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PHOTOVOLTAIC PROPERTIES OF LEAD TELLURIDE THIN FILM

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Polycrystalline PbTe thin film is prepared on glass substrate at 200 °C. PbTe thin film is *N*-type and the carriers are electrons. The incident energy of photons, 3.4 eV, generates more electron carriers as the distance decreases which give rise to photoelectric current. The density of donors N_d was determined to be 1.1×10^{20} cm^{-3} which is consistent with the *N*-type conduction of PbTe. The activation energies of *N*-type PbTe thin films are 0.139, 0.139 and 0.126 eV below 60 °C which change to *P*-type above 60 °C. This may be due to generation of Pb vacancies in the lattice. The piezoresistivity is measured, the increase of conductivity may be due to displacements of lattice defects under applied stress.

Studies on PbTe thin film have shown that it was a direct transition semiconductor with small energy gap of 0.32 eV at 300 K [1] and had a positive temperature coefficient of the gap [2, 3] and that PbTe was an extrinsic material in which the carriers were generated by deviation from the stoichiometry. considerable structural information on this material has been obtained. From an engineering point of view PbTe thin films are preferable for applications such as strain gauge, for large piezoresistance effect. Polycrystalline PbTe thin films are prepared on glass substrates by means of evaporation under various conditions of substrate temperature [4]. The transition of conduction type from *N*-type to *P*-type occurs in the vicinity of the substrate temperature of 270 °C.

This paper reports measurements of I–V characteristic of illuminated thin film and piezoresistance effect.

Experimental

The samples used in the present experiment are prepared by means of evaporation in a high vacuum on clean glass plate. Polycrystalline PbTe having a purity of 99.99% are evaporated under substrate temperature of 200°. In this

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experiment, pressure and evaporation rate are 10^{-5} Torr and 10 Å/sec. The shape of the sample for the measurement of I–V characteristic and piezoresistance effect is (1.5×1.2 cm^2). The thickness of the film determined by means of an optical interferometer is 0.01 μm. The I–V characteristic was measured using a D.C. microvoltmeter type TM10 and power supply (Leybold-Heraeus, Germany). The piezoresistance was determined by pressing the thin film with different weights and recording the I–V at each stress. The kinetic run was carried out at room temperature.

Results and discussion

The film prepared was examined by the X-ray diffraction method. The typical results shown in Fig. 1 indicate that PbTe thin film is polycrystalline of cubic structure.

I–V characteristic

The I–V characteristic of PbTe thin film is shown in Fig. 2. The dark sample was exposed to mercury light of 3.4 eV energy. The photoelectric current increased as the distance between light source and the thin film decreased. This can be explained as follows:

PbTe thin film is a *N*-type conductor below substrate temperature of 270° [4]. The substrate temperature in the present work is 200°, the carriers are electrons due to excess Pb atoms. The incident energy of the mercury light is 3.4 eV which generates

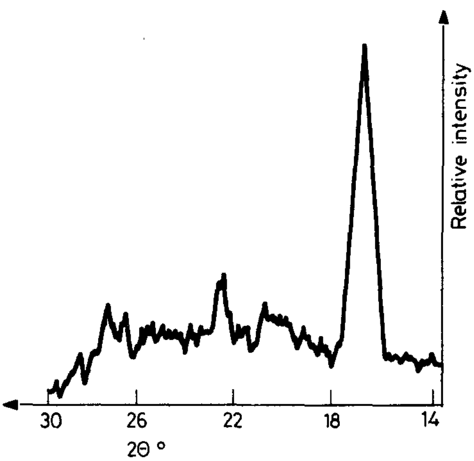

Fig. 1 X-ray diffraction pattern of PbTe thin film

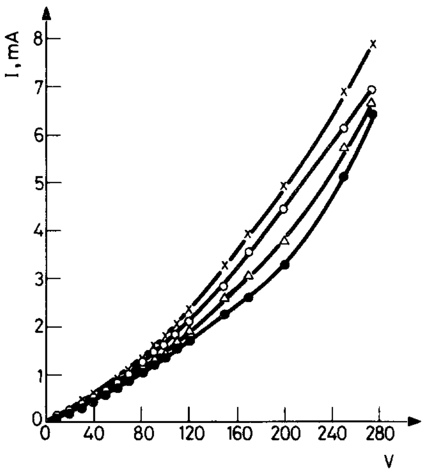

Fig. 2 I–V characteristic of illuminated PbTe thin film. ● dark sample, × apart distance 3.5 cm, ○ apart distance 7.5 cm, △ apart distance 12 cm

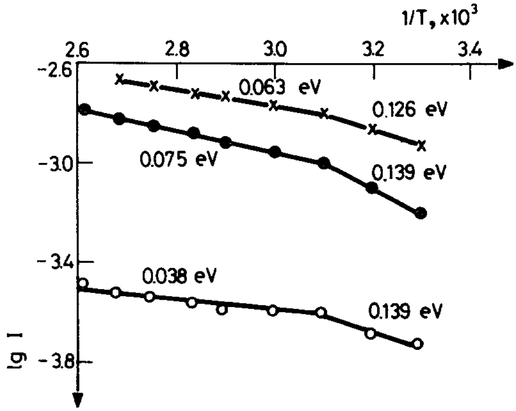

Fig. 3 Temperature dependence ot log I at different applied voltage. ○ 20 V; ● 50 V; × 100 V

more electron carriers as the distance decreases. This causes the increase ot photoelectric current.

