Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-012-2405-y

Nanostructuring and Thermoelectric Characterization of $(GaSb)_{3(1-x)}(Ga_2Te_3)_x$

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GaSb is a promising thermoelectric material that exhibits good electrical properties. However, it has a high lattice thermal conductivity (κ_{lat}). Nanostructured bulk materials have been attracting interest because they effectively scatter phonons, significantly reducing κ_{lat}. $AgPb_mSbTe_{m+2}$ (LAST-m) compounds have recently been reported to have low κ_{lat}. These compounds have a NaCl structure, similar to that of binary PbTe, where Ag and Sb occupy the Pb site. In these compounds, two divalent Pb atoms are replaced with a monovalent Ag atom and a trivalent Sb atom to maintain charge compensation. In the present study, we reduced κ_{lat} of GaSb by applying the same principle as in LAST-m. Specifically, we substituted Te for Sb and generated vacancies at the Ga site to maintain charge compensation. This produced compounds with chemical compositions of $(GaSb)_{3(1-x)}(Ga_2Te_3)_x$ (x = 0, 0.05, 0.10, and 0.25), where GaSb and Ga_2Te_3 both have the zincblende crystal structure. We employed two different annealing conditions: annealing at 833 K followed by quenching, and annealing at 833 K followed by cooling to room temperature over 3 days. The former annealed samples with compositions of x = 0.05 and 0.10 had nanoscale Ga-rich precipitates and exhibited a large reduction in κ_{lat}.

Key words: Thermoelectric, thermal conductivity, gallium antimonide, LAST, nanostructure

INTRODUCTION

Thermoelectric (TE) energy is utilized in power generation devices that convert waste heat into electrical energy.[1] The efficiencies of such devices depend on the TE properties of the generator materials and the temperature gradient across the device. The effectiveness of TE materials is determined by the dimensionless figure of merit, $ZT = S^2\sigma T/\kappa$, where S is the Seebeck coefficient, σ is the electrical conductivity, T is the absolute temperature, and κ is the total thermal conductivity; κ is the sum of the lattice (phonon) contribution (κ_{lat}) and the electronic contribution (κ_{el}). Since S, σ, and κ_{el} are interrelated, it is difficult to control them independently. It is thus necessary to reduce κ_{lat} to enhance the TE performance.

Nanostructured bulk materials are attracting interest because they scatter phonons more effectively than electrons, leading to a significant reduction in κ_{lat}.[2–5] Recently, lead–antimony–silver–tellurium (LAST) compounds have been reported to have low κ_{lat}.[6–8] LAST compounds consist of PbTe and $AgSbTe_2$, which have NaCl crystal structures.[9,10] LAST-18 prepared by specific melting and annealing is a solid solution consisting of PbTe and $AgSbTe_2$ in the ratio 18:1.[11] Nanostructures in LAST-18 enhance phonon scattering, which enhances ZT.[6,12] LAST-18 has a maximum ZT value of 2.1 at 800 K.[6]

(Received July 6, 2012; accepted December 26, 2012; published online January 25, 2013)