

# TL and OSL dosimetric properties of $\text{Ge}_{30}\text{As}_4\text{S}_{66}$ chalcogenic glass system doped with DY

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In this work were studied the thermoluminescence (TL) and optically stimulated luminescence (OSL) dosimetric characteristics of  $\text{Ge}_{30}\text{As}_4\text{S}_{66}$  chalcogenide glass doped with  $\text{Dy}_2\text{O}_3$  at various concentrations. The material displayed good sensitivity for  $\beta$ -irradiation and showed that TL and OSL signals are dependent on  $\beta$ -irradiation dose and  $\text{Dy}_2\text{O}_3$  content. The dosimetric characteristics of  $\text{Ge}_{30}\text{As}_4\text{S}_{66}$  glass specimens were read from the TL  $\beta$ -dose response curve, which showed a reasonably good linearity behavior between glow peak areas and  $\beta$ -dose values. Due to its encouraging characteristics such as acceptable batch homogeneity and good measurement reproducibility, the  $\text{Ge}_{30}\text{As}_4\text{S}_{66}$  chalcogenide glass can be considered as a candidate material for dosimetry in the range from 0.5 to approximately 100 Gy.

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## 1. Introduction

In recent years, TL and OSL dosimetry has become a well-established technique of monitoring ionizing radiation [1-7]. Successful applications of TL dosimetry are a result of the search for materials that can be used as detectors of ionizing radiation and analysis of their properties [8]. TL glass dosimeters are of particular interest due to their outstanding properties such as their good thermal stability, having a tissue equivalent identity, relatively low cost, easily shaped, good ability to host luminescent activators in elevated concentrations and an increasing possibility of providing optical fibers that are used in manufacturing bidimensional detectors [9].

Amorphous chalcogenide semiconductors are characterized by their sensitivity to the influence of external factors, especially ionizing radiation, due to their flexible structure [10-12]. For the investigation of the effect of ionizing radiation by induced in chalcogenic glass, have been used different methods [13-15], including thermoluminescence method [16]. According to the studies mentioned above, amorphous chalcogenide semiconductors in addition to their traditional use in optoelectronics can be successfully used for radiation measurements in a wide range of absorbed doses of high-energy ionizing radiation.

In this work were studied, the TL and optically stimulated luminescence (OSL) dosimetric characteristics

of  $\text{Ge}_{30}\text{As}_4\text{S}_{66}$  chalcogenide glass doped with  $\text{Dy}_2\text{O}_3$  at various concentrations.

## 2. Materials and methods

### 2.1 Glass preparation

The chalcogenide glassy samples with a chemical composition of  $\text{Ge}_{30}\text{As}_4\text{S}_{66+x}\text{Dy}_2\text{O}_3$ , (where  $x = 0.1, 0.5, 1.0$  mol %) were prepared by the conventional melt quenching technique [17]. Elemental Arsenic (99.999% purity), elemental Germanium (99.999% purity), elemental sulfur (99.999% purity) and  $\text{Dy}_2\text{O}_3$  (Alfa Aesar, 99.9% purity) were used as the starting materials. The mixture of high-purity precursors was melted in sealed evacuated quartz ampoules ( $p=5 \cdot 10^{-6}$  Torr) placed in a rocking furnace. The temperature of quartz ampoule was slowly increased to 550 °C at the rate of 50 °C/hour and kept, at this temperature was increased up to 980 °C at the rate of 50 °C/hour, and homogenized at this temperature during 72 hours.

For TL and OSL measurements were used samples of approximately 5 mg with grains ranging in diameter from 0.085 to 0.180 mm.

### 2.2 Thermoluminescence and optical luminescence measurements

All measurements were performed on a RISØ TL/OSL DA-20 reader (Risø National laboratory, Roskilde, Denmark). TL signals were recorded at a

controlled heating rate of 5 °C/s in nitrogen atmosphere. Optically stimulated luminescence was measured at room temperature with high-power (36 mW/cm<sup>2</sup>) blue LEDs (470 nm, FWHM 20 nm). All luminescence emissions were detected with a bialkali EMI 9235QA photomultiplier tube using a Hoya U-340 filter (transmission between 290 and 390 nm).

### 2.3 Sample irradiation

Irradiations were carried out at room temperature using automatically in the luminescence reader a <sup>90</sup>Sr–<sup>90</sup>Y beta source with a dose rate of 0.05 Gy/s.

