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Dose Linearity Studies Of Thermoluminescence Of $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$ Multiphased Mixed Crystals Irradiated With 15MV Photon Beams

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ABSTRACT

Alkali halides are being used as radiation dosimetric tools in the field of radiation because of their thermoluminescence property. Thermoluminescent properties of ternary alkali halide mixed crystals are not yet studied in depth. The present study is to analyse the dose linearity response of thermoluminescence of the ternary mixed multiphased mixed crystals $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$. Nine different combinations of $(KCl)_x(KBr)_{y-x}(KI)_{1-y}$ are prepared by melt method and irradiated with 15 MV X-ray photons to the doses of 10 Gy, 50Gy, 100 Gy at the dose rate of 5 Gy/min. Thermoluminescence glow curves are studied in the temperature range of 50 ºC - 400ºC at a heating rate of 3ºC/sec. The thermoluminescent (TL) output and the TL glow peak temperature have been analyzed for different doses and different combinations of x and y. It is observed that KBr rich (KCl) 0.1 (KBr) 0.8 (KI) 0.1 sample shows a glow peak around 85ºc. This low temperature glow peak is vanishing as the KBr contribution reduces. Contribution of KCl and KI are seen as a combined glow at temperatures beyond 200ºc. Out of all the studied combinations and doses, the maximum TL output is obtained for (KCl) 0.1 (KBr) 0.8 (KI) 0.1 when it is irradiated for a dose of 100Gy. In conclusion, addition of KBr makes the difference at low temperature region while KCl and KI dominates in the higher temperature regions.

Key words: Thermoluminescence, Glow curve, Glow peak, thermoluminescent output.

I. INTRODUCTION

Thermoluminescence of alkali halide crystals has been studied for decades and it has a role in the field of radiation dosimetry. LiF2 is an excellent example for this which is being used extensively in personal radiation monitoring devices. Most of the alkali halides are studied for thermoluminescence in their pure, doped forms [1-6]. The major disadvantage of these alkali halide crystals is their hygroscopic nature. Recently Mahadevan and co workers have prepared multiphased alkali halide mixed crystals by melt method [8-12]. These studies suggest that multiphased alkali halide mixed crystals are harder and less hygroscopic than the end member crystals. Though some of their physical characteristics are studied, the thermoluminescence properties of this multiphased mixed alkali halide crystals are not yet studied in depth dosimetrically. In view of the dosimetric advantage of alkali halide crystals in thermoluminescent radiation dosimetry, the present study is intended to analyse the thermo luminescence nature and the dosimetric advantages of one such multiphased mixed crystal. Perumal et al [10] prepared (KCl) x (KBr) y-x (KI) 1-y mixed crystals successfully by melt method and analysed some of its physical properties. Recently Ananda kumari el al., [13] have studied the thermoluminescence in $(KCl)_{0.9-x} (KBr)_x (KI)_{0.1}$ mixed crystals under gamma photons. These studies strongly supporting the presence of thermoluminescence in these mixed crystals. The dose linearity analysis in the clinical radiation dose range for these mixed crystals is not known. In the present study (KCl) x (KBr) y-x (KI) 1-y multiphased mixed crystals were taken and the linear thermoluminescence response in the clinical dose range in a 15 MV clinical photon beam from a medical linear accelerator were analysed. The composition dependence of thermoluminescence also studied and analysed.

II. MATERIALS AND METHODS

Solid solutions (KCl) x (KBr) y-x (KI) 1-y ternary alkali halides are prepared by melt method as explained in Priya et al [8, 9]. The chosen combinations are x=0.1, 0.3, 0.5, 0.7 with y=0.9, x=0.1, 0.3, 0.5 with y=0.7, and x=0.1, 0.3 with y=0.5. 100 milligram of each sample is taken uniformly for thermoluminescent studies. These samples are irradiated for different radiation doses of 10Gy, 50Gy, 100Gy and 200 Gy in a 15MV X-Ray photon beam derived from a medical linear accelerator. The irradiation dose rate is maintained as 5Gy per minute. Source to axis distance (SAD) set up method is used for irradiation. 5cm virtual water phantom slabs are kept above the samples. 30cm x 30 cm radiation field size is used. The irradiation time is calculated in terms of monitor units. The number of monitor units is calculated as follows.

