Preparation and sensitization of tin telluride infrared detectors

S SANTHANAM and A K CHAUDHURI

Department of Physics, Indian Institute of Technology,
Kharagpur 721 302, India

Abstract. The compound tin telluride was prepared with the constituent elements (Sn and Te) by using the standard fusing technique. From x-ray studies the compound was identified as tin telluride. The detectors in the form of thin films were prepared by vacuum evaporation. Conductivity and photoconductivity measurements of the detectors were carried out in the temperature range of 130 to 300 K. These detectors were sensitized by baking them in air at a fixed temperature (413 K) for a fixed time (1800 sec). Resistivity measurements of the detectors with consecutive bakings were also carried out. The photosensitivity of the detectors increases as it is baked reaching an optimum value after which the sensitivity decreases whereas the resistivity of the detectors increases continuously with baking. It is observed that photosensitivity of the detectors increases with decrease of temperature. The increase of sensitivity with baking has been explained on the basis of modulation of barrier due to the development of photovoltage at SnTe and its oxide heterojunctions.

Keywords. Films; sensitization; infrared detectors; tin telluride; baking heterojunction; resistivity.

1. Introduction

The narrow gap semiconductor SnTe is very useful for fabricating infrared detectors which are sensitive in the far infrared region. There are several methods for preparing the compound (Akhundov *et al* 1963; Biltry and Mecklen 1909; Miles and McEwan 1973). One of the methods is by fusing tin (99.9%) and tellurium (99.99%) with appropriate quantities in an evacuated silica container. This method has been found to be the most convenient for preparing tin telluride. Films of tin telluride deposited on glass and mica substrates by vacuum evaporation were sensitized by baking them in air.

2. Experimental

2.1 *Preparation of the compound*

The melting point of SnTe being about 1078 K, its preparation by fusion involved keeping molten mass of the constituent elements at 1123 K for a comparatively longer time. If the constituents in appropriate proportions are fused in an open vessel in air, complication arises due to : (i) tellurium having a very high vapour pressure compared to tin, the compound would have comparatively

high stoichiometric excess of tin in the sample of SnTe obtained in this way; (ii) SnTe oxidises easily in air and (iii) the compound dissociates partially followed by further reactions of the dissociation products and the compound at the fusion temperature. It is thus necessary to fuse constituent elements in an evacuated and sealed silica ampoule.

A fused silica tube about 0·25 m in length and external diameter 0·030 m was used and it was thoroughly cleaned before the mixture of tin and tellurium was loaded into it. Grease and dust were removed by boiling the tube in hot water with some detergents. Adsorbed detergents and the inorganic materials were removed by washing first with hot nitric acid and then with chromic acid and finally by distilled water. The residual water was removed by washing the tube with some pure inorganic solvent, *e.g.*, absolute alcohol. The other end of the tube was drawn in the shape of a narrow neck. It was then baked at high temperature for about 14.4×10^3 sec at 1073 K to expel the traces of inorganic solvent and of any contaminant left over. Convenient pieces of tin and tellurium in requisite proportion were individually weighed with a semi-microbalance and the total mass of the two elements was about 0·020 kg. The ampoule thus filled with a mixture of tin and tellurium was evacuated to a pressure of 0·1335 pascals and then outgassed at about 373 K. The silica tube was sealed off to an approximate length of 0·2 m at a pressure of 0·1333 pascals by means of a torch flame. The sealed ampoule was then kept in a furnace and the temperature was slowly raised to 1123 K. It was then continuously heated for about 86.4×10^3 sec at that temperature. The temperature was then reduced to 973 K and the ampoule with the contents was heated for another 86.4×10^3 sec. The ampoule was then suddenly taken out of the furnace and quenched in ice-cold water to reduce segregation and to obtain a comparatively homogeneous ingot of tin telluride.

The analysis of the compound by x-ray diffraction showed that the structure was a face-centred cubic with a lattice constant 63·11 nm. On comparing with available data in literature, the compound was identified as tin telluride.

