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Comparison of thermoluminescence in Dy activated KCl, NaCl and (KNa)Cl phosphors

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ABSTRACT

The synthesis and thermoluminescence (TL) properties of γ-irradiated KCl:Dy, NaCl:Dy and (KNa) Cl:Dy phosphors are reported in this paper. All phosphors were prepared by a wet chemical method. TL of all the phosphors has been recorded for different γ-doses. The TL intensity increases in all doped samples. The peak TL intensities is found to be sublinearly varies with γ-irradiation dose and with the concentrations (0.05-0.5mol%) of added Dy in all the samples.

Keywords: Thermoluminescence (TL), radiation dosimetry, KCl:Dy, NaCl:Dy and (KNa)Cl:Dy

INTRODUCTION

The measurement of radiation dose has become a science of ever increasing importance to the estimation of the risk and benefits inherent to the uses of and exposure of ionizing radiation. Thermoluminescence (TL) in alkali halides has been studied for more than sixty years. It is known that the emission is due to radiative recombination of halogen atoms thermally released from the interstitial positions with F centres [1]. In most of the experiments, irradiated alkali halides have been used, and while analyzing the thermoluminescence data it has most often been assumed that the irradiation has created equal number of recombination centres and filled traps.

Colour centres in alkali halides have now been studied for last many years. It is known that the electrolytic ally coloration produced in potassium halides lost within a day [2].

The colour centres have mostly been studied in single crystals, while applications such as dosimetry of the ionizing radiation using thermoluminescence (TL) more often involves measurements on powders. It is generally believed that the mechanism of colour centres production is similar for single crystals and microcrystalline powder. Colour centres production by γ-irradiation in NaCl, KCl and KBr is reported by Deshmukh and et. al. [3-6] in crystal and microcrystalline powder. On development of TL dosimetry materials, investigator concentrated on an enhancement in TL intensity.

Recently, Bangaru and co-workers [7,8] also reported enhanced luminescent properties and TL studies in alkali halides by doping rare earth materials. Bhujbal et. al. also observed the increased luminescence (i.e. LL,TL and ML) intensity in NaCl and KCl, doped with rare earth material [9,10]. Many alkali halide-based materials like LiF exhibit important dosimetric properties. The study of luminescence properties in alkali halides, to find possible dosimetric material is a challenging task in the development of radiation dosimetry.

In this paper TL gamma ray-irradiated KCl:Dy (0.05–0.5mol%), NaCl:Dy (0.05–0.5mol%) and (KNa)Cl:Dy (0.05–0.5mol%) materials are studied and compared with each other for possible applications of dosimetric materials..

METHODOLOGY

All phosphors containing different concentrations of Dy^{3+} (0.05-0.5mol%) were prepared by wet chemical method. The $(K_{0.5}Na_{0.5})Cl$ material was prepared by taking equimolar mass of KCl and NaCl and dissolved in distilled water. For the simplicity the $(K_{0.5}Na_{0.5})Cl$ sample is named as (KNa)Cl, throughout the paper. For preparation of KCl:Dy, NaCl:Dy and (KNa)CL:Dy the required concentration of Dy were added in the respective solutions. Then the solutions were evaporated at 80 ^{0}C in oven for about 4-5 days. The recrystallised residue were normally crushed to powder and heated at 500^{0}C in fabricated furnace for 1 hr and fast quenched to room temperature. Analytical Reagent Grade chemicals were used in present investigation. The samples were exposed to a γ-dose from ^{60}Co source having a dose rate of 0.50 kGy/hr.

Thermoluminescence were studied with PC based Thermoluminesce analyser (1009 I) system set-up. Glow curve were recorded by heating 1 mg sample in temperature range 10 to 300 ^{0}C with constant rate of 10 ^{0}C/min.

All experiments were performed in identical conditions and it is observed that the results are reproducible..

