Improved mid-temperature thermoelectric energy conversion efficiency of nanostructured $FeSi_2$ doped BiSbTe composites

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1. Introduction – The energy crisis has become a major problem globally. In the upcoming years, the world will witness a severe energy shortage. To solve this crisis, the use of sustainable and reusing waste energy must be increased. Thermoelectric technology is the one such solution to the energy problem. Thermoelectric (TE) materials directly and reversibly convert's low-grade waste heat energy into electrical energy from the temperature gradient, the parameter which evaluates the thermoelectric efficiency of the materials is the dimensionless figure of merit (*ZT*). This work demonstrates that mixing $FeSi_2$ nanoparticles into the p-type BiSbTe matrix is effective for its thermoelectric property enhancement; a high *ZT* value up to 1.8 at 350 K was obtained in $Bi_{0.5}Sb_{1.5}Te_3$ alloys by incorporating an optimized amount of nano-$FeSi_2$ particles. The nanostructure including the interfaces between $FeSi_2$ and the matrix was investigated to explore the mechanism why thermoelectric performance can be enhanced in a nanoparticle-dispersed composite fabricated by a mixing method.

2. Experimental – Commercial elemental powders of Bi, Sb, Te and nano-$FeSi_2$ were used as starting materials. The mixtures of these powders were ball mill using a hardened stainless-steel vial and ball. The weight ratio of balls to powders was kept at about 20:1, and the mill vial was filled with N_2 gas to prevent the powders from oxidation during the milling process. The milling was performed at 300 rpm for 8 h, and then the powders were consolidated by hot press at 673 K for 30 min, by which a series of $Bi_{0.5}Sb_{1.5}Te_3 + x$ wt% $FeSi_2$ ($x = 0, 2, 4$) bulk materials were fabricated.

3. Results and Discussion - Seebeck coefficients shows positive value, so its p-type material from 300-500 K. 0 and 4% $FeSi_2$ composites sample shows similar value, where as 2% sample possessed large Seebeck coefficient. Consequently, electronic structure is changed, and these structures influence the improvement of large Seebeck coefficient. Whereas 4% has low Seebeck coefficient due to many precipitations of $FeSi_2$ and affects the thermoelectric properties. Electrical resistivity of 2% samples shows higher resistivity compared to 0 and 4% samples. However, power factor decreased with increasing the temperature due to increase of electrical resistivity and decreased Seebeck coefficient at 400 K. Thermal conductivity of 0 and 4% were higher compared to 2% sample in the temperature range 300-500 K. The high-power factor was achieved due to improvement of Seebeck coefficient by filtering the low energy electron through the $FeSi_2$ substituted into BiSbTe matrix which is also called energy filtering effect. As a result, low thermal conductivity is obtained. High figure merit was achieved about 1.8 at 350 K for 2% sample (Image 1) compared to 0 and 4% sample. Because of high power factor and low thermal conductivity was obtained for 2% sample.

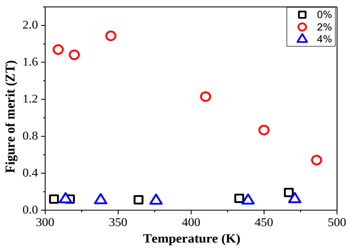

Image 1. Figure of merit of $FeSi_2$ doped BiSbTe

4. Conclusions - The high power factor and low thermal conductivity was obtained for 2% sample. High figure merit was achieved about 1.8 at 350 K for 2% sample compared to other sample.

5. References

[1] J. Li, Q. Tan, J.F. Li, D.W. Liu et.al., *Adv. Funct. Mater.*, **23**, (2013) p. 4317.