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Evaluation of Thermoelectric Properties of $Cu_{3.21}Bi_{4.79}S_9$ Bismuth Chalcogenide

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Abstract. $Cu_{3.21}Bi_{4.79}S_9$ was synthesized from Cu, Bi and S element powders using mechanical alloying method. The formation of $Cu_{3.21}Bi_{4.79}S_9$ was identified using XRD and the changes of morphologies of the mixtures of Cu, Bi, and S powders during milling were observed using table top SEM. The milled powders were sintered using Hot-isostatic pressing at 230°C with a pressure of 50 MPa. Electrical resistivity and Seebeck coefficient of sintered samples were measured using ZEM-3 (Electrical resistivity and Seebeck Coefficient measuring System). $Cu_{3.21}Bi_{4.79}S_9$ and some secondary phases were found in the 5h milled powder but single phase $Cu_{3.21}Bi_{4.79}S_9$ was only obtained after milling for 15 h. A minimum electrical resistivity of sintered $Cu_{3.21}Bi_{4.79}S_9$ sample was found to be 0.66 Ω.m at 170°C. We observed that a *n*- to *p*-type conversion at temperature of around 75 ºC. However, a maximum *n*-type Seebeck coefficient of $Cu_{3.21}Bi_{4.79}S_9$ was of -214 μV/K at 45 ºC. The Seebeck coefficient decreases with increasing temperature and it reaches zero value at around 75 ºC and then *p*-type Seebeck coefficient increases with increasing the temperature. The maximum *p*-type Seebeck coefficient was observed of 202 μV/K at 170ºC.

1. Introduction

Thermoelectric generator (TEG) converts heat to electricity through the Seebeck effect, Joul heating, Peltier effect and heat conduction. TEG modules are consists of an equall number of *n* and *p*-type thermoelectric material legs, which are arranged as an electrically series connected *n-p* couples. Solid-state TEGs are scalable, reliable, silent, without moving parts and ideal for distributed power generation. However, the use of this technology is still not very widespread due to the low efficiency of thermoelectric (TE) materials. In addition, the heat exchangers associated with TE application also need to be improved to enhance TEG efficiency [1]. A high efficiency TE material should possess with a high Seebeck coefficient (S), high electrical conductivity (σ), and low thermal conductivity (*k*). The efficiency of TE materials is expressed via the dimensionless Figure of merit, $ZT=S^2\sigma T/k$, where T is absolute temperature.

Among prospective TE materials for low and middle temperature applications, A_2B_3 (where A = Bi, Sb, Pb and B = S, Se, Te) compounds are considered to be the most promising [2], and these compounds have been extensively studied since the $Bi_2Te_{3-x}Se_x$ and $Bi_{2-x}Sb_xTe_3$ alloys showed high ZT values [3, 4]. In the binary bismuth chalcogenide family, Bi–Te based and Pb–Te based [5, 6] materials showed the best TE properties at room and middle temperatures, respectively.