ACTIVATION ENERGY OF PSEUDOBINARY ALLOY OF Al-Bi-Se MIXED SYSTEMS.

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Abstract: The electronic properties of pseudobinary alloy Al-Bi-Se mixed systems were examined at temperatures 303 – 353K. Current-voltage characteristics were obtained at electric field values 0.20 - 0.65V/m. The results in the study showed that the conductivity of the alloys increases with increase in temperature of the samples. The current-voltage characteristics also show linear relationship which satisfies the Arrhenius relation $\delta = \delta_o \exp(-\varepsilon/kT)$ typical of semiconductor materials. The activation energy of the sample was found to be 0.012eV. This indicates that the Al-Bi-Se mixed systems posses semiconductor properties and can therefore, be used in thermo-electric devices.
Keywords: - Electronic conductivity, Al-Bi-Se, activation energy.

1. INTRODUCTION

The study of the electronic properties of semiconductor-based materials is of great importance in photo electronic and optical devices such as photoconductors, lasers and solar cells [2 - 7]. In particular, tellurium and selenium semiconductor materials are interesting materials with potentially important device applications. They are known to posses different properties in liquid and solid states. For instance, liquid selenium can change its properties from dielectric to semiconductor, i.e., selenium based melts are semiconductors that are metallised on heating. Cutler [8] showed that the dependence of electrical conductivity on the carrier concentration of tellurium and selenium based melts exhibit a minimum while the corresponding dependence of the thermoelectric power has a maximum in the stochiometric composition region. Several other authors [9, 10] had also confirmed these properties. Studies on most selenium alloy materials have been motivated by their importance in long-wavelength sensor devices, diode lasers, and themovoltaic energy converters [11]. Lead salts (PbSe/PbTe) cystallises in the rocksalt structure and are polar semiconductors. They are also known to have some unusual electronic and structural properties, such as a very narrow energy gap, high carrier mobilities, high electric constant and a positive temperature coefficient of the gap that may be unique among polar semiconductors [12]. The band gaps are also known to decrease with increase in pressure [13].

According to estimates based on available crystallographic and phase compilations [14], less than five percent of ternary alloy systems have been studied. The positive part of this is that nature has for our society still an enormous basin of yet not investigated systems/compounds available. In addition to the study of the electronic properties, the alloy system in this study will increase the number of ternary alloys so far investigated.

In this study, we examine the electronic and activation energy properties of the pseudo-binary alloys of Al-Bi-Se mixed systems to determine their suitability in thermo-electric devices.

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2. MATERIALS AND METHOD

The silica glass tube used as containers for melting the elements were cleaned by first boiling in concentrated acid and then ultrasonically agitated in distilled deionised water, trichloroethylene, acetone and ethyl alcohol for twenty minutes each. The elements; Al, Bi, Se are of 95% purity (supplied from Johnson Malthey, U.K).

Powdered samples of proportions 10.52g of Al, 39.03g of Bi and 0.45g of Se were weighed using appropriate weighing balance (Ohaue Triple Beam balance 2650g capacity) and carefully poured into the already cleaned silica tube. The upper end of

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the tube was sealed off and enclosed in a furnace. The materials in the tube were heated over a range of temperature from room temperature to 300^{0}C to form molten alloy. The resulting sample was allowed to homogenize at this temperature for about 30 minutes. The sample was polished with a fine grain sandpaper and electrical contacts were made to opposite ends of the sample with a flux less solder. Thereafter, the sample with contacts was inserted in a thin- walled test tube. The lower part of the tube was immersed in a lagged heatable water bath while uniformity in temperature was ensured with the aid of a magnetic stirrer immersed in the bath. The insulated electrical leads from the contacts were taken out of the test tube with the aid of ports, which were vacuum-sealed with araldite. The current-voltage characteristics were determined with the aid of a digital electrometer (Keithley 160B) and a digital multivoltmeter (Hewlett-Packard 3465A). The sample temperature and that of the water bath were determined with copper-constantan thermocouple whose cold junction was maintained at 0^{o}C. All the measurements were carried out at a number of temperatures between 303 and 353K.

