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Thermoluminescence characterizations of NaF:Ce phosphor for radiation dosimetry.

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ABSTRACT

The thermoluminescence (TL) characterizations of gamma-irradiated NaF:Ce (0.1-0.5 mol%) phosphor for radiation dosimetry are reported in this paper. Peak TL intensities varied sublinearly with gamma-ray dose in all samples. TL peak height was found to be dependant on the concentration (0.1–0.5 mol%) of added Ce in the host. This material may be useful for ionizing radiation dosimetry.

Keywords: Thermoluminescence (TL), ionizing radiation dosimetry, NaF:Ce phosphor.

INTRODUCTION

Luminescent materials are used for various purposes such as making lamps [1–3], CR tubes and TV screens [4], electroluminescent lamp and display panels, LEDs, detectors for X-ray imaging [5–8], scintillation detectors [9],laser crystals [10], paints [11], and solar concentrators [12]. In many of these applications inorganic solids doped with rare-earth impurities are used. Rare-earth (RE) ions possess unique optical behaviors when doped in to materials and have paved the way for the development of optical amplifiers and phosphors. Many workers [13–15] have studied some mixed sulphate system for their applications in dosing of high-energy radiations using TL technique.

They have synthesized and characterized $K_2Ca_2(SO_4)_3$:Eu,Dy [16] and $K_2Ca_2(SO_4)_3$:Eu [17], $NaSO_4$:Eu [18], $LiNaSO_4$:Eu,Dy [19] mixed sulphates. Parret and Bouillet [20] reported that; the presence of a small concentration of random rubidium impurities caused a remarkable shift of the phase transition temperature. Moharil and co-workers [21–24] have reported several phosphors on RE ions-doped mixed sulphate.

Thermoluminescence (TL) has been extensively studied and is being used widely in ionizing radiation dosimetry. The process involves the storage of small percentage of the incident energy in the metastable states (traps) in the crystal. The energy is released when the crystal is heated and a part of this energy appears as visible emission. Thermoluminescence (TL) is a related property shown by phosphors. This phenomenon involves radiative recombination of thermally released electrons or holes from their traps, which were created by exposure to ionizing radiation. This is an efficient tool for studying the electronic trap levels in crystals, and finds practical application in thermoluminescence dosimetry (TLD) used for radiation dose measurements. TLD is based on the principle that the amount of light released by the phosphor material, which has been previously exposed to ionizing radiation, will depend on the radiation dose received by the material. TLD badges, which carry specially tuned phosphor material, are widely used in personnel as well as environmental radiation monitoring. Though a large number of organic and inorganic materials exhibit thermoluminescence, only a small fraction possesses all the ideal characteristics of a good TLD phosphor. Thermoluminescence dosimetry (TLD) has recently attracted special attention because of (i) low cost and high sensitivity of the phosphor (ii) the absence of any associated electronics at the site measurement, and (iii) the fact that the TL phosphor dosimeter can operate unattended; it permits network monitoring with modest expenditure. The small size of solid phosphor would be conducive to carrying out skin transmission studies in vivo. The existence of commercially available TL instrumentation is favorable to uniformity between different laboratories. Different materials are standardized for fabrication as solid state dosimeters [25]. In this paper, we have reported the thermoluminescence characterizations of NaF:Ce(0.1-0.5mol%) phosphors in polycrystalline powder form for the radiation dosimetry.

METHODOLOGY

All chemicals used in this present work were analytical grade and used as received. Distilled water was used in the preparation of solutions. All samples are synthesized by wet chemical route. In the typical synthesis of NaF:Ce (0.1- 0.5 mol %); NaF and $CeCl_3$ were dissolved in distilled water and stirred to prepare clear solution of NaF and $CeCl_3$ and then for required sample the desired $CeCl_3$ solution were mixed in NaF solution. The mixture was appeared as chemically homogenous transparent liquid. These solutions then were kept in hot air oven at 80 ^{0}C for 4-5 days till the solutions were completely dried. The crystal structure of the product was slightly crushed to powder. The prepared residues were used for further study. All samples were annealed at 500 ^{0}C for 1 hr and quenched to room temperature. Samples were irradiated by ^{60}Co source with the dose rate as 0.37 kGy/hr. Thermoluminescences were taken by PC-based thermoluminescence analyzer (1009 I) system with the constant heating rate of 5 ^{0}C/second.

