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Enhancement in thermoelectric power factor of $Bi_{85}Sb_{15-x}Pb_x$ alloys at low-temperatures

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Introduction

- The research on cryogenic technology is benefit to the information technology.
- Compared with a traditional mechanical refrigeration device, a thermoelectric refrigeration device is small, durable, no noise and pollution free.
- However, the efficiency of a thermoelectric refrigeration device is low, and the research on thermoelectric refrigeration is few, especially at the temperature below 200 K.
- In this work, $Bi_{85}Sb_{15-x}Pb_x$ (x=0, 0.5, 1, 2, 3, 4) alloys with partial substitution of Pb for Sb have been synthesized by mechanical alloying followed by high-press sintering under a pressure of 5 GPa for 30 min at 523 K. Their thermoelectric properties have been measured in the temperature range of 77-300 K. The effect of Pb on thermoelectric performance was discussed.

Experiments

The $Bi_{85}Sb_{15-x}Pb_x$ (x=0, 0.5, 1, 2, 3,4) alloys were firstly prepared by vacuum melting and subsequently mechanical alloying in a planetary ball mill with jars and balls made of agate.

Then vessels were evacuated to a residual pressure below 2×10^{-3} Pa, and were hermetically sealed under argon atmosphere in order to prevent possible oxidation. Each milling of powders lasted for 50 hrs. The as-milled powders were preformed under a pressure of 50MPa at room temperature. The preformed samples were finally high-pressure sintered under a pressure of 5Gpa for 30min at 523K.

X-ray diffraction (XRD) and scanning electron microscopy (SEM) were employed to reveal the phase compositions and microstructures. The temperature dependence of electrical conductivity and the Seebeck coefficient was measured in the temperature range of 77-300 K.

Results and Discussion

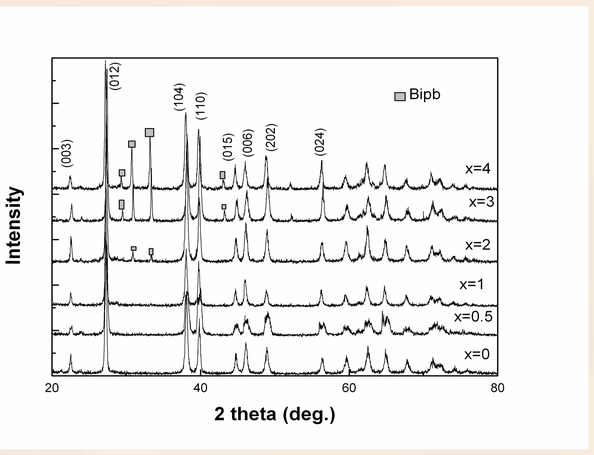

Fig.1. XRD patterns of Pb-substituted Bi-Sb based alloys

It is shown that the $Bi_{85}Sb_{15-x}Pb_x$ samples have a dominating phase with Bi-Sb structure (the space group R-3m). The positions of the peaks correspond well to that of the $Bi_{85}Sb_{15}$.

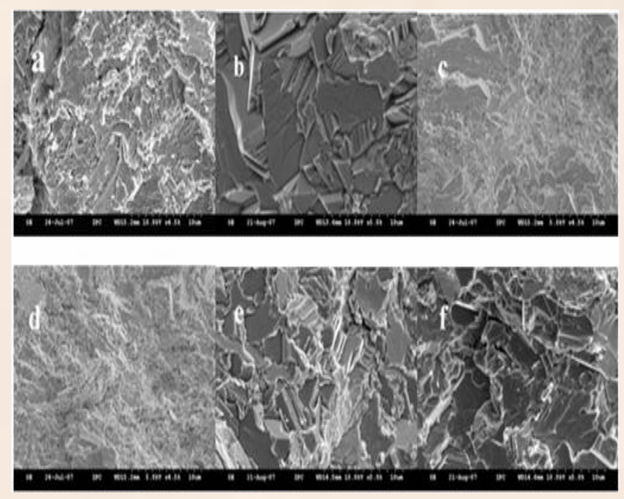

Fig.2. SEM micrographs of the bulk samples

There are lots of pores in the $Bi_{85}Sb_{15}$ and the number of pores is decreased with the increase of the content of Pb. So the density of the samples is enhanced.

