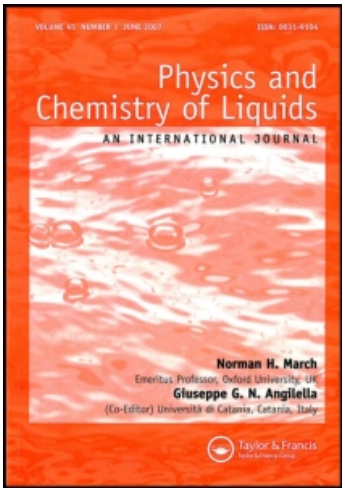

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Thermal Conductivity of Selenium Doped with Indium and Iodine in the Solid and Liquid States

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THERMAL CONDUCTIVITY OF SELENIUM DOPED WITH INDIUM AND IODINE IN THE SOLID AND LIQUID STATES

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We have measured the thermal conductivity in both solid and liquid states for two amorphous samples. The first is selenium doped with indium and the second is selenium doped with iodine. The concentration of In and I in the samples were 50000 ppm. Measurements were taken in a temperature range from 1000 to 370°C, and were carried out using the concentric cylinder method, which is based on the flow of heat through a cylindrical wall.

KEY WORDS: Amorphous state, phonons.

INTRODUCTION

The thermal conductivity of amorphous semiconductors and dielectrics has taken a greal deal of interest in the last three years. Several trials have been made to investigate the phonon processes in such materials and their changes at the phase transition point[1–3].

The aim of the present contribution is to study the thermal conductivity of selenium when doped with relatively high percentage of indium as a sample, and iodine as another sample. The melting point is 230°C for the first sample, and 215°C for the second.

EXPERIMENTAL DETAILS

The samples were prepared from highly pure elements (99.999%), were pure selenium was doped with a concentrations weight percent of 50000 ppm of indium or iodine, which is equal to a concentration of 3.33% for indium and 3.02% for iodine additives in atomic percent. The synthesis of the samples was carried out under high vacuum (10^{-3} Pa) in silica tubes at 450°C for more than 6 hrs with frequent rocking to ensure homogenization of the melt. Then the tubes were quenched in ice to obtain the samples in the glassy state. The solid glassy materials were then heated in an inert atmosphere until melting, then transferred to the measuring cell.

Measurements of thermal conductivity were carried out using the concentric cylinder method under steady state thermal conditions, where the material is placed

in the cylindrical gap between two concentric graphite cylinders kept in nitrogen atmosphere[4].

The thermal conductivity was calculated using the formula:

$$K = Q \ln\left(\frac{d_2}{d_1}\right)[2\pi L(t_1 - t_2)^{-1}] \tag{1}$$

where, d_1 and d_2 are the diameters of the inner and outer cylinders, t_1 and t_2 are the temperatures at both sides of the sample, L is the length of the cylinder, and Q is the quantity of the heat generated and is given by:

$$Q = m\left(\frac{\Delta T}{\Delta t}\right)s$$

where m is the mass of external cylinder, $(\Delta T/\Delta t)$ is the temperature gradient, and s is the specific heat of graphite. Measurements were carried out in a wide range of temperatures below and above the melting point.

RESULTS AND DISCUSSION

It is usually convenient to analyze the thermal conductivity K in terms of four contributions:

$$K = K_e + K_{ph} + K_{am} + K_r$$

where, K_e is the electron component,
K_{ph} is the phonon component,
K_{am} is the ambipolar component, and
K_r is the radiation component which considered zero in this contribution.

Cutler[5] has pointed out that: $K_e = W_0 \sigma T$, where W_0 is constant $= \pi^2 k^2/3e^2$ and this is equal to 2.45×10^{-8} V^2/deg^2.

Taking into consideration that σ of our samples is of the order 10^{-2} ohm^{-1} m^{-1} as a max. value[6], we could say that the contribution of K_e is relatively small value, and its increase with temperature is so small to be of a remarkable effect on K.