RESULTS AND DISCUSSION

The TL glow curves of prepared samples for 0.006166 kGy gamma ray exposure is shown in **Figure 1**. In the case of alkali halides, F and V centres are generally responsible for the release of energy in the form of cold light on heating of pre-irradiated crystalline solids [26]. In all samples, the TL intensity increased with temperature, attained maximum value and then decreased with the further increase in temperature. The peak TL intensity was found to be good for all Ce-doped samples, (0.2-0.5 mol%) but for NaF:Ce (0.3 mol%), the increase in TL intensity is comparatively greater than for all other concentrations. This may be due to more colour centres formed in this sample after irradiation by γ-rays [26]. There are two peaks in all samples. The first peak is at around 180 ^{0}C and second peak is at around 375 ^{0}C.

The TL glow curve for NaF:Ce contains two peaks at 180 ^{0}C and 375 ^{0}C **(Figure 1)** thereby showing that there are two different kinds of traps created due to high energy irradiation. On F bleaching, both the peaks reduce in intensity [27].

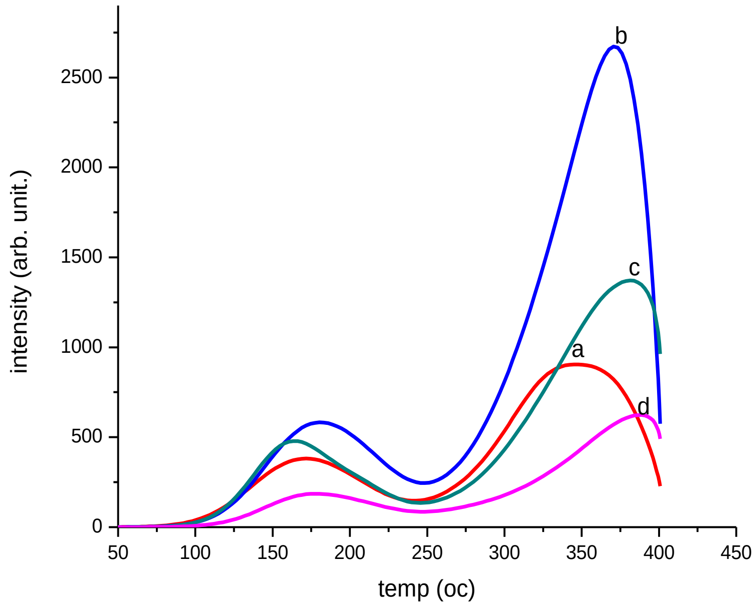

Figure 1: TL glow curve of NaF:Ce (0.2–0.5 mol%) exposed to a gamma ray dose = 0.0061kGy. (a) NaF:Ce (0.2 mol%) (b) NaF:Ce (0.3 mol%) (c) NaF:Ce (0.4 mol%) (d)NaF:Ce (0.5 mol%)

