Investigation of the Properties of Electrochemically Deposited Semiconductor Materials for Thermoelectric Applications

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At JPL, it is our desire to fabricate thermoelectric micro-devices for power generation and cooling applications using an electrochemical deposition (ECD) technique. We believe that the performance of our current micro-device developed is limited by the properties of the ECD materials. Therefore, the objective of this study is to develop ECD methods for obtaining n-type Bi_2Te_3 and p-type $Bi_{2-x}Sb_xTe_3$ thermoelectric materials with near bulk properties, as well as optimizing morphology and transport properties. The substrates used for ECD are SiO_2/Si wafers with either 1μm Bi_2Te_3 or 1μm $Bi_{2-x}Sb_xTe_3$ sputtered on top. From our experimental observations, ECD at higher temperatures typically leads to higher deposition rates but also increases film porosity. In general, the ECD films change their morphology from porous to smooth when the ECD potentials change from very negative to less negative vs. saturated calomel electrode (SCE) reference. The films of Bi_2Te_3 and $Bi_{2-X}Sb_XTe_3$ were initially obtained under various deposition conditions. Seebeck coefficients and transport properties were then measured along the direction parallel to the substrates before and after annealing at 250°C for 2hrs. From the data obtained, ECD n-Bi_2Te_3 material can achieve a high Seebeck coefficient (-189 μV/K) when it is deposited at –200 mV vs. SCE. The in-plane resistivity, in-plane mobility, and carrier concentration are 3.0 mohm-cm , 31 cm^2 V^{-1} S^{-1}, and 6.79E19 cm^{-3}, respectively. As for the p-type $Bi_{2-x}Sb_xTe_3$, it is possible to achieve a high Seebeck coefficient (+145 μV/K) when it is deposited at –110 mV vs. SCE. The in-plane resistivity, in-plane mobility, and carrier concentration are 5.9 mohm-cm, 42 cm^2 V^{-1} S^{-1}, and 2.5E19 cm^{-3}, respectively. From the results of our preliminary study, we have found the best conditions for depositing high quality Bi_2Te_3 and $Bi_{2-X}Sb_XTe_3$ materials with thermoelectric properties comparable to those of their state-of-the-art bulk samples.