JOURNAL OF MATERIALS SCIENCE 27 (1992) 5536–5538

Thermoluminescence study of semiconductor materials $Si_xTe_{60-x}As_{30}Ge_{10}$

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The effect of gamma irradiation on $Si_xTe_{60-x}As_{30}Ge_{10}$, where $x = 5$, 12 and 20, has been studied using thermoluminescence (TL). As expected in semiconductor materials, both $x = 5$ and 20 chalcogenides showed a wide TL peak ranging from ~80–300 °C. However, these two materials also exhibited a sharp peak at ~360 and ~380 °C for $x = 5$ and 20, respectively. On the other hand, the material with $x = 12$ showed very little response to gamma radiation, but if the sample was exposed to ultraviolet light (after being glowed of any TL up to 500 °C) and then glowed (called phototransfer-thermoluminescence), several peaks appeared at ~80, 180, 300, and 350 °C. The $x = 5$ and 20 samples did not show any response to ultraviolet light. Because the TL response depended on the ratio of Te/Si, it can be concluded that the TL technique can also be used to characterize semiconductor materials, and it would complement other techniques such as electrical conductivity and differential thermal analysis.

1. Introduction

In recent years, considerable attention has been focused on amorphous semiconductors, especially those known as chalcogenide glasses. The trend to study these glasses is not only due to their valuable technological applications such as switches, solar cells and thin film transistors but also because of their cheapness relative to other semiconducting materials. Recent advances in the understanding of the electronic structure of amorphous semiconductors have followed from the postulate that well-defined defects are present [1] and are known to influence electrical and optical properties of these materials. So far, the properties of these materials have been determined by d.c. conductivity [2], differential thermal analysis (DTA), and differential scanning calorimetry (DSC) [3, 4].

As thermoluminescence (TL) also involves the trapping (during irradiation) and detrapping (during heating) of charges from traps (which can be point defects), it is therefore possible to classify the chacogenide glasses based on its TL properties.

2. Experimental procedure

Three glasses of the system $Si_xTe_{60-x}As_{30}Ge_{10}$, with $x = 5$, 12 and 20, were prepared from very pure silicon, tellurium, arsenic and germanium (99.999% purity) by melting the constituents together under vacuum (10^{-6} torr; 1 torr = 133.322 Pa) in precleaned silica tubes at 800 °C for about 8 h and then subsequently quenching in liquid nitrogen [2].

For TL measurement, ~ 5 mg powdered sample in an aluminium planchet was placed on the heating strip in a chamber filled with nitrogen. The sample was then heated at 5 °C s^{-1} to 500 °C. The light emitted from the sample was detected by a photomultiplier tube, EMI Type 9804QA, and the signal was then processed by a microcomputer.

3. Results and discussion

Fig. 1 shows the natural TL, i.e. the glow curve, prior to exposure to any radiation for composition $x = 12$. Clearly there is a peak present at about 320 °C and this peak is not affected by gamma or ultraviolet light exposure. The presence of this intrinsic peak can be explained as due to some electrons being trapped during sample synthesis and its subsequent quenching in liquid nitrogen. However, the peak is not observed in the $x = 5$ and 20 chalcogenides.

Although the $x = 12$ sample did not show any response to γ-irradiation, up to the dose of 2.98 kGy, it

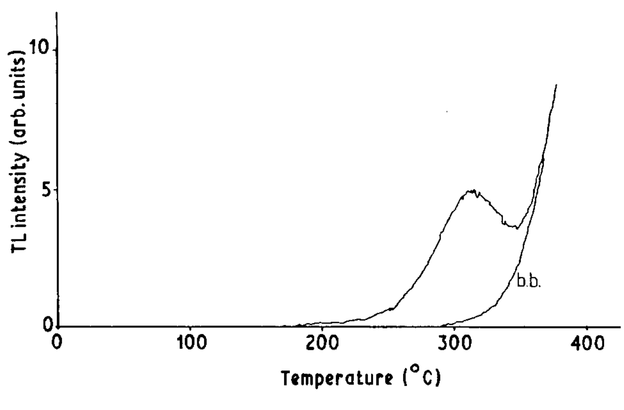

Figure 1 TL glow curve of the $x = 12$ composition. This "natural" TL is present even though the sample is not exposed to any irradiation.

