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PHONON KNUDSEN FLOW IN GaAs/AlAs SUPERLATTICES

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PHONON KNUDSEN FLOW IN GaAs/AlAs SUPERLATTICES

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The measured in-plane thermal conductivity, σ_{SL} , of GaAs/AlAs superlattices with even moderate layer thicknesses (see diamonds in figure) are significantly smaller than the weighted average, $\sigma_l = 67$ W/Km, of the bulk GaAs and AlAs conductivities. One expects a suppression of the thermal conductivity to that of an actual $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ alloy (dashed curve in figure) when the thickness of the GaAs and AlAs layers approaches that of a single monolayer. However, the observed superlattice thermal conductivity remains suppressed even at layer thickness $\gtrsim 10$ nm. The low thermal conductivities, and very high mobilities, make n -doped GaAs/AlAs superlattices attractive possibilities for thermoelectric devices.

Ratio of superlattice thermal conductivity, σ_{SL} , to weighted average, $\sigma_l = 67$ W/K m, of GaAs and AlAs conductivities as a function of individual layer thickness. The set of diamonds shows experimental results from T. Yao, *Appl. Phys. Lett.* 51, 1798 (1987). Solid (dashed) curve shows reduction of thermal conductivity assuming a phonon Knudsen flow within each GaAs and AlAs layer (assuming an actual $\text{Al}_{0.5}\text{Ga}_{0.5}\text{As}$ alloy.)

With Molecular-Beam-Epitaxial grown GaAs/AlAs superlattices one can expect the individual GaAs and AlAs layers to be extremely clean. Defect and/or alloy scattering is limited to be near the heterostructure interfaces. We estimate the room-temperature phonon mean-free-path to be 42 (22) nm for the longitudinal (transverse) mode and thus comparable to or smaller than the layer thicknesses. Thus we expect an important phonon scattering at the interfaces.

We study this phonon scattering at the superlattice interfaces assuming a Knudsen flow characterized by diffusive scattering, see for example K. Fuchs, *Proc. Cambridge Philos. Soc.* 34, 100 (1938). The solid curve in the figure shows our Knudsen-flow theory estimated for the superlattice thermal conductivity which shows a significant reduction when the layer thickness is shorter than the estimated phonon mean free paths.