Magomedov[7] has mentioned that the temperature dependence of phonon thermal conductivity K_{ph} limited by umkllapp processes could be considered as:

$$K_{ph} = BT_{mp}^{3/2}\rho^{2/3}/A^{7/6}T$$

where B is a coefficient ($B = 13$ for covalent crystals and 1.5 for ionic crystals), T_{mp} is the melting point, ρ is the density of the sample, A is the average atomic weight, and T is the temperature.

Cutler[5] stated that:

$$K_{am} = \frac{\sigma_h \sigma_e}{\sigma_h + \sigma_e}(S_h - S_e)T$$

where σ is the electrical conductivity,
S is the thermoelectric power
both due to holes generation (h) or electrons (e)

Figure 1 sets out the experimental temperature dependence of the thermal conductivity of both Se doped with In and Se doped with I. According to the previously stated analysis of the thermal conductivity components, the decrease of K could be attributed to the decrease of K_{ph}. The abrupt decrease before the melting point in both samples is due to the decrease of density on melting, and the subsequent increase of the distance between molecules which leads to a weakening of the bonds between molecules and an increase in the disordered arrangement.

We have found in a previous work[6] that for selenium doped with In, the thermoelectric power S remains positive for all temperatures, and also indium favour P-type conduction in liquid selenium. So, one could conclude that the conduction due to electrons, i.e. σ_e, is nearly zero, and therefore K_{am}, which is the ambipolar component of thermal conductivity, could be neglected. This explains why there is no slight increase in K after the melting point.

CONCLUSIONS

The thermal conductivity K of $Se_{1-x}In_x$ ($x = 0.0333$) and $Se_{1-x}I_x$ ($x = 0.0302$) varies with temperature as T^{-1} indicating that the thermal conductivity is of phonon type, K_{ph}. Because of the low electrical conductivity σ for both samples, the electron

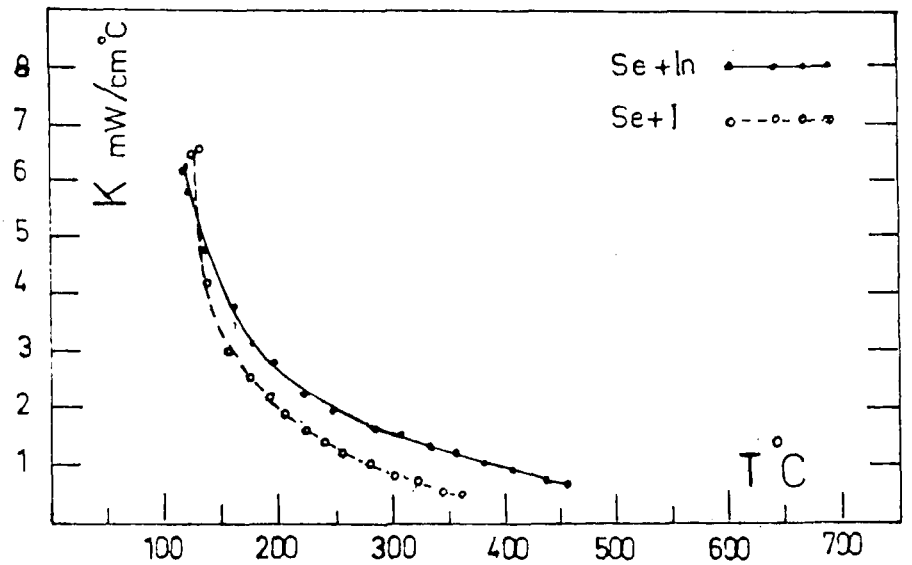

Figure 1 Temperature dependence of the thermal conductivity of Se doped with In and Se doped with I in the solid and liquid states.

component, K_e, and the ambipolar component, K_{am}, are very small, and the temperature dependence of K can be explained by the influence of thermal effects on the lattice structure.

The figure of merit for both samples at 170°C have been calculated, and the values were:

45.7×10^{-6} for selenium doped with indium and,
14.7×10^{-6} for selenium doped with iodine.

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