RESULTS AND DISCUSSION

Thermoluminescence glow curves:
Figure 1, 2 and 3 shows typical thermoluminescence glow curves of KCl (pure) and KCl:Dy, NaCl (pure) and NaCl:Dy and (KNa)Cl (pure) and (KNa)Cl:Dy respectively. An isolated single peak is observed due to only one type of luminescence centre is formed during irradiation by γ-rays in each sample. For KCl:Dy (0.1 mol%) and NaCl:Dy (0.1 mol%) the increase in TL intensity is about four times more than pure material. But for (KNa)Cl:Dy (0.1 mol%) sample the TL intensity increased about 1.25 times than pure sample. For KCl pure and Dy doped materials the temperature of TL peak intensity is remained same around 162 ^{0}C. For NaCl Pure and higher concentration (0.3 to 0.5 mol%) of Dy doped in hose materials the temperature of TL peak intensity is remained same around 220 ^{0}C and for other low concentration (0.05 to 0.2 mol%) of Dy doped in NaCl it remained same and is around 216 ^{0}C. This may be due to change of phase in prepared samples for low and high concentrations of Dy doping in NaCl host. But for (KNa)Cl pure sample TL peak intensity is observed at about 230 ^{0}C and all Dy doped samples shows the maximum TL intensity at about 213^{0}C. This may be due to change of phase on doping of rare earth material, Dy in the (KNa)Cl host material.

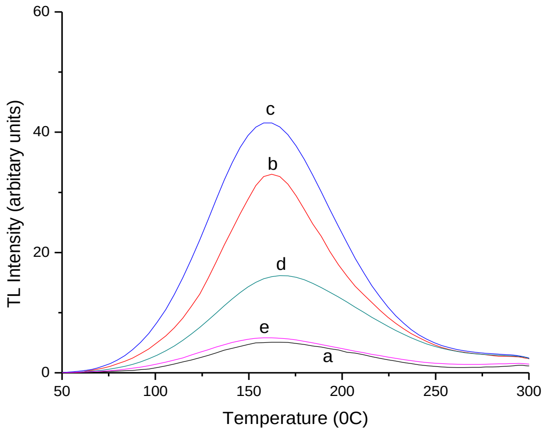

Figure 1: TL glow curve of KCl (pure) and KCl:Dy (0.05-0.3 mol%) exposed to gamma-dose = 0.50 kGy. (a)KCl (pure), (b)KCl:Dy (0.05 mol%), (c)KCl:Dy (0.1 mol%),(d)KCl:Dy (0.2 mol%), (e)KCl:Dy (0.3 mol%).

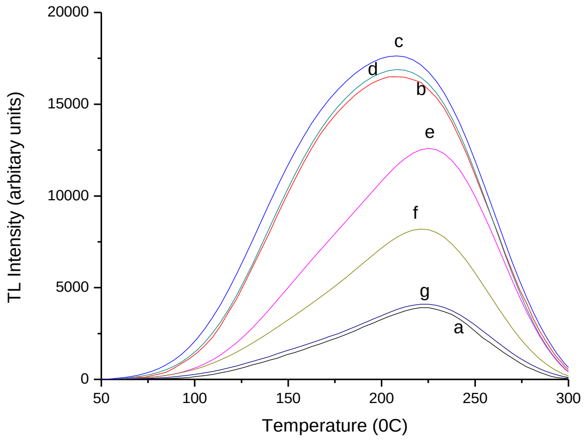

Figure 2: TL glow curve of NaCl (pure) and NaCl:Dy (0.05-0.5 mol%). exposed to gamma-dose = 0.50 kGy. (a)NaCl (pure) , (b)NaCl:Dy (0.05 mol%), (c)NaCl:Dy (0.1 mol%), (d)NaCl:Dy (0.2 mol%),(e)NaCl:Dy (0.3 mol%), (f)NaCl:Dy (0.4 mol%), and (g)NaCl:Dy (0.5 mol%).

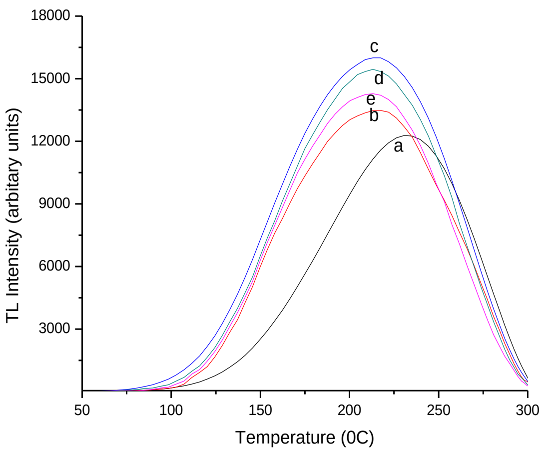

Figure 3: TL glow curve of (KNa)Cl (pure) and (KNa)Cl:Dy (0.05-0.3 mol%) exposed to gamma dose = 0.50 kGy.

