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Hall mobility of amorphous $\text{Ge}_2\text{Sb}_2\text{Te}_5$

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The electrical conductivity, Seebeck coefficient, and Hall coefficient of 3 micron thick films of amorphous $\text{Ge}_2\text{Sb}_2\text{Te}_5$ have been measured as functions of temperature from room temperature down to as low as 200 K. The electrical conductivity manifests an Arrhenius behavior. The Seebeck coefficient is p -type with behavior indicative of multi-band transport. The Hall mobility is n -type and low (near $0.07 \text{ cm}^2/\text{V sec}$ at room temperature).

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Chalcogenide glasses have attracted considerable attention because of their utility in switching devices.¹ In particular, thin films of non-crystalline $\text{Ge}_2\text{Sb}_2\text{Te}_5$ are currently used in many applications. However, the fundamental nature of the steady-state electronic transport of these covalent glasses remains unresolved. Is the intrinsic mobility of the charge carriers high ($\gg 1 \text{ cm}^2/\text{V sec}$) or low ($\ll 1 \text{ cm}^2/\text{V sec}$)?

Here we address steady-state electronic transport of the non-crystalline state of $\text{Ge}_2\text{Sb}_2\text{Te}_5$ films. Three-micron-thick films were deposited on water-cooled cover-glass substrates by radio-frequency sputtering from stoichiometric targets in 10 mTorr of Argon at the University of Utah. In-plane electronic transport measurements were made at the University of New Mexico. Conductivity measurements were performed with a 4-probe technique. Seebeck coefficients were measured using a pair of heaters and a differential thermocouple. Hall-effect measurements utilized the van der Pauw method.² Reference 3 provides details of the electrical transport measurements.

As illustrated in Fig. 1, the electrical conductivities of non-crystalline films were found to be thermally activated between room temperature and about 200 K: $\sigma = \sigma_0 \exp(-E_\sigma/k_B T)$. Each sample has an activation energy, E_σ , between 0.36 eV and 0.43 eV with a pre-exponential factor $\sigma_0 \approx 10^3 \text{ S/cm}$. These observations are consistent with literature values.⁴⁻⁶

The Seebeck coefficients of these films were all large ($\sim 1 \text{ mV/K}$) and p -type. Figure 2 presents results obtained for one sample. The measurements become unreliable below 240 K. The results can be fit with the single-band semiconductor formula,

$$S = \frac{k_B}{q} \left(\frac{E_S}{k_B T} + A \right), \quad (1)$$

where k_B is the Boltzmann constant, q is the carrier's charge, and A is the heat-of-transport constant. Single-

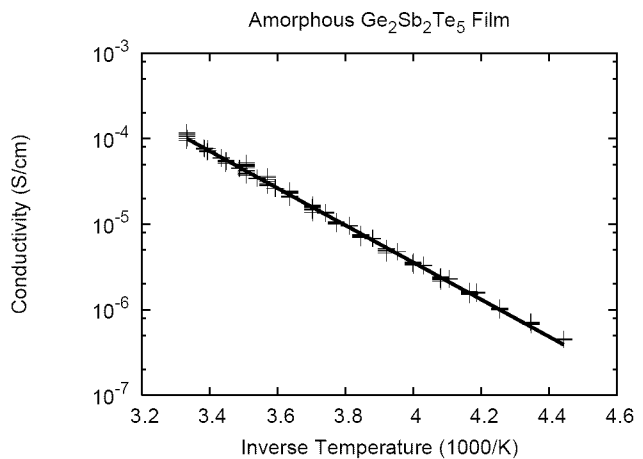


FIG. 1: Conductivity vs. inverse temperature for a typical film, the lines represents a linear least squares fits to the data. The best fit line has an activation energy of 0.43 eV.

band transport requires that $E_S \leq E_\sigma$ and $A > 0$. However, our data yields $E_S \geq E_\sigma$ and $A < 0$. Indeed, these observations are similar to those reported by Vander Plas and Bube for Ge-Te and Sb-Ge non-crystalline films.⁷ We concur with Vander Plas and Bube in concluding that electrical transport in these films does not permit analysis in terms of a single type of charge carrier executing a single mode of motion.