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responded to ultraviolet illumination (after γ-irradiation and then glowed to the temperature of 500 °C). The response, called phototransfer-thermoluminescence (PTTL), is shown in Fig. 2. A subsequent bleaching, i.e. repeated 2 min exposure to ultraviolet light on the same sample, reduced the PTTL observed, as can be seen from the plot of peak heights against the number of 2 min exposures, Fig. 3. The observation of PTTL in the $x = 12$ sample suggested the presence of deep traps situated above 500 °C, which were filled by γ-irradiation, because no PTTL was observed if no prior exposure was performed. The peculiar behaviour of the $x = 12$ sample was also observed in other measurements, such as DTA carried out by Maged [5]. It was found that the crystallization peak decreases with increasing Te/Si ratio with the exception of composition $x = 12$, where two crystallization

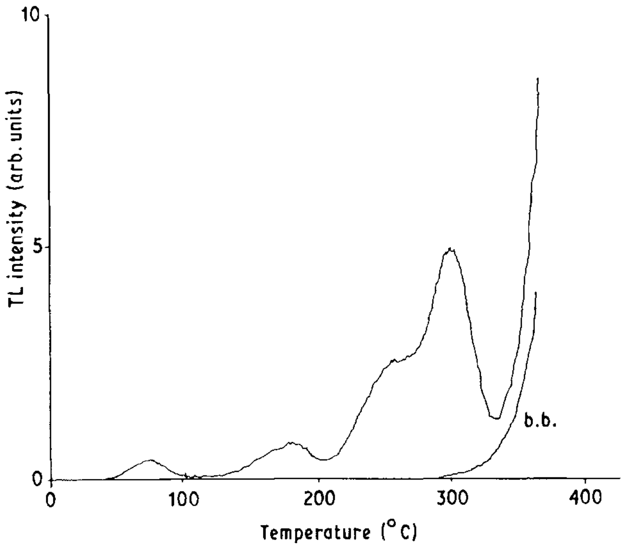

Figure 2 PTTL glow curve in $x = 12$ composition after exposure to ultraviolet light (254 nm) for 2 min.

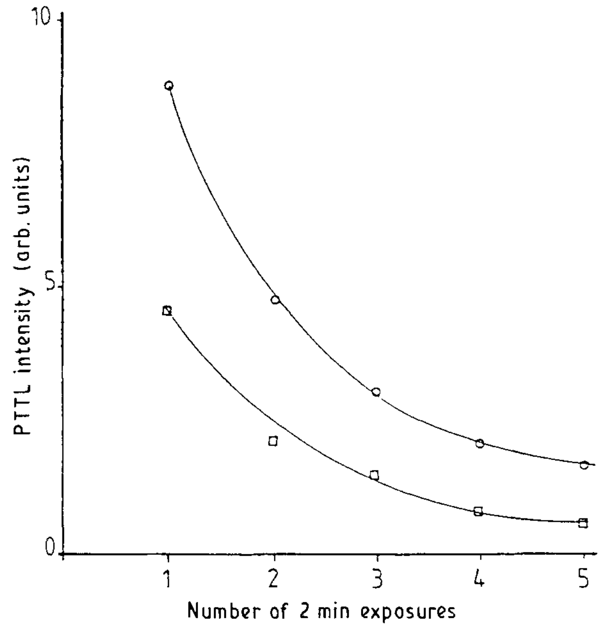

Figure 3 Subsequent optical bleaching of the high-temperature peak (> 500 °C) by ultraviolet light as measured by the PTTL peak height of the (□) 250 and (○) 300 °C peaks in the $x = 12$ composition.

