+ upconverting nanoparticles. Nanoscale RSC, 2, 1417–1419.
Zhang, W. , Ding, F. , and Chou, S.Y. (2012). Large enhancement of upconversion luminescence of NaYF4:Yb3+/Er3+ nanocrystal by 3D plasmonic nanoantennas. Adv. Mater., 24, OP236–OP241.
Johnson, C.M. , Reece, P.J. , and Conibeer, G.J. (2011). Slow-light-enhanced upconversion for photovoltaic applications in one-dimensional photonic crystals. Opt. Lett., 36, 3990–3992.
Suyver, J.F. , Aebischer, A. , Biner, D. , Gerner, P. , Grimm, J. , Heer, S. , Kramer, K.W. , Reinhard, C. , and Gudel, H.U. (2005). Novel materials doped with trivalent lanthanides and transition metal ions showing near-infrared to visible photon upconversion. Opt. Mater., 27, 1111–1130.
Pan, A.C. , del Canizo, C. , Canovas, E. , Santos, N.M. , Leitao, J.P. , and Luque, A. (2010). Enhancement of up-conversion efficiency by combining rare earth-doped phosphors with PbS quantum dots. Sol. Energy Mater. Sol. Cells, 94, 1923–1926.
Zou, W. , Visser, C. , Maduro, J.A. , Pshenichnikov, M.S. , and Hummelen, J.C. (2012). Broadband dye-sensitized upconversion of near-infrared light. Nat. Photonics, 6, 560–564.
Fan, B. , Chlique, C. , Merdrignac-Conanec, O. , Zhang, X. , and Fan, X. (2012). Near-infrared quantum cutting material Er3+/Yb3+ doped La2O2S with an external quantum yield higher than 100%. J. Phys. Chem. C, 116, 11652–11657.
Hernandez-Noyola, H. , Potterveld, D.H. , Holt, R.J. , and Darling, S.B. (2012). Optimizing luminescent solar concentrator design. Energy Environ. Sci., 5, 5798–5802.
Billmeyer F. (1984). Text Book of Polymer Science, Wiley, Singapore.
Jeong, S.K. , Jo, Y.K. , and Jo, N.J. (2006). Decoupled ion conduction mechanism of poly (vinyl alcohol) based Mg-conducting solid polymer electrolyte. Electrochim. Acta, 52, 1549–1555.
Zhang, H. , and Wang, J. (2009). Vibrational spectroscopic study of ionic association in poly (ethylene oxide)–NH4SCN polymer electrolytes. Spectrochim. Acta Part A: Mol. Biomol. Spectrosc., 71, 1927–1931.
Hirankumar, G. , Selvasekarapandian, S. , Kuwata, N. , Kawamura, J. , and Hattori, T. (2005). Thermal, electrical and optical studies on the poly (vinyl alcohol) based polymer electrolytes. J. Power Sources, 144, 262–267.
Obula Reddy, M. , and Chandra Babu, B. (2015). Structural, optical, electrical, and magnetic properties of PVA:Gd3+ and PVA:Ho3+ polymer film. Indian J. Mater. Sci., 927364, 1–8.
Sadhu, S.D. , Soni, A. , Garg, M. , and Varmani, S.G. (2014). Preparation of starch-poly vinyl alcohol (PVA) blend using potato and study of its mechanical properties. Int. J. Pharma Sci. Invention, 3, 33–37.
Ghoshal, S. , Denner, P. , and Stapf, C.S. (2012). Study of the formation of poly (vinyl alcohol) films. Macromolecule, 45, 1913–1923.
Ratner B.D. , Hoffman A.S. , Schoen F.J. , and Lemons J.E. (2004). Biomaterial Science: An Introduction to Materials in Medicine, 2nd Ed. Elsevier Academic Press.
Werber, A. , and Zappe, H. (2005). Tunable microfluidic microlenses. Appl. Opt., 44, 3238–3245.
Yen, D.A.C. , Eich, R.K. , and Gale, B.K. (2005). A monolithic PDMS waveguide system fabricated using soft-lithography techniques. J. Light wave Technol., 23, 2088–2093.
Wang, S. , Kallur, A. , and Goshu, A. (2011). Fabrication and characterization of PDMS thin film. Proc. of SPIE, 7935, 79350M, 1–6.
Bilent, S. , Hong, T. , Dinh, N. , Martincic, E. , and Joubert, P.Y. (2019). Influence of the porosity of polymer foams on the performances of capacitive flexible pressure sensors. Sensors, 1968, 1–12.

Lippert, B.S.T. , Graubner, V.M. , Kotz, U. , Nuyken, O. , and Wokaun, A. (2003). UV irradiation induced modification of PDMS films investigated by XPS and spectroscopic ellipsometry. Surf. Sci., 532–535, 1067–1071.
Trupke, T. , Green, M.A. , and Würfel, P. (2002). Improving solar cell efficiencies by downconversion of high-energy photons. J. Appl. Phys., 92, 1668–1674.
Badescu, V. , De Vos, A. , Badescu, A.M. , and Szymanska, A. (2007). Improved model for solar cells with down-conversion and down-shifting of high-energy photons. J. Phys D: Appl. Phys., 40, 341–352.
Pugliese, D. , Boetti, N.G. , Lousteau, J. , Ceci-Ginistrelli, E. , Bertone, E. , Geobaldo, F. , and Milanese, D. (2016). Concentration quenching in an Er-doped phosphate glass for compact optical lasers and amplifiers. J. Alloys Compd., 657, 678–683.
Dvoyrin, V.V. , Mashinsky, V.M. , Bulatov, L.I. , Bufetov, I.A. , Shubin, A.V. , Melkumov, M.A. , Kustov, E.F. , Dianov, E.M. , Umnikov, A.A. , Khopin, V.F. , Yashkov, M.V. , and Guryanov, A.N. (2006). Bismuth-doped-glass optical fibers - a new active medium for lasers and amplifiers. Opt. Lett., 31, 2966–2968.
Shaw, R. , and Uhlmann, D. (1973). Neodymium glass laser having room temperature output at wavelengths shorter than 1060 nm U.S. Patent US3717583 A.
Boulon, G. (2008). Why so deep research on Yb-doped optical inorganic materials? J. Alloys Compd., 451, 1–11.
Brenier, A. (2001). A new evaluation of Yb3+ -doped crystals for laser applications. J. Lumin., 92, 199–204.

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Chandra, B. P. (1998). Mechanoluminescence in Luminescence of Solids, 1st ed., Vij, O.-R. , Ed., Springer Science Business Media, LLC, New York, NY, USA, pp. 361–387, ISBN 978-1-4613-7446-6.
Harvey, K. N. (1957). Triboluminescence, Piezoluminescence, Crystalloluminescence and Lyoluminescence. In A History of Luminescence: From Earliest Times until 1900, 1st ed., Harvey, K.-N. , Ed., The American Philosophical Society, Philadelphia, PA, USA, pp. 378–379. 10.5962/bhl.title.14249
Bacon, F. (1901). The Advancement of Learning, 1st ed., Devey, J. , Ed., Press of P. F Collier & Son, New York, NY, USA, pp. 208–209. Fourth Book. https://oll.libertyfund.org/title/bacon-the-advancement-of-learning
Boyle, R. (1664). Experiments and Consideration Touching Colours (London). 413. eBook #14504.
Longchambon, H. (1922). Study of the spectrum of the light emitted in the triboluminescence of sugar. J. Franklin Inst., 195 (2), 269–270. 10.1016/S0016-0032(23)90249-8
Bhatnagar, S. S. , Mathur, K. G. , and Budhiraja, K. L. (1933). Untersuchungen ueber Tribolumi-neszenz. Z. Phys. Chem. A, 163, 8–16.
Inoue, T. , Kunitomi, M. , and Shibata, E. (1939). Triboluminescence. Hiroshima J. Sci., 9, 129–136.
Carriere, Z. (1964). Triboluminescence of rubbers. Cah Phys., 46, 63. (in French).
Hoff, M. C. , and Boord, C. E. (1950). Triboluminescence in cis-4-octane. J. Am. Chem. Soc., 72, 2770–2771. 10.1021/ja01162a511
Jenny, D. A. (1957). Triboluminescence in semiconductors. J. Appl. Phys., 28 (12), 1515. 10.1063/1.1722694
Tschugaeff, L. (1901). Ueber Triboluminiscenz. Eur. J. Inorg. Chem., 34, 1820–1825.
Trautz, M. (1910). Triboluminescence. Ion, 2, 77–89.
Gernez, D. (1905). Triboluminescence des composes metaliques. C. R. hebd. Seanc. Acad. Sci, 140, 1337–1339.
Wick, F. G. (1940). Triboluminescence of sugar. J. Opt. Soc. Am., 30 (7), 302–306. 10.1364/JOSA.30.000302
Jha, P. , and Chandra, B. P. (2014). Survey of the literature on mechanoluminescence from 1605 to 2013. Luminescence, 29, 977–993. 10.1002/bio.2647
Chandra, B. P. (2008). Mechanoluminescence induced by elastic deformation of coloured alkali halide crystals using pressure steps. J. Lumin., 128, 1217–1224. 10.1016/j.jlumin.2007.12.001
Chandra, B. P. , and Bisen, D. P. (1992). Electronic excitation during elastic deformation of γ-irradiated LiF single crystals. Phys. Status Solidi (A), 132(2), K101-K104. https://doi.org/10.1002/pssa.2211320237
Akiyama, M. , Xu, C. N. , Liu, Y. , Nonaka, K. , and Watanabe, T. (2002). Influence of Eu, Dy co-doped strontium aluminate composition on mechanoluminescence intensity. J. Lumin., 97, 13–18. 10.1016/S0022-2313(01)00419-7
Wang, X. , Xu, C. N. , Yamada, H. , Nishikubo, K. , and Zheng, X. G. (2005). Electro-mechano-optical conversions in Pr3+-doped BaTiO3-CaTiO3 ceramics. Adv. Mater., 17, 1254–1258. 10.1002/adma.200401406
Akiyama, M. , Nishikubo, K. , and Nonaka, K. (2003). Intense visible light emission from stress-activated SrMgAl6O11:Eu. Appl. Phys. Lett., 83, 650–652. 10.1063/1.1594828
Jia, Y. , Yei, M. , and Jia, W. (2006). Stress induced mechanoluminescence in SrAl2O4:Eu2+, Dy3+ . Opt. Mater., 28, 974–979. 10.1016/j.optmat.2005.05.014
Akiyama, M. , Xu, C. N. , Matsui, H. , and Nonaka, K. (1999). Recovery phenomenon of mechanoluminescence from Ca2Al2SiO7:Ce by irradiation with ultraviolet light. Appl. Phys. Lett., 75, 2548–2550. 10.1063/1.125073

