BCYRCs

BHIWAPUR MAHAVIDYALAYA

Bhiwapur, Dist- Nagpur (M.S.) India- 441201

A

PROJECT REPORT

ON

PREPERATION OF WATERPROOF DOSIMETERS FOR OPTICALLY STIMULATED LUMINESCENCE DOSIMETRY

SUBMITTED TO

DEPARTMENT OF PHYSICS

SUBMITTED BY

STUDENTS OF B. Sc. III

1. ADITYA SORDE
2. ADITYA BANDE
3. ANIKET KASE
4. ANIKET DAHARE
5. ASAL PENDAM
6. VRUSHABH MOHOD
7. LOKESH BHAJBHUJE

UNDER THE GUIDANCE OF

ASST. PROF. DR. YOGESH MORE
DEPARTMENT OF PHYSICS
BHIWAPUR MAHAVIDYALAYA, BHIWAPUR

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2022-23

DECLARATION

This Project wok entitled **"Preparation of Waterproof Dosimeters for Optically Stimulated Luminescence Dosimetry"**, is our own work carried out under the guidance of **Asst. Prof. Dr. Yogesh More**, Department of Physics, Bhiwapur Mahavidyalaya in Bachelor of Science, Bhiwapur Mahavidyalaya, Bhiwapur. Nagpur. This work in the same form or in any other form is not submitted by me or by anyone else for the award of any degree.

Signature:

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2. ADITYA RAVINDRA BANDE - A.Bande.
3. ANIKET GAJRAJSINGH KASE -
4. ANIKET RAMA DAHAKE A.R.Dahake
5. ASAL BANDUJI PENDAM – A.B.Pendam
6. VRUSHABH DIWAKAR MOHOD V.D.Mohod
7. LOKESH DNYANESHWAR BHAJBHUJE L.D.Bhajbhuje

Date: 4th May 2023

Place: Bhiwapur

CERTIFICATE

This is to certify that the Project work entitled **"Preparation of Waterproof Dosimeters for Optically Stimulated Luminescence Dosimetry"**, is the work done by students listed below and is submitted to Department of Physics, Bhiwapur Mahavidyalaya, Bhiwapur for the partial fulfilment of the requirements for the degree of Bachelor of Science in the subject Physics.

Name of the Students:

1. ADITYA NARAYAN SORDE

2. ADITYA RAVINDRA BANDE

3. ANIKET GAJRAJSINGH KASE

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Date: 4th May, 2023

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We wish to express our gratitude to our parents for their support.

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1. Introduction

Optically stimulated luminescence (OSL) originally developed for geological/archaeological dating, has been found very useful for diverse applications in the field of radiation dosimetry. In the past decade there have been tremendous developments in the field of OSL dosimetry [1, 2]. There is a discernable paradigm shift in personnel dosimetry from thermoluminescence dosimeter based systems to OSL based dosimetry systems for monitoring of exposure of workers to ionizing radiation. This is primarily due to the attractive features of OSL mode of readout like multiple readouts, no need of thermal annealing which avoids problems like thermal quenching thermal stability of dosimeters, etc. Precise control of stimulation light intensity, wide dynamic dose range of linearity, high sensitivity, and the possibility of re-estimation of dose and remote dose measurement are the other advantages of OSL technique over the conventional thermoluminescence (TL) technique [3].

There is still a scarcity of OSL materials with demonstrated properties suited to dosimetry applications. Progress on the development of OSL materials with engineered properties has been slow and most research has focused on the

[1] L.Bøtter-Jensen, S.W.S.McKeever, A.G.Wintle, Optically Stimulated Luminescence, (2003), Elsevier Science B.V.

[2] S. W. S. McKeever. Radiat. Prot. Dosim. 100 (2002) 27.

[3] M.S.Kulkarni International Journal of Luminescence and Applications 2 (2012) 84.

OSL characterization of existing materials [4]. Yukihara and McKeever remark that "the development of synthetic materials with optimal characteristics, such as was the case with Al_2O_3:C, will require a more focused effort and one in which material synthesis and characterization of luminescence and physical properties are carried out hand-in-hand".

