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Enhanced Thermoelectric Properties of $(PbTe)_{0.88}(PbS)_{0.12}$ Composites by Sb Doping

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The effects of Sb doping on $(PbTe)_{0.88}(PbS)_{0.12}$ composites prepared by melting, ball milling, and spark plasma sintering were investigated. The x-ray diffraction results indicate that all samples $Sb_xPb_{1-x}Te_{0.88}S_{0.12}$ with $x = 0$, 0.002, 0.004, 0.006 and 0.008 are composites containing PbTe with NaCl-type structure as the major phase and PbS with NaCl-type structure as the minor phase. The electrical resistivity is reduced with increasing Sb doping, from 1.95×10^{-5} Ωm for Sb content $x = 0$ to 5.55×10^{-6} Ωm for $x = 0.008$ at 298 K, showing that Sb is an efficient electron donor. However, the absolute Seebeck coefficient decreases, from 196 μV/K for $x = 0$ to 57.0 μV/K for $x = 0.008$ at 298 K, and the thermal conductivity increases, from 0.989 W/m K for $x = 0$ to 1.64 W/m K for $x = 0.008$, with Sb doping. The power factor and figure of merit ZT can be enhanced by proper Sb doping. The maximum dimensionless figure of merit ZT of 1.20 was obtained in the sample $Sb_{0.004}Pb_{0.996}Te_{0.88}S_{0.12}$ at 773 K.

Key words: PbTe/PbS alloys, Sb doping, thermoelectric property

INTRODUCTION

Solid-state thermoelectric materials capable of creating electricity from waste heat sources can play an important role in energy conservation and production.[1,2] The efficiency of thermoelectric energy converters is determined by the dimensionless figure of merit, $ZT = S^2T/\rho\kappa$, where S is the Seebeck coefficient, ρ is the electrical resistivity, T is the absolute temperature, and κ is the thermal conductivity. The thermal conductivity is the combination of carriers (electrons or holes) transporting heat (κ_{el}) and phonons traveling through the lattice (κ_{ph}).[3] To maximize ZT, a large Seebeck coefficient, low electrical resistivity, and low thermal conductivity are required. In addition, both n- and p-type materials with similar thermoelectric performance and compatible mechanical properties are needed to construct an efficient thermoelectric device.[2]

PbTe-based compounds are promising materials for thermoelectric (TE) devices for application in the temperature range of 400 K to 800 K.[4] Recently, efforts to improve the ZT value of PbTe have focused on preparing nanostructures to reduce the thermal conductivity, or element doping to increase the power factor (S^2/ρ). Spinodal decomposition,[5–7] nucleation and growth,[8] matrix encapsulation,[9,10] and eutectic phase transformation-based mechanisms[11–13] have been used to introduce nanostructure in bulk nanostructured materials to reduce the thermal conductivity by phonon scattering at the interfaces of nanoscale features. The system $(PbTe)_{1-x}(PbS)_x$ separates into PbTe-rich and PbS-rich regions to produce coherent nanoscale heterogeneities, and for $x = 0.08$, the material achieves very low room-temperature lattice thermal conductivity (about 30% that of PbTe), and $ZT = 1.5$ at 650 K is achieved.[7] Precipitates of 2 nm to 5 nm in size are revealed by transmission electron microscopy (TEM) in the $(PbSe)_{1-x}(PbS)_x$ system and show a marked impact on the lattice thermal conductivity (about 1.3 W/m K), and $ZT = 1.3$ is obtained in nanostructured $(PbSe)_{0.88}(PbS)_{0.12}$ doped with 0.30 mol.% $PbCl_2$.[14] Detailed study of the influence of the microstructure of thermoelectric $PbTe_{0.7}S_{0.3}$

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