Journal of ELECTRONIC MATERIALS, Vol. 42, No. 7, 2013
DOI: 10.1007/s11664-013-2479-1

Electrodeposition of MWNT/Bi_2Te_3 Composite Thermoelectric Films

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The effect of multiwalled carbon nanotubes (MWNTs) on the electrochemical behavior of the Bi-Te binary system in nitric acid baths was investigated by means of cyclic voltammetry and electrochemical impedance spectroscopy. Based on the results, MWNT/Bi_2Te_3 composite thermoelectric films were prepared by potentiostatic electrodeposition at room temperature. The morphology, composition, and structure of the MWNT/Bi_2Te_3 composite films were analyzed by environmental scanning electron microscopy, energy-dispersive spectroscopy, and x-ray diffraction. The results show that addition of MWNTs to the electrolyte did not change the electrochemical reduction mechanisms of Bi^{3+}, $HTeO_2^+$ or their mixture, but the reduction processes of Bi^{3+}, $HTeO_2^+$, and their mixture become easier. MWNT/Bi_2Te_3 composite thermoelectric films can be obtained by potentiostatic electrodeposition at a wide range of potentials with subsequent annealing. The MWNTs in the films act as nucleation sites for Bi_2Te_3 compound and thereby elevate the film deposition rate. The content of Bi element and MWNTs in the films increased as the potential was shifted negatively. In addition, the MWNTs can enhance the crystallization of Bi_2Te_3 film.

Key words: Electrochemical behavior, potentiostatic electrodeposition, Bi_xTe_y, carbon nanotubes, composite thermoelectric films

INTRODUCTION

Thermoelectric materials (TE) and cells have attracted considerable interest due to the requirements for environmental protection and military applications. Good thermoelectric materials should possess large Seebeck coefficient (S), low thermal conductivity (ρ), and high electrical conductivity (σ). Generally, the performance of thermoelectric materials can be expressed by the dimensionless quantity ZT ($ZT = S^2\sigma/\rho$), where T is the temperature and Z is the thermoelectric figure of merit.[1,2] The thermoelectric conversion efficiency of thermoelectric materials increases with the increase of ZT. As a green power source, the greatest virtue of thermoelectric power generators is that they can make use of all kinds of heat (solar heat, ocean heat, geothermal heat, waste heat, body heat, etc.) for transformation to electric power with great efficiency. They have a long working life (over 20 years) over a wide temperature range with highly stable performance.

Bi_2Te_3-based materials are of great interest for thermoelectric applications in the temperature range of 200 K to 400 K. In general, Bi_2Te_3-based film materials can be fabricated by chemical vapor deposition (CVD),[3] physical vapor deposition (PVD),[4] the high-pressure injection method,[5] electrodeposition,[6–8] etc. Compared with traditional techniques, electrodeposition shows many advantages such as simple equipment, low cost, and easy operation. The most advantageous feature of electrodeposition is the high controllability of the doping concentration and that the crystalline state of the thermoelectric film can be easily controlled by adjusting the parameters of electrodeposition. Electrodeposition of bismuth telluride, bismuth antimony telluride, and bismuth selenium telluride

(Received July 4, 2012; accepted January 10, 2013; published online March 5, 2013)