One of the reasons for availability of only a handful of OSL dosimetry materials with adequate properties is that they have to satisfy certain stringent conditions necessary for such applications. The important conditions which have been listed quite often are [5]-

1. Tissue equivalence (Zeff =7.22)
2. Sufficiently high sensitivity and accuracy
3. Linearity of dose response over a wide range (μGy – few Gy)
4. Dose rate independence of the response
5. Negligible thermal as well as anomalous (tunneling) fading (loss of luminescence signal due to ambient conditions, temperature etc.), ~ 5% over the monitoring period.
6. Emission spectra preferably in the range 300-400 nm
7. Stimulation spectrum having good overlap with 470 nm LED emission
8. Long-term stability under varying environmental conditions

---

[4] E.G.Yukihara and S.W.S.McKeever, Optically Stimulated Luminescence Fundamentals and Applications (2011) John Wiely & Sons Ltd., UK.

[5] M. P. Chougaonkar, Munish Kumar and B. C. Bhatt International Journal of Luminescence and Applications 2 (2012) 194.

9. Reusability

10. Low cost of preparation

Several materials have been excluded from the "starting list" due to condition 8. Especially, hygroscopic materials are considered totally unsuitable. Example of NaCl is a case in hand. OSL in NaCl has been reported several times [6,7,8,9,10]. However, it is not included in the list of suitable phosphors [4], presumably due to its hygroscopic nature and water solubility. In this chapter, we have described development of suitable, "water-proof" dosimeters from hygroscopic materials such as NaCl and NaF.

2. Experimental

2.1 Preparation of phosphors

2.1.1 NaCl:Cu

NaCl:Cu was prepared by wet chemical process For the preparation of NaCl:Cu, A.R. grade NaCl was first dissolved in double distilled water. The aqueous solution of $CuCl_2$ was added to it so as to give the ratio Na:Cu 10^4:1 and then the resultant solution was evaporated to dryness on a hot plate. It yielded white powder of NaCl:Cu. This powder was melted in graphite crucible at 810^{o}C and quenched to room temperature.

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[6] R.M. Bailey, G. Adamiec, E.J. Rhodes Radiat. Meas. 32 (2000) 717.

[7] H.Nanto, T.Usuda, K.Murayama, S.Nakamura, K.Inabe, and N.Takeuchi. Radiat. Prot. Dosim. 47 (1993) 293.

[8] K.J. Thomsen, L. Bøtter-Jensen and A. S. Murray, Radiat. Prot. Dosim. 101 (2002) 515.

[9] Ch. Bernhardsson, M. Christiansson, S. Mattsson and Ch. L. Raaf, Radiat.Environ. Biophys. 48 (2009) 21.

[10] Magdalena Biernacka, Arkadiusz Mandowski, Radiat. Meas. 56 (2013) 31.

2.1.2 NaF:Ca,Cu

NaF:Cu was prepared by simple melt-quenched technique. For the preparation of NaF:Ca,Cu , a certain amount of HF was taken in the Teflon beaker. Analytical grade Na_2CO_3 was added slowly in the HF till the effervescence was observed. Then the mixture was dried in open air for 5 to 6 days, which yielded white powder of NaF. Then the solutions of $CuCl_2$ and $CaCl_2$ in water were sprinkled over it and again dried under the lamp. Phosphor is heated with an appropriate RAP agent like NH_4Cl in a closed glass tube at about 400^0C for 1 hour with loosely closed lid. Then it was melted at 1000^oC in graphite crucible and quenched to room temperature.

The samples thus obtained in above preparations were ground and sieved to the particle size of 72 - 200 micron.

2.2 Preparation of pellets

The epoxy based pellets of both the phosphors were prepared as described in section 2.5.4 of chapter 2 using the epoxies 5012 A and 5012 B. The epoxies were mixed in the ratio 2:1. The phosphors in weight ratio 1:5 were added to the epoxy and mixed thoroughly. The mixture was then poured into the mould to make the pellets of 10 mm diameter with the thickness of 0.25 mm. Pellets weighing 42 ± 0.1 mg (phosphor content 7 mg) were selected for the experiments. These will be referred to as $NaCl_{SCP}$ for singly coated pellets of NaCl and NaF_{SCP} for that of NaF. Some of the pellets were given additional coating of the same epoxy. These will be referred to as $NaCl_{DCP}$ and NaF_{DCP}. To ensure that there is no contribution of epoxy to OSL, some blank pellets were also included in the OSL studies.