(a)(KNa)Cl (pure) , (b)(KNa)Cl:Dy (0.05mol%), (c)(KNa)Cl:Dy (0.1mol%), (d)(KNa)Cl:Dy (0.2 ol%),(e)(KNa)Cl:Dy (0.3 mol%).

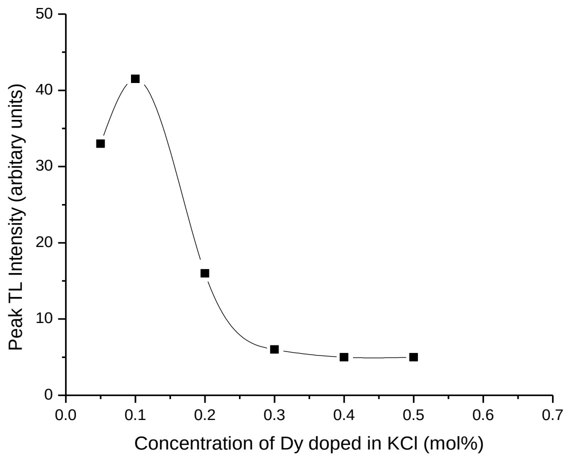

Figure 4: Variation of Peak TL Intensity with different concentration of Dy doped in KCl, exposed to gamma-dose = 0.50 kGy

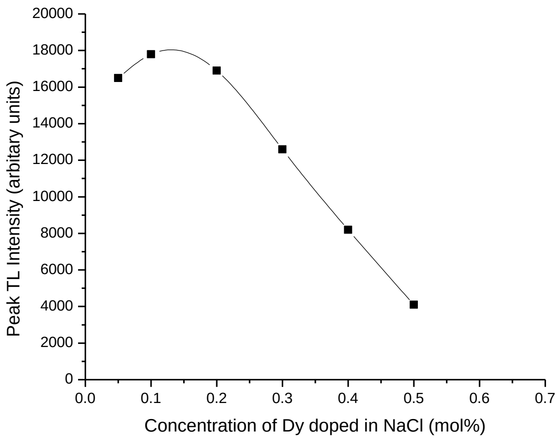

Figure 5: Variation of Peak TL Intensity with different concentration of Dy doped in NaCl, exposed to gamma-dose = 0.50 kGy

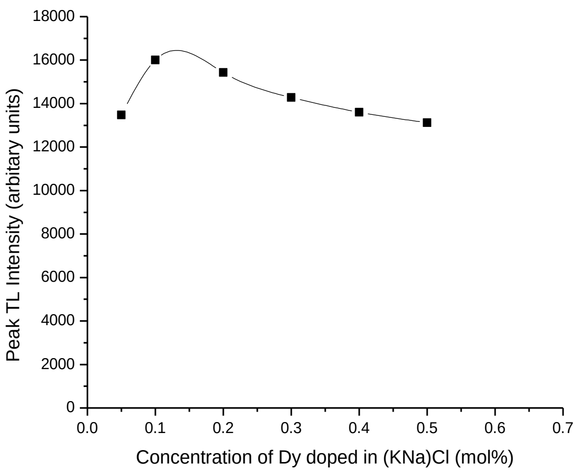

Figure 6: Variation of Peak TL Intensity with different concentration of Dy doped in (KNa)Cl, exposed to gamma-dose = 0.50 kGy

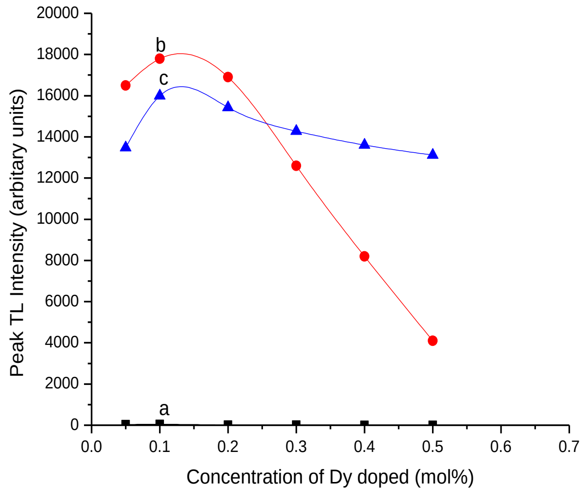

Figure 7: Comparison of Variation of Peak TL Intensity with different concentration of Dy doped in (a)KCl, (b) NaCl and (c) (KNa)Cl, exposed to gamma-dose = 0.50 kGy.