Xu, C. N. (2002). Coatings. In: Encyclopedia of Smart Materials, 1, Schwartz, M. , Ed., John Wiley and Sons, Inc., pp. 190–201.
Xu, C. N. , Yamada, H. , Wang, X. , and Zheng, X. G. (2004). Strong elasticoluminescence from monoclinic-structure SrAl2O4 . Appl. Phys. Lett., 84, 3040–3042. 10.1063/1.1705716
Fu, X. , Yamada, H. , and Xu, C. N. (2009). Property of highly oriented SrAl2O4:Eu film on quartz glass substrates and its potential application in stress sensor. J. Electrochem. Soc., 156, J249–J253. 10.1149/1.3156652
Sohn, K. S. , Seo, S. Y. , Kwon, Y. N. , and Park, H. D. (2002). Direct observation of crack tip stress field using the mechanoluminescence of SrAl2O4:(Eu,Dy,Nd). J. Am. Ceram. Soc., 85, 712–714. 10.1111/j.1151-2916.2002.tb00158.x
Xu, C. N. , Watanabe, T. , Akiyama, M. , and Zheng, X. G. (1999). Artificial skin to sense mechanical stress by visible light emission. Appl. Phys. Lett., 74, 1236–1238. 10.1063/1.123510
Reynold, G. T. , and Ausin, R. H. (2001). Mechanoluminescence of plastic scintillation counters. J. Lumin., 92, 79–82. 10.1016/S0022-2313(00)00230-1
Chandra, B. P. (2010). Persistent mechanoluminescence induced by elastic deformation of ZrO2:Ti phosphors. J. Lumin., 130 (11), 2218–2222. 10.1016/j.jlumin.2010.06.023
Chandra, B. P. , Goutam, R. K. , Chandra, V. K. , Raghuwanshi, D. S. , Luka, A. K. , and Baghel, R. N. (2010). Mechanoluminescence induced by elastic and plastic deformation of coloured alkali halide crystals at fixed strain rates. Radiat. Eff. Defects Solids, 165, 907–919. 10.1080/10420150.2010.487903
Xu, C. N. , Watanabe, T. , Akiyama, M. , and Zheng, X. G. (1999). Direct view of stress distribution in solid by mechanoluminescence. Appl. Phys. Lett., 74, 2414–2416. 10.1063/1.123865
Gerlach, R. L. , Houston, J. E. , and Park, R. L. (1970). Ionization spectroscopy of surfaces. Appl. Phys. Lett., 16, 179. 10.1063/1.1653152
Kim J. S. , Kibble K. , Kwon Y. N. , and Sohn K. S. (2009). Rate-equation model for the loading-rate-dependent mechanoluminescence of SrAl2O4:Eu2+, Dy3+ . Opt. Lett., 34, 1915–1917. 10.1364/OL.34.001915
Jha, P. , and Chandra, B. P. (2014). Survey of literature on mechanoluminescence from 1605 to 2013. Luminescence, 29 (8), 977–993. 10.1002/bio.2647
Wenbo, W. , Yukun, D. , and Bin, L. (2020). Mechanoluminescence: Quantitative pressure-brightness relationship enables new applications. Matter, 2, 291–296. 10.1016/j.matt.2020.01.007
Wiedemann, E. , and Schmidt, G. C. (1895). Ann. Phys. Leipzig, 56, 210.
Ahnstrom, G. , and Ehrenstein, G. V. (1959). Luminescence of aqueous solutions of substances irradiated with ionizing radiationin the solid state. Acta Chem. Scand., 13, 855–856. 10.3891/acta.chem.scand.13-0855
Ahnstrom, G. , and Ehrenberg, L. (1960). Dosimetry of mixed neutron-gamma radiations in the Stockholm reactor. RISO Rep., 16, 15.
Ahnstrom, G. (1965). Physical and chemical processes accompanying the dissolution of irradiated substances studies by means of luminescence measurements. Acta Chem. Scand., 19 (300–312), 1965. 10.3891/acta.chem.scand.19-0300
Lelievre, B. , and Adloff, J. P. (1964). Étude de la luminescence accompagnant la dissolution du chlorure de sodium irradié par le rayonnement γ du cobalt 60. J. Phys., 25 (8–9), 789–796. 10.1051/jphys:01964002508-9078900ff.jpa-00205871
Reynolds, G. T. (1992). Lyoluminescence. J. Lumin., 54, 43–69. 10.1016/0022-2313(92)90048-E
Burns, W. , and Williams, T. (1955). Chemical effects associated with ‘Colour Centres’ in alkali halides. Nature, 175, 1043–1044. 10.1038/1751043a0
Mittal, J. P. (1970). Proc. Symp. on Radiat. Chem. Trombay, BARC. Bombay; Rept. BARC-489, 40.
Atari, N. A. (1980). Lyoluminescence mechanism of gamma and additively coloured alkali halides in pure water. J. Lumin., 21 (3), 305–316. 10.1016/0022-2313(80)90009-5
Atari, N. A. , Ettinger, K. V. , and Fremlin, J. H. (1973). Lyoluminescence as a possible basis of radiation dosimetry. Radiat. Eff., 17, 45–48. 10.1080/00337577308232596
Bartlett, D. T. (1973). A comparison of responses to irradiation by photons, electrons, protons and neutrons of some lyoluminescent materials. M.Sc. Thesis, University of Birmingham, U.K.
Bartlett, D. T. , Brown, J. K. , and Durrani, S. A. (1982). Lyoluminescence and electron spin measurements on D-mannose. Effect of storage time and annealing. Radiat. Effects, 66, 233. 10.1080/00337578208222483
Burkill, J. A. (1977). A study of high sensitivity dosimetry with lyoluminescence materials. M Sc. Thesis, University of Aberdeen, U. K.
Takavar, A. , Ettinger, K. V. , Mallard, J. R. , Atari, N. A. , and Srirath, S. (1977) Progress in lyoluminescence dosimetry using saccharides. In Proc. 5th In:. Conf on Luminescence dosimetry Isot. 33, 1139. Dosimetry, Sao Paulo, pp. 169.
Hanig, R. E. (1984). Enhancement of lyoluminescence by radiation sensitization and chemical dopants. Int. J. Appl. Radiat. Isot., 35 (10), 987–989. 10.1016/0020-708X(84)90220-5
Chatterjee, B. K. , Sur, T. , and Roy, S. C. (1993). Theory of light emission from γ-ray-irradiated organic substances when dissolved. Phys. Rev. B, 47, 555. (R) 10.1103/PhysRevB.47.555
Ettinger, K. V. , and Puite, K. J. (1982). Lyoluminescence dosimetry Part I. Principle. Int. J. Appl. Radiat. Isot., 33, 1115–1138. 10.1016/0020-708X(82)90239-3

Puite, K. J. , and Ettinger, K. V. (1982). Lyoluminescence dosimetry Part II. State- of- the-Art. Int. J. Appl. Radiat. Isot., 33, 1139–1157. 10.1016/0020-708X(82)90240-X
Russel, G. A. (1957). Deuterium isotope effects in the autoxidation of aralkyl hydrocarbons. Mechanism of the interaction of peroxy radicals. J. Am. Chem. Soc., 79, 3871–3877. 10.1021/ja01571a068
Vassil'ev, R. F. (1967). Chemiluminescence in liquid phase reactions. Prog. React. Kinet., 4, 305–352.
Kundu, H. K. (1992). In: Murthy, K. V. R. , Prasad, L. H. H. , Joshi, T. R. , Eds., Thermoluminescence and its Applications, Tata McGraw Hill, New Delhi, p. 3X. ISBN:0074622757.
Kundu, H. , and Mitra, B. (1984). A study of self-quenching of lyoluminescence yield from gamma-irradiated saccharides and amino acides. Radiat. Effects Lett., 85, 123.
Kundu, H. K. , Banerjee, D. , and Mitra, B. (1992). Mass-effect in the lyoluminescence yield from the tissue-equivalent dosimetric materials. Ind. J. Pure Appl. Phys., 30, 340.
Arnikar, H. J. , Rao, B. S. M. , Gijare, M. A. , and Sardesai, S. S. (1975). Variation of aquoluminescence during the decay and regeneration of thermoluminescence under F-light. J. Chim. Phys. (Paris), 72, 654–658. 10.1051/jcp/1975720654
Copty Wergles, K. , Nowotny, R. , and Hille, P. (1990). Lyoluminescence of calcium carbonate and possible applications in the dating of loess and soils. Rad. Prot. Dos., 34, 79–82. 10.1093/oxfordjournals.rpd.a080852
Kulmala, S. M. , and Haapaka (1994). Terbium (III) lyoluminescence induced by the dissolution of UV-irradiated potassium paroxodisulfate in aqueous solutions. Ann. Chem. Acta, 294, 1325SSDI 0003-2670(94)00106-V.
Matachescu, C. , Kulama, S. , Loine, E. , and Racrinne, P. (1997). Luminol-specific extrinsic lyoluminescence of X-ray irradiated sodium chloride. Anal. Chem. Acta, 349, 1–10. 10.1016/S0003-2670(97)00233-X
Vickery, J. C. , Olmstead, M. M. , Fung, E. Y. , and Balch, A. L. (1997). Solventstimulated luminescence from the supramolecular aggregation of a trinuclear gold(I) complex that displays extensive intermolecular AuċAu interactions. Angew. Chem. Int. Ed. Engl., 36, 1179–1181. 10.1002/anie.199711791
Chattopadhyay, A. K. , Mahapatra, G. S. , and Chaudhury, P. (2000). Lyoluminescence: A theoretical approach. Phys. Rev. B, 62, 906–908. 10.1103/PhysRevB.62.906
Raman, A. , Oommen, I. K. , and Sharma, D. N. (2001). Lyoluminescence characteristics of trehalose dihydrate. Appl. Radiat. Isot., 54 (3), 387–391.
Dhoble, S. J. (2002). Preparation of (K: Eu) NaSO4 phosphor for lyoluminescence dosimetry of ionising radiation. Radiat. Prot. Dosim., 100 (1-4), 285–287.
Gour, A. S. , Choudhary, V. , Chourasia, B. , and Chandra, B. P. (2004). Proc. Int. Conf. Lumin. Appl., 2004, 377–379.
Banerjee, M. , Mehta, M. , Gulahre, V. , Kher, R. S. , and Khokhar, M. S. K. (2005). Lyoluminescence of gamma-irradiated sodium bromide samples. Proc. Natl. Conf. Lumin. Appl., 2005, 430–431.
Håkansson, M. , Jiang, Q. , Spehar, A. M. , Suomi, J. , and Kulmala, S. (2006). Extrinsic lyoluminescence of aluminum induced by lanthanide chelates in alkaline aqueous solution. J. Lumin., 118 (2), 272–282. 10.1016/j.jlumin.2005.09.012
Upadhyay, A. , Dhoble, S. J. , Rai, R. , and Kher, R. S. (2008). Synthesis of KNaSO4:Tb3+ and MgSO4:Dy3+ phosphors for lyoluminescence dosimetry. Nucl. Instrum. Methods Phys. Res. B, 266, 2594–2598. 10.1016/j.nimb.2008.03.236
Kher, R. S. , Upadhyay, A. K. , Dhoble, S. J. , and Khokhar, M. S. K. (2008). Luminescence studies of MgSO4:Dy phosphors. Indian J. Pure Appl. Phys., 46 (9), 607–610.
Sahare, P. D. , and Saran, M. (2016). Effect of pH on Lyoluminescence of K3Na(SO4)2:Eu3+ phosphor for its application in dosimetry of high energy radiations. J. Lumin., 179, 254–259. 10.1016/j.jlumin.2016.06.040
Sahu, V. , Brahme, M. , Bisen, D. P. , and Sharma, R. (2009). Effect of lyoluminescence decay in impurity doped KCl microcrystalline powder in lyoluminescence dosimetry of ionization radiations. J. Optoelectron. Biomed. Mater., 1 (3), 297–302.
Nayar, V. , Chowdhary, P. S. , Bhujbal, P. M. , and Dhoble, S. J. (2011). Studies on the mass and temperature dependence of lyoluminescence intensity of microcrystalline powder of KCl. Luminescence, 26 (5), 324–330. 10.1002/bio1232
Puppalwar, S. P. , Dhoble, S. J. , and Kumar, A. (2011). Rare earth Ce3+, Dy3+ activated Li2BPO5 phosphors for lyoluminescence dosimetry. Indian J. Pure Appl. Phys., 49 (4), 239–244, http://nopr.niscair.res.in/handle/123456789/11320.
Mishra, G. C. , Upadhyay, A. K. , Kher, R. S. , and Dhoble, S. J. (2011). Thermoluminescence and lyoluminescence in γ-ray irradiated and Ce3+-doped YCa4O(BO3)3 phosphors. J. Mater. Sci., 46, 7275–7278. 10.1007/s10853-011-5687-1
Mishra, G. C. , Dhoble, S. J. , Srivastava, A. , Dwivedi, S. , and Kher, R. S. (2018). Study of lyoluminescence of gamma irradiated GdCa4O(BO3)3:Ce phosphors: Mass of solute and pH of solvent as a key factor. Optik, 158, 826–830. 10.1016/j.ijleo.2017.12.189
Timilsina, S. , Kim, J. S. , Kim, J. , *et al.* (2016). Review of state-of-the-art sensor applications using mechanoluminescence microparticles. Int. J. Precis. Eng. Manuf., 17, 1237–1247. 10.1007/s12541-016-0149-y
Camara, C. G. , Escobar, J. V. , Hird, J. R. , and Putterman, S. J. (2008). Correlation between nanosecond X-ray flashes and stick–slip friction in peeling tape. Nature, 455 (7216), 1089–1092. 10.1038/nature07378