It is shown that the main fracture of these samples was intergranular fracture.

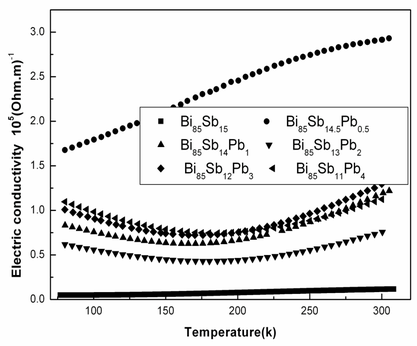

Fig. 3 The electrical conductivities as a function of temperature

The electrical conductivity of $Bi_{85}Sb_{15-x}Pb_x$ (x=3, 4) is smaller than that of $Bi_{85}Sb_{15}$ when the temperature is larger than 100 K. We think such result is due to the generation of BiPb when the sample is heavily doped.

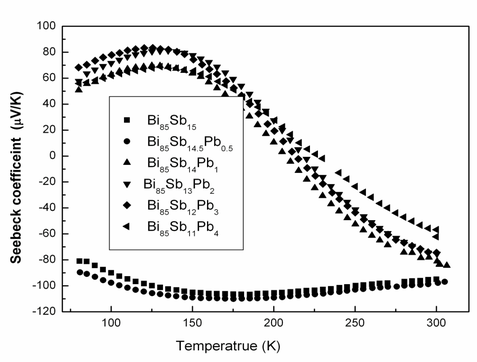

Fig. 4 The Seebeck coefficients as a function of temperature

The $Bi_{85}Sb_{15-x}Pb_x$ (*x*=3) alloy shows the largest value of the Seebeck coefficient (83.36 μV/K at about 125 K) of all the samples, and it changes sign from positive to negative at 220 K. This result agrees with the previous result . And it may be attributed to the variation of carrier concentration by the increased Pb content in the alloys.

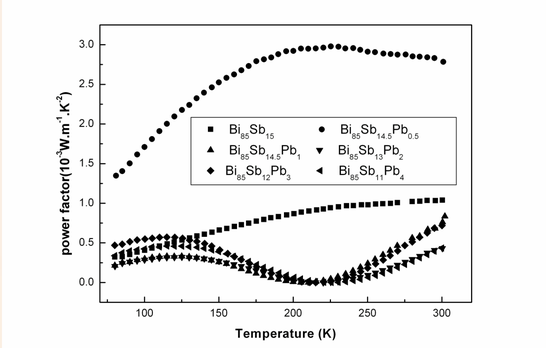

Fig. 5 The power factors as a function of temperature

It is obvious that the powers factors of the samples increase with increasing temperature and reach a maximum value. The maximum power factor is $2.97\times10^{-3}W/(mK^2)$ at 255 K for $Bi_{85}Sb_{14.5}Pb_{0.5}$ alloy, which is about two times larger than that of the reference sample $Bi_{85}Sb_{15}$ at the same temperature.

Conclusions

- ✓ $Bi_{85}Sb_{15-x}Pb_x$ (x=0, 0.5, 1, 2, 3, 4) alloys were prepared by high-pressure sintering.
- ✓ The maximum power factor is $2.97\times10^{-3}W/(mK^2)$ at 255 K for $Bi_{85}Sb_{14.5}Pb_{0.5}$ alloy, which is about two times larger than that of the reference sample $Bi_{85}Sb_{15}$.
- ✓ These results indicate that the thermoelectric properties could be improved by doping Pb in $Bi_{85}Sb_{15}$ alloys using high-pressure sintering.

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