Effect of dopant concentrations on TL intensity :

The TL intensity is saturated at 0.1 mol% of Dy ions impurity doped in all samples and then it decreases (Figure 4 to figure 6). Low concentration of impurity ions shows the maximum intensity, which is a good characteristic for the development of materials for radiation dosimetry by cost wise.

Figure 7 shows the comparison of TL intensity of the prepared materials with different concentrations of Dy doped in respective host materials. The nature of variation of TL intensity is nearly same in all the materials. The TL the intensity for NaCl:Dy material is more than KCl:Dy sample and for (KNa)Cl:Dy material the TL intensity is in between the intensities of KCl:Dy and NaCl:Dy. The KCl:Dy sample is found to be very weak for TL intensity in comparison to that of NaCl:Dy and (KNa)Cl:Dy. Thermoluminescence intensity of (KNa)Cl:Dy material is less than NaCl:Dy but just below it. This is due to orientation of ionic radii of K^+ ions and the Na^+ ions in the (KNa)Cl:Dy materials since as the ionic radius of both the ions is different. Formation of color centres in this orientations of positive ions with Cl negative ions, as well as release of luminescence centres during thermally heating of the powder are responsible for TL intensity of (KNa)Cl:Dy sample.

Dependence of TL on radiation dose :

The TL intensity increases with the γ-rays exposure upto 0.5 kGy and then it becomes saturated after 0.5 kGy γ-rays exposure in all the materials. (Figure 8 to Figure 10). This is due to, when alkali halide crystal is exposed to high energy radiation like γ-rays or x-rays; excitation of electrons of halides atoms from valence band to 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 get trapped in the negative ion vacancies during their movement and consequently the formation of colour centres takes place. Initially the number of colour centres increases with the radiation doses given to the crystals and thereby, the luminescence intensity increases with the radiation dose. However for long duration of the irradiation of the crystals the recombination between electrons and holes takes place and consequently the density of colour centres in the crystals attains a saturation value. In fact, the luminescence intensity attains a saturation value for high radiation doses given to the crystallites [11]. Figure 11 shows the comparison of TL intensity with different gamma exposure. This also shows that the TL intensity of (KNa)Cl:Dy material lies in between the TL intensities of KCl:Dy and NaCl:Dy materials respectively. But the sublinear increase in TL intensity upto 0.5 kGy high dose for (KNa)Cl:Dy sample shows that the sample may be useful for high radiation dosimetry.

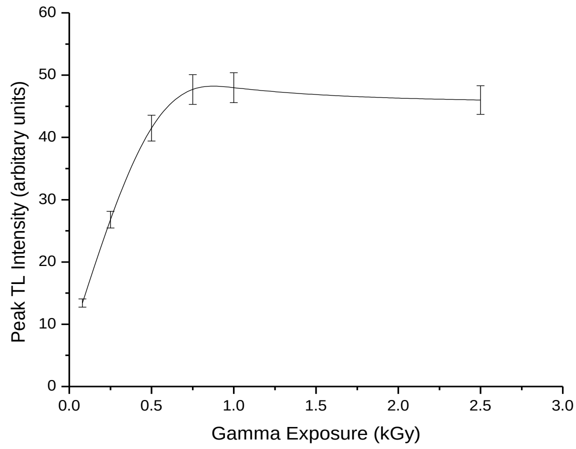

Figure 8: Variation of Peak TL with different gamma exposure of KCl :Dy (0.1 mol%).

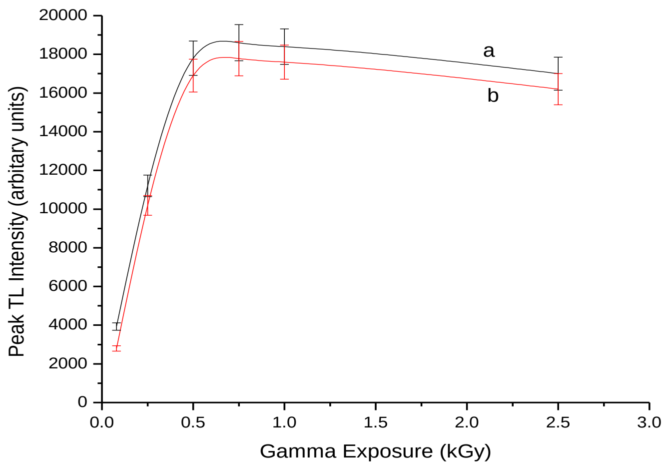

Figure 9 : Variation of Peak TL with different gamma exposure of (a)NaCl :Dy (0.1 mol%), (b)NaCl : Dy (0.2 mol%)