Jia Y. , Yei M. , and Jia W. (2006). Stress-induced mechanoluminescence in SrAl2O4:Eu2+, Dy3+ . Opt. Mater., 28, 974–979. 10.1016/j.optmat.2005.05.014
Xu, C. N. , Li, C. , Imai, Y. , Yamada, H. , Adachi, Y. , and Nishikubo, K. (2006). Development of elastico-luminescent nanoparticles and their applications. Adv. Sci. Technol., 45, 939–944. 10.4028/www.scientific.net/AST.45.939
Chandra, B. P. , and Rathore, A. S. (1995). Classification of mechanoluminescence. Crystal Res. Technol., 30, 885–896. 10.1002/crat.2170300702
Chandra, B. P. , Chandra, V. K. , and Jha, P. (2013). Models for intrinsic and extrinsic fracto-mechanoluminescence of solids. J. Lumin., 135, 139–153. 10.1016/j.jlumin.2012.10.009
Chandra, B. P. , Chandra, V. K. , Jha, P. , Patel, R. , Shende, S. K. , Thaker, S. , and Baghel, R. N. (2012). Fracto-mechanoluminescence and mechanics of fracture of solids. J. Lumin., 132, 2012–2022. 10.1016/j.jlumin.2012.03.001
Moon, S. J. , Song, S. , Lee, S. K. , and Choi, B. (2013). Mechanically driven light-generator with high durability. Appl. Phys. Lett., 102, 051110-1-5. 10.1063/1.4791689
Jha, P. , Khare, A. , Singh, P. K. , Chandra, V. K. , and Sonwane, V. D. (2018). Ball impact induced elastico-mechanoluminescence for impact sensor. J. Lumin, 195, 40–43. 10.1016/j.jlumin.2017.10.063
Meyer, K. , Obrikat, D. , and Rossberg, M. (1970a). Progress in triboluminescence of alkali halides and doped zinc sulphides (II). Kristall u. Technik, 5 (1970a), 181–205. 10.1002/crat.19700050202
Keszthelyi, C. P. , and Bard, A. J. (1973). Triboluminescence and triboelectrification by the motion of mercury over glass coated with scintillator dyes. J. Electrochem. Soc., 120 (1973), 1726–1729. 10.1149/1.2403353
De Paoli, S. , and Strausz, O. P. (1970). Gaseous reactions and luminescence initiated by triboelectricity. Can. J. Chem., 48, 3756–3757. 10.1139/v70-630
Chapman, G. N. , and Walton, A. J. (1983). Triboluminescence of glasses and quantz. J. Appl. Phys., 54, 5961–5965. 10.1063/1.331773
Chandra, B. P. (1985). Squeezing light out of crystals: Triboluminescence. Nucl. Tracks Radiat. Meas., 10 (1-2), 225241. 10.1016/0735-245X(85)90028-6
Chandra, B. P. , and Zink, J. I. (1980). Triboluminescence and the dynamics of crystal fracture. Phys. Rev. B, 21 (2), 816–826. 10.1103/PhysRevB.21.816
Chandra, B. P. , and Zink, J. I. (1980). Mechanical characteristics and mechanism of triboluminescence of fluorescent molecular crystals. J. Chem. Phys., 73, 5933–5941. 10.1063/1.440151
Chandra, B. P. (1983). Mechanoluminescence and high pressure photoluminescence of (Zn, Cd)S phosphors. Pramana, 19, 455–465. https://www.ias.ac.in/article/fulltext/pram/019/05/0455-0465.
Kobakhidze, L. , Guidry, C. J. , Hollerman, W. A. , and Fontenot, R. S. (2013). Detecting mechanoluminescence from ZnS: Mn powder using a high speed camera. IEEE Sensors J., 13 (8), 3053–3059. 10.1109/JSEN.2013.2261489
Belyaev, L. M. , and Martyshev, Yu. N. (1969). Triboluminescence of some alkali halide crystals. Phys. Status Solidi, 34 a (1), 57–62. 10.1002/pssb.19690340105
Rai, R. K. , Kher, R. S. , Khan, S. A. , Dhoble, S. J. , and Upadhyay, A. K. (2012). Device for mechanoluminescence excitation by applying gradually varying pressure on the sample. Indian J. Pure Appl. Phys., 50, 534–537.
Xu, C. N. , Akiyama, M. , Nonaka, K. , and Watanabe, T. (1998). Electrical power generation characteristics of PZT piezoelectric ceramics. IEEE Trans. Ultrason. Ferroelect. Freq. Control, 45, 1065–1070. 10.1109/58.710589
Fontenot, R. S. , Hollerman, W. A. , Aggarwal, M. D. , Bhat, K. N. , and Goedeke, S. M. (2012). A versatile low-cost laboratory apparatus for testing triboluminescent materials. Measurement, 45, 431–436. 10.1016/j.measurement.2011.10.031
Sakai, K. , Koga, T. , Imai, Y. , Maehara, S. , and Xu, C. N. (2006). Observation of mechanically induced luminescence from microparticles. Phys. Chem. Chem. Phys., 8, 2819–2822. 10.1039/B604656H
Kamimura, S. , Yamada, H. , and Xu, C. N. (2012). Development of new elasticoluminescent material SrMg2(PO4)2:Eu. J. Lumin., 132, 526–530. 10.1016/j.jlumin.2011.09.033
Shohag, M. A. S. , Tran, S. A. , Ndebele, T. , Adhikari, N. , and Okoli, O. I. (2018). Designing and implementation of triboluminescent materials for real-time load monitoring. Mater. Des., 153, 86–93. 10.1016/j.matdes.2018.05.006
Persits, N. , Aharoni, A. , and Tur, M. (2017). Quantitative characterization of ZnS:Mn embedded polyurethane optical emission in three mechanoluminescent regimes. J. Lumin., 181, 467–476. 10.1016/j.jlumin.2016.09.015
Peng, D. F. , Chen, B. , and Wang, F. (2015). Recent advances in doped mechanoluminescent phosphors. Chem. Plus Chem., 80, 1209–1215. 10.1002/cplu.201500185
Jeong, S. M. , Song, S. , Lee, S. K. , and Ha, N. Y. (2013). Color manipulation of mechanoluminescence from stress-activated composite films. Adv. Mater., 25, 6194–6200. 10.1002/adma.201301679
Shin, S. W. , Oh, J. P. , Chang, W. H. , Kim, E. M. , Woo, J. J. , Heo, G. S. , and Jin, H. K. (2016). Origin of mechanoluminescence from Cu-doped ZnS particles embedded in an elastomer film and its application in flexible electro-mechanoluminescent lighting devices. ACS Appl. Mater. Interfaces, 8, 1098–1103. 10.1021/acsami.5b07594

Chen, L. , Wong, M. C. , Bai, G. X. , Jie, W. J. , and Hao, J. H. (2015). White and green light emissions of flexible polymer composites under electric field and multiple strains. Nano Energy, 14 (2015), 372–381. 10.1016/j.nanoen.2014.11.039

Molotskii, M. I. (1989). Sov. Sci. Rev. B: Chem., 13, l.

Brady, B. T. , and Rowell, G. A. (1986). Laboratory investigation of the electrodynamics of rock fracture. Nature, 321, 488–492. 10.1038/321488a0

Glass, C. (1977). A Light Activated Fuse System, BRL MR 2726 (US Army Report).

Glass, C. , Dante, J. , CjaIella, C. , and Golaski, S. (1975). An Electro-Optical Fuse System, BRL MR 2552 (US Army Report).

Orel, V. E. , Opov, Va. Z. , Goraiskii, E. K. , Leshchinskii, I. V. , and Khazanovish, D. M. (1989). The TRA-2 triboluminometer, a rapid analyzer of lipid peroxidation of the blood. Meditsinskaia tekhnika, 4, 34-37.

Dickinson, J. T. , and Donaldson, E. E. (1987). Autographs from peeling pressure sensitive adhesives: Direct recording of fracture-induced photon emission. J. Adhes., 24 (2-4), 199–220. 10.1080/00218468708075427

Terasaki, N. , Xu, C. N. , Imai, Y. , and Yamada, H. (2007). Photocell system driven by mechanoluminescence. Jpn. J. Appl. Phys., 46, 2385–2388. 10.1143/JJAP.46.2385

Terasaki, N. , Zhang, H. , Imai, Y. , Yamada, H. , and Xu, C. N. (2009). Hybrid material consisting of mechanoluminescent material and TiO2 photocatalyst. Thin Solid Films, 518, 473–476. 10.1016/j.tsf.2009.07.026

Terasaki, N. , Yamada, H. , and Xu, C. N. (2011). Mechanoluminescent light source for a fluorescent probe molecule. Chem. Commun., 47, 8034–8036. 10.1039/C1CC11411E

Terasaki, N. , Yamada, H. , and Xu, C. N. (2013). Ultrasonic wave induced mechanoluminescence and its application for photocatalysis as ubiquitous light source. Catal. Today, 201, 203–208. 10.1016/j.cattod.2012.04.040

Chandra, B. P. (2011). Development of mechanoluminescence technique for impact studies. J. Lumin., 131, 1203–1210. 10.1016/j.jlumin.2011.02.027

Wang, W. X. , Imai, Y. , Xu, C. N. , Matsubara, T. , and Takao, Y. (2011). A new smart damage sensor using mechanoluminescence material. Mater. Sci. Forum, 675– 677, 1081–1084. 10.4028/www.scientific.net/MSF.675-677.1081

Sohn, K. S. , Seo, S. Y. , Kwon, Y. N. , and Park, H. D. (2002). Direct observation of crack tip stress field using the mechanoluminescence of SrAl2O4:(Eu, Dy, Nd). Am. Ceram. Soc., 85 (3), 712–714. 10.1111/j.1151-2916.2002.tb00158.x

Zhang, H. , Xu, C. N. , Terasaki, N. , and Yamada, H. (2010). Detection of stress distribution using Ca2MgSi2O7:Eu,Dy microparticles. Physica E, 42, 2872–2875. 10.1016/j.physe.2010.02.013

Hyodo, K. , Xu, C. , Mishima, H. , and Miyakawa, S. (2010). In: C. T. Lin , J. C. H. Goh (Eds.), Proceedings of the sixth World Congress of Biomechanics (WCB 2010), August 1–6, 2010, Singapore, IFMBE, vol. 31, Part 2, pp. 545–548.

Xu, C. N. (2010). Monitoring system for safety management of structures using elastico-luminescent materials. AIST Today, 10 (7), 18.

Freund, F. (2003). Rocks that crackle and sparkle and glow: Strange pre-earthquake phenomena. J. Sci. Explor., 17 (1), 37–71. http://www.isfep.com/FF_EQ_SSE_2003.pdf.

Freund, F. (2002). Charge generation and propagation in igneous rocks. J. Geodyn., 33, 543–570. 10.1016/S0264-3707(02)00015-7

Takeuchi, A. , Lau, B. W. S. , and Freund, F. T. (2006). Current and surface potential induced by stress activated positive holes in igneous rocks. Phys. Chem. Earth, 31, 240–247. 10.1016/j.pce.2006.02.022

Patel, D. K. , Bat-El, C. , Etgar, L. , and Magdassi, S. (2018). Fully 2D and 3D printed anisotropic mechanoluminescent objects and their application for energy harvesting in the dark. Mater. Horiz., 5 (4), 708–714. 10.1039/c8mh00296g

Xu, H. , Wang, F. , Wang, Z. F. , Zhou, H. , Zhang, G. , Zhang, J. , Wang, J. , and Yang, S. (2019). Intelligent solid lubricant materials with failure early-warning based on triboluminescence. Tribol. Lett., 67, 13. 10.1007/s11249-018-1120-0

Sahu, M. K. (2013). Theoretical approach to the laser-stimulated luminescence in II-VI semiconductor. J. Pure Appl. Indus. Phys., 3 (1), 1–67.