2·2 *Preparation of the film*

The detectors in the form of films were prepared by subliming tin telluride powder from a molybdenum boat in a vacuum of the order of 133.3×10^{-5} Pa onto a clean pyrex glass and freshly cleaved mica substrates. The rate of deposition was controlled by varying the current through the evaporator and it was maintained at approximately 83·3 nm/sec. No attempt was made to heat the substrate. The thickness of deposits was determined by the weighing and interference methods.

X-ray diffraction was taken for the films deposited on mica and glass substrates. In mica, a polycrystalline film was obtained whereas on glass substrates films were observed to be amorphous in nature.

The resistances of the detectors were measured with a simple circuit connecting in series of a voltage source, the detector and a standard resistance. The current in the circuit was determined by measuring the potential drop across
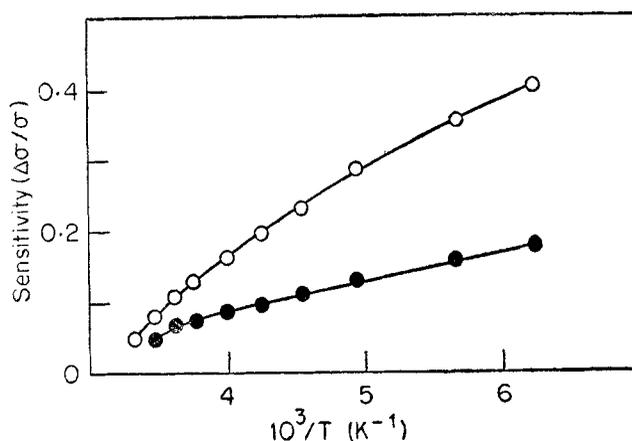
Figure 1. Variation of photosensitivity with temperature ● As-grown film ○ air baked film.

the standard resistance. The photosensitivity of fairly good sensitive layers was determined by noting directly the change in current in the circuit. In the case of samples with poor sensitivity a standard compensating circuit was used and the change in voltage was measured. For the photoconductivity measurements an infraphil lamp was used for illumination with a intensity of 2500 W/m².

3. Results and discussion

The conductivity variation of SnTe films in the temperature range of 130 to 300 K was studied to calculate the photosensitivity of the films at different temperatures. The nature of variation of conductivity in dark and under illumination was observed to be similar to that observed in thin layers of lead chalcogenides. As-grown films were poorly sensitive at room temperature (300 K). The films were baked at 413 K for 1800 sec and the measurements were repeated. Figure 1 shows the variation of photosensitivity of the As-grown and air-baked films with temperature. It shows that there is no appreciable change in sensitivity at room temperature if it is baked once but on the other hand as the temperature decreases photosensitivity starts increasing and the effect of baking becomes quite prominent. With baking the sensitivity of the film improves considerably in the low temperature range (220 to 130 K). Similar observations have been reported by other workers for lead chalcogenide films (Chen-nown and Bube 1974; Espevik *et al* 1971). Hall and thermoelectric measurements were carried out for these films. The films were found to be *p*-type throughout the temperature and the carrier concentration was of the order of $10^{27}/m^3$.

