

Optimization of Bi₂Te₃ and Sb₂Te₃ thin films deposited by co-evaporation on polyimide for thermoelectric applications

L.M.Goncalves¹, P.Alpuim², Gao Min³, D.M.Rowe³, C.Couto¹, J.H.Correia¹

1 University of Minho, Department of Electronics, Portugal

2 University of Minho, Department of Physics, Portugal

3 University of Cardiff, School of Engineering, United Kingdom

lgoncalves@dei.uminho.pt

The optimization of the deposition process for n-type Bi₂Te₃ and p-type Sb₂Te₃ semiconductor thin films for thermoelectric applications is reported. The films were deposited on a 25 μm thick flexible polyimide (Kapton) substrate by co-evaporation of Bi and Te, for the n-type element, and Sb and Te, for the p-type element. The evaporation rate of each material was monitored by two oscillating crystal sensors and the power supplied to each evaporation boat was controlled with a PID algorithm in order to achieve constant evaporation rates. Substrate was heated to a fixed temperature value during deposition.

In-plane electrical resistivity and Hall mobility were measured using conventional four probe van der Pauw geometry, at room temperature. Seebeck coefficient was measured by connecting one side of the film to a heated metal block at a fixed temperature and the other side to a heat sink at room temperature. The film composition was obtained by Energy-dispersive X-ray spectroscopy (EDX) and X-ray diffraction (XRD) analysis and reveals the polycrystalline structure of the films. Fourier-transform infrared spectroscopy (FT-IR) and Raman spectroscopy confirmed the formation of Bi₂Te₃ and Sb₂Te₃ thin films.

The substrate temperature and the influence of evaporation rates of Bismuth, Tellurium and Antimony in the deposition process were studied and optimized to get the highest thermoelectric figures-of-merit. This corresponds to the ability of depositing materials with low electrical resistivity and high Seebeck coefficient. Evaporation rates between 0.5 Å/sec and 4 Å/sec and substrate temperatures between 240°C and 300°C were tested. The best n-type and p-type films have Seebeck coefficients of -189 μVK⁻¹ and +140 μVK⁻¹ respectively, and electrical resistivities of 7.7 μΩm and 15.1 μΩm at room temperature, respectively. The n-type Bi₂Te₃ film was obtained at a substrate temperature of 270°C using a 1 Å/s evaporation rate of Bi and 2.2 Å/s of Te. The p-type Sb₂Te₃ film was obtained at a substrate temperature of 230°C using a 1 Å/s evaporation rate of Sb and 2.2 Å/s of Te. The high figures of merit (0.93 and 0.26 for n and p-type films, respectively) obtained with these films make them suitable for fabrication of Peltier cooling and thermopile devices.