Quickenden, T. I. , Selby, B. J. , and Freeman, C. G. (1998). Ice triboluminescence. J. Phys. Chem. A, 102 (34), 6713–6715. 10.1021/jp981657y

Jeong, S. M. , Song, S. , Joo, K. I. , Kim, J. , Hwang, S. H. , Jeong, J. , and Kim, H. (2014). Bright, wind driven white mechanoluminescence from zinc sulphide microparticles embedded in a polydimethylsiloxane elastomer. Energy Environ. Sci., 7, 3338–3346. 10.1039/c4ee01776e

Cheng, J. , Ding, W. B. , Zi, Y. , Lu, Y. , Ji, L. , Liu, F. , Wu, C. , and Wang, Z. L. (2018). Triboelectric microplasma powered by mechanical stimuli. Nat. Commun., 9, 11. 10.1038/s41467-018-06198 -x

Wang, X. D. , Zhang, H. L. , Yu, R. M. , Dong, L. , Peng, D. F. , Zhang, A. , Zhang, Y. , Liu, H. , Pan, C. , and Wang, Z. L. (2015). Dynamic pressure mapping of personalized handwriting by a flexible sensor matrix based on the mechanoluminescence process. Adv. Mater., 27 (14), 2324–2331. 10.1002/adma.201405826

Chen, C. , Zhuang, Y. , Tu, D. , Wang, X. , Pan, C. , and Xie, R. J. (2020). Creating visible-to-near-infrared mechanoluminescence in mixed-anion compounds SrZn2S2O and SrZnSO. Nano Energy, 68, 104329. 10.1016/j.nanoen.2019.104329
Satapathy, K. , and Mishra, G. (2013). Dose dependence of Mechanoluminescence properties in MgAl2O4: Dy phosphor. J. Chem., 2013, Article ID 930818, 4. 10.1155/2013/930818
Atari, N. A. , and Ettinger, K. V. (1974). Lyoluminescent tissue equivalent radiation dosimeter. Nature, 247 (1974), 193–194. 10.1038/247193a0
Takavar, A. , Ettinger, K. V. , Mallard, J. R. , Atari, N. A. , and Srirath, S. (1977). In Proc. 5th Int. Cant on Luminescence Dosimetry Sag Paulo, 1977 (Ed. Scharmann A.) pp. 169–174 (Phys. Inst. Giessen, BRD, 1978).
Becker K. (1973). Solid State Dosimetry, CRC Press, Cleveland, 1973 ISBN: 0878190465 9780878190461.
McKeever S. W. S. (1985). Thermoluminescence of Solids, Cambridge University Press, Cambridge. Online ISBN: 9780511564994 10.1017/CBO9780511564994
Sonder, E. , and Sibley, W. A. (1965). Influence of lead impurity on the low temperature color centre production in KCl. Phys. Rev., 140, A539–A546. 10.1103/PhysRev.140.A539
Alvarez-Rivas, J. L. (1980). PLENARY SESSION Thermoluminescence and lattice defects in alkali halides. Journal de Physique Colloques (J. Phys.), 41 (C6), C6-353–C6-358. 10.1051/jphyscol:1980691
Ramani, R. (1984). Effect of inorganic metal ion impurities on lyoluminescence. Radiat. Eff. Lett., 86, 47–56. 10.1080/01422448408205213
Kalkar, C. D. (1984). Aqualuminescence from γ-irradiated NaCl in the presence of metal ions. J. Radioanal. Nucl. Chem. Lett., 86, 65–78. 10.1007/BF02164902
Chandra, B. P. , Tiwari, R. K. , Mor, R. , and Bisen, D. P. (1997). Theoretical approach to the lyoluminescence of alkali halides. J. Lumin., 75 (2), 127–133. 10.1016/S0022-2313(97)00108-7
Galand, E. , Pagnoulle, C. , Niezette, J. , Vanderschueren, J. , and Garsou, J. (1997). Lyoluminescence of inorganic salts. J. Lumin., 75, 27–33. 10.1016/S0022-2313(97)00100-2
Hunter, C. , Temperton, D. H. , Ettinger, K. V. , and Forrester, A. R. (1982). Lyoluminescence spectra of typical dosimeter materials. Int. J. Appl. Radiat. Isot., 33 (11), 1291–1297. 10.1016/0020-708X(82)90249-6
Shindl, A. , Shindy, A. B. , Al-Hashimi , Ali, H. M. , AlThaher, S. , and Ghania, T. (2004). Tissue equivalent personal X-ray dosimeter. Bas. J. Surg., 10, 2004, https://www.researchgate.net/publication/315099990.
Ettinger, K. V. (1989). Free radical dosimetry techniques and their suitability for precise and accurate measurements of radiation. Appl. Radiat. Hot., 40, 865–870. 10.1016/0883-2889(89)90008-7
Ettinger K. V. , Forrester A. R. , and Mallard J. R. (1980). Proc. Int. Symp. Bio-Medical Dosimetry Paris, IAEA, Vienna, 533-551. ISBN 92-0-010281-6.
Sailaja, S. , Dhoble, S. J. , Brahme, N. , and Reddy, B. S. (2011). Synthesis, photoluminescence and mechanoluminescence properties of Eu3+ ions activated Ca2Gd2W3O14 phosphors. J. Mater. Sci., 46, 7793–7798. 10.1007/s10853-011-5759-2
Zhang, J. C. , Wan, Y. , Xin, X. , Han, W. P. , Zhang, H. D. , Sun, B. , Long, Y. Z. , and Wang, X. (2014). Elastico-mechanoluminescent enhancement with Gd3+ codoping in diphase (Ba, Ca)TiO3:Pr3+ . Opt. Mater. Express, 4 (11), 2300–2309. 10.1364/OME.4.002300
Hollerman, W. A. , Fontenot, R. S. , Bhat, K. N. , Aggarwal, M. D. , Guidry, C. J. , and Nguyen, K. M. (2012). Comparison of triboluminescent emission yields for 27 luminescent materials. Opt. Mater., 34 (9), 1517–1521. 10.1016/j.optmat.2012.03.011
Ronfard-Haret, J. C. , Valat, P. , Wintgens, V. , and Kossanyi, J. (2000). Triboluminescence of trivalent rare earth ions inserted in polycrystalline zinc oxide. J. Lumin., 91, 71–77. 10.1016/S0022-2313(00)00204-0
Chandra, B. P. , Chandra, V. K. , and Jha, P. (2015). Mechanoluminescence of coloured alkali halide crystals. Defect Diffus. Forum, 361, 121–176. 10.4028/www.scientific.net/DDF.361.121
Chen, C. , Zhuang, Y. , Tu, D. , Wang, X. , Pan, C. , and Xie, R. J. (2020). Creating visible-to-near-infrared mechanoluminescence in mixed-anion compounds SrZn2S2O and SrZnSO. Nano Energy, 68, 104329. 10.1016/j.nanoen.2019.104329
Jha, P. , Khare, A. , Singh, P. , and Chandra, V. K. (2020). Fracto-mechanoluminescence of ZrO2:Ti nanophosphor excited by impulsive excitation. Opt. Mater., 99, 109477. 10.1016/j.optmat.2019.109477
Zhang, H. W. , Terasaki, N. , Yamada, H. , and Xu, C. N. (2009). Mechanoluminescence of europium-doped SrAMgSi2O7(A=Ca, Sr, Ba). Jpn. J. Appl. Phys., 48, 04C109-1-4 10.1143/JJAP.48.04C109
Zhang, H. W. , Yamada, H. , Terasaki, N. , and Xu, C. N. (2007). Stress-induced mechanoluminescence in SrCaMgSi2O7:Eu. Electrochem. Solid State Lett., 10, J129–J131. 10.1149/1.2762205
Zhang, H. W. , Yamada, H. , Terasaki, N. , and Xu, C. N. (2008). Green mechanoluminescence of Ca2MgSi2O7:Eu and Ca2MgSi2O7:Eu,Dy. J. Electrochem. Soc., 155, J55–J57. 10.1149/1.2816215
Sun, H. , Wu, C. , Dai, K. , Chang, J. , and Tang, T. (2006). Proliferation and osteoblastic differentiation of human bone marrow-derived stromal cells on akermanite-bioactive ceramics. Biomaterials, 27, 5651–5657. 10.1016/j.biomaterials.2006.07.027
Akiyama M. , Xu C. N. , Nonaka K. , and Watanabe T. (1998). Intense visible light emission from Sr3Al2O6:Eu, Dy. Appl. Phys. Lett., 73, 3046–3048. 10.1063/1.1494463
Xu, C. N. , Watanabe, T. , Akiyama, M. , and Zheng, X. G. (1999). Direct view of stress distribution in solid by mechanoluminescence. Appl. Phys. Lett., 74 (17), 2414–2416. 10.1063/1.123865

Zhang, H. W. , Yamada, H. , Terasaki, N. , and Xu, C. N. (2007). Ultraviolet mechanoluminescence from SrAl2O4:Ce and SrAl2O4:Ce,Ho. Appl. Phys. Lett., 91, 0819051-3. 10.1063/1.2772768

Jia, D. (2006). Relocalization of Ce3+ 5d electrons from host conduction band. J. Lumin., 117, 170–178. 10.1016/j.jlumin.2005.05.008

Terasawa, Y. , Xu, C. N. , Yamada, H. , and Kubo, M. (2011). Near infra-red mechanoluminescence from strontium aluminate doped with rare-earth ions. IOP Conf. Ser.: Mater. Sci. Eng., 18, 2120131-4. 10.1088/1757-899X/18/21/212013

Jha P. , and Chandra B. P. (2017). Mechanoluminescence of SrAl2O4:Eu,Dy nanophosphors induced by low impact velocity. Luminescence. 32, 171–176. 10.1002/bio.3162

Metz, F. I. , Schweiger, R. N. , Leidler, H. R. , and Girifalco, L. A. (1957). Stress activated luminescence in X-irradiated alkali halide crystals. J. Phys. Chem. B, 61 (1), 86–89. 10.1021/j150547a016

Molotskii, M. I. , and Shmurak, S. Z. (1992). Elementary acts of deformation luminescence. Phys. Lett. A, 166 (1992), 286. 10.1016/0375-9601(92)90378-Y

Kher, R. S. , Pandey, R. K. , Dhoble, S. J. , and Khokhar, M. S. K. (2002). Mechano and thermoluminescence of Gamma irradiated CaSO4:Dy phosphor. Radiat. Prot. Dosim., 100 (1-4), 281–284. 10.1093/oxfordjournals.rpd.a005868

Brahme, N. , Bisen, D. P. , Kher, R. S. , and Khokhar, M. S. K. (2009). Mechanoluminescence and thermoluminescence in γ-irradiated rare earth doped CaF2 crystals. Phys. Procedia, 2, 431–440. 10.1016/j.phpro.2009.07.028

Feng, A. , and Smet, P. F. (2018). A review of mechanoluminescence in solids: Compounds, mechanism and applications. Materials, 11, 484. 10.3390/ma11040484

Becker, P. (1998). Borate materials in nonlinear optics. Adv. Mater., 10, 979–992. 10.1002/(SICI)1521-4095(199809)10:13<979::AID-ADMA979>3.0.CO;2-N

Cavalcante, L. S. , Sczancoski, J. C. , Albarici, V. C. , Matos, J. M. E. , Varela, J. A. , and Longo, E. (2008). Synthesis, characterization, structural refinement and optical absorption behaviour of PbWO4 powders. Mater. Sci. Eng., 150, 18. 10.1016/j.mseb.2008.02.003

Liu, J. , Wang, X. D. , Wu, Z. C. , and Kuang, S. P. (2011). Preparation, characterization and photoluminescencs properties of BaB2O4:Eu3+ red phosphor. Spectrochim. Acta Part A, 79(2011), 1520. 10.1016/j.saa.2011.05.009.

Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2013). Synthesis and Photoluminescence study of Ca3B2O6:Pb2+ . AIP Conf. Proc., 1536, 601–602. 10.1063/1.4810370

Vecht, A. , Newport, A. C. , Bayley, P. A. , and Crossland, W. A. (1998). Narrow band 390 nm emitting phosphors for photoluminescent liquid crystal displays. J. Appl. Phys., 84, 3827–3829. 10.1063/1.368561

Sonekar, R. P. , Omanwar, S. K. , Moharil, S. V. , Dhopte, S. M. , Muthal, P. L. , and Kondawar, V. K. (2007). Combustion synthesis of narrow UV emitting rare earth borate phosphors. Opt. Mater., 30 (4), 622–625. 10.1016/j.optmat.2007.02.016

Thakre, D. S. , Omanwar, S. K. , Muthal, P. L. , Dhopte, S. M. , Kondawar, V. K. , and Moharil, S. V. (2004). UV-emitting phosphors: Synthesis, photoluminescence and applications. Phys. Status Solidi, 201 (3), 574–581. 10.1002/pssa.200306720

Ropp R. C. (2004). Luminescence and the Solid State, 2nd ed., Elsevier, Amsterdam, Volume 21, eBook ISBN: 9780080473239.

