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Room temperature transport measurements on Bridgman-grown p-type $CuIn_{1-x}Ga_xSe_2$

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Abstract

Room temperature measurements were made of electrical conductivity (σ), Hall coefficient (R_H) and Seebeck coefficient (α) on filamentary samples of p-type $CuInSe_2$ and $CuIn_{1-x}Ga_xSe_2$ with $x \leqslant 0.3$, cut from vertically grown Bridgman ingots. Analysis of the results was done on a two-carrier basis, due to the higher ratio of electron to hole mobility (b) in these materials compared to elemental semiconductors. This treatment yielded a preferred b-value of 5 and to lower calculated hole concentrations than $(R_He)^{-1}$ and higher hole mobilities than $R_H\sigma$, based on a one-carrier interpretation. This effect was particularly marked in p-type samples with a hole concentration below $10^{17}\,cm^{-3}$, where even a few percent of minority electrons can play an important role.

Keywords: Copper–indium–diselenide; Hall coefficient; Seebeck coefficient; Mobility ratio; Bridgman growth

1. Introduction

The chalcopyrite semiconductors $CuIn_{1-x}Ga_xSe_2$, in p-type form, are important candidate materials for the absorber layer in a thin film solar cell, so that it is useful to know their transport properties at room temperature. A feature of these materials is that they have a higher ratio b of electron mobility μ_n to hole mobility μ_p [1] than elemental semiconductors. This means that if sufficient electron compensation exists in a p-type sample, measurements of transport effects, such as Hall effect and electrical conductivity, can yield apparent hole concentrations which are too high and hole mobilities that are too low, if calculated on a one-carrier basis. This error can be significant, even if the electron concentration (n) is only a few percent of the hole concentration (p) because of the high b-value.

In order to characterize sufficiently p-type material grown in this laboratory by a vertical Bridgman method [2,3], measurements were made on filamentary samples with nominal compositions $CuInSe_2$ and $CuIn_{1-x}Ga_xSe_2$ ($x \leqslant 0.3$) cut from the ingots. These measurements were electrical conductivity (σ), Hall coefficient (R_H) and thermoelectric power or Seebeck coefficient (α). While conventionally, just σ and R_H are usually used to characterize the transport properties of semiconductors, the addition of Seebeck coefficient enables a deeper analysis to be made of the parameters, resulting in a better estimation of b in a given sample and more realistic values to be obtained for hole concentration p and mobility μ_p. Estimation of true mobility values in solar cells is important, since the device photogenerated current increases with minority carrier diffusion length, which in turn increases with electron mobility in a p-type absorber substrate.

2. Samples and measurements

Slices about 2 mm thick were cut abrasively from p-type chalcopyrite Bridgman-grown ingots [2,3] and from these, filamentary samples were cut with typical dimensions of $2 \times 2 \times 10\,mm^3$. Each filament was first soaked in trichloroethylene and then in acetone and DI water. Small gold

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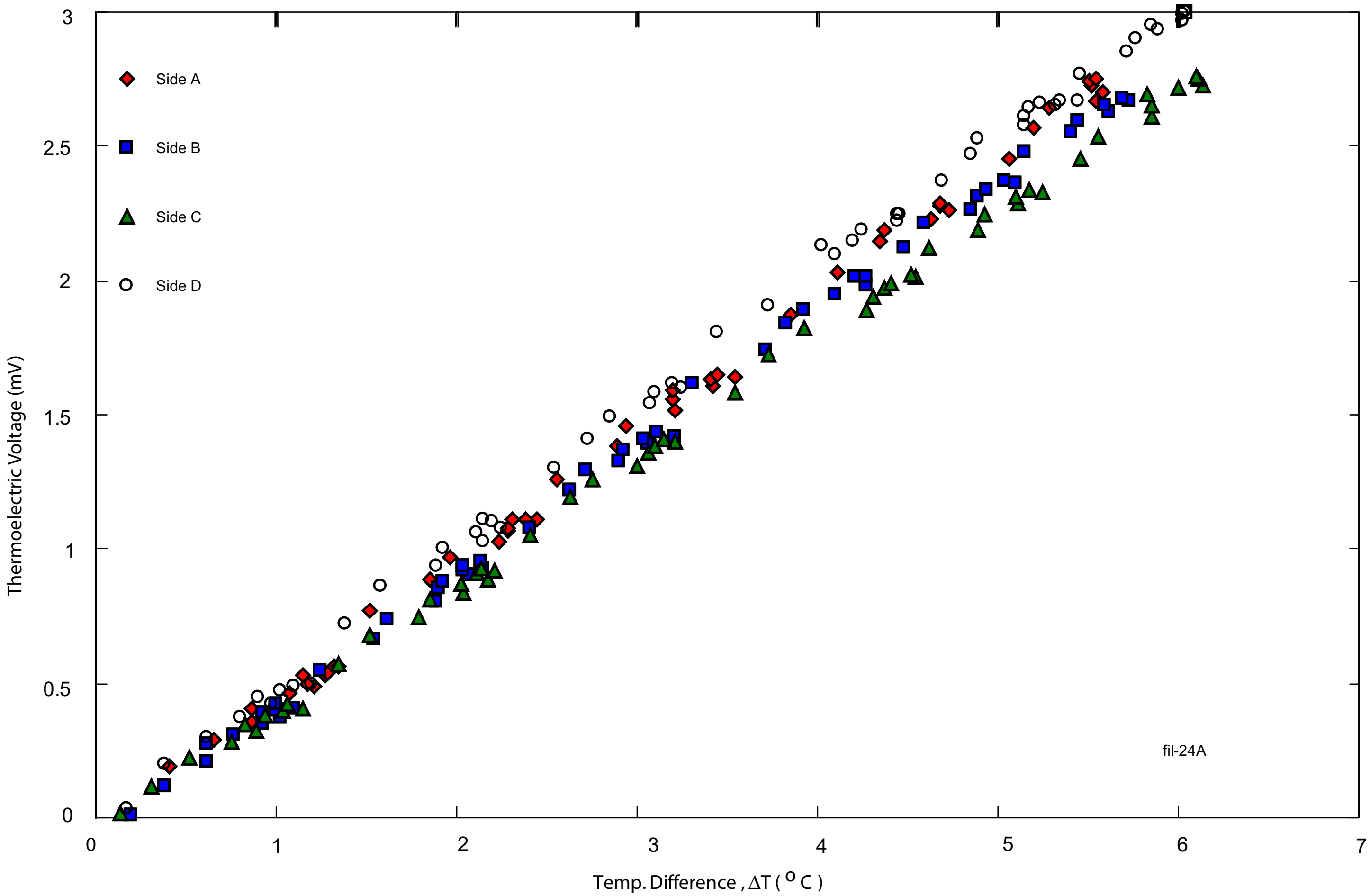

Fig. 1. Variation of thermoelectric voltage with temperature difference, ΔT along filamentary $CuInSe_{2.2}$ sample 24A.