The density of donors N_d can be determined by the following Eq. (5) and from Fig. 3.

$$E_c = 1.9 \times 10^{-3}\left(\frac{VN_d}{\epsilon_r}\right)^{-\frac{1}{2}}.$$

where: V_c is the applied voltage and
ϵ_r the relative dielectric constant
E_c the electric field.

N_d was estimated to be 1.1×10^{20} cm^{-3}. This value corresponds to N_d reported previously [4]. The depletion region extends to a distance λ and can be estimated using the relation

$$\lambda = 1052\left(\frac{\epsilon_r V_c}{N_d}\right)^{\frac{1}{2}}$$

The depletion layer was estimated to be 2.1×10^{-6} cm. This value is consistent with PbTe thin film of N-type conduction.

Temperature dependence of log I

Temperature dependence of $\log I$ is shown in Fig. 3. The slope of log 1 at temperature below 60° gives the activation energies of 0.139, 0.139 and 0.126 eV for potential drop 20, 50 and 100 V, respectively. There is no remarkable change in activation energy below 60° and the values are due to carriers which dominate by the impurity band scattering. The film shows N-type conduction and the carrier density increases up to 10^{20} cm^{-3} which due to the precipitation Pb atoms is supersaturated in PbTe crystallines. Above 60° the breaking of the lines is noticed and the activation energies of 0.038, 0.075 and 0.063 eV show P-type conduction due to generation of Pb vacancies in the lattice. The activation energy values in the present work have been reported previously [4].

Stress dependence of piezoresistivity

The effect of stress on the resistivity of PbTe thin film is shown in Fig. 4. The conductivity increases with increasing stress due to the following:

The compound exists as a stable phase over a range of composition near the stoichiometric proportions, and this is possible through the incorporation of vacancy, interstitial or place-exchange point defect into the crystal. These defects

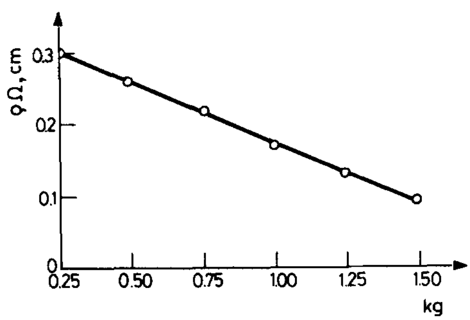

Fig. 4 Effect of stress on piezoresistivity of PbTe thin film

correspond to the densities of donor levels in the energy-band structure. The applied stress on the thin film encourages the displacement of these defects among the cubic crystallites of the thin film. This causes the increase of conductivity for the stressed thin film.

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Zusammenfassung — Auf einem Glassubstrat wurde ein dünner, polykristalliner PbTe-Film aufgetragen. Der PbTe-Film ist ein Leiter vom *N*-Typ, deren Träger Elektronen sind. Die Einfallsenergie der Photonen von 3,4 eV setzt mehr Trägerelektronen frei, wodurch sich der Abstand verringert und der fotoelektrische Strom ansteigt. Die Anzahl der N_d Donoren wurde mit $1,1 \cdot 10^{20}$ cm^{-3} festgestellt, was dem *N*-Leitfähigkeitstyp des PbTe entspricht. Die Aktivierungsenergien der *N*-Typ PbTe-Schicht betragen unterhalb von 60 °C 0,139, 0,139 und 0,126 eV. Overhalb 60 °C geht dies in den *P*-Typ über. Dies ist wahrscheinlich der Entstehung von Pb-Lücken im Gitter zuzuschreiben. Der piezoelektrische Widerstand wurde gemessen. Die erhöhte Leitfähigkeit unter Spannung folgt wahrscheinlich aus einer Beseitigung von Gitterdefekten.

Резюме — На стеклянной подложке при 200° получены поликристаллические пленки теллурида свинца. Тонкопленочный теллурид свинца является проводником *n*-типа, где электроны являются носителями тока. Фотоны с энергией 3,4 эВ генерируют больше электронов-носителей, вследствии чего уменьшение длины пробега приводит к увеличению фотоэлектрического тока. Плотность доноров N_d была разной $1,1 \cdot 10^{20}$ см$^{-3}$, что согласуется с *n*-типом проводимости теллурида свинца. Энергии активации тонких пленок теллурида свинца (п-типа) составляют 0,139, 0,139 и 0,126 эВ ниже 60°, которые выше 60° изменяются до *p*-типа проводимости. Это явление может быть обусловлено образованием в решетке Pb-вакансий. Измерено удельное пьезосопротивление, а наблюдаемое увеличение электропроводности может быть обусловлено смещением решеточных дефектов при наложении напряжения.