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Effects of Reaction Temperature on Thermoelectric Properties of *p*-Type Nanostructured $Bi_{2-x}Sb_xTe_3$ Prepared Using Hydrothermal Method and Evacuated-and-Encapsulated Sintering

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We report fabrication of nanostructured $Bi_{2-x}Sb_xTe_3$ using hydrothermal method followed by cold-pressing and evacuated-and-encapsulated sintering techniques. To obtain lower resistivity, the reaction temperature in the hydrothermal synthesis is investigated, and the effects on the ZT values of $Bi_{2-x}Sb_xTe_3$ are reported. Both the x = 1.52 and 1.55 samples hydrothermally synthesized at 160°C show lower resistivity than the x = 1.55 sample hydrothermally synthesized at 140°C. However, the power factor is lower for the samples synthesized at 160°C due to the accompanying smaller thermopower. All three samples exhibit remarkably low thermal conductivity of around 0.41 W m^{-1} K^{-1} at room temperature. The peak ZT value occurs at 270 K for all three samples, being ZT = 1.75, 1.29, and 1.17 for x = 1.55 (synthesized at 140°C), 1.55 (synthesized at 160°C), and 1.52 (synthesized at 160°C), respectively.

Key words: Thermoelectrics, bismuth antimony telluride, hydrothermal synthesis

INTRODUCTION

Thermoelectric materials can be used to directly convert solar or waste heat to electricity via the Seebeck effect and for solid-state cooling via the Peltier effect without using synthetic refrigerants. Thermoelectric materials can thus be viewed as green energy materials. Developing high-efficiency thermoelectric materials requires optimization of three transport parameters in order to achieve high dimensionless figure of merit via $ZT = T\sigma S^2/(\kappa_{el} + \kappa_{ph})$, where σ, S, κ_{el}, and κ_{ph} are the electrical conductivity, Seebeck coefficient (thermopower), and electronic and lattice thermal conductivity, respectively.

Since there is abundant unexploited natural heat below 100°C in our surroundings, it is desirable to develop high-efficiency thermoelectric materials for use in this temperature region, where the bismuth telluride alloys are the most promising candidates. When optimizing ZT, the task is often limited by the Wiedemann–Franz law, assuming there are no inelastic scattering processes in the conductor. Nevertheless, high-efficiency thermoelectric materials can be developed through material nanostructuring to reduce the lattice thermal conductivity.[1–3]

We recently demonstrated that very low thermal conductivities of *p*-type nanostructured $Bi_{2-x}Sb_xTe_3$ can be achieved by synthesizing $Bi_{2-x}Sb_xTe_3$ nanocrystals using hydrothermal method and consolidating the nanocrystals using evacuated-and-encapsulated sintering.[4–6] Due to this very low thermal conductivity, the x = 1.55 sample shows state-of-the-art dimensionless figure of merit ZT of 1.65 at 290 K and 1.75 at 270 K. Since the resistivity of 3.24 mΩ-cm at 295 K is relatively high, we further investigate the effects of reaction temperature in the hydrothermal synthesis on the ZT values of $Bi_{2-x}Sb_xTe_3$. We find that both the x = 1.52 and 1.55

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