Photosensitivity of the films at room temperature can be considerably improved by successive baking in air at a fixed temperature (413 K) for a fixed time of 1800 sec. The resistances and photosensitivity of SnTe films
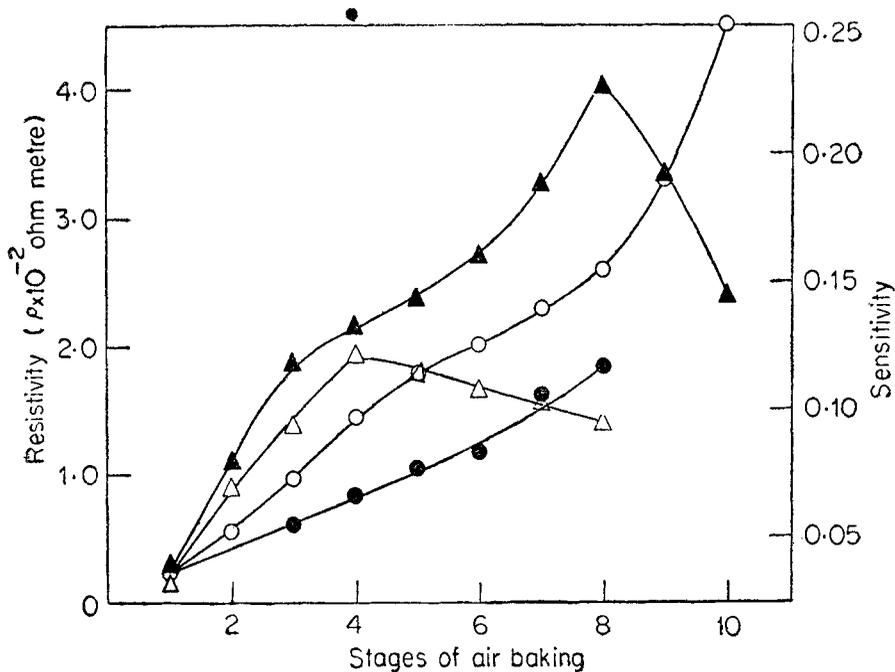
Figure 2. Variation of resistivity and photosensitivity as a function of air baking of SnTe films. 1. On mica substrates ◯ Resistivity ▲ Sensitivity. 2. On glass substrate ● Resistivity △ Sensitivity.

deposited on glass and mica substrates at room temperature were measured with successive bakings. Figure 2 shows the variation of resistivity and photosensitivity of SnTe films with consecutive bakings in air at 413 K for 1800 sec. The resistivity of the film increased continuously with successive bakes, but the photosensitivity increased initially, reaching a maximum value and then decreased.

These results indicate that baking has a complicated effect on the properties of SnTe films. The main processes during baking seems to be volatization of tellurium, diffusion of oxygen and development of new phases. From x-ray diffraction studies it is confirmed that an oxide compound is formed during baking at the grain boundaries as a separate phase (Freik *et al* 1977). Oxygen diffuses to the vacant sites created due to evaporation of tellurium during baking and forms a new oxide phase. The initial improvement of sensitivity after baking seems to be due to the formation of SnTe and its oxide heterojunction. Baking for a longer time leads to the formation of large percentage of oxide compounds. Oxygen vacancy in the oxide compounds will act like acceptor centres. When the film is put under illumination electrons from the valence band are excited to these traps creating excess holes which will drift away to SnTe regions. Due to physical separation they will not be able to recombine. Consequently a photo-voltage will develop which will lower the barrier height. With baking the concentration of acceptor centres in the oxide compound is expected to

increase which will reduce the life-time of the carrier (Freik *et al* 1977). As a result diffusion length of holes in the oxide will be reduced and the photovoltage generated at the junction will decrease leading to a reduction in the sensitivity of the film. Samesh and Zemel (1975) have also reported that with increasing PbO content in PbS film, the life-time of the carrier decreases and the film sensitivity virtually vanishes. They have further reported that the PbS-PbO structure gives rise to multiple scattering which reduces the absorption coefficient enormously. Similarly in SnTe film it is observed that with increasing oxide compound content photosensitivity reduces significantly.

4. Conclusions

The photosensitivity after baking is mainly due to the photovoltage developed between the oxide compounds and SnTe heterojunctions. Prolong baking reduces the film sensitivity due to the formation of a large amount of oxide compound.

References

Akhundov G A, Abdullaev G B, Aliever M Ch and Efetdinov G A 1963 Semiconductor materials conference, Moscow
Biltry W and Mecklen W 1909 *Z. Anorg. Chem.* **64** 226
Chen-nown and Bube R H 1974 *J. Appl. Phys.* **45** 648
Freik D M, Galushchak M A and Avgustimov V L 1977 *Inorg. Mater.* **13** 1709
Miles M H and McEwan W S 1973 *J. Electrochem. Soc.* **120** 1069
Samesh Said M and Zemel J N 1975 *J Appl. Phys.* **47** 871
Sveign Espevik, Chen-nown and Bube R H 1971 *J. Appl. Phys.* **42** 3513