Hydrodynamic Phonon Transport in Graphitic Materials

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Graphitic materials, including carbon nanotubes, graphene, and graphite, have recently drawn much attention for a wide range of applications due to their exceptional electronic, mechanical, and thermal properties. The transport of phonons, a major heat carrier in those graphitic materials, have been discussed in two regimes: diffusive regime represented by the Fourier's law and ballistic regimes where there are few internal scattering events of phonons. However, two recent theoretical studies revealed that another regime of phonon transport, called hydrodynamic regime, can be significant in graphitic materials[1,2]. The significant hydrodynamic phonon transport in graphitic materials is due to the strong momentum-conserving three-phonon scattering (N-scattering) compared to momentum-destroying three-phonon scattering (U-scattering).

In this presentation, we will discuss two representative phenomena of hydrodynamic phonon transport: phonon Poiseuille flow and second sound. The phonon Poiseuille flow is a phonon analogue of Poiseuille flow, a fully-developed internal fluid flow. The phonon Poiseuille flow is much different from thermal transport in diffusive or ballistic regimes in that hydrodynamic phonon viscous damping is a primary mechanism for thermal resistance. We will quantitatively present the contribution of phonon viscous damping effects to the thermal resistance in graphitic materials. The second sound is a wave-propagation of temperature pulse, just like the acoustic sound in fluids is a wave-propagation of pressure pulse. The dispersion of second sound in graphitic materials will be discussed to elucidate its propagation speed and attenuation rates.

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References
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