3. RESULTS AND DISCUSSION

The results of the current – voltage characteristics are shown in figure 1. The current in the samples increases with increase in voltage and temperature respectively. The conductivity of the alloys were found to be 1.3, 1.52, 1.63, 1.78, 1.79 and 1.81$(\Omega\text{-m})^{-1}$ for temperatures 303, 313, 323, 333, 343 and 353K respectively which gave rise to an activation energy of 0.012eV. In each case, the conductivity (δ|) increases with temperature as in the relation

$$\delta = \delta_0 \exp(-\varepsilon/kT) \qquad (1)$$

where ε is the activation energy, k is Boltzman's constant, T is the absolute temperature and δ_0 is the conductivity at zero resistance. The increase in conductivity with temperature could be attributed to the fact that, at low temperature, there is a high resistance offered to the flow of charge carriers due to intercrystalline regions in the sample. At high temperature however, sufficient thermal energy is available for electrons to be excited from their mean position. In recent study of the A. C. conductivity and dielectric properties of $AgPO_3$ glass [5], it is argued that when the temperature of the sample is increased to higher values, the conductivity also increases due to an increase in Ag mobile ions. Therefore, increase in temperature results to subsequent increase in the number of mobile electrons and hence, increase in conductivity. The value of the activation energy also reveals that the alloy system is a narrow energy gap semiconductor material.

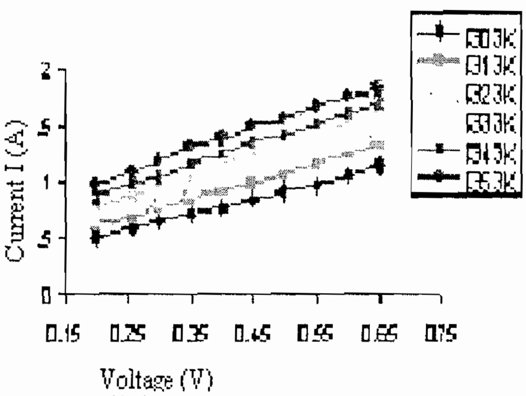

Fig. 1. Current-Voltage characteristics of the samples.

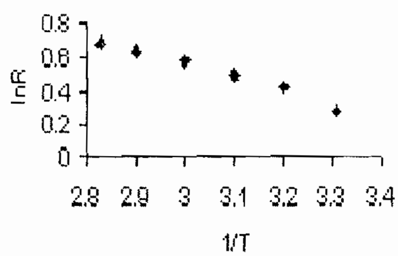

Fig 2: lnr-1/T plots for the samples

Although the concentration of selenium in the alloy sample is small, the properties of the bulk sample certify that of basic semiconductor materials that have attracted researches due to their numerous applications in thermoelectric and optical devices.

The conductivity (δ) is evaluated from the microscopic form of Ohms law. This involves the measurement of current when a potential difference is placed across a finite specimen of conducting material, such that [16, 17, 18]

$$J = \delta E$$

where J = current density, E = field produced within the material by applied voltage. Figure 2 illustrates the conductivity against inverse of temperature. The activation energy is then determined with a least square fit to the relation:

$$\delta = \delta_0 \exp(-\varepsilon/kT)$$

4. CONCLUSION

We have examined the electronic properties of the pseudobinary alloys of Al-Bi-Se mixed systems with selenium concentration of 0.45g. The elements were homogenized together at a temperature of about 300°C after melting in a furnace. The current – voltage characteristics were then measured at temperature between 303 – 353K. The results in the analysis showed that the conductivity of the samples increases with increase in temperature of selenium in the alloy system. The current voltage relationship and the value of the activation energy (ε=0.012eV) indicate that the samples posses semiconductor properties. Therefore, the sample can be used in thermoelectric devices.

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