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BORATE SILICA GLASS SYSTEM DOPED WITH SODIUM AS A DOSIMETRIC MATERIAL SUBJECTED TO ELECTRON AND PHOTON BEAM

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Varies concentration of Sodium doped borate silica glasses are studied in term of thermoluminescence properties to find their option to use as glass radiation dosimeter. The optimum samples $44.9ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}0.1Na_2O$ were exposed to 6 MeV, 6 MV and 10 MV photon beams in a dose range of 0.5–4.0 Gy. There is a single and broad thermoluminescence glow curve that exhibits its maximum intensity at about 160 °C. Linear dose response behavior has been found in this dose range for the both electron and photon beam. The sensitivity of $44.9ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}0.1Na_2O$ glass sample is 1145.87 ($nC.Gy^{-1}.g^{-1}$) and 1224.46 ($nC.Gy^{-1}.g^{-1}$) for 6MeV and 6MV. The results indicate that this glass has a potential to be used as a radiation dosimetry.

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1. Introduction

Different conventional types of TLDs in radiation protection and medical dosimetry are used to determine the energy response of electron and photon [1-7]. However, limited response and complexities involved in the annealing of these type of dosimeters have caused most researchers to focus on the commercially obtainable Ge and Al doped SiO_2 optical fibers in electron radiotherapy treatment[4, 5, 8-10].Glass phosphors are extensively used to determine patient doses in radiation diagnostic and radiotherapy because of their exceptional features and application over dose ranges of approximately 0.1 -100 mGy for clinical x-ray diagnostics, and 1-5 for radiotherapy[11],[12]. The characteristics of glasses phosphor doped with several elements prepared using the melt quenching method and irradiated with photons and electron to doses in the 0.5–4.0 Gy range such as reproducibility of the response, dose threshold, thermal fading have been studied [6, 12, 13]. This study is an attempt to explore TL properties, such as the glow curve, dose response, sensitivity to radiation, and fading characteristics of zinc borate glasses doped with Na_2O that has been subjected to irradiation via electron and photon beams.

2. Materials and method

2.1. Sample preparation

The compositions of optimum doped and co-doped glass systems are summarized in Table 1. $(45\text{-}x)\ ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}xNa_2O$, $0.05 \leq x \leq 0.7$ were prepared using the melt quenching technique inside electronic furnace (Nabertherm more than 30-3000^oC) at 1300^oC for 1 hour. The melt mixture was taken out; poured inside another furnace, and then annealed at 400$^oC$for 4 hours to avoid thermal stress. Small sized pieces of glass (TL) were weighed using an analytical balance (Presica XT 220A). Model harshaw4500 TLD reader located at physics laboratory in University

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Technology Malaysia at Skodai, Johor was used to read out the TL yield. Every data point in this research represents an average of 3 or 5 individual TL glass readings.

Glass	Batches Composition (mol%)				
	ZnO	B_2O_3	SiO_2	Na_2O	
S1	44.95	45	10	0.05	
S2	44.9	45	10	0.1	
S3	44.7	45	10	0.3	
S4	44.5	45	10	0.5	
S5	44.3	45	10	0.7	

2.2. Exposure samples

- **Gamma radiation**

Borate silica glass samples (ZBS) doped with Na_2O was prepared with varying mol percentage of zinc oxide (according to the amount in Table.1) and exposed to 50Gy cobalt-60 gamma radiation to study the characteristics of this glass samples.

Fig. 1 and Fig. 2 show the glow curve and TL response glass (ZBS) with different concentration of Na_2O. The highest TL intensity was set up to be that sample with 0.1 mol% of Na_2O. Defined glow curve shape and the high TL intensity displayed by the basic compound of ZBS doped by Na_2O indicated that the materials intrinsic are enough to traps and center of recombination electrons and holes.