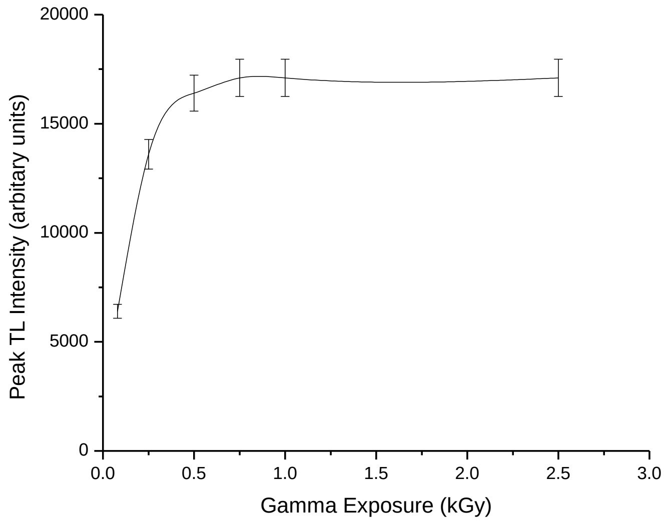

Figure 10 : Variation of Peak TL with different gamma exposure of (KNa)Cl :Dy (0.1 mol%).

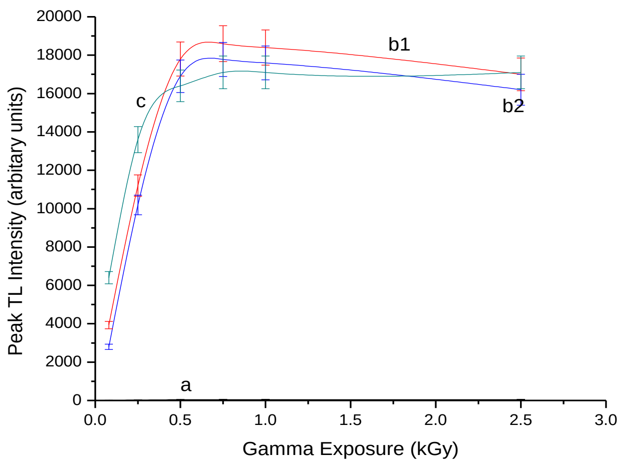

Figure 11: Comparison of Variation of Peak TL Intensity with different Gamma Exposure of
(a)KCl:Dy (0.1 mol%), (b1)NaCl:Dy (0.1 mol%), (b2) NaCl : Dy (0.2 mol%) and (c) (KNa)Cl : Dy (0.1 mol%).

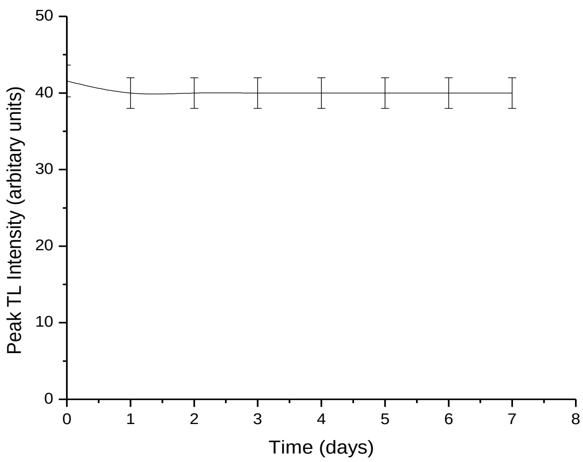

Figure 12: Effect of storage on the TL glow Peak in KCl:Dy (0.1 mol%), exposed to gamma dose = 0.50 kGy.