PL spectra in the spectral range 220-700 nm were recorded at room temperature on Hitachi F-4000 spectro-fluorimeter with spectral slit widths of 1.5 nm. $^{90}Sr/^{90}Y$ beta-ray source with dose rate of 20 mGy/min was used for irradiation. The CW-OSL and TL response of the samples are recorded on the integrated TL-OSL reader system. CW-OSL readouts were carried out using blue (470 nm) light stimulation and a Schott UG 1 filter (UV band pass filter with maximum transmittance at 360 nm having a transmittance 0.02 at 420 nm) in front of the photomultiplier tube. The stimulation light intensity at the sample position was 48 mW/cm^2 and signal was recorded for 200 s with a 100 ms acquisition time. Details of the integrated TL-OSL reader system are described elsewhere [11]. OSL data integrated for the first four seconds of stimulation was used to compare the OSL sensitivities of the phosphors and commercial OSL phosphor Al_2O_3:C (Landauer)

3 Results and Discussions:

3.1 PL spectra of NaCl:Cu and NaF:Ca,Cu

[11] Kulkarni M.S., Mishra D.R. and Sharma D.N., Nucl. Instrum. Meth. Phys. Res. B 262 (2007) 348.

The PL spectra were studied. For NaCl:Cu strong emission (figure 1 d) is observed for Cu^+ (0.01 mol %) in near UV region in form of a peak around 357 nm. The corresponding excitation spectrum shows a peak around 254 nm (figure 1 c). This is consistent with the information available on Cu^+ PL [12]. For NaF:Ca,Cu The broad band emission was observed around 330 nm to 450 nm. The Cu^+ emission was observed at 365 nm (figure 1b) for the excitation of 254 nm (figure 1a). This is consistent with the information available on Cu^+ PL [13].

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[12] J. Simonetti, D.S. McClure, Phys. Rev. B, 16 (1977) 3887.

[13] S. A. Payne, A.B. Goldberg and D.S. McClure, J. Chem. Phys. 78 (1983) 3688.