Zheng, Y. , Qu, Y. , Tian, Y. , Rong, C. , Wang, Z. , Li, S. , Chen, X. , and Ma, Y. (2009). Effect of Eu3+-doped on the luminescence properties of zinc borate nanoparticles. Colloid Surf. A: Physicohem. Eng. Asp., 349 (19), 10.1016/j.colsurfa.2009.07.039

Nagpure, P. A. , and Omanwar, S. K. (2012). Synthesis and luminescence characteristics of terbium (III) activated NaSrBO3 . J. Rare Earth, 30 (9), 856–859. 10.1016/S1002-0721(12)60145-8

Chikte (Awade) D. , Omanwar S. K. , and Moharil S. V. (2013). Luminescence properties of red phosphor NaSrBO3:Eu3+prepared with novel combustion synthesis method. J. Lumin., 142(2013), 180–183, 10.1016/j.jlumin.2013.03.045

Mishra, G. C. (2012). Development of borate based phosphors for mechanoluminescence and lyoluminescence radiation dosimetry. http://hdl.handle.net/10603/18211)

Ballato, J. , Lewis, III, J. S. , and Holloway, P. (1999). Display applications of rare-earth-doped materials. MRS Bull., 24, 51, WOS:000082817900020.

Zhang, Z. , Ten Kate, O. M. , Delsing, A. , van der Kolk, E. , Notten, P. H. L. , Dorenbos, P. , Zhao, J. , and Hintzen, H. T. (2012). Photoluminescence properties and energy level locations of RE3+ (RE = Pr, Sm, Tb, Tb/Ce) in CaAlSiN3 phosphors. J. Mater. Chem., 22, 9813. 10.1039/c2jm30220a

Dorenbos, P. (2003). f → d transition energies of divalent lanthanides in inorganic compounds. J. Phys.: Condens. Matter, 15 (2003), 575. 10.1088/0953-8984/15/3/322

Dorenbos, P. (2009). Lanthanide charge transfer energies and related luminescence, charge carrier trapping, and redox phenomena. J. Alloys Compd., 488 (2009), 568. 10.1016/j.jallcom.2008.09.059

Henderson B. , and Imbusch F. C. (1989). Optical Spectroscopy of Inorganic Solids (Oxford: Clarendon), Chapter 5. Clarendon Press, Oxford University Press, New York.

Su, Q. , Pei, Z. , Chi, L. , Zhang, H. , Zhang, Z. , and Zou, F. (1993). The yellow-to-blue intensity ratio (Y/B) of Dy3+ emission. J. Alloys Compd., 192 (1–2), 25–27. 10.1016/0925-8388(93)90174-L

Judd, B. R. (1962). Optical absorption intensities of rare earth ions. Phys. Rev., 127, 750–761. 10.1103/PhysRev.127.750

Ofelt, G. S. (1962). Intensities of crystal spectra of rare earth ions. J. Chem. Phys., 37, 511–520. 10.1063/1.1701366

Liu, J. , Wang, X. D. , Wu, Z. C. , and Kuang, S. P. (2011). Preparation, characterization and photoluminescence properties of BaB2O4: Eu3+ red phosphor. Spectrochim. Acta Part A, 79 (5), 1520–1523. 10.1016/j.saa.2011.05.009

Porwal, N. K. , Kadam, R. M. , Seshagiri, T. K. , Natarajan, V. , Dhobale, A. R. , and Page, A. G. (2005). EPR and TSL studies on MgB4O7 doped with Tm: Role of in TSL glow peak at 470K. Radiat. Meas., 40 (1), 69–75. 10.1016/j.radmeas.2005.04.007

Ettinger, K. V. , Forrester, A. R. , and Hunter, C. H. (1982). Lyoluminescence and spin trapping. Can. J. Chem., 60, 1549–1559. 10.1139/v82-502

Xie, R. , Hirosaki, N. , and Takeda, T. (2009). Wide color Gamut backlight for liquid crystal displays using three-band phosphor-converted white light-emitting diodes. Appl. Phys. Express, 2 (2), 022401. 10.1143/APEX.2.022401

Peng, M. , and Wondraczek, L. (2010). Orange-to-red emission from Bi2+ and alkaline earth codoped strontium borate phosphors for white light emitting diodes. J. Am. Ceram. Soc., 93, 1437–1442. 10.1111/j.1551-2916.2009.03590.x

Wang, Y. , Yiguang , Wang, Y. , Chi, N. , Yu, J. , and Shang, H. (2013). Demonstration of 575-Mb/s downlink and 225-Mb/s uplink bi-directional SCM-WDM visible light communication using RGB LED and phosphor-based LED. Opt Express, 21, 12031208. 10.1364/OE.21.001203

Do, Y. R. , and Bae, J. W. (2000). Application of photoluminescence phosphors to a phosphor-liquid crystal display. J. Appl. Phys., 88, 4660–4665. 10.1063/1.1311825

Gracia, C. R. , Diaz-Torres, L. A. , Oliva, J. , and Hirata, G. A. (2014). Green EuAlO3:Eu2+ nanophosphor for applications in WLEDs. Opt. Mater., 37, 520–524. 10.1016/j.optmat.2014.07.016

Raikwar, V. , Bhatkar, V. , and Omanwar, S. (2018). Morphological and photoluminescence study of NaSrB5O9: Tb3+ nanocrystalline phosphor. J. Asian Ceram. Soc., 6 (4), 359–367. 10.1080/21870764.2018.1529014

Hedaoo, V. P. , Bhatkar, V. B. , and Omanwar, S. K. (2015). PbCaB2O5 doped with Eu3+: A novel red emitting phosphor. Opt. Mater., 45, 91–96. 10.1016/j.optmat.2015.02.037

Hedaoo (Raikwar), V. P. , Bhatkar, V. B. , and Omanwar, S. K. (2015). Synthesis, characterization and photoluminescence in novel lead calcium diborate doped with Mn2+ . Optik, 126 (24), 4813–4816. 10.1016/j.ijleo.2015.09.192

Gawande, A. B. , Sonekar, R. P. , and Omanwar, S. K. (2014). Synthesis and enhancement of luminescence intensity by codoping of M+ (M=Li, Na, K) in Ce3+ doped strontium haloborate. Opt. Mater., 36 (7), 1143–1145. 10.1016/j.optmat.2014.02.017

Ingle, J. T. , Sonekar, R. P. , Omanwar, S. K. , Wang, Y. , and Zao, L. (2014). Combustion synthesis and photoluminescence study of novel red phosphor (Y1−x−y, Gdx)BaB9O16:Eu3+y for display and lighting. J. Alloys Compd., 608, 235–240. 10.1016/j.jallcom.2014.04.079

Sahare, P. D. , and Srivastava, S. K. (2016). Lyoluminescence dosimetry of high-energy gamma radiation using MgB4O7:Mn2+ . J. Radioanal. Nucl. Chem., 307, 31–36. 10.1007/s10967-015-4117-2

Wu, W. , Duan, Y. , and Liu, B. (2020). Mechanoluminescence: Quantitative pressure-brightness relationship enables new applications. Matter, 2 (2), 291–293. 10.1016/j.matt.2020.01.007

Wang, C. , Yu, Y. , Yuan, Y. , Ren, C. , Liao, Q. , Wang, J. , Chai, Z. , Li, Q. , and Li, Z. (2020). Heartbeat-sensing mechanoluminescent device based on a quantitative relationship between pressure and emissive intensity. Matter, 2 (1), 181–193. 10.1016/j.matt.2019.10.002

Wang, C. , Yu, Y. , Chai, Z. , He, F. , Wu, C. , Gong, Y. , Han, M. , Li, Q. , and Li, Z. (2019). Recyclable mechanoluminescent luminogen: Different polymorphs, different self-assembly effects of the thiophene moiety and recovered molecular packing via simple thermal-treatment. Mater. Chem. Front., 3, 32–38. 10.1039/C8QM00411K

Wu, W. , Duan, Y. , and Liu, B. (2020). Mechanoluminescence: Quantitative pressure-brightness relationship enables new applications. Matter, 2, 284–296. 10.1016/j.matt.2020.01.007

Peng, D. , Wang, C. , Ma, R. , Mao, S. , Qu, S. , Ren, Z. , Golovynskyi, S. , and Pan, C. (2021). Mechnoluminescent materials for athletic analytics in sports science. Sci. Bull., 66, 206–209. 10.1016/j.scib.2020.09.029

Borate Phosphors for Neutron Radiography

Craft, A. E. (2013). Design, construction, and demonstration of a neutron beamline and a neutron imaging facility at a Mark-I TRIGA reactor. http://hdl.handle.net/11124/78115

Bossi, R. H. , Iddings F. A. , and Wheeler, G. C. (2002). Nondestructive Testing Handbook, Vol. 4, Radiographic Testing, American Society for Nondestructive Testing, Inc., USA.

Whittemore, W. L. (1990). Neutron radiography. Neutron News, 1(3), 24–29. 10.1080/10448639008202041

Berger, H. (1976). Detection systems for neutron radiography: Practical applications of neutron radiography and gaging. Am. Soc. Testing Mater. STP, 586, 35–57.

Lehmann, E. H. , Frei, G. , Kuhne, G. , and Boillat, P. (2007). The micro-setup for neutron imaging: A major step forward to improve the spatial resolution. Nucl. Instrum. Methods Phys. Res. A, 576, 389–396. 10.1016/j.nima.2007.03.017

Tremsin, A. S. , McPhate, J. B. , Vallerga, J. V. , Siegmund, O. H. W. , Feller, W. B. , Lehmann, E. , Butler, L. G. , and Dawson, M. (2011). High-resolution neutron microtomography with noiseless neutron counting detector. Nucl. Instrum. Methods Phys. Res. A, 652(1), 400–403. 10.1016/j.nima.2010.08.009

Salvato, G. , Aliotta, F. , Finocchiaro, V. , Tresoldi, D. , Vasi, C. S. , and Ponterio, R. C. (2010). An apparatus for measuring the timing properties of scintillators for neutron imaging. Nucl. Instrum. Methods Phys. Res. A, 621(1–3), 489–492. 10.1016/j.nima.2010.05.054

Lehmann, E. H. , Vontobel, P. , Frei,G. , and Bronimann, C. (2004). Neutron imaging-detector options and practical results. Nucl. Instrum. Methods Phys. Res. A, 531(1), 228–237. 10.1016/j.nima.2004.06.010

Kallmann, H. (1948) Neutron radiography. Research, 1(6), 254–260. PMID: 18910022.H.