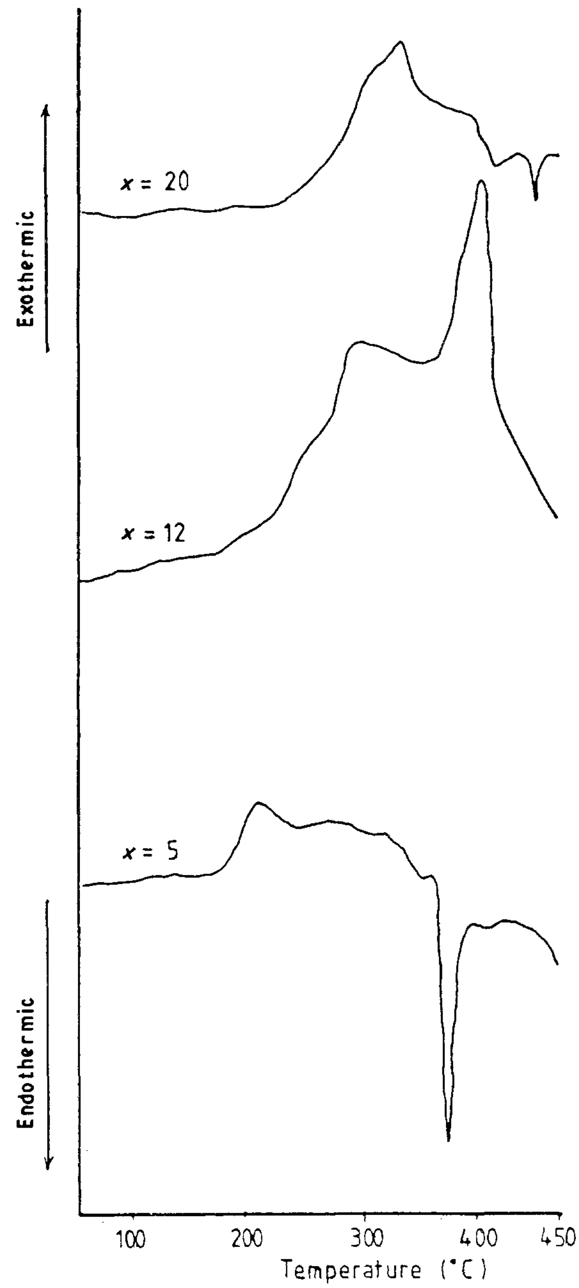

Figure 4 DTA thermograms for $Si_xTe_{60-x}As_{30}Ge_{10}$ semiconductors. Heating rate was 10 °C min^{-1} [4].

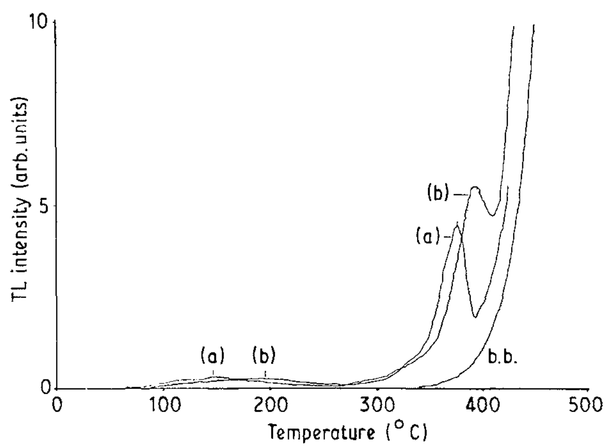

Figure 5 TL glow curves after γ-irradiation (dose = 2.98 kGy) for (a) $x = 5$ and (b) $x = 20$. The heating rate was 5 °C s^{-1}.

peaks appeared, as shown in Fig. 3 [4]. This result supported our observation of a different TL response for the composition $x = 12$, compared to compositions $x = 5$ and 20.

Compositions $x = 5$ and 20 did not show any PTTL response after γ-irradiation. Instead the sample responded to the γ-irradiation itself, as can be seen from the glow curves in Fig. 5. The glow curves show a broad peak centring at $\sim 150\,^{\circ}\mathrm{C}$ and a sharp peak at $\sim 370\,^{\circ}\mathrm{C}$ for $x = 5$, and ~ 180 and $\sim 390\,^{\circ}\mathrm{C}$ for $x = 20$, as can be seen in Fig. 5a and b, respectively. Again this observation shows that the TL technique can differentiate these compositions.

4. Conclusion

The TL properties of semiconductor materials Si_x-$Te_{60-x}As_{30}Ge_{10}$, seem to depend on the silicon content. As such, TL and PTTL can be used to provide further information on their characteristics and would complement other analysis.

Acknowledgements

A. F. Maged acknowledges the financial support of the IAEA. Y. M. Amin thanks the CEC for awarding a fellowship under the EC-Malaysia S and T co-operation.

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Received 26 June 1991
and accepted 7 February 1992