Effect of Sn and Co addition on the thermoelectric properties of β-$FeSi_2$

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Introduction

The most comon method to improve thermoelectric performance of β-$FeSi_2$ is to introduced various impurities. In particular, heavy elements produce the phonon scattering which is capable for the suppression of lattice thermal conductivity and for the reduction of thermal conductivity [1]. In addition, the reduction of the electrical resistivity can be achieved by enhancement of carrier concentration or mobility which can basically done by doping transition metal element having different valence electrons [2]. The objective of this study is to discuss the effect of Sn and Co on thermoelectric properties of β-$FeSi_2$.

Experimental method

β-$FeSi_{2-x}Sn_x$ (x = 0, 0.005, 0.01, 0.02) and β-$Fe_{1-y}Co_ySi_2$(y =0.005, 0.010, 0.015) ingots were prepared by arc-melting under Ar atmosphere. The bulk samples was then vacuum-sealed, heat treated at 1423K for 3hours, and annealed at 1113K for 20hours. The Seebeck coefficient and resistivity was measured by ResiTest8300 and homemade apparatus. The thermal conductivity was measured by power conversion efficiency apparatus (PEM-2, ULVAC-RIKO).

Results and discussions

As increasing the doping level of Sn, the resistivity (***ρ***) decreased, and the values varied between 1 to 10 [Ω.cm] at temperature ≤450K. However, the ***ρ*** of Co-doped sample was significantly lower than other samples where the values were less than 0.1 [Ω.cm] and approximately stable at all temperature ranges. The reduction of ***ρ*** maybe was affected by the increase of carrier concentration. Thus, doping with element having different valence (Co) result in the reduction of ***ρ.***

All samples were n-type. The lowest Seebeck coefficient |*S*| was found in Sn-doped sample (x=0.02)**.** On the other hand, Co-doped sample consisted of higher |*S*| than Sn-doped samples where |*S*| ≥ 300μV/K and approximately stable at all temperature ranges. It is considered that this is because the carrier scattering process is stabilized by the scattering of ionized impurities.

The minimum value of total thermal conductivity (*κ*) was found in Sn-doped samples (x=0.005) at all temperature ranges. At room temperature, lattice thermal conductivity of Sn doped (x=0.005) was lower than other samples resulting in the significant reduction of total thermal conductivity at various temperature range.

However, the highest *ZT*=0.03 was found in Co doped sample at 450K. This enhancement was obtained from the stability of |*S*| and significant reduction of ***ρ.***

Conclusion

ZT can be improved by doping with element having different valence electrons like Co and heavier element like Sn because the Seebeck coefficient, resistivity, and lattice thermal conductivity can be enhanced, respectively.

References

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