Monitor Units = (Dose to be delivered) / (Output of the Linear accelerator*Tissue Maximum Ratio)

Output of the Linear accelerator is measured by using the protocol recommended by IAEA Technical Reports Series number 398.Tissue Maximum ratio is a measured data and it is 0.975 for 15 MV photon beam having radiation field size of 30cm x 30cm and for a depth of 5 cm. The calculated Monitor units for different doses are given in table 1.

Table 1: Calculated Monitor Units for irradiation.

Dose (in Gy)	Monitor units
10	891
50	4455
100	8910
200	17820

Harshaw 3500 thermoluminescent reader is used for this study. The samples have been studied at the heating rate of 3ºc per minute. The thermoluminescent glow curves have been studied in the temperature range of 50ºc to 400 ºc. The samples are heated in the nitrogen environment Time temperature files are created according to this temperature range and heating rate. The TL output is calculated from the area under the glow curve after subtracting the background reading. Background reading is measured for the measuring temperature range without keeping any sample in the reader. The glow peak temperature and the area under the glow curve are noted using the Harshaw 3500 reader.

III. RESULTS AND DISCUSSION
3.1 Glow curve analysis

Table 2: Glow curve temperature data of (KCl) x (KBr) y-x (KI) 1-y solid solutions

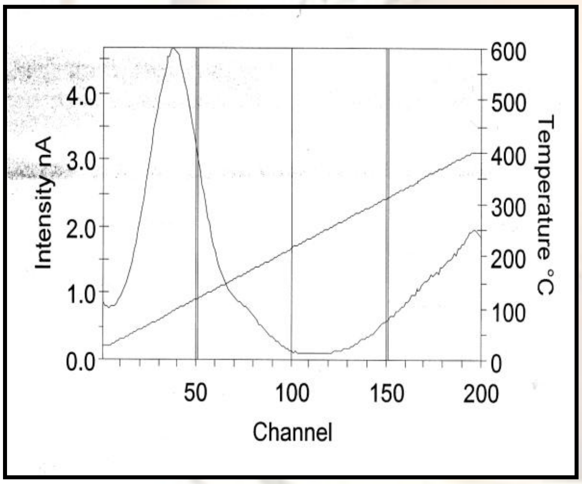
Composition	Type of region	Temperature (in ºc)			
		10 Gy	50 Gy	100 Gy	200 Gy
(KCL)0.1 (KBr)0.8(KI)0.1	Glow peak	83	85	82	87
	Shoulder	>240	140-220, >260	140-225, >260	150-220, >250
(KCL)0.3 (KBr)0.6(KI)0.1	Glow peak	115,192	105,173,240	135,183,265	111,187,290
	Shoulder	>220	>270	290-350, >350	295-340, >340
(KCL)0.5 (KBr)0.4(KI)0.1	Glow peak	93	192,265	111,190,257	116,185,253
	Shoulder	160-230, >230	290-375, >375	290-320, 320-385, >385	315-360, >360
(KCL)0.7(KBr)0.2(KI)0.1	Glow peak	-	223	118,204	128,202
	Shoulder	165-235, >235	85-175, >240	280-325, 325-385, >385	230-290, 290-340, 340-390, >390
(KCL)0.1 (KBr)0.6(KI)0.3	Glow peak	169	165	156	146
	Shoulder	230-315, >315	225-300, >300	225-300, >300	220-295, 295-380, >380
(KCL)0.3 (KBr)0.4(KI)0.3	Glow peak	-	185	251	239
	Shoulder	205-270, 270-345, >345	210-280, 280-370, >370	110-210, 280-355, 355-380, >380	85-200, >270
(KCL)0.5 (KBr)0.2(KI)0.3	Glow peak	-	-	-	-
	Shoulder	210-310, 310-385, >385	215-310, 310-375, >375	100-210, 220-310, 310-385, >385	90-210, 210-300, 300-375, >375
(KCL)0.1 (KBr)0.4(KI)0.5	Glow peak	113,173	122,169	120,163	111,165
	Shoulder	220-270, 270-310, >310	220-270, 270-315 >315	230-295, 295-385, >385	210-315, >315
(KCL)0.3 (KBr)0.2(KI)0.5	Glow peak	-	-	-	-
	Shoulder	220-310, >310	220-320, >320	220-335, >335	210-280, 280- 330,>330

Glow peak temperature details are shown in table 1.The KBr rich **(**KCl) $_{0.1}$ (KBr) $_{0.8}$ (KI) $_{0.1}$ sample was having a peak nearer to 85 °C. This glow peak shows a noticeable difference from all other combinations. The glow peak temperatures of all other samples were higher than or closer to 100 °C. Contribution of KCl and KI to the thermoluminescence was seen only the higher temperature regions. It was observed that the samples with very low contribution of KBr like (KCl) $_{0.3}$ (KBr) $_{0.2}$(KI) $_{0.5}$, and (KCL) $_{0.5}$ (KBr) $_{0.2}$(KI) $_{0.3}$ were having nil peaks. This was observed in all the three radiation doses.

