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Thermoluminescence in Copper Doped Potassium Tetraborate Phosphor

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ABSTRACT
We have prepared copper doped K2B4O7 phosphor by using simple and modified solution combustion method. This sample is confirmed with the help of X-ray diffraction (XRD). Apart from this, Scanning Electron Microscope (SEM) and FTIR studies of the prepared sample were carried out. Thermoluminescence properties of K2B4O7: Cu phosphor is observed. Two distinct peaks at 235 °C and 340 °C with a shoulder at 420 °C were witnessed. The kinetic parameters and the effect of dose variation on K2B4O7: Cu phosphor is also studied.
Keywords: Borates, Luminescence, Copper doping, Activation Energy

I. INTRODUCTION

Low synthetic temperature, high luminescent brightness and easy preparations etc are the plus points of borates in comparison with the other investigated hosts [1]. The simplistic synthesis with quite cheap raw materials like boric acid and urea results in excellent chemical and thermal stabilized alkaline earth borate [2,3]. Following Daniels et al (1953) [4] lots of researchers have applied the thermoluminescence phenomenon on dosimetry purpose. Some of the investigations on the TL characteristics of borates are un-doped and Ce-doped BaB4O7 [5], un-doped and Cu- and Mn-doped K2B4O7 [6], MgB4O7: Dy, Na [7], SrB4O7: Dy [8], Li2B4O7: Cu, In [9] and BaB4O7: Dy [10]. The studies for the TL phenomenon of borates were started by the work of Schulman et al (1967) [11] Thermoluminescence dosimetry (TLD) has been widely applied in areas such as clinical, personal and environmental monitoring of ionizing radiation. Much research has been carried out to find better dosimetric materials and borates fulfilled the needs of sensitivity with near tissue equivalent absorption coefficient, to some extent [12]. The copper containing materials are among the most sensitive known thermoluminescence (TL) phosphors [13]. These phosphors are suggested to be used for dosimetry applications [14]. We studied the TL characteristics and some dosimetric properties of copper activated K2B4O7 under the irradiation of γ-rays, which was presented in this paper

II. METHODS AND MATERIAL

The K2B4O7: Cu Phosphor was obtained by the combustion of aqueous solution containing stoichiometric amounts (using oxidizer/fuel ratio) of potassium nitrate, copper chloride, ammonium nitrate, urea and Ammonium Pentaborate as boron source [15, 16]. All the precursors (AR grade) were

dissolved in a china dish using minimum amount of water. The dish containing the solution was introduced into a muffle furnace maintained at 823±10 K. The solution undergoes dehydration followed by decomposition with the evolution of large amount of gases (oxides of nitrogen and ammonia) and ignited to burn with a flame yielding voluminous powder of K2B4O7: Cu This raw powder was sintered for 2 h at 1023 K and cooled to room temperature on aluminium plate and crushed into a fine powder. The same process is repeated for the different concentration of copper. The prepared powder samples were then subjected to the powder XRD analysis. Samples were exposed to gamma rays from a 60Co-source at room temperature. After the desired exposure, TL glow curves were recorded for samples at a heating
rate of 5 K/s. The photoluminescence of as prepared sample of $K_2B_4O_7$: Cu (0.007 mol) over 200–400 nm excitation range was taken on a HITACHI F-7000 fluorescence spectrophotometer

Table 1: Balanced reaction for $K_2B_4O_7$: Cu

Product	Corresponding reaction with balance molar ratios of precursors
$K_2B_4O_7$: Cu	KNO_3 + H_3BO_3 + 5 $CO(NH_2)_2$ +7.5 NH_4NO_3 + x $CuCl_2$ $\longrightarrow$ $K_2B_4O_7$: Cu + Gaseous (H_2O, NH_4 and NO_2 etc)

III. RESULTS AND DISCUSSION

Figure-1 represents the XRD pattern for polycrystalline sample of $K_2B_4O_7$: Cu. It is found to be Monoclinic with space group P21/n (14) and lattice parameter a = 12.26 A.U, b = 9.895 A.U, c = 7.796 A.U. The results are confirmed by comparing the observed XRD with standard ICDD file (00-031-0253) which is in good agreement and show peak to peak matching.