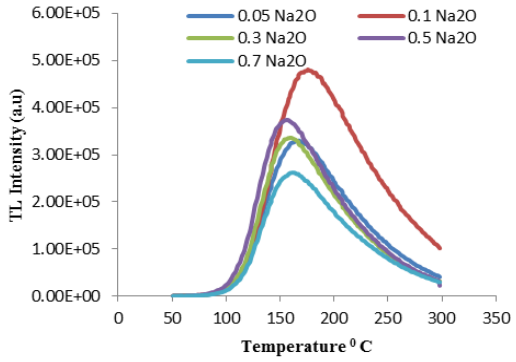

Fig. 1. The intensity of (ZBS) with various Na_2O%.

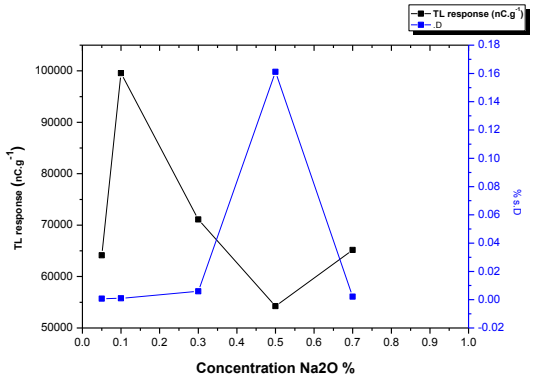

Fig. 2. TL response of (ZBS) with various Na_2O %.

- **Electron and photon radiation**

To study the effect of electron and photon, The optimum sample series $44.9ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}0.1Na_2O$ was irradiated with 6MeV and 6MV from (0.5-4) Gy using a linear accelerator (LINAC)(Elekta PRECISE) provided by Department of Radiotherapy and Oncology, Pantai Hospital, Palau Penang. The samples were placed (on the surface of a solid phantom) [4],[14]at standard source surface distance (SSD) for 100 cm and the beam field size set up was 10x10 cm^2. The LINAC machine delivered doses ranging from 50 to 400 MU (Monitor unit) using a constant dose rate of 400 MU min^{-1}.

3. Result and discussion

3.1. Glow curve

The glow curve of thermoluminscence is a plot of luminescence intensity against temperature. The response of the TLD material is represented by the area under the curve and expressed as radiation energy. Fig 3 illustrates the glow curve of doped glass samples irradiated with 4 Gy dose from 6MeV (electron) and 6MV (photon). The single glow curve of doped samples with Na_2O show a decline after maximum intensities was attained around 155^oC and 160^oC respectively for both radiation (electron and photon beam). Both samples show that the TL response to irradiation dose from electron beam was slightly higher compared to similar dose from photon beam.

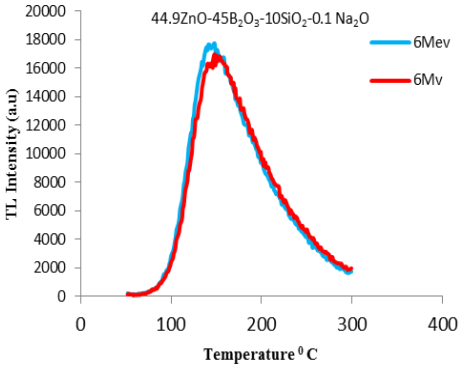

Fig. 3. Doped glass samples with Na_2O glass glow curve irradiated with 6MeV and 6MV.

3.2. Dose response

To study the effect of dose response of the optimum glass sample $44.9ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}0.1Na_2O$, the samples subjected to 6MeV and 6MV at a range of (0.5-4) Gy. It seems that the beam of 6MeV and 6MV rising when the dose range elevated gradually for both types of radiations as shown in Fig 4. This means that the TL response of the samples is dose-dependent. The sensitivity of the data point for samples can be determined by the slope of the plotting TL response as a function of dose. The sensitivity of $44.9ZnO\text{-}45B_2O_3\text{-}10SiO_2\text{-}0.1Na_2O$ glass sample is 1145.87 ($nC.Gy^{-1}.g^{-1}$) and 1224.46 ($nC.Gy^{-1}.g^{-1}$) for 6MeVand 6MV photon beams respectively, the response dose of sample irradiated with 6 MV has sensitivity 1.07 times higher than the sensitivity of same glass sample irradiated with 6 MeV in the same condition.

