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A Raman spectroscopy-based investigation of thermal conductivity and role of surface stress in deformation of stressed silicon microcantilevers at high temperatures

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ABSTRACT

Multiscale experiments and models have repeatedly shown that thermal and mechanical properties of materials are a strong function of the length scale of measurement. For example, in the case of silicon (Si) length scale dependent inter-relationship of thermal and mechanical properties has been used to improve the thermal dissipation and performance of the microscale electronic devices. This study uses a newly established nanomechanical Raman spectroscopy approach to analyze thermal conductivity of microscale Si cantilevers as a function of temperature and mechanical strain. The results are compared to available experimental data on Si by other researchers and explanations are offered regarding the effect of the length scale on the obtained results. The results show that the thermal conductivity of Si increases from 114 to 145 with compressive strain level increase from 0% to 0.25% at room temperature. At higher temperatures, the dependence of thermal conductivity on strain significantly increases. Phonon mean free path shows an increase with uniaxial compression that is accompanied with free surface deformation but it shows decrease with increase in temperature. Analyses establish the notion that the phonon affected thermal conduction in Si is coupled to mechanical deformation at microscale where surface to volume ratio is high. Analyses are also used to establish a surface stress relation in one dimensional nano structures subjected to mechanical loading at high temperatures.