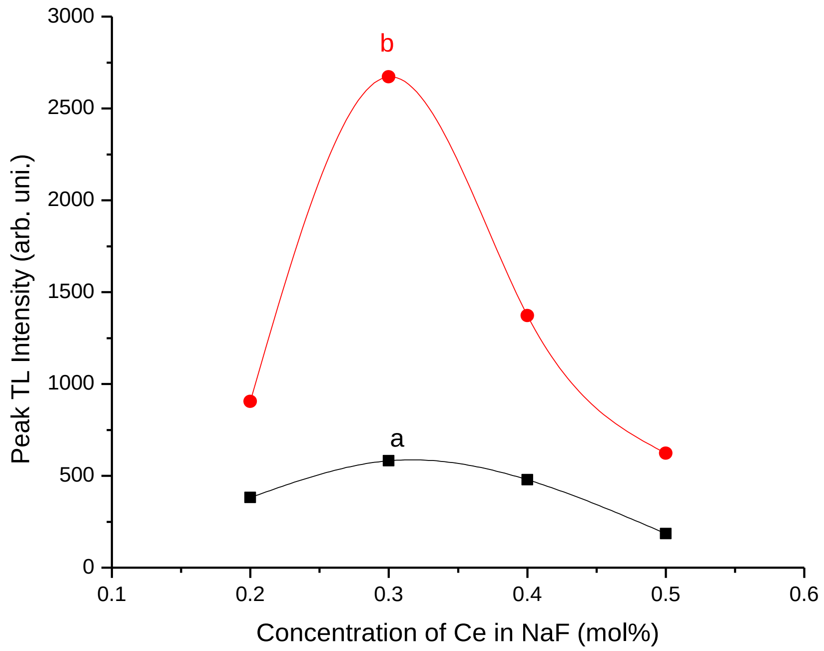

Figure 2: Variation in peak TL intensity with different concentrations of Ce doped in NaF (a) peak at around 180 ^{0}C and (b) peak at around 375 ^{0}C

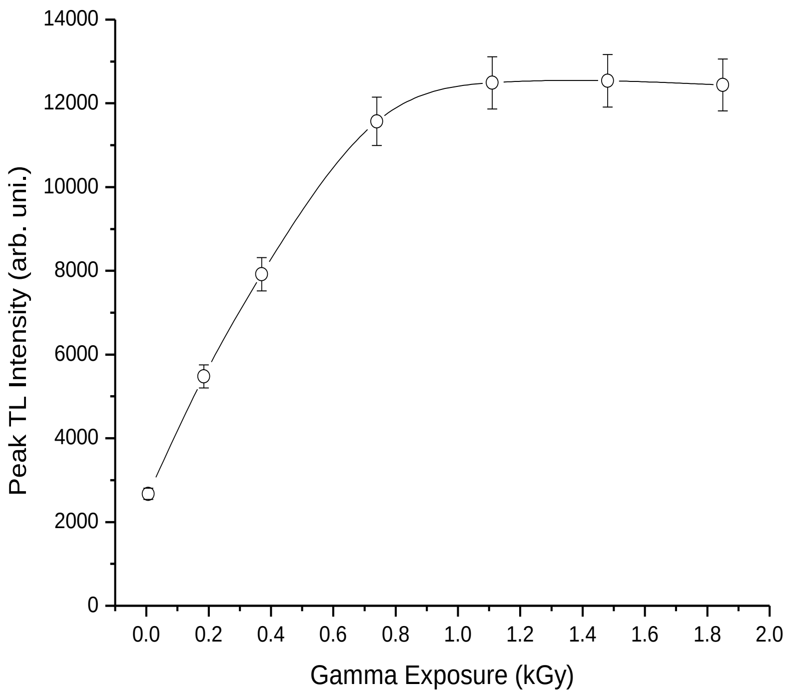

Figure 3: Variation of peak TL Intensity (at around 375 ^{0}C) of NaF:Ce (0.3 mol%) sample with different gamma exposure

