KF:Ce^{3+} Polycrystalline Phosphor for Accidental Dosimetry

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Abstract

Mechanoluminescence (ML) properties of the prepared KF:Ce^{3+} (0.1-10 mol%) polycrystalline powder sample technique are reported in this paper. The samples were coloured by gamma dose. All samples were prepared by a wet-chemical method. The ML intensities are found to be dependant on concentrations of Ce^{3+} and gamma radiation dose. The variation of peak ML intensity of KF:Ce^{3+} (0.5 mol%) with different gamma dose is found to be linear upto about 2.00 kGy high dose. Negligible fading in the prepared sample is observed.

Keywords: Mechanoluminescence (ML), gamma irradiation, accidental dosimetry, KF:Ce^{3+}.

1. Introduction

Luminescence properties are dependant on the formation of colour centres in crystalline solids and are useful for radiation dosimetry. Mechanoluminescence (ML) induced in crystalline materials due to deformation of solids by the application of strain. Mechanoluminescence (ML) is a kind of the technique for high radiation measurements and is useful for accidental dosimetry [1].

In alkali halide crystals, the electron dislocation band lies just above the F-centre level where the energy gap between the bottom of the dislocation band and ground state of an F-centre is of the order of 0.10 eV [2,3]. Near an edge dislocation, some of F-centres lie in the compression region and some of them lie in the expansion region. As the energy gap between two levels in alkali halide crystals decreases with decrease in the local density of crystals, the energy gap between dislocation band and ground state of F-centre may increase in the compression region due to the increase in local density of the crystals. The electrons captured by a dislocation have a finite lifetime. If the moving dislocation containing electrons encounters the defect centres containing holes, the dislocation electrons may be captured by these centres and luminescence may arise due to the radiative recombination of electrons from F-centres with the hole in V_2 centres.

Schematically, the ML process can be described by the following equations:

$$F + D \rightarrow ed + [-]$$

$$V_2 \ (= X^- + X^- + X^0) + ed \rightarrow V_2^- \ (= 3X^-) + D + h\nu$$

Where F and D represent the F-centre and dislocation, respectively, ed is the dislocation electron i.e. the electron captured by a dislocation, (-) is the negative ion vacancy, X^- is the halogen ion, X^0 is the self trapped hole and V_2^- is the V_2 centre with captured electron [1].

S.Bangaru et. al. [6,7] reported the enhanced luminescent properties and thermoluminescence studies in alkali halides by doping rare earth materials. Recently, we have been reported the ML, LL and TL characteristics in rare earths activated alkali halides based materials [4,5].

2 Experimental

All phosphors containing different concentrations of Ce^{3+}(0.1-10 mol%) were prepared by a wet chemical method. For preparation of KF:Ce^{3+} the required concentration of Ce^{3+} were added in the solutions of KF prepared in distilled water. Then the solutions were evaporated at 80 ^{0}C in oven for about one week. The recrystallised residue were normally crushed to powder and heated at 500 ^{0}C in fabricated furnace for 1 hr and quenched. The prepared samples were used for further study. The samples were exposed to γ-dose from a ^{60}Co source having a dose rate of 0.50 kGy/hr.

Mechanoluminescence were recorded with the usual set-up consisting of photomultiplier tube (RCA931) amplifier and storage oscilloscope (Scientific SM 340). The ML was excited impulsively using a technique in which a load of 200 gm was dropped on to the 1 mg sample from a height of 10 cm using a guiding cylinder. For recording the ML spectra, filters of different wavelength were placed between the sample holder (Lucite plate) and PM tube.

All samples were stored in dark at room temperature during all experiments. All experiments were performed in identical conditions and it is observed that the results are reproducible.