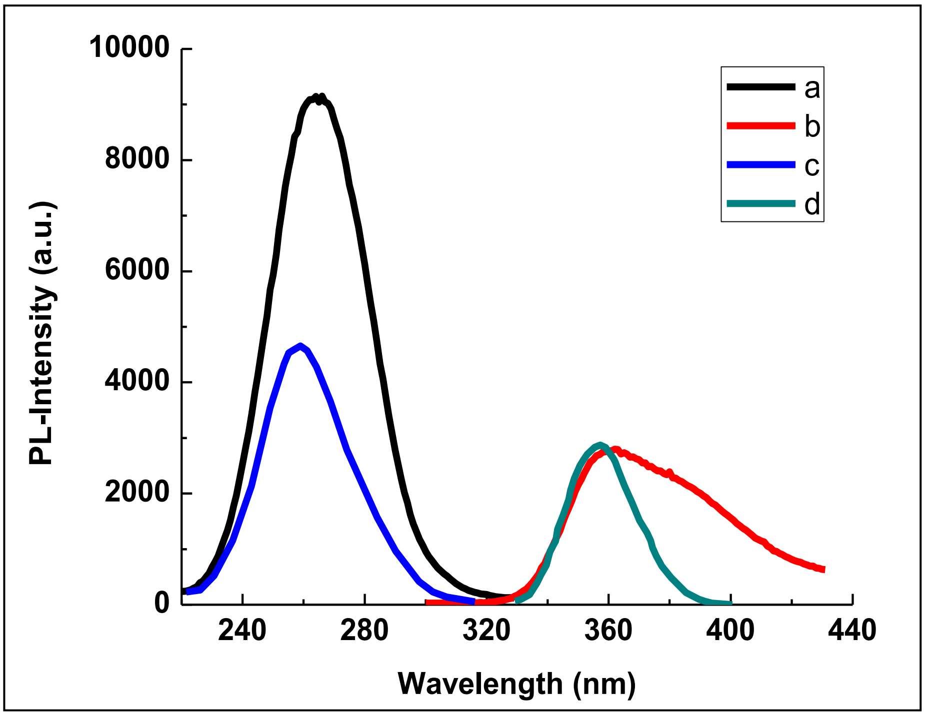

Figure 1 PL spectra of NaCl:Cu and NaF:Ca,Cu

a) NaF:Ca,Cu excitation for 365 nm emission
b) NaF:Ca,Cu emission for 254 nm excitation
c) NaCl:Cu excitation for 357 nm emission
d) NaCl:Cu emission for 254 nm excitation

3.2 TL in NaCl:Cu and NaF:Ca,Cu

The glow curves of the powders for the exposure of 100 mGy of beta rays are as shown in figure 2. TL glow curve was recorded with the heating rate of 5°C/second. The glow peaks for NaCl:Cu were observed around 121°C and 155°C. Whereas for NaF:Ca,Cu the glow peaks were observed around 160°C and 208°C.

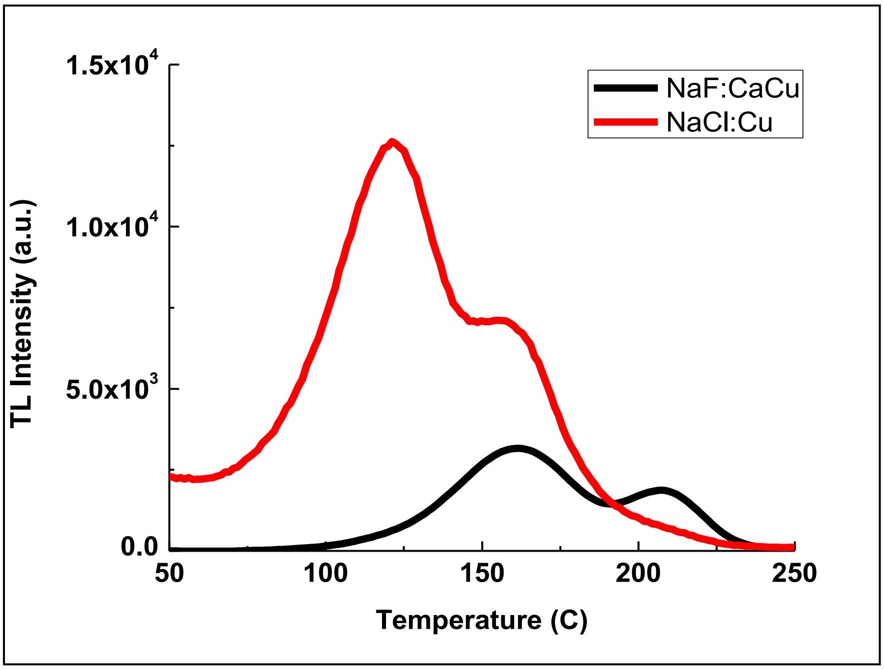

Figure 2: TL glow curves for NaCl:Cu and NaF:Ca,Cu for 100 mGy of beta exposure.

All these properties are more or less similar to those reported in the literature. However, samples in the form of loose powder are not suitable as dosimeter due to hygroscopic nature. The pellets of the phosphor are free from this drawback, as shown in following sections.

3.3 CW-OSL in NaCl:Cu and NaF:Ca,Cu

Figure 3 shows the CW-OSL curves of the powders for 100 mGy of beta exposure. The CW-OSL signals of the phosphors were compared with that of commercial phosphor Al_2O_3:C (Landauer). The comparison of CW-OSL signals is given in table 1. The CW-OSL in NaF:Cu was also studied. NaF:Ca,Cu was found to be more sensitive than NaF:Cu hence further studied were done using NaF:Ca,Cu.

