TSC curves in (ZnO-MgO): Fe, O photoconductor: existence of negative and oscillatory characters

S. SINGH
Department of Physics, Th.D.S.B. Government College, Nainital, India

Three peculiar features associated with thermally stimulated current (TSC) curves for different cooling schedules in a (ZnO–MgO):Fe, O photoconductor have been observed. The first and most important is the development of exceptionally high currents, up to 5 μA, at $T_r = 40°C$*. Such currents are uncommon in such large band-gap photoconductors, suggesting that the system is thus an efficient photoconducting material. Secondly, results on negative TSC followed by a positive one (a study in support of the earlier work manifesting the existence of negative TSC [4]) are reported. The third feature is the oscillatory behaviour of the current at higher temperatures. An attempt has been made to give a plausible explanation of these phenomena.

1. Introduction

Negative and oscillatory photoeffects have for a long time been a subject of investigation, e.g. Grigorovich and Ruvinskii [1] recently reported measurements of room temperature oscillations of the current in the negative photoconductivity region of high resistivity ZnTe–CdTe crystals. Similarly negative impurity photoconductivity in n-type InSb and oscillatory photoconductivity in InSb and ZnTe have been reported by other workers [2, 3]. The negative and oscillatory characters of TSC are still, however, largely unexplored. This note will deal with these two aspects and TSC curves for different cooling schedules. An attempt to study the existence of negative TSC in ZnS:Cu:Co photoconductor along with a general method of approach has been made and reported earlier [4]. Material preparation, its infra-red analysis and photocurrent-voltage characteristics also are described elsewhere [5].

2. Results and discussion

2.1. TSC curves for three different cooling schedules (at 20, 35 and 40° C)

These are shown in Fig. 1. With the heating rate maintained constant at 2° per min, the primary peak shifts towards higher temperature, as T_r increases – a result consistent with the earlier TSC studies by the author in ZnS:Cu:Co photoconductor [6] and by Cowell and Woods in the study of photochemical effects in CdS crystals [7]. This shift, is attributed to the change in total trap density, though most of the carriers released from the traps undergo fast retrapping and, therefore, the methods of Luschik [8] and Halperin and Braner [9] (with some retrapping) are applicable to these studies. Analysis of the curves reveals the presence of three major groups of traps; (i) shallow, 0.25 to 0.27 eV with an average trap-depth of 0.26 eV, (ii) intermediate, 1.518 to 1.87 eV and (iii) deep, 4.34 to 5.24 eV. The trap occurring at 4.743 eV is due to the presence of excess Mg and this value is similar to that reported independently by Day [10] and Weber [11]. The deeper traps fall within the MgO band-gap region and a number of bands in the region 4 to 6 eV have been reported due to the iron impurity in two different valence states [12]. The system, a combination of IIa-VIa and IIb-VIa compounds incorporated with suitable impurities thus acts as an efficient photoconductor, because exceptionally high

*Initially the material is heated in the dark to 125 °C to empty all traps and is then allowed to cool to some temperature, T_r, at which it is then subjected to optical illumination.

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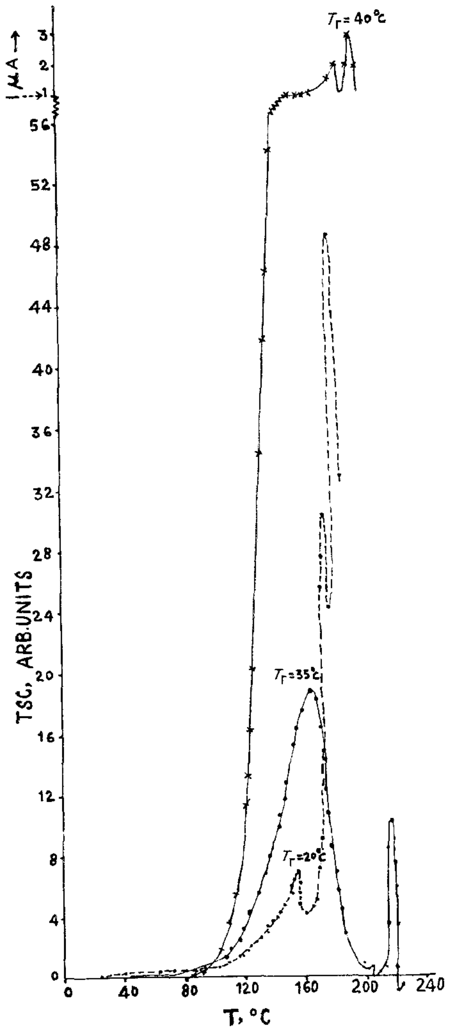

Figure 1 TSC curves for three different cooling schedules.

currents are developed, which are uncommon in such large band-gap photoconductors.