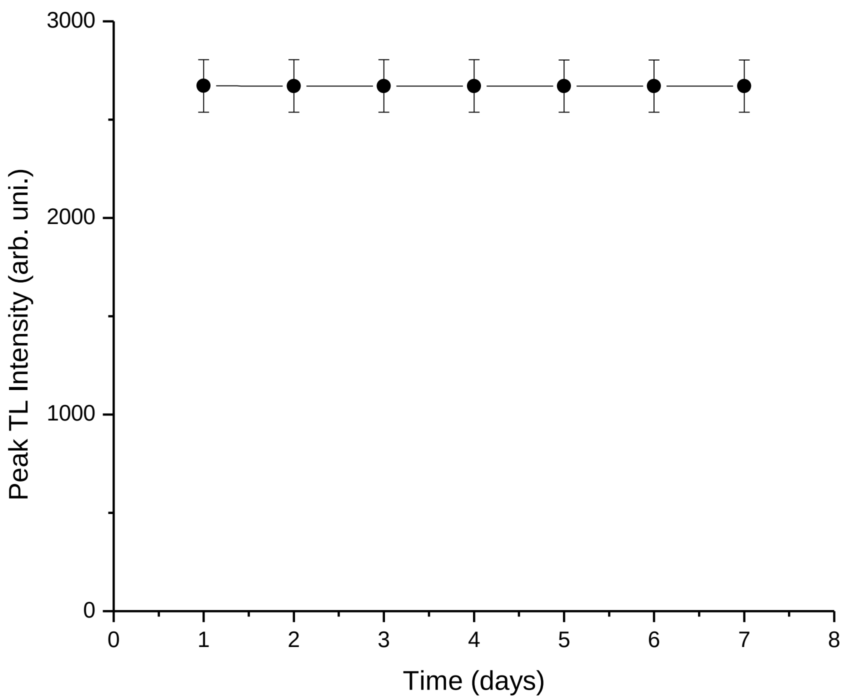

Figure 4: Fading in peak TL Intensity (at around 375 ^{0}C) of NaF:Ce (0.3 mol%) sample

The variation in peak TL intensity with different concentrations of Ce doped in NaF is shown in **Figure 2**. The TL intensity of the prepared samples was found to be dependant on the concentrations of Ce doped in the host material. It is observed that the TL intensity is varied on added concentration of rare earth impurity in the host [26, 27]. The TL intensity is maximum at 0.3 mol% in the prepared NaF:Ce sample. The TL intensity then decreases as the concentration of Ce in NaF increases. This may be due to concentration quenching. A low concentration of impurity ions gives the maximum intensity. In terms of cost, this is a good characteristic for the development of materials for radiation dosimetry.

Figure 3 shows the variation of peak TL intensity of NaF:Ce (0.3 mol%) sample with different gamma exposure. It indicates that the curve is sublinear but TL intensity varies linearly upto about 0.8 kGy and then it increases sublinearly. This is because, when an alkali halide crystal is exposed to high energy radiation like gamma-rays or X-rays, excitation of the electrons of halides atoms from the valence band to the conduction band takes place. Some of the excited electrons return immediately from the conduction band to the valence band, however, some of the electrons in the conduction band become trapped in the negative ion vacancies during their movement and consequently formation of colour centres takes place. Initially, the number of colour centres increases with the radiation dose given to the crystals and therefore luminescence intensity increases with radiation dose. However, with long duration of the irradiation of the crystals, recombination between electrons and holes takes place and consequently the density of colour centres in the crystals attains saturation. The curve becomes get saturated after for higher dose of gamma exposure. This is due to as gamma dose increase the concentrations of colour centres in the sample increases upto certain gamma dose and then there is concentration quenching [26, 28]. The error bars in **Figure 3** indicates that there is a slight change in the TL intensity of about 5%, as noted by repeating the experiment a number of times.

Measurement of high-dose radiation is a challenging task and it is required for accidental dosimetry. The NaF:Ce (0.3 mol%) phosphor shows the dose measurements possible upto about 0.8 kGy gamma exposure using thermoluminescence technique, and has a negligible fading. Therefore the prepared phosphor may be useful for accidental radiation dosimetry.

The fading of TL intensity is found to be minimal and shown in **Figure 4**. The samples were stored in dark at constant room temperature. The loss of TL intensity in dark is always less in darkness [26]. The error bars indicate that there is a change in the values of peak TL intensity in NaF:Ce (0.3 mol%) material of about 5%.

CONCLUSION

TL is reported in NaF:Ce material. The thermoluminescence (TL) characterizations of gamma irradiated NaF:Ce phosphor shows one peak at around 180 ^{0}C and other peak at around 375 ^{0}C. This may be due to formations of different phases of traps in the doped sample. TL intensities is found to be dependant on the concentration (0.1–0.5 mol%) of added Ce in the host. The material shows a negligible reduction in TL intensity on storage in dark. These characteristics show that the prepared NaF:Ce (0.3 mol%) phosphor may be applicable in TL dosimetry for high-dose measurements, i.e. in the case of accidental ionizing radiation dosimetry.

