

Electric Property of $\text{Bi}_{0.4}\text{Ti}_3\text{Sb}_{1.6}$ Thermoelectric Material Prepared by Powder Metallurgy Process

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Abstract

In the present study, the powder metallurgical fabrication of $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ thermoelectric materials has been studied with specific interest to control the microstructure by the mechanical grinding process. The $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ thermoelectric powders with a various particle size distribution were prepared by the combination of the mechanical milling and blending processes. The specific electric resistivity of the $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ sintered bodies mainly depended on the orientation of the crystal structure rather than the particle size of the raw powders.

Keywords : thermoelectric materials, powder, mechanical grinding, bismuthe telluride, crystal structure

1. Introduction

With the development of new materials in environment, energy, and energy conversion application, thermoelectric materials have received considerable attention in recent years. Solid solutions of Bi_2Te_3 and Sb_2Te_3 have excellent p-type thermoelectric properties and are the best materials for use in thermoelectric cooling and thermoelectric power generation at room temperature.¹⁾

However, they have not been used in various industrial field due to their lower efficiency for cooling and power generation. The efficiency of the thermoelectric materials estimated by the figure of merit (ZT). The key to improve the figure of merit is increasing Seebeck coefficient, and decreasing specific electric resistivity and thermal conductivity. These electric and thermal properties depend not only on chemical composition but also on microstructure of the thermoelectric material.³⁾ A number of processes exist for manufacturing thermoelectric materials, such as casting, co-precipitation and powder metallurgy. Generally, the thermoelectric materials manufactured by the powder metallurgy process have the low efficiency compared to the one of the casting process.

The control of the microstructure was very important, in the powder metallurgy process, since the thermoelectric properties; electric resistivity, thermal conductivity and seebeck coefficient were strongly effected by the grain boundary and defects.

In the present study, the focus is on the manufacture of Bi-Te-Sb thermoelectric material by the powder metallurgy process. And also the verify of the correlation between the electric properties of the Bi-Te-Sb and microstructure of one for the optimizing the microstrure of thermoelectric materials.

2. Experimental

The raw materials Bi, Sb, Te were weighed to obtain the target composition ($\text{Bi}_2\text{Te}_3\text{-}4\text{Sb}_2\text{Te}_3\text{-}4\text{wt}\%\text{Te}$). The major elemental components were first sealed in a quartz ampoul and melted together. The pre-alloyed bulk alloy was mechanical milled by the ball mill for 6 hours under an argon atmosphere. The mechanical milled pre-alloyed powder heat treated at 350 °C for 2hours under a hydrogen atmosphere. The hydrogen heat-treated powder sieved as table 1. And these sieved powders blended with a specific fraction. The blended powders compacted to the columnar shape; diameter is 22mm and height is 2.2mm. The compacted green bodies were sintered at 350 °C for 3minutes by the spark plasma sintering. The sintering pressure maintained at 50MPa during sintering. The specific electric resistivity of the sintered bodies measured along the perpendicular direction to the sintering pressure direction. The X-ray diffraction analysis performed on the perpendicular surface to the sintering pressure direction.

Table 1. The particle size of the classified powders.

Powder	Particle size (um)
A	200~125
B	under 34

3. Results

Figure 1 shows the change of the specific electric resistivity of the sintered body with weight fraction of the small size powder (powder B). The specific electric

resistivity increase with increasing the fraction of the small size powder until 60w% of one. However the specific electric resistivity at pure small size powder (100% powder B) drastically decreased.

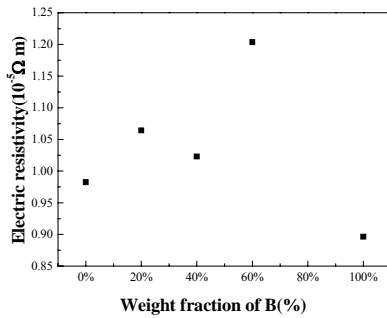


Fig. 1. The change of the specific electric resistivity of the sintered body with the weight fraction of the small size powder.

The specific electric resistivity of the Bi-Te-Sb thermoelectric material has been known strongly depended on the direction of the crystal structure.²⁾ Therefore, this study considered the orientation of the crystal structure of the sintered bodies. The orientation of the crystal structure was analyzed by the XRD techniques. In Bi-Te-Sb materials, the orientation of higher performance is (00-l). The orientation factor F is defined as follows:⁴⁾

$$F = \frac{\sum I_{00l}}{\sum I_{hkl}}$$

Where $\sum I_{00l}$ indicates the sum of intensities of the XRD patterns from the 00-l plane, and $\sum I_{hkl}$ represents the sum of intensities within the measurement angle.

Figure 2 shows the X-ray diffraction patterns of the sintered bodies with various blending fractions. The intensity of the XRD patterns from the 00-l plane little changed with the changing blending fraction of the small powder.

Figure 3 shows the change of the specific electric resistivity of the sintered body with the orientation factor. The specific electric resistivity continuously decrease with increasing the orientation factor. The increase of the orientation factor means increase the degree of the orientation of the (00-l) plane to the perpendicular direction of the sintering pressure direction. It knows that the specific electric resistivity of the sintered bodies of the $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ depend on the orientation of the crystal structure. And the control of the orientation of the crystal structure was very important for the manufacturing Bi-Te-Sb thermoelectric materials by the powder metallurgy process.

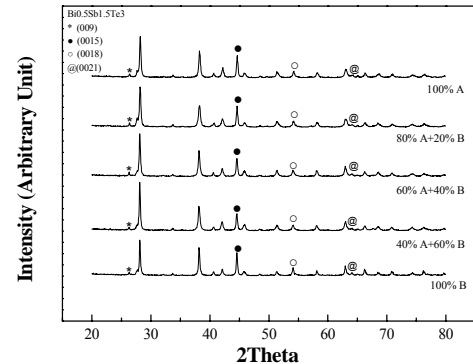


Fig. 2. The X-ray diffraction patterns of the sintered bodies.

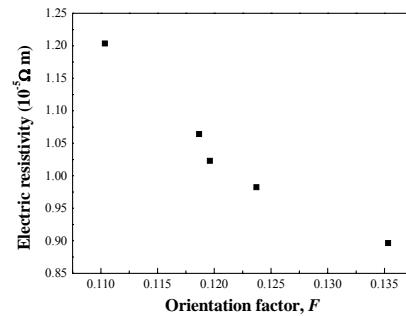


Fig. 3. The change of the specific electric resistivity of the sintered body with the orientation factor.

4. Summary

The specific electric resistivity of the sintered body of $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ decreased with increasing the degree of the orientation of the (00-l) plane. The specific electric resistivity of the $\text{Bi}_{0.4}\text{Te}_3\text{Sb}_{1.6}$ sintered body depended on the orientation of the crystal structure rather than the particle size of the raw powder.

5. References

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