Effect of Fe_3O_4 on the Thermoelectric Properties of $Bi_1Sb_4Te_{7.5}$ Alloy

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1. Introduction

Generally, the effectiveness of thermoelectric materials is determined by the figure of merit $Z(=S^2\sigma/\kappa)$ where S is the Seebeck coefficient, σ is the electrical conductivity, and κ is the thermal conductivity. The large Seebeck coefficient, high electrical conductivity, and low thermal conductivity are required for high performance thermoelectric materials. Today, It is known that heavily degenerated Bi-Sb-Te thermoelectric materials and narrow energy band gap semiconductor compounds show the high figure of merit in room temperature

Fe_3O_4, a one of the mixed-valance material, charge transfer between Fe^{3+} and Fe^{2+} reduce the thermal conductivity. It is well known that the mixed-valence material has low thermal conductivity

In this study, the main purpose is to improve the Z value by reducing the thermal conductivity, the effect of Fe_3O_4 addition to the thermoelectric properties of $Bi_1Sb_4Te_{7.5}$ alloy fabricated with MA process was studied.

2. Experimental Procedure

Samples were prepared according to this composition $Bi_1Sb_4Te_{7.5}$ + Fe_3O_4(0, 0.01, 0.02, 0.03, 0.05, 0.07. 0.1wt%). In the Ar gas was filled glove box, Mechanical alloying was carried out in the vibratory ball mill with a frequency of 25Hz during 200hr. The mass ratio of ball-to-powder was 80%. Mechanically alloyed powders were sieved and the powders under 75㎛ were consolidated into bulk in graphite dies by pulse discharge sintering(PDS). Sintering was carried out at 618K, under 56MPa and for 10min

The Seebeck coefficient was determined by applying a temperature gradient of 10-30K between the two ends of the pillar type sample. The hall effect was measured from 80 to 360K by using the direct current van der Pauw method. The density of the sintered compact was determined by the Archimedes principle. Specific heat capacity was determined by using the laser flash method. The thermal conductivity ($d\times C_p\times\kappa_d$) was calculated by multiplying the experimental values of density (d), heat capacity (C_p), and thermal diffusivity.

3. Results

Fig. 1 shows the variations of the Seebeck coefficient at room temperature and power factor by Fe_3O_4 content in $Bi_1Sb_4Te_{7.5}$ alloys. The Seebeck coefficient increases with $Bi_1Sb_4Te_{7.5}$, but the power factor decreases with $Bi_1Sb_4Te_{7.5}$ because of decreased electrical conductivity.

Fig. 2 illustrates the variation of thermal conductivity at room temperature with $Bi_1Sb_4Te_{7.5}$ content. The thermal conductivity decreases with Fe_3O_4, as expected previously.

The variation of Z value at room temperature with $Bi_1Sb_4Te_{7.5}$ content is shown Fig. 3. The Z value of 0.02 wt.% $Bi_1Sb_4Te_{7.5}$ alloy is 3.05×10^{-3} /K, the highest value among the prepared alloys.

The calculated carrier concentration measured by the Hall effect measurement is shown

in Fig. 4. It could be suggested that the carrier concentration decreases with $Bi_1Sb_4Te_{7.5}$ content.

4. Conclusions

The thermal conductivity of 0.1 wt.% Fe_3O_4 alloy is 0.814 W/Km, lower than that of Fe_3O_4 free alloy by 20%. On the other hand, the Seebeck coefficient increases with Fe_3O_4, but the electrical conductivity and power factor decrease with Fe_3O_4.

Finally, the maximum Z value is achieved in 0.01 wt.% Fe_3O_4 alloy, which is somewhat higher than that of Fe_3O_4 free alloy.

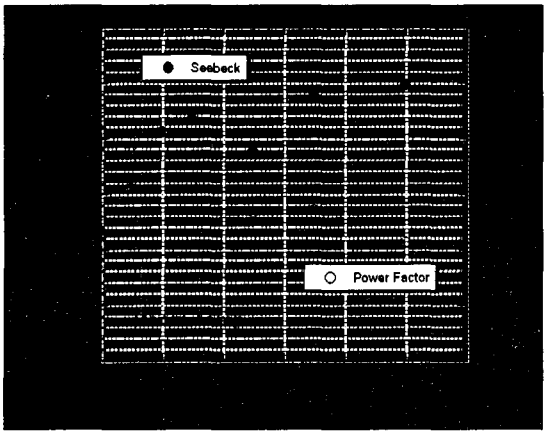

Fig. 1. Seebeck and power factor of Fe_3O_4 added $Bi_1Sb_4Te_{7.5}$ alloys

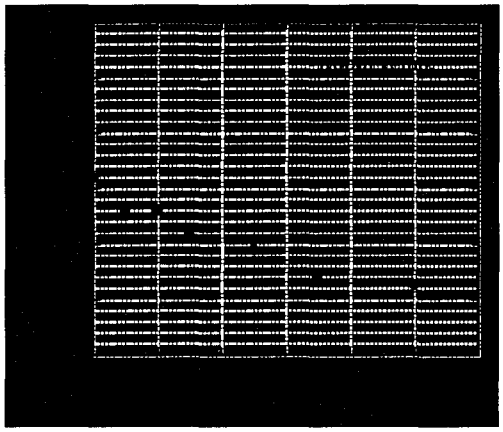

Fig. 2. Thermal conductivity of Fe_3O_4 added $Bi_1Sb_4Te_{7.5}$ alloys

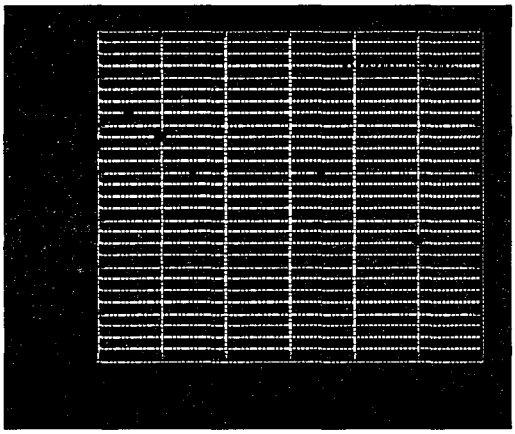

Fig. 3. Figure of Merit of Fe_3O_4 added $Bi_1Sb_4Te_{7.5}$ alloys

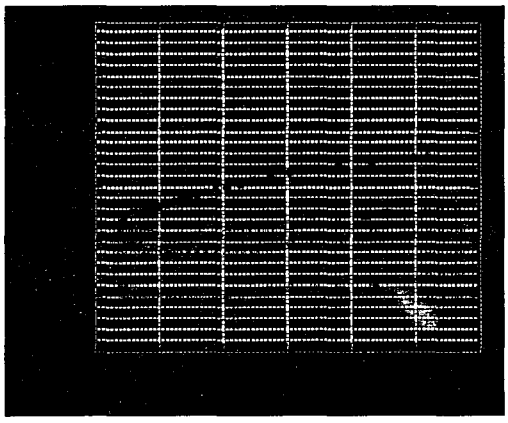

Fig. 4. Effect of Fe_3O_4 addition on the carrier concentration of $Bi_1Sb_4Te_{7.5}$ alloys