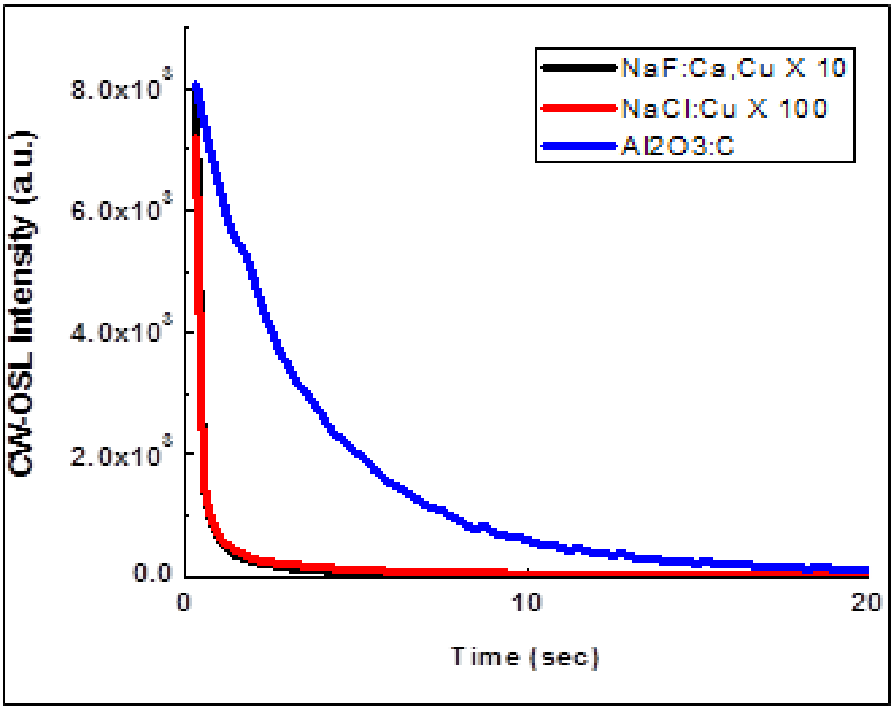

Figure 3: CW-OSL curves for NaCl:Cu and NaF:Ca,Cu compared with Al_2O_3:C for 100 mGy beta exposure

Name of phosphor	**Area integration over 60 seconds**	**Averaging the OSL counts for first 5 second**
Al_2O_3:C	1.00	1.00
NaCl:Cu	13.00	16.00
NaF:Ca,Cu	1.00	2.00

Table 1: Comparison of CW-OSL sensitivities of NaCl:Cu and NaF:Ca,Cu with Al_2O_3:C

3.4 Leachability NaCl:Cu and NaF:Ca,Cu pellets

Measurements were made for 25 numbers each of singly and doubly coated pellets. The sensitivity variation from pellet to pellet was within ±5 %. Sensitivity of pellets is about 20 % lower than that of powders. This is due to loss of signal by scattering, internal reflections, etc. within the epoxy. Blank pellets did not show any OSL, thus confirming that there is no contribution of epoxy to OSL signal.

