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Photoconductivity of Si_2Te_3 Single Crystals

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Very few experimental data concerning the photoconductivity of silicon telluride Si_2Te_3 have been published up to now (1); in no case a surface treatment has been applied to eleminate the influence of the tellurium surface layer. This layer is usually formed by a chemical reaction with water vapour, even if the partial pressure of H_2O is very low.

Here photoconductivity results are reported which were obtained after a regeneration of the crystal surface by vacuum sublimation as described in the preceding short note (2). The spectral distribution of the normalized photocurrent is shown in Fig. 1. There is a maximum in the region of fundamental absorption at 580 nm, a side band at 700 nm, and another maximum at 1.3 μm. The maximum in the infrared region can only be observed, if the crystal has been exposed to bandgap light before. During the measurement the photocurrent decreases, therefore only the initial values of the photocurrent immediately after exposure are used in Fig. 1. Without pre-exposure the dashed curve is obtained. These results can be interpreted by the following assumptions: By illumination with bandgap light the traps will be filled with holes, because Si_2Te_3 is a p-type semiconductor. The infrared light then causes the holes to return to the valence band.

In the case of the side band the pre-exposure is not necessary, the electrons being excited from the valence band into the recombination centres, which are not filled in the dark. Using a theory of Lucovsky (3) the curve can be fitted and the energy levels

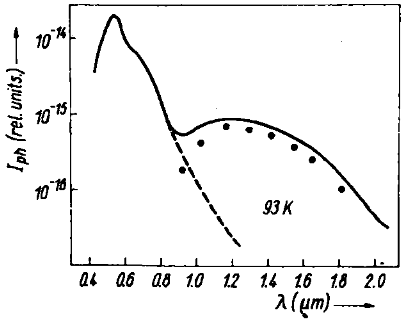

Fig. 1. Spectral distribution of the normalized photocurrent; dashed curve: without pre-illumination, dots: fit according to Lucovsky (3)

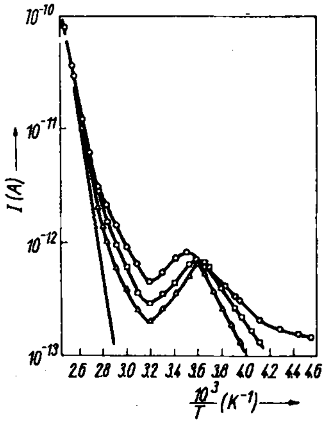

Fig. 2. Thermally stimulated currents for three heating rates. Curve without dots: no pre-exposure with light

of the impurity centres can be obtained (E_{i1} = 0.45 eV and E_{i2} = 0.9 eV above the valence band). The dots in Fig. 1 represent the fit for the trap centre. Once the energy levels are known, from thermally stimulated currents the mobility μ of the defect electrons in Si_2Te_3 can be calculated. Fig. 2 shows that the thermally stimulated currents exhibit a maximum near 283 K. It is assumed that the Fermi level passes the impurity centre at this temperature:

$$E_F - E_v = E_{i1} = kT_{max} \ln \frac{N_v e \mu}{\sigma_{max}} .$$

Using a value for the density of states $N_v = 10^{20}$ cm^{-3}, which is in agreement with the thermoelectric results of the preceding paper, a mobility $\mu = 2\text{x}10^{-3}$ $cm^2V^{-1}s^{-1}$ is obtained for 283 K. At this temperature the hole density is $p = 3\text{x}10^6$ cm^{-3} and the Fermi level $E_F - E_v = 0.8$ eV.

Using these results it is possible to explain the dependence of the photocurrent on the generation rate (Fig. 3) quantitatively. At low generation rate (region I) sublinear, at high generation (region II) linear behaviour is observed. Using a model with a trap and recombination centre (0.45 eV and 0.9 eV above the valence band) the hole density can be shown to obey the following relations:

$$p = \sqrt{\frac{G\, p_Y}{r_p p_Y + r_p Y}} \quad \text{region I;} \qquad p = \frac{G}{r_p Y} \quad \text{region II}$$

($p_Y = N_v \exp(-(E_Y - E_v)/kT$; r_p recombination coefficient of the holes, Y trap density, E_Y trap level).

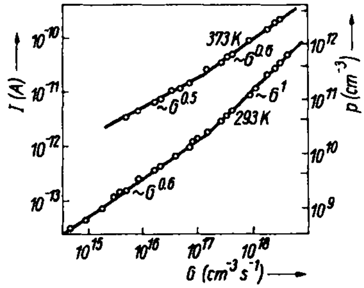

Fig. 3. Photocurrent as a function of generation rate for two temperatures; left scale: absolute photocurrent; right scale: density of holes in the valence band (only valid for 293 K)

The recombination coefficient r_p is found to be of the order 10^{-10} cm^{3}s^{-1}. By response time measurements (4) the trap concentration could be determined ($Y = 10^{17}$ cm^{-3}). With these data a hole lifetime $\tau_p = 10^{-7}$ s is obtained.

The high density of impurity centres and the low mobility of the charge carriers probably are related to the fact that Si_2Te_3 has a complicated layer structure (5) with van der Waals bonding between the Te layers and statistical distribution of the atoms in the silicon layers.

References

(1) J.W. RAU and C.R. KANNEWURF, J. Phys. Chem. Solids 27, 1097 (1966).

(2) K. ZIEGLER, H.D. JUNKER, and U. BIRKHOLZ, phys. stat. sol. (a) 37, K97 (1976).

(3) G. LUCOVSKY, Solid State Commun. 3, 299 (1965).

(4) H.B. DE VORE, RCA Rev. 20, 79 (1959).

(5) U. ZWICK, Dissertation, Max-Planck-Institut für Festkörperforschung, Stuttgart 1976.

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