3 Results and discussions

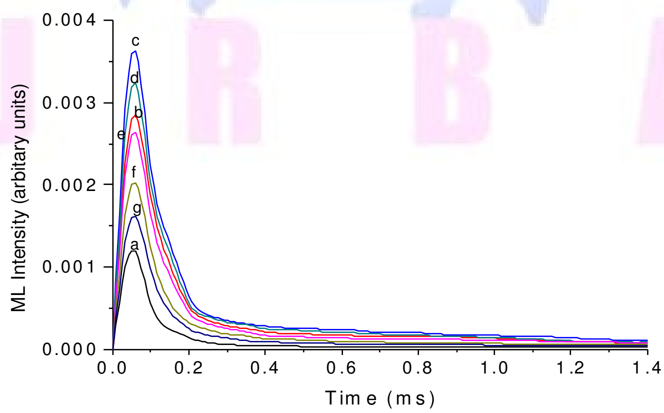

Figure 1: ML Glow Curves of a) KF (pure), b) KF:Ce^{3+} (0.1 mol%), c) KF:Ce^{3+} (0.5 mol%), d) KF:Ce^{3+} (1 mol%), e) KF:Ce (2 mol%), f) KF:Ce (5 mol%) and g) KF:Ce (10 mol%), exposed to gamma dose = 0.50 kGy

Mechanoluminescence in KF (pure) and KF:Ce^{3+} (0.1-10 mol%) are shown in Figure 1. ML glow curve shows the isolated single peak in all samples. For KF:Ce^{3+} (0.5 mol%) sample, ML intensity peak height is about four times more as compared to pure KF material. The observed ML is due to the mechanical deformation of solid during the collision. Single ML peak shows that only one type of luminescence centre is formed during irradiation. The enhancements of ML intensity by Ce^{3+} ion impurity in the KF host indicate that more trapping centres are formed during the irradiation in this material than the host material. This luminescence may arise due to the radiative recombination during the impulsive deformation of the sample due to application of load, as suggested by Chandra in 1998 [1]. The peak is due to emitted ML on radiative recombination and then after the ML intensity decreases with increase in time.

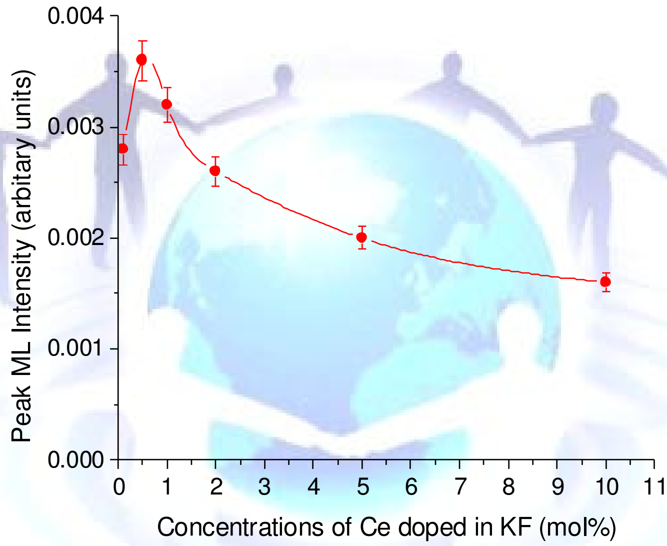

Figure 2: Variation of Peak ML Intensity with Concentrations of Ce^{3+} doped in KF, exposed to Gamma dose = 0.50 kGy

Figure 2 indicates the variation of Peak ML intensity with different concentration of Ce added in host KF. The ML intensities are increases with increase in concentration of added Ce impurity and get saturated at 0.5 mol% concentration of Ce in KF. Then after both the intensities are decreases considerably on further increase of concentration of added impurity. This is due to concentration quenching and ML intensities are decreases above 0.5 mol%.

Figure 3 shows the variation of ML peak intensity with γ-rays exposure of KF (pure) (Curve a) and KF:Ce (0.5 mol %)(Curve b). The ML intensity linearly increases with the γ-rays exposure upto about 2.00 kGy high exposures and then tends to saturation. For the KF (pure) material the ML Intensity is linearly increases upto about 1.5 kGy γ-rays dose also, but for Ce doped sample the comparative increase in ML intensity is found to be more. This indicates that 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. As a matter of fact, the luminescence intensity attains a saturation value for high radiation doses given to the crystallites [8].