The Hall effect remains the most promising means to probe charge carriers' intrinsic (trap-free) steady-state transport.⁷ The Hall mobility measures charge carriers' deflection by a magnetic field. The Hall mobility is intrinsic in that it is unaffected by trapping since the Lorentz force only operates on moving charges.⁸ For free carriers the Hall mobility equals the intrinsic (conductivity) mobility, the mobility that enters into the steady-state electrical conductivity. Trapping affects the electrical conductivity by reducing the carrier density. By con-

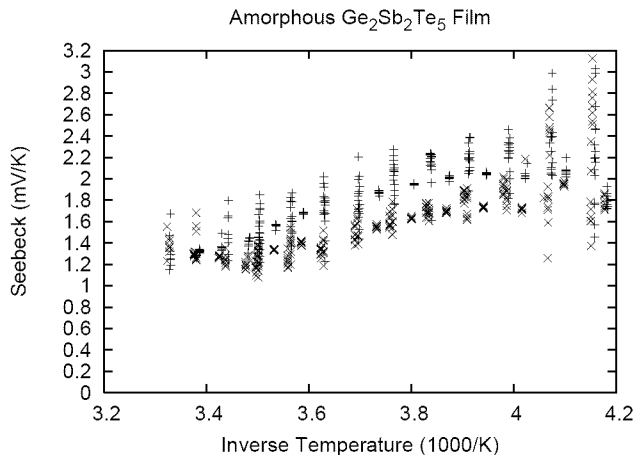


FIG. 2: Seebeck coefficient vs. temperature with datapoints denoted by 'X' symbols taken using twice the heater power of those denoted by '+' symbols.

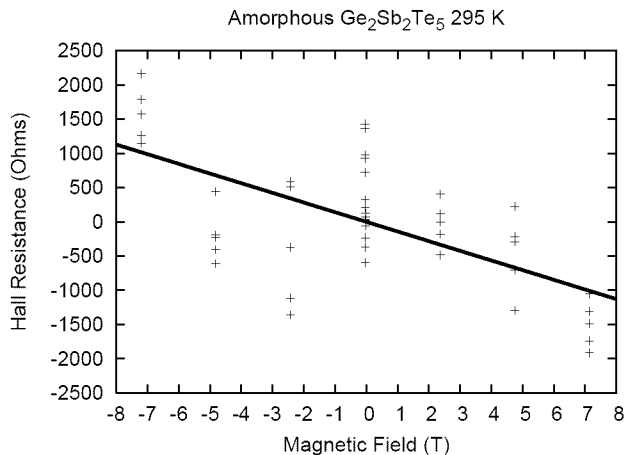


FIG. 3: Hall data at 295 K, the line represents a linear least squares fit.

trast, the relationship between the Hall mobility and the intrinsic (conductivity) mobility is more complex for carriers that move by thermally assisted hopping.⁸ In particular, the Hall mobility for such carriers is frequently significantly larger and less temperature dependent than the conductivity mobility. In addition, the sign of the Hall effect for hopping-type carriers is often anomalously signed.^{8–14} Then, for example, carriers that produce a *p*-type Seebeck effect produce an *n*-type Hall effect.

Hall effect measurements on low-conductivity films are difficult. Nonetheless, we made sufficiently symmetric contacts to one film to enable us to isolate the Hall signals. These small signals, presented in Figs. 3 and 4, correspond to *n*-type Hall mobilities of 0.07 ± 0.01 cm²/V sec and 0.07 ± 0.02 cm²/V sec at temperatures of 295 K and

275 K, respectively.

These measurements indicate that the Hall mobility is truly low, $\ll 1$ cm²/V sec. Were the Hall mobility to be high, > 1 cm²/V sec, it would have been easily detected.

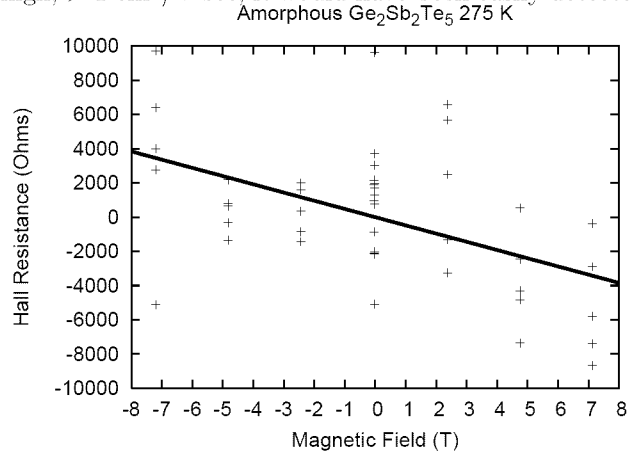


FIG. 4: Hall data at 275 K, the line represents a linear least squares fit.

Furthermore, the low mobility is unlikely to be the result of a fortuitous cancellation of contributions from electrons and holes as their relative contributions would have changed considerably with changing temperature.

Our measurement of an anomalously signed, very low Hall mobility possessing a weak temperature-dependence is consistent with the predominance of charge carriers that move by thermally assisted hopping. Indeed, these observations and conclusions are in accord with measurements and analysis of steady-state transport measurements of related chalcogenide glasses: As-Te based glasses, As₂Se₃, As₂S₃, and Sb₂Te₃.^{3,9,10,15,16}

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