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Fabrication of Bismuth Telluride Thermoelectric Films Containing Conductive Polymers Using a Printing Method

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We prepared a mixture of thermoelectric bismuth telluride particles, a conductive polymer [poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS)], poly(acrylic acid) (PAA), and several organic additives to fabricate thermoelectric films using printing or coating techniques. In the mixture, the organic components (PEDOT:PSS, PAA, and an additive) act as a binder to connect bismuth telluride particles mechanically and electrically. Among the organic additives used, glycerol significantly enhanced the electrical conductivity and bismuth telluride particle dispersibility in the mixture. $Bi_{0.4}Te_{3.0}Sb_{1.6}$ films fabricated by spin-coating the mixture showed a thermoelectric figure of merit (*ZT*) of 0.2 at 300 K when the $Bi_{0.4}Te_3Sb_{1.6}$ particle diameter was 2.8 μm and its concentration in the elastic films was 95 wt.%.

Key words: Conductive polymer, bismuth telluride, microparticles, thermal conductivity

INTRODUCTION

Thermoelectric generators can convert low-grade waste heat into electricity, making it a key technology contributing to sustainability through scavenging of waste heat or heat sources.[1] The performance of the thermoelectric device is determined by the thermoelectric figure of merit, *ZT*, which is defined as $ZT = S^2\sigma T/\kappa$, where S is the Seebeck coefficient, σ is the electrical conductivity, κ is the thermal conductivity, and T is the temperature.

For practical use of thermoelectric devices to spread, improvements in device performance and reductions in manufacturing costs are required. It has recently been reported that using nanostructured thermoelectric materials efficiently increases *ZT* as a result of reduced thermal conductivity due to phonon scattering.[2–7] Generally, thermoelectric devices are fabricated by vacuum processing, particularly for thin-film applications. There are many deposition methods for obtaining high-quality thermoelectric thin films.[8–10] Thermoelectric thin films with good thermoelectric properties can be prepared using the thin-film deposition processes mentioned above, but these processes are expensive because vacuum processing is a lengthy procedure. Printing or coating processes such as screen- and inkjet-printing are attractive methods for reducing the manufacturing costs of thermoelectric devices. In recent reports, a number of methods for obtaining thermoelectric materials by printing using polymer materials have been described.[11–17] The electrical conductivities and Seebeck coefficients of printed thermoelectric materials are lower than those of bulk materials. To improve the electrical conductivity and Seebeck coefficient of a thermoelectric compound, it is necessary to anneal the thermoelectric compound or fill the grain boundaries with conductive materials. Polymer materials are very attractive as they have low thermal conductivity, good flexibility, and good printability. We fabricated flexible printed thermoelectric thin films containing thermoelectric particles, a conductive polymer, and various additives, and here we report the

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