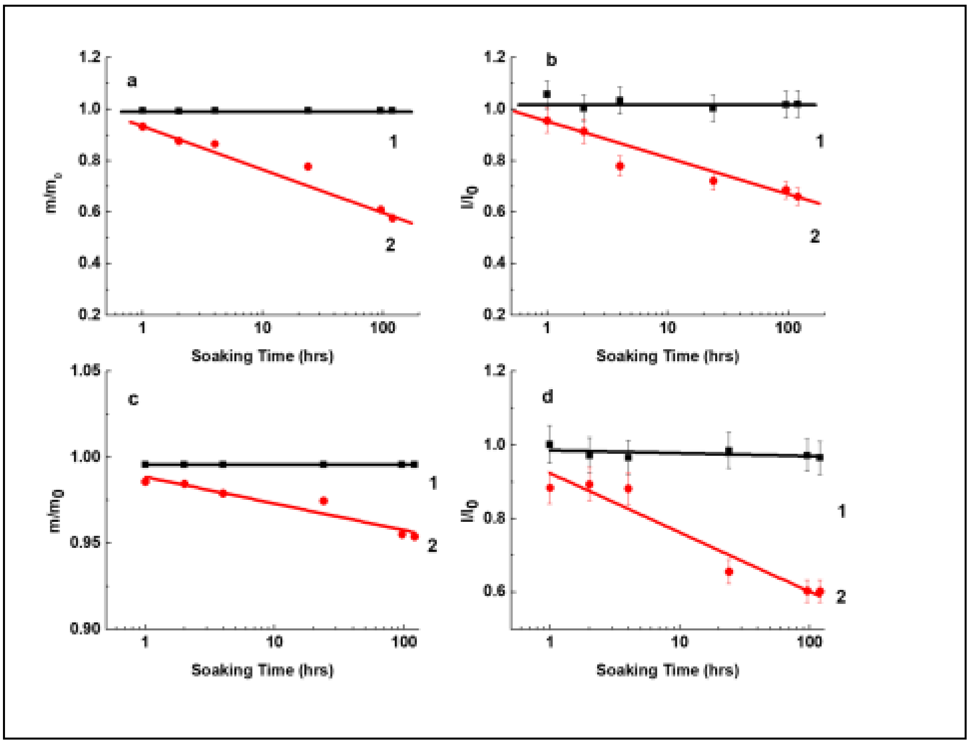

Figure 4: Effect of leaching on

a) Phosphor mass of 1. $NaCl_{DCP}$ and 2. $NaCl_{SCP}$
b) OSL sensitivity of 1. $NaCl_{DCP}$ and 2. $NaCl_{SCP}$
c) Phosphor mass of 1. NaF_{DCP} and 2. NaF_{SCP}
d) OSL sensitivity of 1. NaF_{DCP} and 2. NaF_{SCP}

For studying the leaching behaviour, the pellets were kept in distilled water for different duration of time ranging from 1 hour to 5 days. These wet pellets are allowed to dry by gently wiping and soaking water with help of tissue paper. The CW-OSL sensitivities for the pellets after soaking for different durations were measured by exposing them to 20 mGy. Results are presented in figures 4. It is seen from figures 4a and 4c, that after immersing in water, phosphor gets partially dissolved for both $NaCl_{SCP}$ and NaF_{SCP}. The amount of dissolved phosphor goes on increasing monotonously. In 100 hours about 50 % of the phosphor is leached away for $NaCl_{SCP}$ whereas only 5% leaching of phosphor was observed in NaF_{SCP}. However no such leaching is observed for $NaCl_{DCP}$ and NaF_{DCP} pellets and weight remains constant. Difference in the OSL sensitivities follows similar trend (figure 4b and figure 4d). Both $NaCl_{DCP}$ and NaF_{DCP} do not show any variation beyond the statistical errors in the measurements (about ±3%). The OSL sensitivities for $NaCl_{SCP}$ and NaF_{SCP} pellets go on monotonously decreasing with the leaching time. About 35% reduction of OSL sensitivity was observed for $NaCl_{SCP}$ whereas for NaF_{SCP}, OSL sensitivity decreases by about 40% when compared with the OSL sensitivity of corresponding unsoaked pellets.

4 Conclusions

PL and TL properties of the phosphors are more or less similar to those reported in the literature. Both phosphors show good OSL signals as compared to commercial phosphor Al_2O_3:C. The OSL signal of NaCl:Cu was about 16 times more intense when compared with Al_2O_3:C whereas NaF:Ca,Cu was found to be equally sensitive as Al_2O_3:C.

OSL dosimeters can be prepared from the hygroscopic materials like NaCl and NaF. Not only, that the prepared dosimeters are insensitive to moisture, but these can even be immersed in water and still the OSL sensitivity remains unaffected. Though here NaCl:Cu and NaF:Ca,Cu phosphors were taken as an example, the work can be extended to other hygroscopic and/or water soluble materials. Hygroscopic materials, hitherto considered as unsuitable for use as OSL phosphors, can be in the reckoning, if the other properties like sensitivity, etc. are adequate. This will be of help in finding new OSL materials.