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Seebeck Effect in *p*-Type SnTe Crystals

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Preliminary results of the thermoelectric power measuremnts are presented on a few samples of *p*-type SnTe crystals with and without Mn impurities over the temperature range from 300 to 77 K. As the temperature is decreased, the Seebeck coefficients decrease and tend to rise near at 100 K; the magnetic impurities are found to be ineffective to this enhancement,

1. Introduction

For magnetic dilute alloys considerable progress has been achieved in understanding the interaction of the localized magnetic moment of the impurity with the conduction electrons of the metal host. In recent years the similar studies have been investigated for narrow-gap semiconducuors,[1] for which various properties have been interpreted in terms of the *s-d* interaction model to a large extent. However, it should be noted that the local (crystalline) environment around the magnetic impurities is different between the metals and the semiconductors.

Thus far we have been interested in the manganese impurities dissolved in SnTe crystals from the standpoint of the galvanomagnetic and EPR measurements. As part of our research projects, we have attempted to measure the thermoelectric power or the Seebeck effect in the Mn-doped SnTe crystals. The Seebeck effect is easily measured and provides us many information about the type of scattering of the charge carriers in the crystal and the density-of-states effective mass of the carriers.[2] For IV-VI semiconductors the Seebeck effect is already reported by several workers; for example, J. A. Kafalas *et al.*[3] have shown the carrier density dependence of the Seebeck coefficient at 300 K to verify the two-valence-band model of SnTe, and L. M. Rogers[4] has discussed the various scattering mechanisms in the II-IV-VI alloy semiconductors. In this paper, we shall describe the preliminary results of Mn-doped SnTe over the temperature range 300-77 K.

2. Experimental

The samples were grown by the Bridgman method and the details of the material preparation were given in the previous paper.[5]

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The cryostat for the Seebeck effect measurements in a steady state was slightly modified from the previous one used for Bi thin films,[6] as shown schematically in Fig. 1. The upper and lower ends of the sample were soldered by a wood's metal to the copper block around which a manganin heater was wound noninductively. The copper-constantan thermocouples were soldered directly to both ends of the samples for temperature and thermoelectric voltage measurments in the temperature range 300-77 K; carbon resistors were also fixed at the ends of the blocks drilled close to the sample for the measurements at liquid helium temperatures. The sample was supported by the two bakelite plates.

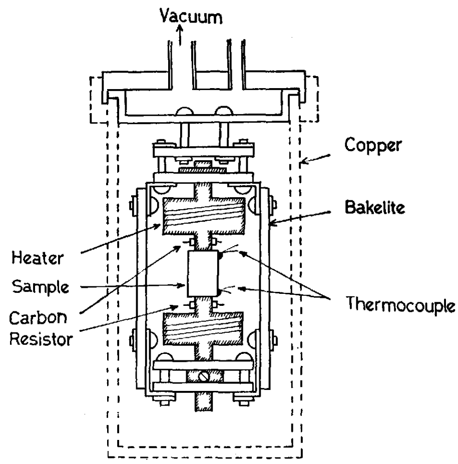

Fig. 1. Schematic diagram of apparatus used for the thermoelectric power. Both ends of the sample are soldered to the copper block around which a heater is wound noniductively.

3. Results and discussion

The present thermoelectric effects have shown that all the samples are p-type in agreement with the Hall effect measurement. The proportionality between the emf V and the temperature difference ΔT at both ends of the sample was measured at each temperature. Typical data at 94 K and 237 K are illustrated in Fig. 2, where no correction is made for the observed thermoelectric voltage and the temperature difference ΔT is expressed by the emf V of the two thermocouples; the slope gives the Seebeck coefficient α for the respective temperature.

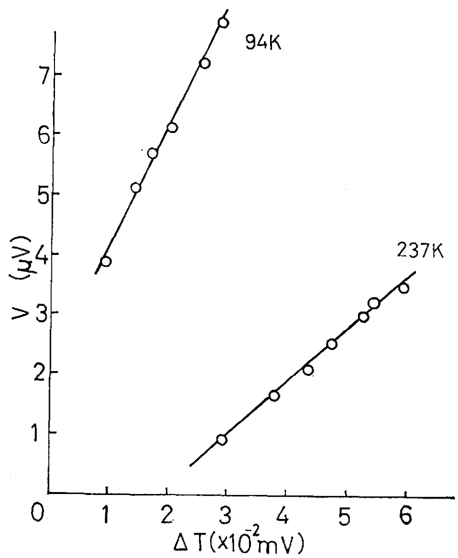

Fig. 2. The observed proportionality between the emf V and the temperature difference ΔT in unit of the emf of the two copper-constantan thermocouples.

Figure 3 shows the temperature dependence of the Seebeck coefficient for a few samples of SnTe over the temperature range from 300 to 77 K; the carrier density p is determined by the Hall effect measurement at room temperature. The observed values of α at 300 K are approximately in agreement with those

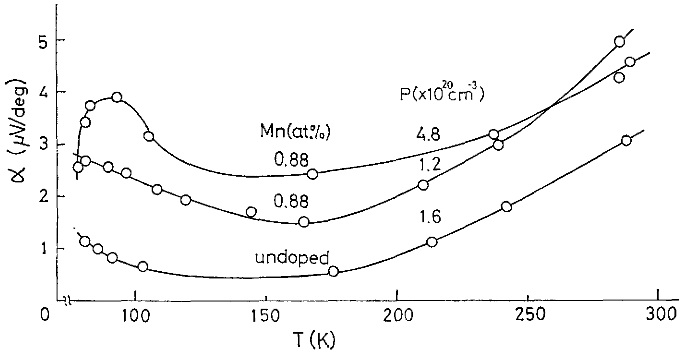

Fig. 3. Seebeck coefficient α plotted as a function of temperature for undoped and Mn (0.88 at. %)-doped SnTe crystals, the carrier density of each sample being indicated.

found by Kafalas *et al.*[2] It is worth mentioning that with decreasing temperature the coefficient decreases and tends to rise below 150 K. The increase in α at low temperatures can be seen for both undoped and Mn-doped crystals, so that this enhancement is not ascribed to the magnetic impurities in the crystal. The contribution of the localized magnetic moment to the transport properties of the magnetic semiconductor will occur at lower temperatures below 10 K as found by various measurements such as resistivity, magnetic susceptibility and Hall effect (see a review article[1]).

A possible reason may be attributed to the so-called "phonon drag effect", as observed in many semiconductors.[2] That is, the heat flux is transferred by the conduction carriers as well as by the phonons through a carrier-phonon interaction. One might note another possibility of the increase in α, which is related to a phase transition of SnTe at about 100 K: the weak-field Hall effect measurements of SnTe crystals ($p \sim 1\times10^{20}$ cm^{-3})showed an anomaly at 100 K which was ascribed to the softening of a TO phonon.[7] In our case, such an increase in the Hall coefficient at 100 K was not oberved. Detailed discussion will be accomplished by the further measurements over a wide range of temperature.

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