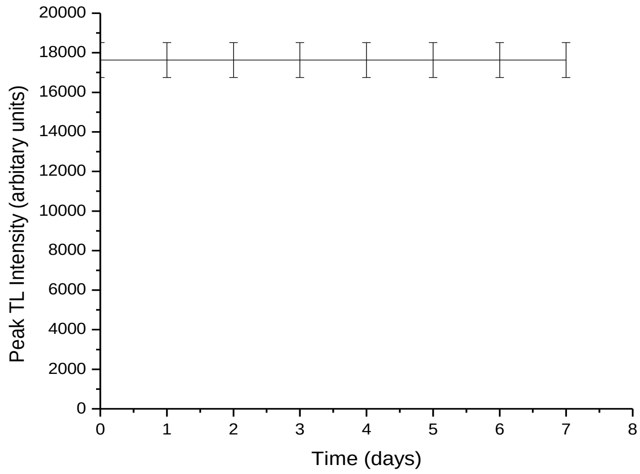

Figure 13: Effect of storage on the TL low peak in NaCl:Dy (0.1mol%), exposed to gamma dose = 0.50 kGy.

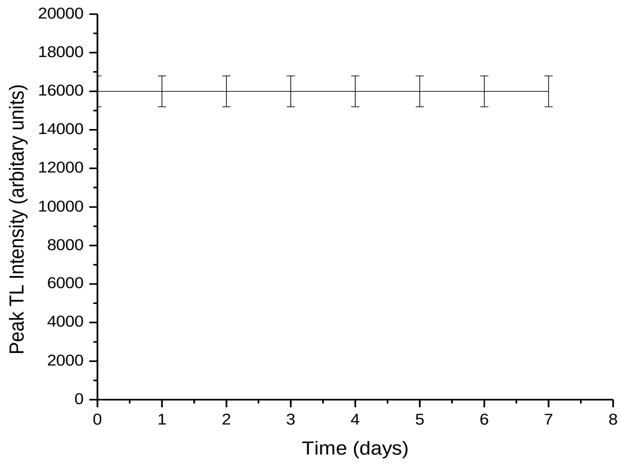

Figure 14: Effect of storage on the TL glow Peak in (KNa)Cl:Dy (0.1 mol%), exposed to gamma dose = 0.50 kGy.

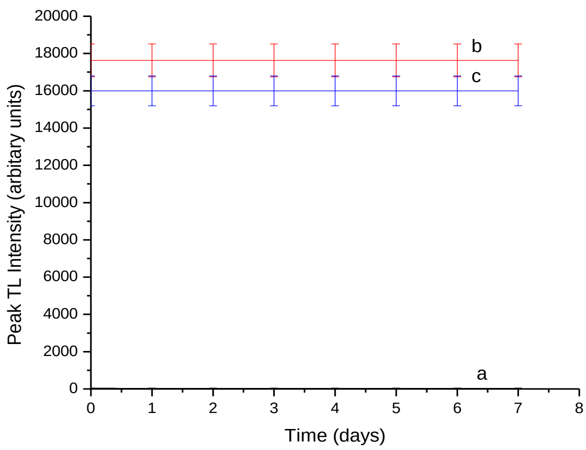

Figure 15: Effect of storage on the TL glow Peak in (a) KCl: Dy (0.1 mol%),
(b) NaCl : Dy (0.1 mol%) and (c) (KNa)Cl : Dy (0.1 mol%), exposed to gamma dose = 0.50 kGy.

Fading:

Figure 12 to Figure 14 shows the effect of storage in dark at room temperature on the peak TL intensity in all samples and Figure 15 shows the comparison of fading in TL intensities respectively in all samples. From these graphs it is seen that the TL peak intensity of all the samples are quite stable since there is not much fading of intensities as the loss of colouration is less in darkness [12-14].

Today, the measurement of high dose radiation is a challenging task and it is required for accidental dosimetry. The prepared (KNa)Cl:Dy phosphor shows the dose measurement is possible upto 0.5 kGy gamma exposure using thermoluminescence technique, and has a negligible fading. Therefore the prepared phosphor may be useful for accidental radiation dosimetry.

CONCLUSION

Thermoluminescence in KCl:Dy, NaCl:Dy and (KNa)Cl:Dy materials are reported. TL in these materials shows the single TL peak due to only one type luminescence centre is formed. The TL peak intensity is dependent on concentration of Dy doping in the host material in all the samples. Similarly the peak intensity increases with γ-ray dose upto 0.5 kGy and then it becomes saturated after 0.5 kGy γ-rays exposure in all the materials.

All materials have negligible fading on storage in TL intensity. These characteristics are shows the prepared (KNa)Cl:Dy phosphors may be applicable for TL dosimetry for high dose measurement i. e. for the case of accidental radiation dosimetry.

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

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