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Improved Thermoelectric Performance of Free-Standing PEDOT:PSS/Bi_2Te_3 Films with Low Thermal Conductivity

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Free-standing poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS)/Bi_2Te_3 thermoelectric (TE) composite films have been successfully prepared by a simple physical mixing method with different contents of Bi_2Te_3. x-Ray diffraction (XRD) and scanning electron microscopy were used to analyze the phase composition and microstructure of the composite films. Their TE performance from 100 K to 300 K was systematically investigated. The maximum electrical conductivity of the composite polymer film reached up to 421 S/cm when the film contained 10 wt.% Bi_2Te_3, corresponding to the highest power factor of 9.9 μW/m/K^2, while their Seebeck coefficient fluctuated smoothly in a tiny range (14.2 μV/K to 18.6 μV/K). In addition, a relatively low thermal conductivity of 0.07 $\pm$ 0.02 W/m/K has been obtained. The maximum figure of merit of the composite reached up to 0.04 at room temperature, which is a relatively high value in the organic TE field.

Key words: Thermoelectrics, thermal conductivity, PEDOT:PSS, free-standing film

INTRODUCTION

Thermoelectric (TE) materials have great potential for applications in both power generation and solid-state cooling or heating, and can effectively and directly convert heat from a waste heat source to electricity.[1–3] Especially since combustion of fossil fuels has caused very alarming environmental problems, the conversion of waste heat to electric power by using TE devices has become more urgent.[4,5] TE devices can also be operated in cooling mode. Their simple leg-type structures, without moving parts, provide enormous advantages over conventional turbines, engines, and compressors. Thus, larger cooling systems using vapor compression cycles could be built to replace classic units. This would reduce the use of toxic chlorofluorocarbons and their substitutes; it would also reduce the weight and expense of coolers and save energy.[6] In a simplified model, the TE efficiency is determined by the dimensionless figure of merit $ZT = S^2\sigma T/\kappa$, where S, σ, κ, and T are the Seebeck coefficient (or thermopower), electrical conductivity, thermal conductivity, and absolute temperature, respectively.

To date, most studies on high-efficiency TE materials have mainly focused on the field of inorganic semiconductors, such as $AgPb_{18}SbTe_2$,[7] Bi_2Te_3/Sb_2Te_3,[8] BiSbTe,[9] and $Bi_{0.52}Sb_{1.48}Te_3$ bulk materials.[10] However, the high cost of raw materials and production facilities as well as heavy-metal pollution considerations[11] and the poor processability[11–14] of inorganic semiconductors are limiting their wide application to TE systems. In the past few decades, much attention has been focused on reducing the physical dimensionality of inorganic TE materials (quantum confinement), since it is believed that this may lead to greatly enhanced TE performance by increasing the magnitude of the

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