Thermal Conductivity of Nano-porous Bismuth Telluride Thin Films

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The thermal conductivity of a nano-porous bismuth telluride (Bi_2Te_3) thin film of nano-particles is measured by use of the 3ω method (Cahill and Pohl 1987 Lee and Cahill 1997) with a temperature range from 100 K to 300 K. The Bi_2Te_3 nano-particles with an average size of approximately 60 nm are fabricated by a beads-milling method. The nano-particle solution is prepared by mixing with toluene. The nano-particles solution is dropped onto alumina substrates (50 mm length, 25 mm wide and 0.5 mm thick) which are then tilted to remove the excess solution. The thickness of the thin films is approximately 1.0 μm, and the thin films have a uniform thickness across the substrate. After the printing process, the thin films are sintered to evacuate the toluene and the surfactant, and to melt and consolidate the nano-particles. Samples are placed in an electric furnace that is evacuated to 1.0 Pa and purged five times with high-purity (99.999 %) argon gas. Then the furnace is filled with hydrogen gas at atmospheric pressure to prevent the surface of the nano-particles from oxidation, and the hydrogen gas flow rate is maintained at 0.3 $L \cdot min^{-1}$ throughout the sintering process. The measured thermal conductivities of nano-porous Bi_2Te_3 are from 0.09 $W \cdot m^{-1} \cdot K^{-1}$ to 0.14 $W \cdot m^{-1} \cdot K^{-1}$, these results are one order of magnitude lower the thermal conductivity values than that of the bulk values. The bulk thermal conductivity increases with decreasing temperature, but the thermal conductivity of nano-porous Bi_2Te_3 thin film was constant at approximately 0.1 $W \cdot m^{-1} \cdot K^{-1}$ at low temperature. It is considered that the phonon scattering at the nano-porous in the thin film is responsible for the measured reduction in thermal conductivity.