

Nano Engineering Thermal Transport in Semiconductors by High-Pressure Torsion

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Materials with length scales on the order of few nanometers exhibit unique abilities to control thermal transport. Tailoring the thermal properties of nanostructured systems have a promising application in the field of micro electronics and thermoelectrics. In this work, we demonstrate a novel technique using high-pressure torsion (HPT) to create a high density of lattice defects on nanometer length-scales in semiconductor materials such as silicon and germanium. We report a dramatic reduction in the thermal conductivity of bulk crystalline silicon and germanium when subjected to severe plastic strain under a pressure of 24 GPa at room temperature using HPT. Thermal conductivity of the HPT-processed samples were measured using pico-second time domain thermoreflectance. The reduction in thermal conductivity is attributed to the formation of nanograin boundaries and metastable phases which act as phonon scattering sites. Subsequent annealing shows a reverse transformation from metastable phases to cubic diamond phase and a nominal increase in thermal conductivity due to the reduction of the density reduction of secondary phases and nanocrystalline defects.