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Thermoelectric Generators Using *p*-$Pb_{0.925}Yb_{0.075}Te$:Te and *n*-$Pb_{0.925}Yb_{0.075}Se_{0.2}Te_{0.8}$ Thin Films Prepared by the Thermal Evaporation Method

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In this study, *p*-$Pb_{0.925}Yb_{0.075}Te$:Te and *n*-$Pb_{0.925}Yb_{0.075}Se_{0.2}Te_{0.8}$ ingots were used in a standard solid-state microwave synthesis route for fabricating thermally evaporated thin films. The nanostructure and composition of the films were studied through x-ray diffraction, field-emission scanning electron microscopy, and energy-dispersive x-ray spectroscopy. Measurements of the Seebeck coefficient and electrical conductivity were performed at 298 K to 523 K. The microthermoelectric devices were composed of 20 pairs and 10 pairs of *p*-$Pb_{0.925}Yb_{0.075}Te$:Te and *n*-$Pb_{0.925}Yb_{0.075}Se_{0.2}Te_{0.8}$ thin films on glass substrates, respectively. The 20-pair *p*–*n* thermocouples in series generated a maximum output open-circuit voltage of 275.3 mV and a maximum output power of 54.37 nW at a temperature difference ΔT = 162 K, and 109.4 mV and 16.68 nW at ΔT = 162 K for 10 pairs, respectively.

Key words: Thin films, thermal evaporation method, thermoelectronics, thermoelectric generators

INTRODUCTION

Interest in locally converted heating and low-power energy-scavenging applications has increased in the last decade. These applications have been used to generate a few microwatts of power at relatively high voltage to power small electronic devices and wireless sensors in biotechnology and medical technology processes as well as other industrial heat-generating processes.[1,2] Technology to achieve extremely low power will become necessary for such low-power electronics; microscale devices, which have so far been portable, will become wearable and even implantable in the future. Advanced thermoelectric (TE) materials with potential conversion between thermal and electrical energy have been produced as a result of greater scientific understanding of quantum wells and nanostructural effects on TE properties as well as the development of modern, thin-layer, and nanoscale manufacturing technologies.[3] The advent of these advanced TE materials offers new opportunities to recover waste heat more efficiently and economically by using highly reliable and relatively passive systems that produce no noise or vibration.[4,5] A TE power generation (TEG) device produces voltage between the hot and cold sides when a temperature difference (ΔT) between the two sides exists as a result of the Seebeck TE effect. Other TE effects include the Peltier and Thomson effects. TE is also associated with other effects, such as the Joule and Fourier effects.[6,7] TE generation has primarily focused on increasing the material figure of merit (ZT), which is the standard measure of a material's TE performance, 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 absolute temperature. The product $S^2\sigma$ is the TE power factor.[8] The power factor should be maximized and the thermal conductivity minimized to achieve high-efficiency TE materials. Earlier developments in micro-TE devices utilized thin-film deposition of

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