Thewlis, J. (1956). Neutron radiography. Br. J. Appl. Phys., 7(10), 345–350. 10.1088/0508-3443/7/10/301

Thewlis, J. (1958). Progress in Nondestructive Testing: edited by E. G. Stanford and J. H. Fearon , Heywood, London, 1, 113–119. 10.1007/BF00551079

Berger, H. (1965). Neutron Radiography, Elsevier Publishing Company, Amsterdam, London, New York

Hawkesworth, M. R. , and Walker, J. (1969). Review: Radiography with neutrons. J. Mater. Sci., 4, 817–835. 10.1007/BF00551079

Zboray, R. , Adams, R. , Morgano, M. , and Kis, Z. (2019). Qualification and development of fast neutron imaging scintillator screens. Nucl. Instrum. Methods Phys. Res. A, 930, 142–150. 10.1016/j.nima.2019.03.078

Stedman, R. (1960). Scintillator for thermal neutrons using Li6F and ZnS (Ag). Rev. Sci. Instrum., 31, 1156. 10.1063/1.1716833

van Eijk, C. W. E. (2001). Inorganic-scintillator development. Nucl. Instrum. Methods Phys. Res. A, 460, 1–14. 10.1088/0031-9155/47/8/201

Spowart, A. R. (1969). Measurement of the absolute scintillation efficiency of granular and glass neutron scintillators, Nucl. Instrum. Methods Phys. Res. A, 75(1), 35–42. 10.1016/0029-554X(69)90644-2

van Eijk, C. W. E. , Bessiere, A. , and Dorenbos, P. (2004). Inorganic thermal-neutron scintillators. Nucl. Instrum. Methods Phys. Res. A, 529(1–3), 260–267. 10.1016/j.nima.2004.04.163

Van Eijk, C. W. E. (2012). Inorganic scintillators for thermal neutron detection. IEEE Trans. Nuclear Sci., 59(5), 2242–2247. 10.1109/TNS.2012.2186154

Sakasai, K. , Katagiri, M. , Toh, K. , Takahashi, H. , Nakazawa, M. , and Kondo, Y. (2004). Characteristics of SrBPO5:Ce3+ based materials as a neutron storage phosphor. Nucl. Instrum. Methods Phys. Res. A, 529(1–3), 378–383. 10.1016/j.nima.2004.05.015

Karasawa, Y. , Niimura, N. , Tanaka, I. , Miyahara, J. , Takahashi, K. , Saito, H. , Tsuruno, A. , and Matsubayashi, M. (1995). An imaging plate neutron detector. Physica B, 213–214, 978–981. 10.1016/0921-4526(95)00341-6

Thoms, M. , Lehmann, M. S. , and Wilkinson, C. (1997). The optimization of the neutron sensitivity of image plates. Nucl. Instrum. Methods Phys. Res. A, 384(2–3), 457–462. 10.1016/S0168-9002(96)00865-0

Chen, J. , Li, Y. , Song, G. , Yao, D. , Yuan, L. , and Wang, S. (2006). Growth and characterization of pure Li6Gd(BO3)3 single crystals by the modified Bridgman method. J. Crystal Growth, 294(2), 411–415. 10.1016/j.jcrysgro.2006.06.011

An, D. , Zhang, M. , Li, D. , Pan, S. , Chen, H. , Yang, Z. , Zhu, Y. , Sun, Y. , Zhang, H. , and Li, Y. (2015). Linear and non-linear optical properties of aluminum borate crystal Al5BO9: Experiment and calculation, J. Mater. Res., 30(15), 2319–2326. 10.1557/jmr.2015.204

Sasaki, T. , Mori, Y. , Yoshimura, M. , Yap, Y. K. , and Kamimura, T. (2000). Recent development of non-linear optical borate crystals: Key materials for generation of visible and UV light, Mater. Sci. Eng. R, 30(1–2), 1–54. 10.1016/S0927796X(00)000255

Katsumata, T. , Yoshimura, T. , Kanazawa, K. , and Aizawa, H. (1994). Growth of lithium borate crystals from the vitreous state. J. Mater. Res., 9(8), 2051–2056. 10.1557/JMR.1994.2051

Chen, C. T. , Wu, B. C. , Jiang, A. D. , and You, G. M. (1985). A new-type ultraviolet SHG crystal beta- BaB2O4 . Sci. Sin. Ser. B, 28(3), 235–243. 10.1360/yb1985-28-3-235.

Chen, C. T. , Wu, B. C. , Jiang, A. D. , You, G. M. Li, R. K. , and Lin, S. J. (1989). New non-linear optical crystal: LiB3O5. J. Opt. Soc. Am. B, 6(4), 616–621. 10.1364/JOSAB.6.000616

Mori, Y. , Kuroda, I. , Nakajima, S. , Sasaki, T. , and Nakai, S. (1995). New non-linear optical crystal: Cesium lithium borate. Appl. Phys. Lett., 67, 1818–1820. 10.1063/1.115413

Wu, B. C. , Tang, D. Y. , Ye, N. , and Chen, C. T. (1996). Linear and non-linear optical properties of the KBe2BO3F2 (KBBF) crystal, Opt. Mater., 5(1), 105–109. 10.1016/0925-3467(95)00050-X
Wu, H. , Yu, H. , Yang, Z. , Hou, X. , Su, X. , Pan, S. , Poeppelmeier, K. R. , and Rondinelli, J. M. (2013). Designing a deep-ultraviolet non-linear optical material with a large second harmonic generation response, J. Am. Chem. Soc. 135(11), 4215–4218. 10.1021/ja400500m
Wu, H. , Yu, H. , Yang, Z. , Hou, X. , Su, X. , Pan, S. , Poeppelmeier, K. R. , and Rondinelli, J. M. (2014). Cs3Zn6B9O21: A chemically benign member of the KBBF family exhibiting the largest second harmonic generation response, J. Am. Chem. Soc., 136(4), 1264–1267. 10.1021/ja4117389
Zhang, M. , Su, X. , Pan, S. , Zheng, W. , Zhang, H. , Yang, Z. , Zhang, B. , Dong, L. , Wang, Y. , Zhang, F. , and Yang, Y. (2014). Linear and non-linear optical properties of K3B6O10Br single crystal: Experiment and calculation. J. Phys. Chem. C, 118(22), 11849–11856. 10.1021/jp500858q
Hu, Z. G. , Higashiyama, T. , Yoshimura, M. , Yap, Y. K. , Mori, Y. , and Sasaki, T. (1998). A new non-linear optical borate crystal K2Al2B2O7(KAB). Jpn. J. Appl. Phys., 37, L1093. 10.1143/JJAP.37.L1093
Liu, L. Liu, C. Wang, X. , Hu, Z. G. , Li, R. K. , and Chen, C. T. (2009). Impact of Fe3+ on UV absorption of K2Al2B2O7 crystals. Solid State Sci., 11(4), 841–844. 10.1016/j.solidstatesciences.2009.01.003
Zhou, Y. , Yue, Y. , Wang, J. , Yang, F. , Cheng, X. , Cui, D. , Peng, Q. , Hu, Z. , and Xu, Z. (2009). Nonlinear optical properties of BaAlBO3F2 crystal. Opt. Express, 17(22), 20033–20038. 10.1364/OE.17.020033
Chen, C. , Lin, Z. and Wang, Z. (2005). The development of new borate-based UV non-linear optical crystals. Appl. Phys. B, 80, 1–25. 10.1007/s00340-004-1645-9
Becker, P. (1998). Borate materials in non-linear optics. Adv. Mater., 10(13), 979–992.10.1002/(SICI)1521-4095(199809)10:13<979::AID-ADMA979>3.0.CO;2-N
Zhou, J. , Fang, W. H. , Rong, C. , and Yang, G. Y. (2010). A series of open framework alumino borates templated by transition-metal complexes. Chem. Eur. J., 16(16), 4852–4863.10.1002/chem.200902664
Sokolova, Y. V. , Azizov, A. V. , Simonov, M. A. , Leonyuk, N. I. , and Belov, N. V. (1978). The crystal structure of the synthetic ortho-tri-borate Al5(BO3)O6 . Dokl. Akad. Nauk SSSR, 243(3), 655–658.
Gatta, G. D. , Lotti, P. , Merlini, M. , Liermann, H. P. , Fisch, M. , Rotiroti, N. , and Armbruster, T. (2013). High-pressure behaviour and phase stability of Al5BO9, a mullite-type ceramic material. J. Am. Ceram. Soc., 96(8), 2583–2592. 10.1111/jace.12411
Shin, Y. , Lee, D. W. , Hong, J. , Kawk, K. , and Ok, K. M. (2012). Second harmonic generating properties of polar noncentrosymmetric aluminoborate solid solutions Al5-xGaxBO9 (0.0 < x < 0.5). Dalton Trans., 41, 3233–3238. 10.1039/C2DT11971D
Czirr, J. B. , MacGillivray, G. M. , MacGillivray, R. R. , and Seddon, P. J. (1999). Performance and characteristics of a new scintillator. Nucl. Instrum. Methods Phys. Res. A, 424 15–19. 10.1016/S0168-9002(98)01295-9
Fu, Z. , Pan, S. , Yang, F. , Gu, S. , Lei, X. , Heng, Y. , Ren, G. , and Qi, M. (2015). Neutron detection properties of Li6Y(BO3)3:Ce crystal. Radiat. Meas., 72, 39–43. 10.1016/j.radmeas.2014.11.010
Singh, A. K. , Tyagi, M. , Desai, D. G. , Singh, S. G. , Sen, S. , and Gadkari, S. C. (2018). A comparative study of Li6R(BO3)3; R = Gd, Lu, & Y), single crystals for thermal neutron detection. Phys. Status Solidi A, 215, 1800224. 10.1002/pssa.201800224
Fujimoto, Y. , Yanagida, T. , Tanaka, H. , Yokota, Y. , Kawaguti, N. , Fukuda, K. , Totsuka, D. , Watanabe, K. , Yamazaki, A. , and Yoshikawa, A. (2011). Growth and characterization of Ce-doped Ca3(BO3)2 crystals for neutron scintillator. J. Crystal Growth, 318, 784–787. 10.1016/j.jcrysgro.2010.10.189
Fujimoto, Y. , Yanagida, T. , Tanaka, H. , Yokota, Y. , Kawaguti, N. , Fukuda, K. , Totsuka, D. , Watanabe, K. , Yamazaki, A. , and Yoshikawa, A. (2011). Optical and scintillation properties of Pr3+ doped Ca3(BO3)2 single crystals. Phys. Status Solidi B, 248(2), 444–447. 10.1002/pssb.201000635
Fujimoto, Y. , Yokota, Y. , Yanagida, T. , Pejchal, J. , Konno, H. , Sugiyama, K. , Nikl, M. , and Yoshikawa, A. (2010). Crystal growth and characterization of Sr3Y(BO3)3 . IEEE Trans. Nucl. Sci., 57(3), 1264–1267. 10.1109/TNS.2009.2035695
Kawaguchi, N. , Okada, G. , Futami, Y. , Nakauchi, D. , Kato, T. , and Yanagida, T. (2020). Scintillation and dosimetric properties of monocrystalline and polycrystalline Li2B4O7 . Sens. Mater., 32(4), 1419–1426. 10.18494/SAM.2020.2752
Kusachi, I. , Henmi, C. , & Kobayashi, S. (1995). Takedaite, a new mineral from Fuka, Okayama Prefecture, Japan. Mineral. Mag., 59(396), 549–552. 10.1180/minmag.1995.059.396.1
Lu, X. , You, Z. , Li, J. , Zhu, Z. , Jia, G. , Wu, B. , Tu, C. (2006). Optical transition properties of the Nd3+ ions in Ca3(BO3)2 crystal. Phys. Status Solidi A, 203(3), 551–557. 10.1002/pssa.200521453
Lu, X. , You, Z. , Li, J. , Zhu, Z. , Jia, G. , Wu, B. , and Tu, C. (2005). Growth and properties of pure and rare earth-doped Ca3(BO3)2 single crystal. J. Cryst. Growth, 281(2-4), 416–425. 10.1016/j.jcrysgro.2005.04.028
Lu, X. , You, Z. , Li, J. , Zhu, Z. , Jia, G. , Wu, B. , and Tu, C. (2005). Spectroscopy of Ca3(BO3)2: Dy3+ crystal. J. Phys. Chem. Solids, 66, 1801–1805. 10.1016/j.jpcs.2005.08.088
Lu, X. , You, Z. , Li, J. , Zhu, Z. ., Jia, G. , Wu, B. , and Tu, C. (2006). Optical properties of Er3+ doped Ca3(BO3)2 crystal. J. Appl. Phys., 100,033103. 10.1063/1.2227264
Fujimoto, Y. , Yanagida, T. , Yokota, Y. , Kawaguchi, N. , Fukuda, K. , Totsuka, D. , Watanabe, K. , Yamazaki, A. , Chani, V. , and Yoshikawa, A. (2011). Scintillation and optical properties of Pb-doped YCa4O(BO3)3 crystals. Nucl. Instrum. Methods Phys. Res. A, 652, 238–241. 10.1016/j.nima.2010.10.046

Mercer, C. J. , Tsang, Y. H. , Binks, D. J. , Zhang, H. , and Wang, J. (2009). Q-switched operation of a Nd:YCOB laser. Opt. Commun., 282(1), 97–100. 10.1016/j.optcom.2008.09.076

Shimizu, H. , Nishida, T. , Takeda, H. , and Shiosaki, T. (2009). Dielectric, elastic and piezoelectric properties of RCa4O(BO3)3 (R=rare-earth elements) crystals with monoclinic structure of point group m. J. Cryst. Growth, 311(3), 916 -920. 10.1016/j.jcrysgro.2008.09.144

ArunKumar, R. , and Dhanasekaran, R. (2009). Flux growth of yttrium calcium oxyborate (YCOB) single crystals for non-linear optical applications. J. Cryst. Growth, 311(3), 541–543. 10.1016/j.jcrysgro.2008.09.195

Knitel, M. J. , Dorenbos, P. , van Eijk, C. W. E. , Plasteig, B. , Viana, B. , Kahn-Harari , and Vivien, A. (2000). Photoluminescence, and scintillation/thermoluminescence yields of several Ce3+ and Eu2+ activated borates. Nucl. Instrum. Methods Phys. Res. A, 443(2–3), 364–374. 10.1016/S0168-9002(99)01154-7

Yang, H. C. , Li, C. Y. , He, H. , Tao, Y. Xu, J. H. , and Su, Q. (2006). VUV–UV excited luminescent properties of LnCa4O(BO3)3:RE3+ (Ln = Y, La, Gd; Re = Eu, Tb, Dy, Ce). J. Lumin., 118(1), 61–69. 10.1016/j.jlumin.2005.06.007

Abdullaev, G. K. , and Mamedov, K. S. (1977). Crystal structure of the double lithium ytterbium orthoborate Li6Yb(BO3)3 . Sov. Phys. Crystallogr., 22(2), 220–222.

