Development of LED based OSL dosimeters for personal monitoring

P. J. Yadav

Department of Electronics, RTM Nagpur University, Nagpur, 440033

E-mail: yadav.pooja75@yahoo.in

Abstract. A subset of solid state materials have long been used as integrating dosimeters because they store energy deposited as a result of their interactions with ionizing radiation and then, when stimulated appropriately, release a proportionate amount of visible or near-visible light. During the 1960s, thermoluminescent dosimeters (TLDs), for which heat is used to extract the stored dosimetric signal, began to replace the photographic film as occupational dosimeters of record and for medical dosimetry. At the end of the twentieth century, a viable optically stimulated luminescent (OSL) material was developed which is now gaining in popularity as both an occupational and medical dosimeter. In this paper we give the designing and study of LED based OSL dosimeters for personal monitoring.

1. Introduction

OSL reader systems [1-3] are in great demand in all the research and academic institutions for their applications in advanced radiation dosimeters research. This type of OSL measurement systems are not available for the routine personnel and environmental radiation monitoring, medical and research applications. Hence most of the OSL readers are designed by researchers to record the dosimeters readings. These types of OSL readers are specially designed for to be used in dating of archaeological and geological samples. In the market, these dosimeters are very costly and are not that much easy to use for researchers. Therefore for laboratory applications and experiments with different excitation and various intensity, excitation sources are used. In any OSL reader three different excitation wavelengths i.e. blue, green, and infrared LEDs are used. For the OSL measurement of Al2O3:C [1-4] a bunch of blue LEDs are found to be very useful and maximum light energy of 100 mW/cm² [5] were recorded for these LEDs. Hence, for research applications, blue LEDs were found to be very useful. Instead of the very expensive laser systems, the high brightness blue, green and infrared LEDs can be used in any OSL reader systems. The main thing to be kept in account is that only the luminescence emitted from the sample should be detected and the stimulating wavelength is to be filtered out. Hence a good absorbent material filter is to be connected between the PMT and the sample. This filter material will allow only the emission wavelength from the sample to reach to the detector. There are three modes for detecting recording the OSL signals as continuous wave OSL, pulsed OSL and linearly modulated OSL methods. The CW-OSL mode, the stimulation intensity is kept constant (in time domain) throughout the readout and the decay of OSL signal with time is recorded. The POSL mode, measures a train of short pulses (<500 ns) of stimulation light are flashed on the sample and the emitted luminescence is synchronously detected in the period between the stimulation pulses [6-7].
Danby et al. [8] has designed the OSL reader system which can read user defined variable pulse width for POSL measurements. This technique requires less optical filtering as compared to the other OSL technique. The linear mode OSL technique the stimulation is increased gradually with time [9-11] and the OSL curve is recorded with multiple peaks related to different trap levels.

2. Experimental
Dosimeters for personnel monitoring are required in radiation department. This type of dosimeter should be small in size and easy to wear, so that the employs can carry it easily. Also, the readouts of the radiation exposure should be fast and accurate. In this part of our work we have developed the OSL reader for personnel monitoring. The entire setup of LED based OSL reader consists of following blocks:

- Excitation Source (LEDs)
- OSL material (Dosimeter Pellets)
- Filters
- Optical Detector (MPPC Module)
- Interfacing circuit
- Display Unit

In any OSL reader both the stimulation and emission spectra are characteristic of the phosphor. Blue excitation is needed for phosphors like Al2O3:C [6], BeO [12] and LiMgPO4:Tb [13], green excitation for MgO:Tb [14], Y2SiO5 [15], Porcelain [16] red for KBr:Eu [17] and IR excitation for feldspar [18]. Even for Al2O3:C some workers prefer green excitation over blue [19]. Hence, a versatile OSL reader should incorporate a variety of excitation sources. Usually, separate optical paths are chosen for different excitation sources which are located at separate physical locations. This makes design of OSL reader rather complicated.

We propose use of dual colour LED sources to tackle this problem. Metal clad PCB designed for this purpose is shown in Fig.1

![Metal Clad PCB](image)

Fig. 1 Metal Clad PCB

Thus, physically a single location is needed in the OSL reader for accommodating blue/green stimulation sources. This has become possible due to availability of single chips capable of delivering high optical power. Due to small sizes of the chips, optical paths are not altered much for two wavelengths. Though, here we have fabricated blue/green LED, any other combination can be chosen in a similar way. The concept can be easily extended to multi-colour LED which can be very useful for studying wavelength dependence of OSL properties.

3. Results and Discussions
The conventional OSL dosimeters for personal monitoring used in radiation departments are made in the form of circular pellets by mixing the Al2O3:C phosphor in Teflon. These pellets were then put into badges inside a light tight packet. During the readout of the radiation exposure, pellets were put in
the OSL reader without exposing it to light. But the OSL material pellets made with Teflon is not transparent and hence some of the emitted signal in the form of light (410 nm) will be absorbed by the Teflon material and the exposure readout will not be accurate. To solve this problem we have made the pellets of various samples of Al2O3:C phosphor in various concentrations for 7 mm diameters. Pellets were made by mixing the phosphor in epoxy resin, (A+B in the ratio of 2:1) the blend was poured in a mould having uniform circular holes and allowed to cure at room temperature for 24 hrs.