3.2 Composition dependence of thermoluminescence output of (KCl) x (KBr) y-x (KI) 1-y

TL output was calculated by means of the area under the glow curve .It is observed that KBr component in (KCl) $_x$ (KBr) $_{y-x}$ (KI) $_{1-y}$ affects the TL output effectively. Out of all studied samples (KCl) $_{0.1}$ (KBr) $_{0.8}$ (KI) $_{0.1}$ shows the maximum response at 100Gy [Fig 1].

Fig1: Glow curve of **(**KCl) $_{0.1}$ (KBr) $_{0.8}$ (KI) $_{0.1}$ sample



In KCl and KI rich samples the shoulders above 200ºC are appreciably contributing to the thermoluminescent output**.** This shows the influence of KCl in the TL output. The composition dependence of TL output of (KCl) $_x$ (KBr) $_{y-x}$ (KI) $_{1-y}$ multiphased mixed crystals for different x and y are shown in [Figure 2-5].

Fig2: Variation of TL output with composition x when y = 0.9

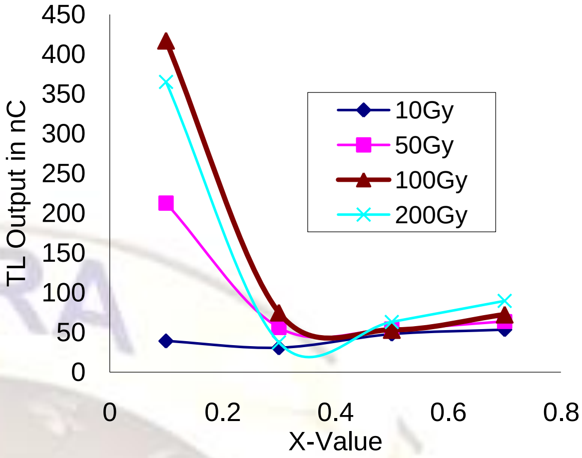


Fig3 : Variation of TL output with composition x when y=0.7

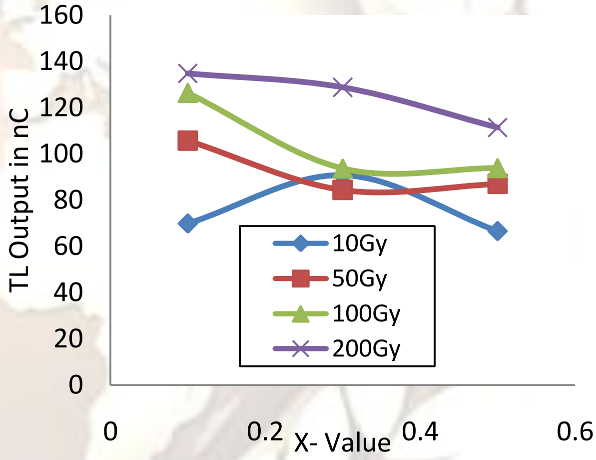


Fig4: Variation of TL output with composition y when x=0.1

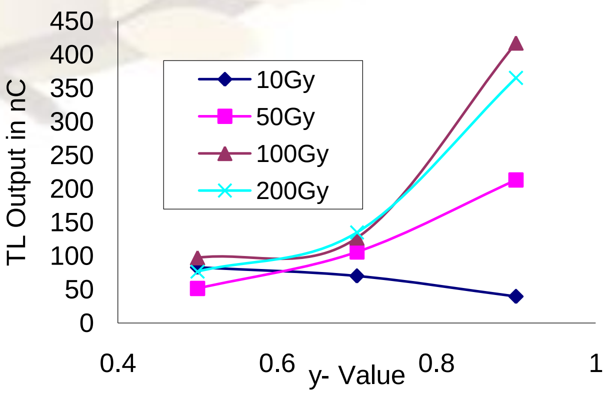
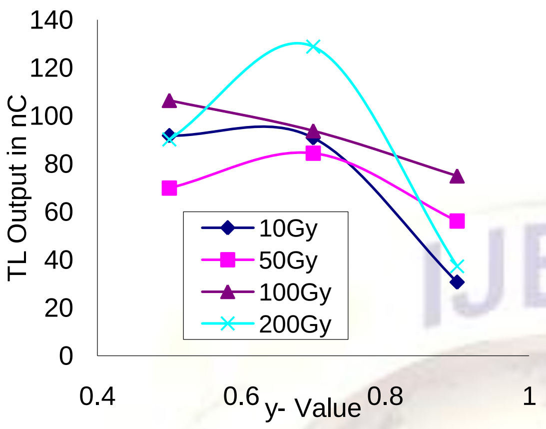