## 3. Results and discussion

First of all, the chalcogenide glass samples with a chemical composition of Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+ xDy<sub>2</sub>O<sub>3</sub>, (where x = 0.1, 0.5, 1.0 mol %) were tested, if they after exposure to ionizing radiation have TL and OSL emission. For this, all three chalcogenide glass samples were beta irradiated to the same Dose (20Gy) and TL and OSL signal were observed.

The TL glow curves of the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> chalcogenide glass doped with Dy<sub>2</sub>O<sub>3</sub> at various concentrations obtained after beta irradiation to the same dose (20Gy) at a constant heating-rate of 5 °C/s are shown in Fig. 1.

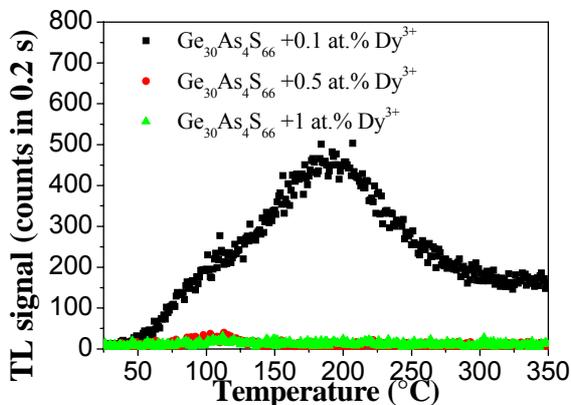


Fig. 1. TL glow curves of the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> chalcogenide glass doped with Dy<sub>2</sub>O<sub>3</sub> at various concentrations freshly irradiated with <sup>90</sup>Sr–<sup>90</sup>Y to 20 Gy

The resultant glow curve of the β-irradiated Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> system doped with a 0.1% Dy showed TL glow peaks around 190 °C. The TL and OSL signal of Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+ xDy<sub>2</sub>O<sub>3</sub>, (where x = 0.5, 1.0 mol %) chalcogenide glass was not detectable till 20 Gy doses. Considering the low TL signal emitted after beta irradiation from Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+ xDy<sub>2</sub>O<sub>3</sub>, (where x = 0.5, 1.0 mol %) samples, the further investigation were performed using only on the sample Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> system doped with a 0.1% Dy<sup>3+</sup>.

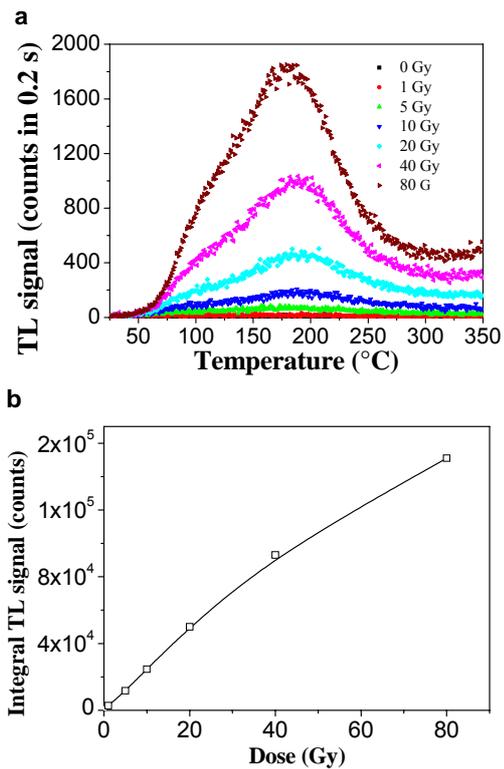


Fig. 2. (a) TL glow curves of the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+0.1at.%Dy<sup>3+</sup> chalcogenide glass freshly irradiated with <sup>90</sup>Sr–<sup>90</sup>Y. (b) Integral TL response of the same material as a function of the absorbed dose.