| Sample Name and No. | Epoxy (A+B) gm | Sample Wt. gm | Pellets diameter |
|---------------------|----------------|---------------|-----------------|
| Al2O3:C Sample 4    | 3 gm           | 0.6 gm        | 7 mm            |
| Al2O3:C Sample 15   | 3 gm           | 0.3 gm        | 7 mm            |
| Al2O3:C Sample(20-37um) | 3 gm         | 0.6 gm        | 7 mm            |
| Al2O3:C Sample(37-53um) | 3 gm         | 0.6 gm        | 7 mm            |
| Al2O3:C Sample(70-75um) | 3 gm         | 0.6 gm        | 7 mm            |
| Al2O3:C Sample(53-75um) | 3 gm         | 0.6 gm        | 7 mm            |
| Al2O3:C Sample 3    | 3 gm           | 0.6 gm        | 7 mm            |
| Al2O3:C Sample 1    | 3 gm           | 0.6 gm        | 7 mm            |

Photographs of Al2O3:C phosphor pellets are shown below,

In the next batch 1000 pellets of 7 mm dia and 0.2 mm thick were made for batch testing. The phosphor concentration in each pellet was kept same. A histogram for weight distribution is shown in Fig. 2. Nearly 60 % of the pellets are within +1 mg.

![Fig. 2: A histogram showing variation of weight of pellets with its equivalent number.](image)
Study on epoxy based Al2O3:C Pellets

All the readings were taken in BARC (Bhabha Atomic Research Centre, Mumbai) made photon counting module based OSL reader. 5 discs of epoxy based samples selected randomly. All samples are bleached and exposed to a known beta dose of 20 mGy using 90Sr/90Y source. OSL decay curves are recorded in COSL mode. Table 2 shows the data of all 5 samples.

| Disc | Counts | Icount in mGy | decay time | decay curve ht |
|------|--------|---------------|------------|----------------|
| d1   | 411148 | 0.559e-4      | 6.3        | 2454           |
| d2   | 379056 | 0.606e-4      | 5.5        | 2192           |
| d3   | 371051 | 0.619e-4      | 5.5        | 2217           |
| d4   | 336505 | 0.683e-4      | 5.5        | 2029           |
| d5   | 374019 | 0.614e-4      | 6.1        | 2238           |

Table 2: Shows the data of 5 samples exposed to 20 mGy of beta dose of 90Sr/90Y source

Decay curves of the 5 samples are shown in Fig. 3 below:

Fig. 3: Decay curves of 5 samples exposed to 25 mGy of Beta dose of 90Sr/90Y source

As the decay curves of the taken samples nearly overlap each other hence, they can be interpreted in the bar graph of five samples as exposed to 25 mGy of beta source is as shown in Fig. 4. Comparison of decay constants of epoxy based samples, pure powder based Al2O3:C dosimeter and Teflon based
Al₂O₃:C dosimeter. Fig. 5 shows the selected 5 dosimeters of each type and exposed to same dose of 25 mGy and decay curves of three samples was compared.

![Decay curves of three different types of samples exposed to 25 mGy of beta dose](image)

Fig. 5: Decay curves of three different types of samples exposed to 25 mGy of beta dose

4. Conclusions
As seen from the characterization and study of pellets made with epoxy in comparison with those made by Teflon shows a large variation in the resultant parameters. The decay counts in epoxy based pellets are less and also the decay is fast as compared to Teflon based pellets. This problem can be overcome by using other epoxy resin with good absorption characteristics.

References
[1] V.J. Bortolot, Radiat. Meas. 32 (2000) 751.
[2] T. Hashimoto, T. Nakagawa, D.-G. Hong, M. Takano, J. Nucl. Sci. Technol. 39 (2002) 108.
[3] L. Botter-Jensen, G.A.T. Duller, Table 1: A brief summary of prepared pellets is given.
[4] L. Botter-Jensen, V. Mejdahl, A.S. Murray, Quatern. Geochronol. 18 (1999) 303.
[5] K.J. Thomsen, L. Botter-Jensen, P.M. Denby, P. Moska, A.S. Murry, Radiat. Meas. 41 (2006) 768.
[6] S.W.S. McKeever, Nucl. Instr. and Meth. B 184 (2001) 29.
[7] S.W.S. McKeever, M.S. Akselrod, B.G. Markey, Radiat. Prot. Dosim. 65 (1996) 267.
[8] P.M. Denby, L. Botter-Jensen, A.S. Murry, K.J. Thomsen, P. Moska, Radiat. Meas. 41 (2006) 774.
[9] E. Bulur, Radiat. Meas. 26 (1996) 701.
[10] M.S. Akselrod, S.W.S. McKeever, Radiat. Prot. Dosim. 81 (1999) 167.
[11] V.H. Whitley, S.W.S. McKeever, Radiat. Prot. Dosim. 100 (2002) 61.
[12] M. Sommer, A. Jahn, and J. Henniger, Beryllium oxide as optically stimulated luminescence dosimeter, Radiat. Meas., 43 (2008) 353.
[13] Bhushan Dhabekar, S.N. Menon, E. Alagu Raja, A.K. Bakshi, A.K. Singh, M.P. Chougaonkar, Y.S. Mayya Nucl. Instrum. Meth. B 269 (2011) 1844
[14] A.J.J. Bos, M. Proke, and J.C. Brouwer, Radiat. Prot. Dosim., 119 (2006) 130.
[15] J.R. Hazelton, E.G. Yukihara, L.G. Jacobsohn, M.W. Blair and R. Muenchausen (2010) Radiat. Meas., 45, 681.
[16] L. Botter-Jensen, B.G., Markey, N.R.J. Pooiton and H. Jungner Radiat. Prot. Dosim. 65 (1996) 369.
[17] D.M. Klein, and S.W.S. McKeever Radiat. Meas., 43 (2008) 883
[18] M.R.Baril, Radiat. Meas.38 (2004) 81.

[19] N.K.Umiedo, E.M. Yoshimura, P.B.R.Gasparian and E.G.Yukiara. *Radiat. Meas* 45 (2010) 151