Abdullaev, G. K. , Mamedov, K. S. , Rza-Zade, P. F. , Guseinova, S. A. , and Dzhafarov, G. G. (1977). Synthesis and structural study of crystals of the double orthoborate of lithium and holmiun. Russian J. Inorg. Chem., 22, 1765–1766.

Kbala, M. , Levasseur, A. , Fouassier, C. , and Hagenmuller, P. (1982). Etude De La Conductivite Ionique De Nouveaux Borates Doubles De Type: Li6-xLn1-xTx(B03)3 . Solid State Ionic, 6(2), 191–194. 10.1016/0167-2738(82)90087-X

Chaminade, J. P. , Viraphong, O. , Guillen, F. , Fouassier, C. , and Czirr, B. (2001). Crystal growth and optical properties of new neutron detectors Ce3+: Li6R(BO3)3 (R = Gd,Y). IEEE Trans. Nucl. Sci., 48, 1158–1161. 10.1109/23.958742

Mascetti, J. , Fouassier, C. , and Hagenmuller, P. (1983). Concentration quenching of the Nd emission in alkali rare earth borates. J. Solid State Chem., 50(2), 204–212. 10.1016/0022-4596(83)90189-5

Garapon, C. T. , Jacquier, B. , Chaminade, J. P. , and Fouassier, C. (1985). Energy transfer in Li6Gd(BO3)3 . J. Lumin., 34(4), 211–222. 10.1016/0022-2313(85)90104-8

Pana, S. , Zhanga, J. , Pana, J. , Ren, G. , Lic, N. , Wuc, Z. , and Heng, Y. (2018). Optimized crystal growth and luminescence properties of Ce3+ ions doped Li6Gd(BO3)3, Li6Y(BO3)3 and their mixed crystals. J. Alloys Compd., 751, 129–137. 10.1016/j.jallcom.2018.04.099

Ogorodnikov, I. N. , and Pustovarov, V. A. (2013). Luminescence of Li6Gd(BO3)3 crystals upon ultraviolet and inner-shell excitations. J. Lumin., 134, 113–125. 10.1016/j.jlumin.2012.09.002

Fawad, U. , Kim, H. J. , Khan, A. , Park, H. , and Kim, S. (2015). X-ray and photoluminescence study of Li6Gd(BO3)3:Tb3+, Dy3+ phosphors. Sci. Adv. Mater., 7 (12), 2536–2544. 10.1166/sam.2015.2436

Zhang, F. , Wang, Y. , and Tao, Y. , (2012). Photoluminescence properties of Li6Gd(BO3)3:Tb3+ Under VUV/UV excitation. Phys. Procedia, 29, 55–61. 10.1016/j.phpro.2012.03.692

Yavetskiy, R. , Tolmachev, A. , Dubovik, M. , Korshikova, T. , and Parkhomenko, S. (2007). Growth of Li6Gd1-xYx(BO3)3:Eu3+ crystals for thermoluminescent dosimetry. Opt. Mater., 30(1), 119–121. 10.1016/j.optmat.2006.11.008

Zhao, Y. W. , Gong, X. H. , Chen, Y. J. , Huang, L. X. , Lin, Y. F. , Zhang, G. , Tian, Q. G. , Luo, Z. D. , and Huang, Y. D. (2007). Spectroscopic properties of Er3+ ions in Li6Y(BO3)3 crystal. Appl. Phys. B, 88, 51–55. 10.1007/s00340-007-2655-1

Delaigue, M. , Jubera, V. , Sablayrolles, J. , Chaminade, J. P. , Garcia, A. , and Manek Honninger, I. (2007). Mode-locked and Q-switched laser operation of the Yb doped Li6Y(BO3)3 crystal. Appl. Phys. B, 87, 693–696. 10.1007/s00340-007-2641-7

Ma, X. , Li, J. , Zhu, Z. , You, Z. , Wang, Y. and Tu, C. (2008). Thermal and optical properties of Tm3+: Li6Gd(BO3)3 crystal: A potential candidate for 1.83 mm lasers. J. Lumin., 128, 1660– 1664. 10.1016/j.jlumin.2008.03.015

Erdogmus, E. , and Yildiz, E. (2020). Structural and luminescence properties of Pb2+ doped Li6Gd(BO3)3 phosphor. J. Appl. Spectrosc., 87(4), 615–620. 10.1007/s10812-020-01044-9

Chen, P. , Mo, F. , Guan, A. , Wang, R. , Wang, G. , Xia, S. , and Zhou, L. (2016). Luminescence and energy transfer of the colour-tunable phosphor Li6Gd(BO3)3:Tb3+/Bi3+, Eu3+ . Appl. Radiat. Isotop., 108, 148–153. 10.1016/j.apradiso.2015.12.042

Rambabu, U. , Annapurna, K. , Balaji, T. , Satyanarayana, J. V. , Rajamohan Reddy, K. , and Buddhudu., S. (1996). Fluorescence Spectra of Eu3+ and Tb3+ doped Na6 Ln (BO3)3 (Ln = La, Gd, Y) phosphors. Spectrosc. Lett., 29(5), 833–839. 10.1080/00387019608001614

Zhang, Y. , Chen, X. L. , Liang, J. K. , and Xu, T. (2003). Phase relations of the system Li2OGd2O3-B2O3 and the structure of a new ternary compound. J. Alloys Compd., 348 (1–2), 314318. 10.1016/S0925-8388(02)00843-5

Shekhovtsov, A. N. , Tolmachev, A. V. , Dubovik, M. F. , Dolzhenkova, E. F. , Korshikova, T. L. , Grinyov, B. V. , Baumer,V. N. , and Zelenskaya, O. V. (2002). Structure and growth of pure and Ce3+ doped Li6Gd(BO3)3 single crystals. J. Cryst. Growth, 242(1–2), 167–171. 10.1016/S0022-0248(02)01137-5

Ogorodnikov, I. N. , Poryvay, N. E. , Pustovarov, V. A. , Tolmachev, A. V. , Yavetskiy, R. P. , and Yakovlev, V.Yu . (2010). Short-living defects and recombination processes in Li6Gd(BO3)3 crystals. Radiat. Meas., 45(3–6), 336–339. 10.1016/j.radmeas.2010.01.039

Yang, F. Pan, S. K. , Ding, D. Z. , Chen, X. F. , Feng, H. , and Ren, G. H. (2010). Crystal growth and luminescent properties of the Ce-doped Li6Lu(BO3)3 . J. Cryst. Growth, 312(16–17), 2411–2414. 10.1016/j.jcrysgro.2010.05.007

Fawad, U. , Rooh, G. , Kim, H. J. , Park, H. , Kim, S. , and Jiang, H. (2014). Crystal growth and scintillation properties of Li6LuxGd1-x(BO3)3:Ce3+ single crystals. Nucl. Instrum. Methods Phys. Res. A, 764, 268–272. 10.1016/j.nima.2014.07.040

Sonoda, M. , Takano, M. , Miyahara, J. , and Kato, H. (1983). Computed radiography utilizing scanning laser stimulated luminescence. RADLAX, 148(3), 833. 10.1148/radiology.148.3.6878707

Wilkinson, C. , Gabriel, A. , Lehmann, M. , Zemb, T. and Ne, F. (1992). Image plate neutron detector: Proceedings Volume 1737, Neutrons, X Rays, and Gamma Rays. Imaging Detectors, Material Characterization Techniques, and Applications, 1737, 324–329. 10.1117/12.138680

Rausch, C. , Bucherl, T. , Gahler, R. , von Seggern, H. , and Winnacker, A. (1992). Proceedings Volume 1737, Neutrons, X Rays, and Gamma Rays: Imaging Detectors, Material Characterization Techniques, and Applications, 1737, 255. 10.1117/12.138666

Niimura, N. , Karasawa, Y. , Tanaka, I. , Miyahara, J. , Takahashi, K. , Saito, H. , Koizumi, S. , and Hidaka, M. (1994). An imaging plate neutron detector. Nucl. Instrum. Methods Phys. Res. A, 349(2–3), 521–525. 10.1016/0168-9002(94)91220-3

Haga, Y. K. , Neriishi, K. , Takahashi, K. , and Niimura, N. , (2002). Optimization of neutron imaging plate. Nucl. Instrum. Methods Phys. Res. A, 487(3), 504–510. 10.1016/S0168-9002(01)02204-5

Meijerink, A. , and Blasse, G. (1989). Luminescence properties of Eu2+ activated alkaline earth haloborates. J. Lumin., 43(5), 283–289. 10.1016/0022-2313(89)90098-7

Knitel, M. J. , Bom,V. R. , Dorenbos, P. , van Eijk, C. W. E. , Berezovskaya, I. , and Dotsenko, V. (2000). The feasibility of boron containing phosphors in thermal neutron image plates, in particular the systems M2B5O9X:Eu2+ (M = Ca, Sr, Ba; X = Cl, Br). Part I: simulation of the energy deposition process. Nucl. Instrum. Methods Phys. Res. A, 449(3), 578–594. 10.1016/S0168-9002(99)01474-6

Knitel, M. J. , Bom,V. R. , Dorenbos, P. , van Eijk, C. W. E. , Berezovskaya, I. , and Dotsenko, V. (2000). Feasibility of boron containing phosphors in thermal neutron image plates, in particular the systems M2B5O9X: Eu2+ (M = Ca, Sr, Ba; X = Cl, Br). Part II: experimental results. Nucl. Instrum. Methods Phys. Res. A, 449(3), 595–601. 10.1016/S0168-9002(99)01475-8

Sakasai, K. , Katagiri, M. , Toh, K. , Takahashi, H. , Nakazawa, M. , and Kondo, Y. (2003). Characteristics of a SrBPO5:Eu2+ material as a neutron storage phosphor. IEEE Trans. Nucl. Sci., 50(4), 788–791. 10.1109/TNS.2003.815309

Karthikeyani, A. , and Jagannathan, R. (2000). Eu2+ luminescence in stillwellite-type SrBPO5 -a new potential x-ray storage phosphor. J. Lumin., 86(1), 79–85. 10.1016/S0022-2313(99)00171-4

Sakasai, K. , Katagiri, M. , Toh, K. , Takahashi, H. , Nakazawa, M. , and Kondo, Y. (2001). A SrBPO5:Eu2+ storage phosphor for neutron imaging. Appl. Phys. A, 74, S1589–S1591. 10.1007/s003390101255

Sakasai, K. , Katagiri, M. , Toh, K. , Takahashi, H. , Nakazawa, M. , and Kondo, Y. (2004). Neutron storage characteristics of CaBPO5:Ce3+ based phosphors. IEEE Trans. Nucl. Sci., 51(4), 1712–1716. 10.1109/TNS.2004.832287

Chernikov, V. V. , Dubovik, M. F. , Gavrylyuk, V. P. , Grinyov, B. V. , Gri, L. A. , Korshikova, T. I. , Shekhovtsov, A. N. , Sysoeva, E. P. , Tolmachev, A. V. , and Zelenskaya, O. V. (2003). Peculiarities of scintillation parameters of some complex composition borate single crystals. Nucl. Instrum. Methods Phys. Res. A, 498(1-3), 424–429. 10.1016/S0168-9002(02)02051-X

Baroni, E. E. , Viktorov, D. V. , Rozman, I. M. , and Shoniya, V. M. (1962). Nucl. Electron, 1, 131.

