Synthesis and Characterization of Bismuth Telluride Nanoparticles for Use in Flexible Polymer-Nanoparticle Hybrid Thermoelectric Devices

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Polymer-based thermoelectric materials, which can have readily-tuned properties through simple control of their chemistry, offer the promise of providing flexible, lightweight, and low-cost modules for the environmentally-friendly conversion of waste heat to electricity without the need for moving parts. As such, they have started to be explored in applications ranging from improved building efficiency to increased mileage in automobiles. However, widespread implementation of these materials is limited due to their low performance relative to their mechanically-rigid, heavy inorganic material-based counterparts. Therefore, a critical need exists to design polymer-nanoparticle composite materials to increase the energy conversion of thin film thermoelectric devices. Specifically, bismuth telluride (Bi_2Te_3) nanoparticles embedded in a conducting polymer matrix of poly(ethylene dioxythiophene) doped with poly(styrene sulfonate) (PEDOT:PSS) have provided promising initial results. Here, we aim to improve upon this system through a combination of designer chemistry and interfacial engineering. Specifically, Bi_2Te_3 nanoparticles were synthesized in an aqueous solution at a low temperature in the presence of PEDOT:PSS. This allowed the conducting polymer to coat the surface of the nanoparticle, which should improve the device performance. The purified polymer-coated nanoparticles were cast into thin films, and the thermoelectric properties of the composite materials were evaluated. Importantly, the performance of the polymer-nanoparticle composite thin films increased by a factor of 2 with increased Bi_2Te_3 loading while still retaining the mechanical integrity associated with polymer-based materials. We anticipate that, with systematic device optimization, this class of materials will provide a solid launching point for the implementation of polymer-based thermoelectric modules.