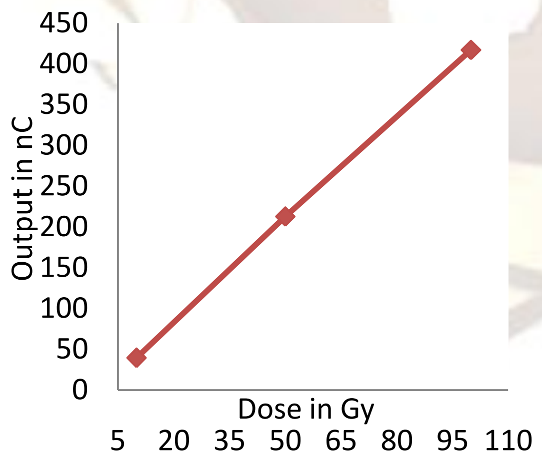
Fig 5: Variation of TL output with composition y when x=0.3



3.3 Effect of radiation dose on thermoluminescence of $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$

Ideal dosimeter should have linear dose response in the useful range. In thermoluminescent dosimetry the TL output is taken as the response. In this study the TL output is measured in terms of the charge collected in the TLD reader system. It is observed that six out of nine samples are showing a linear response to radiation dose in the selected range of 10 Gy to 100Gy. However $(KCl)_{0.1} (KBr)_{0.8} (KI)_{0.1}$ is showing a sensitive linear dose response than all other samples.

Fig6: Linear dose response of KBr rich $(KCl)_{0.1}(KBr)_{0.8}(KI)_{0.1}$.



This sample can be chosen for dosimetry in this dose range after verifying the fading characteristics as the glow peak temperature lies at around 85 °C. The samples namely $(KCl)_{0.3} (KBr)_{0.4}(KI)_{0.3}$, $(KCl)_{0.3} (KBr)_{0.2}(KI)_{0.5}$, $(KCl)_{0.1} (KBr)_{0.4}(KI)_{0.5}$ are not showing a linear response. The dose linearity of TL output of $(KCl)_{0.1} (KBr)_{0.8} (KI)_{0.1}$ multiphased mixed crystal is shown in Fig-6

These results are supporting the thermoluminescence response of $(KCl)_{0.9-x} (KBr)_x (KI)_{0.1}$ mixed crystals to gamma photon doses studied by Amanda kumari et al [13]. Also the results of the present study show that addition of KBr enhances the TL output in the glow curve. These results are agreeing with the results obtained by Brinda Subramanium et al [7] for KCl-KBr binary mixed crystals. As per that the addition of Br- ions increases the thermoluminescent efficiency. Though the KBr rich sample $(KCl)_{0.1}(KBr)_{0.8}(KI)_{0.1}$ shows a differentiable sensitive peak response, the glow peak temperature is below 100ºC. So fading of TL output is the most significant possibility for these samples. The dose response of the TL output is linear for most of the combinations of $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$ multiphased mixed crystals in the dose range between 10 Gy to 100Gy. However the three combinations (x= 0.3, y=0.7), (x= 0.1, y=0.5), (x= 0.3, y=0.5) are showing a non linear response and they cannot be considered for dosimetry. This study can be extended to analyze the fading of TL output with time. Few compositions of $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$ having linear dose response can be used for radiation dosimetry after ensuring its dose rate dependence, energy dependence.

IV. CONCLUSION

The alkali halide mixed crystal $(KCl)_{0.1}(KBr)_{0.8}(KI)_{0.1}$ is found to have a reasonable dose linear response among all the nine combinations of $(KCl)_x (KBr)_{y-x} (KI)_{1-y}$ multiphased mixed crystals taken for this study. However the low glow peak temperature suggests the need for the characterization of fading of TL output. All other samples may not be useful for dosimetric calibration and analysis of 15MV photon beams.

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