Ishii, M. , Kuwano, Y. , Asaba, S. , Asai, T. , Kawamura, M. , Senguttuvan, N. , Hayashi, T. , Koboyashi, M. , Nikl, M. , Hosoya, S. , Sakai, K. , Adachi, T. , Oku, T. , and Shimizu, H. M. (2004). Luminescence of doped lithium tetraborate single crystals and glass. Radiat. Meas., 38(4–6), 571–574. 10.1016/j.radmeas.2004.03.017

Schulman, J. H. , Kirk R. D. , and West, E. J. (1967). Luminescence dosimetry, U.S. Atomic Energy Commission Symposium Series 8, CONF-650637, 113.

Kobayashi, M. , Ishii, M. , and Senguttuvan, N. (2015). Scintillation characteristics of undoped and Cu2+ doped Li2B4O7 single crystals. Problems of Spectroscopy and Spectrometry, 34, 71–89. arXiv:1503.03759

Guarneros-Aguilar, C. , Cruz-Zaragoza, E. , Marcazzo, J. , Palomino-Merino, R. , and Espinosa, J. E. (2013). Synthesis and TL characterization of Li2B4O7 doped with copper and manganese. AIP Conf. Proc., 1544(1), 70–77. 10.1063/1.4813462

Singh, L. , Chopra, V. , and Lochab, S. P. (2011). Synthesis and characterization of thermoluminescent Li2B4O7 nanophosphor. J. Lumin. 131(6), 1177–1183. 10.1016/j.jlumin.2011.02.035

Rawat, N. S. , Kulkarni, M. S. , Tyagi, M. , Ratna, P. , Mishra, D. R. , Singh, S. G. , Tiwari, B. , Soni, A. , Gadkari, S. C. , and Gupta, S. K. (2012). TL and OSL studies on lithium borate single crystals doped with Cu and Ag. J. Lumin., 132(8), 1969–1975. 10.1016/j.jlumin.2012.03.008

Patra, G. D. , Singh, S. G. , Tiwari, B. , Singh, A. K. , Desai, D. G. , Tyagi, M. , Sen, S. , and Gadkari . (2016). Optically stimulated luminescence in Ag doped Li2B4O7 single crystal and its sensitivity to neutron detection

and dosimetry in OSL mode. Radiat. Meas., 88, 14–19. 10.1016/j.radmeas.2016.03.002
Hemam, R. , Singh, L. R. , Prasad, A. I. , Gogoi, P. , Kumar, M. , Chougaonkar, M. P. , Singh, S. D. , and, Sharan, R. N. (2016). Critical view on TL/OSL properties of Li2B4O7 nanoparticles doped with Cu, Ag and co-doping Cu, Ag: Dose response study: Radiat. Meas., 95,44–54. 10.1016/j.radmeas.2016.11.003
Kananen, B. E. , Maniego, E. S. , Golden, E. M. , Giles, N. C. , McClory, J. W. , Adamiv, V. T. , Burak, Ya.V. , and Halliburton, L. E. (2016). Optically stimulated luminescence (OSL) from Agdoped Li2B4O7 crystals. J. Lumin., 177, 190–196. 10.1016/j.jlumin.2016.04.032
Kawamura, I. , Kawamoto, H. , Fujimoto, Y. , Koshimizu, M. , Okada, G. , Koba, Y. , Ogawara, R. , Suda, M. , Takayuki Y. , and Asai, K. (2020). Thermoluminescence properties of Dy3+ doped CaO–Al2O3–B2O3 glasses for neutron detection. Nucl. Instrum. Methods Phys. Res. B, 468, 18–22. 10.1016/j.nimb.2020.02.015
Souza, L. F. , Novais, A. L. F. , Antonio, P. L. , Caldas, L. V. E. , and Souza, D. N. (2019). Luminescent properties of MgB4O7:Ce,Li to be applied in radiation dosimetry. Radiat. Phys. Chem., 164, 108353. 10.1016/j.radphyschem.2019.108353
Yukihara, E. G. , Doull, B. A. , Gustafson, T. , Oliveira, L. C. , Kurt, K. , and Milliken, E. D. (2017). Optically stimulated luminescence of MgB4O7:Ce,Li for gamma and neutron dosimetry. J. Lumin., 183, 525–532. 10.1016/j.jlumin.2016.12.001
Gustafson, T. D. , Milliken, E. D. , Jacobsohn, L. G. , and Yukihara, E. G. (2019). Progress and challenges towards the development of a new optically stimulated luminescence (OSL) material based on MgB4O7:Ce,Li. J. Lumin., 212, 242–249. 10.1016/j.jlumin.2019.04.028
Souza, L. F. , de Souza, D. N. , Rivera, G. B. , Vidal, R. M. , and Caldas, L. V. E. (2019). Dosimetric characterization of MgB4O7:Ce,Li as an optically stimulated dosimeter for photon beam radiotherapy. Perspect. Sci. 12, 100397. 10.1016/j.pisc.2019.100397
Souza, L. F. , Silva, A. M. B. , Antonio, P. L. , Caldas, L. V. E. , Souza, S. O. , d'Errico, F. , and Souza, D. N. (2017). Dosimetric properties of MgB4O7:Dy,Li and MgB4O7:Ce,Li for optically stimulated luminescence applications. Radiat. Meas. 106, 196–199. 10.1016/j.radmeas.2017.02.009
Appleby, G. A. , Edgar, A. , Williams, G. V. M. , and Bos, A. J. J. (2006). Photo-stimulated luminescence from BaCl2:Eu2+ nanocrystals in lithium borate glasses following neutron irradiation. Appl. Phys. Lett., 89, 101902. 10.1063/1.2335807
Appleby, G. A. , Bartle, C. M. , Williams, G. V. M. , and Edgar, A. (2006). Lithium borate glass ceramics as thermal neutron imaging plates. Curr. Appl. Phys., 6(3), 389–392. 10.1016/j.cap.2005.11.025
Appleby, G. A. , and Vontobel, P. (2008). Optimisation of lithium borate–barium chloride glass ceramic thermal neutron imaging plates. Nucl. Instrum. Methods Phys. Res. A, 594, 253–256. 10.1016/j.nima.2008.06.036
Majerus, O. , Tregouet, H. , Caurant, D. , and Pytalev, D. (2015). Comparative study of the rare earth environment in rare earth metaborate glass (REB3O6, RE = La, Nd) and in sodium borate glasses. J. Non-Cryst. Solids, 425, 91–102. 10.1016/j.jnoncrysol.2015.05.031
Qiu, J. , Shimizugawa, Y. , Iwabuchi, Y. , and Hirao, K. (1997). Photostimulated luminescence of Ce3+ doped alkali borate glasses. Appl. Phys. Lett., 71(1), 43–45. 10.1063/1.119463
Valenca, J. V. B. , Silveira, I. S. , Silva, A. C. A. , Dantas, N. O. , Antonio, P. L. , Caldas, L. V. E. , dErrico, F. , and Souza, S. O. (2018). Optically stimulated luminescence of the [20% Li2CO3 +x% K2CO3+(80-x)% B2O3] glass system. J. Lumin., 200, 248–253. 10.1016/ j.jlumin.2018.03.060
Valenca, J. V. B. , Silveira, I. S. , Silva, A. C. A. , Dantas, N. O. , Antonio, P. L. , Caldas, L. V. E. , d'Errico, F. , and Souza, S. O. (2017). Optically stimulated luminescence of borate glasses containing magnesia, quicklime, lithium and potassium carbonates. Radiat. Phys. Chem., 140, 83–86. 10.1016/j.radphyschem.2016.12.017
Sroda, M. , Swiontek, S. , Wojciech, G. , and Bilski, P. (2019). The effect of CeO2 on the thermal stability, structure and thermoluminescence and optically stimulated luminescence properties of barium borate glass. J. Non-Cryst. Solids, 517, 61–69. 10.1016/j.jnoncrysol.2019.03.026
Nanto, H. , Nakagawa, R. , Takei, Y. , Hirasawa, K. , Taniguchi, S. , Miyamoto, Y. , Masai, H. , Kurobori, T. , and Yanagida, T. (2014). Ionizing radiation sensors utilizing optically stimulated luminescence in SnO-doped SrO-B2O3 and ZnO-P2O5 glass. IEEE SENSORS 2014 Proceedings, 416–419. 10.1109/ICSENS.2014.6985023
Souza, L. F. , Silva, C. R. E. , Souza, D. N. , and Nogueira, M. S. (2021). Application of optically stimulated luminescence in tandem systems for diagnostic radiology. Radiat. Phys. Chem., 182, 109354. 10.1016/j.radphyschem.2021.109354
Kitagawa, Y. , Yukihara, E. G. , and Tanabe, S. (2021). Development of Ce3+ and Li+ co-doped magnesium borate glass ceramics for optically stimulated luminescence dosimetry. J. Lumin., 232, 117847. 10.1016/j.jlumin.2020.117847
Barrera, G. R. , Souza, L. F. , Novais, A. L. F. , Caldas, L. V. E. , Abreu, C. M. , Machado, R. , Sussuchi, E. M. , and Souza, D. N. (2019). Thermoluminescence and optically stimulated luminescence of PbO–H3BO3 and PbO–H3BO3–Al2O3 glasses. Radiat. Phys. Chem., 155, 150–157. 10.1016/j.radphyschem.2018.02.005
Richardson, A. E. (1977). Improved images in 14.5 MeV neutron radiography. Mater. Eval., 35(4), 52–58. RN:9374108.
Duehmke, E. , and Greim, L. (1978). Fast Neutron Radiography of Extended Biological and Medical Objects. Proceedings of the International Congress on Radiology, Rio de Janeiro, Brazil,23-29 October, 1977, Atomkernenergie (1977). 30, 175–181.

Atkins, H. L. (1965). Biological application of neutron radiography, Mater. Eval., 23, 453–458.
Barton, J. P. (1964). Some possibilities of neutron radiography. Phys. Med. Biol., 9(1), 33.
Tochilin, E. , (1965). Photographic detection of fast neutrons: Application to neutron radiography. Phys. Med. Biol., 10(4), 477.
Weisman, M. I. , and Brown, M. (1971). Neutron radiography of the dental pulp: A preliminary report. Oral Surg. Oral Med. Oral Pathol., 32(3), 487–492. 10.1016/0030-4220(71)90211-8
Spowart, A. R. (1972). Neutron radiography. J. Phys. E: Sci. Instrum., 5(6), 497–510.
Vontobel, P. , Lehmann, E. , and Carlson, W. D. (2005). Comparison of X-ray and neutron tomography investigations of geological materials. IEEE Trans. Nucl Sci, 52(1), 338–341. 10.1109/TNS.2005.843672
Fioria, F. , Giunta, G. , Hilger, A. , Kardjilov N. , and Rustichelli, F. (2006). Non-destructive characterization of archaeological glasses by neutron tomography, Physica B, 385–86, 1206–1208. 10.1016/j.physb.2006.05.410
Schillinger, B. , Gebhard, R. , Haas, B. , Ludwig, W. , Rausch, C. , and Wagner, U. (1996). 3D neutron tomography in material testing and archaeology. In: Proceedings of the 5th world conference on neutron radiography, Berlin, 688–693.
Dierick, M. , Vlassenbroeck, J. , Masschaele, B. , Cnudde, V. , Hoorebeke, L. Van. , and Hillenbach (2005). High-speed neutron tomography of dynamic processes. Nucl. Instrum. Methods Phys. Res. A, 542(1–3), 296–301. 10.1016/j.nima.2005.01.152