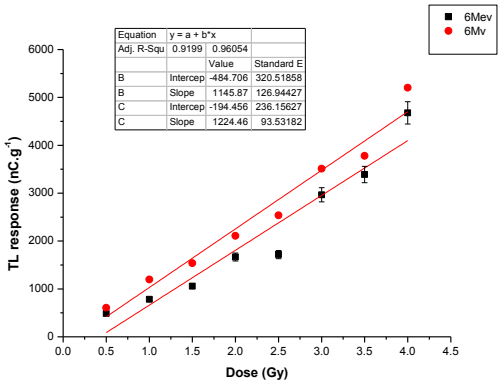

Fig. 4. Dose response of Doped glass samples with Na_2O irradiated with 6MeV and 6MV.

3.3. Photon energies radiation

The glass samples were exposed to 6 MV and 10 MV X-ray photons by using Linear Accelerator (LINAC), provided as mentioned in section 2.2 (photon radiation). Fig. 5 shows the glow curves of borate silica doped with 0.1mol% Na_2O after being irradiated to 4 Gy of 6 MV and 10 MV X-ray photons. The glow curves recorded for dose delivered and falls at around 160 0C. Both samples show that the TL intensity to irradiation dose from 6MV beam was higher compared to similar dose from 10 MV photon beam. The energy response of borate silica doped with 0.1mol% Na_2O for 6 MV and 10 MV shows off that it is energy dependent.

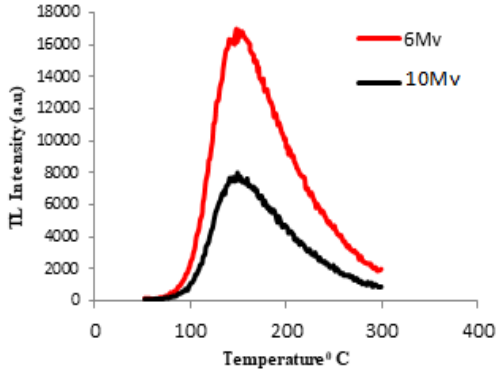

Fig. 5. Doped glass samples with Na_2O glow curve irradiated with 6MV and 10MV.

3.3. Minimum detectable dose

The minimum detectable dose (MDD), which is defined as the minimum dose of ionization radiation with which a detector can produce a measurable degree of any given effect [15]. The MDD of the current sample was calculated using eq. (1) [16]

$$D_o = (B^* + 2\sigma_B)F \quad (1)$$

where D_o is the minimum detectable dose, B^* is the average background TL of the unirradiated dosimeter. σ_B is the standard deviation of the background signal, and F is the calibration factor expressed in Gy nC^{-1} Eq. 2

$$F = \frac{dose(Gy)}{A(nC)} \quad (2)$$

The standard deviation of the background signal and calibration factor was found. Using Eq. (2), the MDD of 44.9ZnO-45B_2O_3-10Si_2O-0.1 Na_2O phosphor is found to be approximately 7.67 mGy and 5.64 mGy for electron and photon.

4. Conclusions

The TL properties of zinc borate silica doped with Na_2O was investigated. The results show the glow curve of proposed samples are single and board that falls after maximum intensity at 160 ^oC. The linear dose response for the range (0.5 to 4)Gy for both electron and photon beam was studied. The sensitivity of the data point for samples can be determined from the slope of the plotting. TL response as a function of dose response of the sample irradiated with 6MV has sensitivity 1.07 times higher than sample irradiated with a 6MeV photon. minimum detectable dose determined. This finding indicated that the present glass system is suitable to be used as thermoluminescence dosimeter Particularly for an electron irradiation.

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