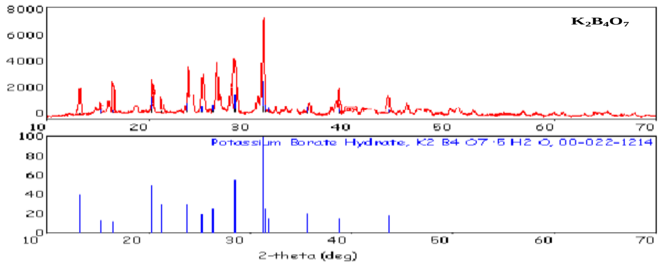

Fig. 1 XRD pattern of $K_2B_4O_7$: Cu

SEM image is represented in Fig. 2 for solution combustion synthesized $K_2B_4O_7$: Cu material. The material shows irregular shape expanded particle structure. It shows the sizes of particles from 0.5 μm to 5 μm range. The irregularity may be caused due to the irregular mass flow during combustion process.

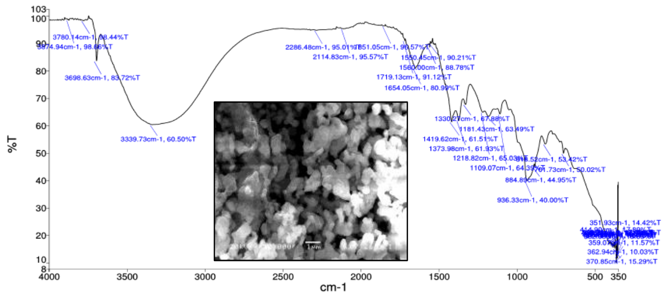

Fig. 2 FTIR and SEM image of $K_2B_4O_7$: Cu

The TL glow curve of newly developed $LiBaBO_3$ with different concentration of Eu^{3+} for a test dose of 1 Gy is shown in the Fig. 3 obtained at heating rate is 5 °C /sec. The glow curve consists of two peaks P_1 and P_2 at 170 °C and 266 °C respectively. This range (175-225 ˚C) is favorable for the desired dosimetry purposes [17]. Here 0.002 mole of Eu^{3+} shows optimum thermoluminescence (TL) intensity for this phosphor. The TL glow curves for $LiBaBO_3:Eu^{3+}$ phosphors were deconvoluted by using the PeakFit software [18] as shown in Fig. 3. We employed the peak shape method to analyze the activation energy of $LiBaBO_3:Eu^{3+}$ phosphors using formula used by Mckeever [19].

Table 2: Kinetic parameters for $K_2B_4O_7$: Cu

	Peak	T_m (˚C)	μ_g	E (eV)	S (s^{-1})
$K_2B_4O_7$: Cu	P_1	235 ˚C	0.47	0.961	7.24 X 10^8

	P_3	420 °C	0.50	1.341	8.97 X 10^8

We have decided 5 Gy to 25 Gy dose for irradiations. After about five hours, TL reading was taken with TL readout heating rate of 5 °C/sec on TL 1009I reader designed by Nucleonix system with the temperature range of integration of the TL signal from 40 °C to 400 °C. The linearity was observed for the first peak in the range from 5 Gy to 25 Gy. The relationship between the TL response of the high intensity peak and the absorbed dose for $K_2B_4O_7$: Cu phosphor was shown in Fig. 3 which was found to be linear.

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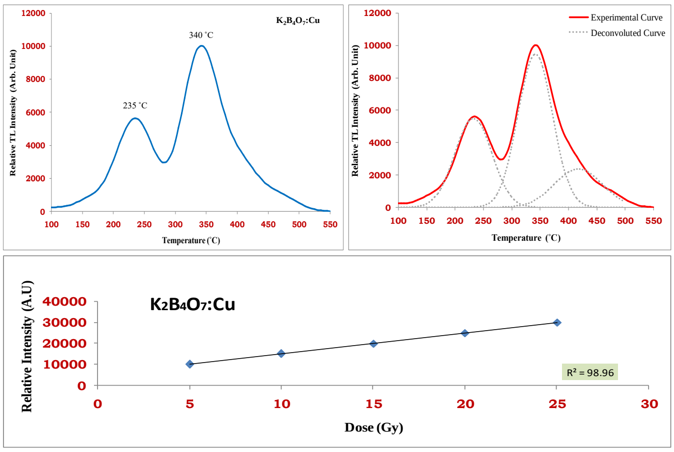

Fig. 3 TL glow peak and deconvoluted TL glow curve with dose response for $K_2B_4O_7$: Cu Phosphor

IV. CONCLUSION

Using combustion method, $K_2B_4O_7$: Cu was successfully prepared. TL and PL properties of $K_2B_4O_7$: Cu is reported with X-ray Diffraction. It witnessed maximum TL at 0.007 mole of copper irradiated with gamma dose for 15 sec. Besides a good candidate for lamp phosphor and display application, this phosphor may be applicable for environmental monitoring applications.

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