Thermoelectric properties of bulk Ni-doped β-$FeSi_2$

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β-$FeSi_2$ is considered a potential thermoelectric material for high-temperature applications due to strong oxidation resistance, good thermal stability, environmental friendliness, and low cost. However, with a narrow band gap of around 0.7 eV and low carrier density (n_H), the bipolar effect that deteriorates the Seebeck coefficient $|S|$ usually occurs as temperature increases. To solve this issue, doping with impurities having larger valences electron to either site of Fe or Si is considered an effective technique for improving (n_H), and simultaneously enhancing $|S|$ and decreasing electrical resistivity (ρ) [1]. Since Ni has two valence electrons larger than that of Fe, doping with Ni on the Fe site should effectively increase the n_H. Tani and Kido [2] reported that the n_H of β-$FeSi_2$ can be increased by Ni substitution and its ρ simultaneously decreases. Therefore, the reduction in bipolar effect can possibly be also obtained by Ni substitution. In addition, Nagai *et al.* [3] reported that the $|S|$ of β-$FeSi_2$ can also be improved with a small amount of Ni addition, resulting in an improvement in power factor ($PF = S^2 \rho^{-1}$). In this study, we are trying to optimize the Ni doping level to improve the TE performance of β-$Fe_{1-x}Ni_xSi_2$ ($0 \leq x \leq 0.03$) fabricated by the conventional arc-melting method. The elemental analysis was performed by a scanning electron microscope (SU8010, Hitachi High-Technologies) equipped with a Bruker EDS XFlash5060FQ detector. The S and ρ were measured by using ResiTest8300 (TOYO Co.) and homemade apparatus. The thermal conductivity (κ_{total}) was measured by using a power efficiency measurement (PEM-2, ULVAC, Inc.). The ZT then can be calculated by $ZT = S^2T / (\rho\kappa_{total})$. The result shows that the ρ can be effectively decreased with x due to the increase in n_H as shown in the inset of Fig. 1. The $|S|$ of all Ni-doped samples is higher and more stable than that of non-doped ones due to the reduction in bipolar effect; however, it becomes decreasing as x increases due to the high n_H and metallic ε-phase. The solid solution limit of Ni into the β-phase can be obtained at below x = 0.01. As a result, the highest PF of around 200 $\mu Wm^{-1}K^{-2}$ is obtained in x = 0.001, leading to the improved ZT value of 0.019 at 600 K as shown in Fig. 1.

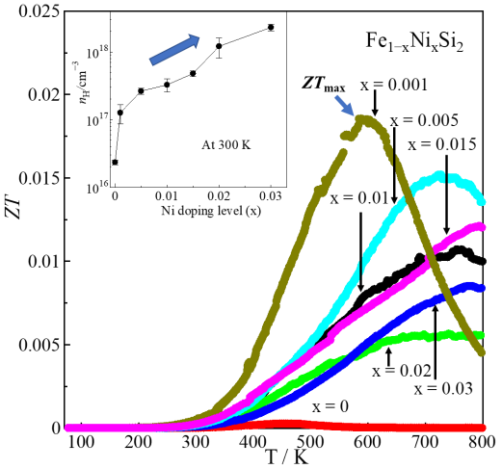

Fig. 1 ZT values of β-$Fe_{1-x}Ni_xSi_2$ with temperature dependence, where n_H is plotted in the inset.

References

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