2.2. Negative TSC

A typical TSC curve at T_r = 60° C showing the appearance of both positive and negative (above 140° C) values is given in Fig. 2. Three smaller peaks corresponding to a shallower group of traps appear in the positive TSC region. The first peak at 20° C is probably associated with 1235 cm^{-1}, as is also confirmed by infra-red analysis. The explanation of the negative TSC is similar to those reported previously [4]. The broken portion of the curve indicates the onset of oscillatory TSC in the sample.

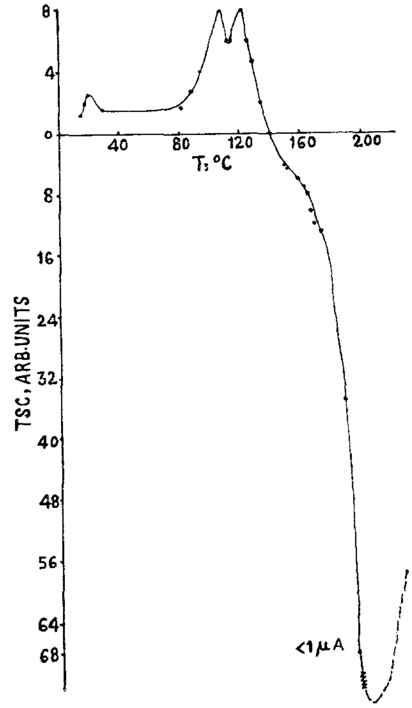

Figure 2 TSC curve for T_r = 60° C showing both positive and negative currents. (For the positive TSC, the scale is amplified × 4 in order to show the smaller peaks.)

2.3. Oscillatory TSC

The pattern of the oscillatory TSC is shown in Fig. 3, and no regularity in behaviour is apparent. The fluctuations of the current owe their origin to the increased thermal agitation, resulting in the thermal disordering and simultaneous capture and release of free carriers. The creation and destruction of certain traps affecting the

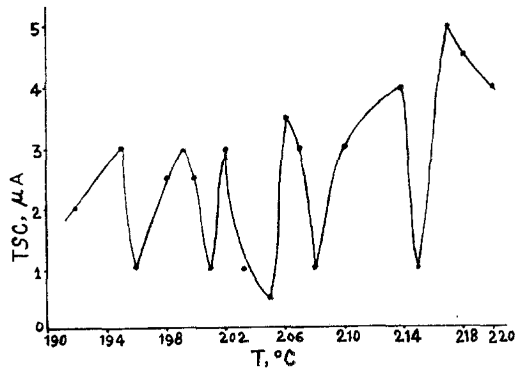

Figure 3 Oscillatory TSC at higher temperatures; T_r = 40° C.

majority and minority carrier densities in the non-equilibria state may also, to some extent, account for such behaviour.

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References

1. G. M. GRIGOROVICH and M. A. RUVINSKII, *Fiz. Tekh. Poluprov.* (*USSR*) **5** (1971) 1132.
2. I. M. ISMAILOV, S. N. KRIVONOGOV, D. N. NASLEDOV, M. A. SIPOVSKAYA, and YU. S. SMETANNIKOVA, *ibid* **5** (1971) 884.
3. MAZURCZYK, Purdue University, Lafayette, Ind, USA, thesis (1970) 114.
4. S. SINGH and B. N. SRIVASTAVA, *Indian J. Pure Appl. Phys.* **10** (1972) 235.
5. S. SINGH, *Solid State Comm.* **11** (1972) 983.
6. S. SINGH, thesis. Agra University, India, (1971) p. 168.
7. T. A. T. COWELL and J. WOODS, *Brit. J. Appl. Phys.* (*J. Phys. D*) **Ser. 2** (1969) 1053.
8. CH. B. LUSCHIK, *Doklady Akad. Nauk. SSSR* **101** (1960) 641.
9. A. HALPERIN and A. A. BRANER, *Phys. Rev.* **117** (1960) 408.
10. H. R. DAY, *ibid* **91** (1953) 822.
11. H. WEBER, *Z. Physik*, **130** (1951) 392.
12. W. T. PERIA, *Phys. Rev.* **112** (1958) 423.

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