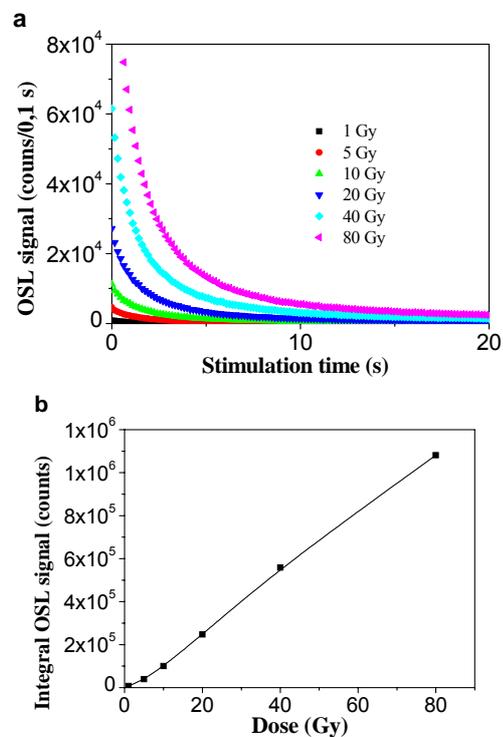


Fig. 3. (a) OSL decay curves of the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+0.1at.%Dy<sup>3+</sup> chalcogenide glass freshly irradiated with <sup>90</sup>Sr–<sup>90</sup>Y. (b) Integral OSL response of the same material as a function of the absorbed dose.

Fig. 2(a) and 3(a) shows the TL glow and OSL decay curves of the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+0.1at.% Dy<sup>3+</sup> chalcogenide glass as a function of the absorbed dose. All measurements were performed with a single aliquot of each glass specimen because it had been observed that the process of recording the TL signal (ramp heating to 500 °C) reduces all signals to a negligible level (3% of the response recorded after an irradiation to 20 Gy). The dependence of the integral TL(150–250 °C) and OSL signal of Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+0.1at.% Dy<sup>3+</sup> chalcogenide glass on the absorbed dose was found to be approximately linear Fig. 2(b) and 3(b), and this makes the investigated material extremely attractive for high-dose measurements

Fig. 4 shows the reproducibility of the TL signal, which was investigated through 10 repeated cycles of annealing, irradiation with 90Sr–90Y to 20 Gy and readout. The results of this investigation showed a very good reproducibility of the TL signal with the maximum standard deviations 1.7%.

The lower detection limits were obtained as three standard deviations of five measurements of their mean zero dose reading (thermal treatment at 300°C/1h and non-irradiated samples, expressed in units of absorbed dose) [18]. The value obtained for lower detection limits to Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+0.1at.%Dy<sup>3+</sup> chalcogenide glass sample was 0.5 Gy.

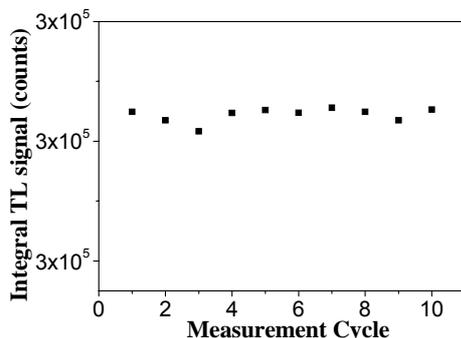


Fig. 4. Reproducibility of the TL signal through 10 repeated cycles of annealing–irradiation–readout.

#### 4. Conclusions

In this work were studied the TL and OSL dosimetric characteristics of chalcogenide glassy samples with a chemical composition of Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+ xDy<sub>2</sub>O<sub>3</sub>, (where x = 0.1, 0.5, 1.0 mol %). Among the studied samples Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub>+ xDy<sub>2</sub>O<sub>3</sub>, (where x = 0.1, 0.5, 1.0 mol %) only for the sample Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> system doped with a 0.1% Dy<sup>3+</sup>, the TL and OSL signal was detectable till 20 Gy doses.

The resultant glow curve of the β-irradiated Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> system doped with a 0.1% Dy showed TL glow peaks around 190 °C and at a constant heating-rate of 5 °C/s. The dosimetric characteristics of Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> system doped with 0.1% Dy specimens were read from the TL β -dose response curve, which showed a reasonably good linearity behavior between glow peak areas and β -dose values.

Due to its encouraging characteristics such as acceptable batch homogeneity and good measurement

reproducibility, the Ge<sub>30</sub>As<sub>4</sub>S<sub>66</sub> chalcogenide glass doped with a 0.1% Dy<sup>3+</sup> can be considered as a candidate material for dosimetry in the range from 0.5 to approximately 100 Gy.

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