Conflicts of interest: The authors stated that no conflicts of interest.

REFERENCES

1. T. Welker, J. Lumin. 48 & 49 (1991) 49.
2. B.M.J. Smets, Mater. Chem. Phys. 16 (1987) 283.
3. B.M.J. Smets, in: Di Bartolo (Ed.), Adv. Non-radiative Progress solids, Plenum Press, NY, 1991, p. 375.
4. R. Raue, A.T. Vink, T. Welker, Phil. Tech. Rev. 44 (1989) 335.
5. M.K. Crawford, L.H. Brixner, J. Lumin. 48 & 49 (1991) 37.
6. H. Von Saggern, Cryst. Lattice Defects Amorph. Mater 18 (1989)399.
7. W. Rossner, B.C. Grabmainer, J. Lumin. 48 & 49 (1991) 29.

8. A. Miejerink, G. Blasse, J. Phys. D. 24 (1991) 626.
9. M. Ishi, M. Kobayashi, Prog. Cryst. Growth Charact. Mater. 23(1991) 245.
10. Penzkoffer, Prog. Quantum Electron 12 (1988) 291.
11. W.H. Byler, J.J. Maffis, in: T.C. Paton (Ed.), Pigment Handbook, Wiley, NY, 1988,p. 881.
12. R. Reisfeld, C.K. Jorgenson, et al. Structure and bonding 49,119, Handbook of Physics and Chemistry of RE, North-Holland, NY, 1982, pp. 1–90.
13. S.M. Dhopate, P.L. Muthal, V.K. Kondawar, S.V. Moharil, P.D. Sahare, J. Phys. D 24 (1991) 1869.
14. P.D. Sahare, S.V. Moharil, Radiat. Eff. Defects Solids 114 (1990)167.
15. P.D. Sahare, S.V. Moharil, Radiat. Eff. Defects Solids 116 (1991)275.
16. A. Pandey, P.D. Sahare, Physica Status Solidi. (a) 199 (2003) 533.
17. A. Pandey, R.G. Sonkawade, P.D. Sahare, J. Phys. D 35 (2002) 2744.
18. A. Pandey, P.D. Sahare, J.S. Bakare, S.P. Lochab, F. Singh, D.Kanjilal, J. Phys. D 36 (2003) 2400.
19. A. Pandey, V.K. Sharma, D. Mohan, R.K. Kale, P.D. Sahare, J. Phys. D 35 (2002) 1330.
20. R. Perret, A.M. Bouillet, Bull. Soc. Fr. Mineral. Crystallogr. 98 (1975) 254.
21. S.V. Upadeo, S.V. Moharil, J. Phys. Condens. Matter 7 (1995) 957.
22. S.V. Upadeo, T.K. Gundurao, S.V. Moharil, J. Phys. Condens. Matter 6 (1994) 9459.
23. S.R. Nair, V.K. Kondawar, S.V. Upadeo, S.V. Moharil,T.K. Gundurao, J. Phys. Condens. Matter, 9 (1997) 8307.
24. S.J. Dhoble, S.V. Moharil, T.K. Gundurao, J. Lumin. 93 (2001) 43.
25. Alvarez Rivas J.L. Thermoluminescence and lattice defects in alkali halides. J. Phys. (Paris) 41-C6 **(1980)** 353–8.
26. P. M. Bhujbal and S. J. Dhoble, Luminescence 28 (2013) 879–881.
27. P.D.Sahare, J.S. Bakare, S.D. Dhole & A.A. Rupasov, J.Lumin. 130, 2010, 258-265.
28. B.P.Chandra, R.K. Tiwari, Reenu Mor, D.P. Bisen, J.Lumin, 75(2) (1997)127-133.