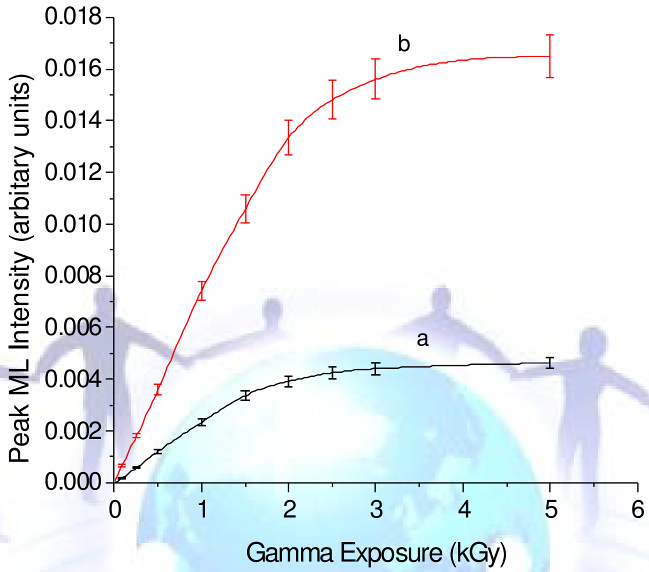

Figure 3: Variation of Peak ML Intensity with different Gamma Exposure of a) KF (pure) and b) KF:Ce^{3+} (0.5 mol%)

Figure 4 shows the effect of storage in dark at room temperature on the peak ML intensity in KF:Ce^{3+} (0.5 mol%) sample. From this graph, it is seen that the ML peak intensity of the sample are quite stable since there is not much fading of intensity as the loss of colouration is less in darkness [9].

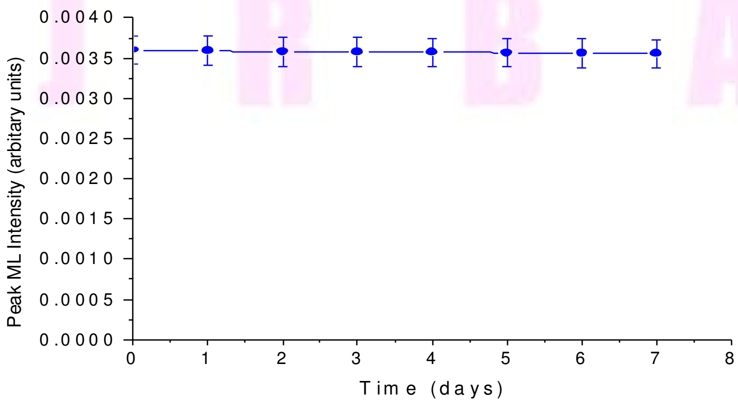

Figure 4: Fading in ML Intensity of KF:Ce^{3+} (0.5 mol%), on storage in dark at room temperature

4. Conclusions

Mechanoluminescence in $KF:Ce^{3+}$ material are reported. ML in these materials shows a single peak since only one type of luminescence centre is formed during γ-irradiation. The ML peak intensity is dependent on the added concentration of Ce^{3+} in the host material in all the samples. The ML peak intensity increases linearly with γ-ray exposure upto about 2.00 kGy high dose for $KF:Ce^{3+}$ (0.5 mol%) sample and then after it becomes saturated.

The prepared phosphors have negligible fading in ML intensity, on storage in dark at constant temperature. These characteristics shows that the prepared $KF:Ce^{3+}$ (0.5 mol%) phosphor may be useful for ML dosimetry for high dose measurement i. e. for the case of accidental radiation dosimetry using ML techniques.

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