185f Electrodeposition of Superlattice Thermoelectric Nanowires [Invited]

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Thermoelectric (TE) materials are attractive for applications as heat pumps and power generators. The efficiency of TE materials is directly related to a dimensionless figure of merit ZT, which is defined as $ZT = (S^2\sigma/K)T$, where S is the Seebeck coefficient, σ is the electrical conductivity, K is the thermal conductivity consisting of lattice thermal conductivity K_L and electronic thermal conductivity K_e, and T is the absolute temperature. In traditional materials (e.g. Bi_2Te_3 based bulk alloys), the upper ZT limit is acknowledged to be about 1 and unlikely to change. This upper limit leaded to the extreme slowdown in thermoelectric interest after the 1950's. Recently, the study of TE materials has once again become an active research field partly due to the significant enhancement of ZT in quantum well structures and phonon-blocking/electron-transmitting superlattice thin films. The major enhancement of ZT in quantum well structures is from an increased Seebeck coefficient that results from an increase in the density of electron states. Whereas, the major enhancement of ZT in superlattice thin films is due to a strong reduction in lattice thermal conductivity K_L that results from the scattering of heart-carrying phonons on layer boundaries. Superlattice nanowires combine the two major enhancement effects together and are expected to have more significant enhancement of ZT. In this work, Bi_2Te_3/ $(Bi_xSb_{1-x})_2Te_3$ zero-dimensional superlattice nanowires were fabricated by cost-effective electrodeposition technique from a single bath containing 0.0005M Bi, 0.0016 Sb and 0.0007M Te in HNO_3. Before fabrication of nanowires, electrodeposition of a single-layer film was investigated in the same bath and the relationship between film compositions and deposition potentials was found out. Then two potentials, 0 mV and -100 mV vs. SCE, were selected to deposit n-type Bi_2Te_3 at 0 mV and p-type $(Bi_xSb_{1-x})_2Te_3$ at -100 mV. The composition of $(Bi_xSb_{1-x})_2Te_3$ can be easily adjusted by controlling the deposition parameters (e.g. deposition potential and solution contents). After that, superlattice nanowires were electrodeposited into a nanotemplate by applying a stepwise potential shifting between 0 mV and -100 mV. By simply changing the deposition period at each potential, 2 nm/2 nm, 5 nm/5 nm, 10 nm/10 nm and 20 nm/20 nm Bi_2Te_3/ $(Bi_xSb_{1-x})_2Te_3$ superlattices were fabricated. The synthesized nanowires were observed under a High-resolution Transmission Electron Microscopy and their thermoelectric properties were evaluated.