# Investigation of phonon Poiseuille flow in purified graphite crystals

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Phonon hydrodynamics has been intensively reviewed owing to its peculiar phenomena, very similar to fluid dynamics. In graphite, the dominance of momentum-preserved normal scattering promoted the demonstration of second sound [1] and phonon Poiseuille flow [2] latterly. However, the impact of isotope scattering on the phonon hydrodynamic conduction in graphite remains vacant.

In this work, we experimentally demonstrate that phonon Poiseuille flow only exists in $^{13}C$ isotopically purified graphite ribbons. We investigate phonon Poiseuille flow (illustrated in Fig.1a) in suspended graphite ribbons (Fig. 1b) with both natural (1.1%) and enriched (0.02%) carbon isotope concentrations. Based on a steady-state μTDTR setup, we first study the suppression of thermal conductivity (κ) by isotope-phonon scattering, as shown with a significant reduction of κ in a natural graphite ribbon at the intermediate temperature range in Fig. 1c. Furthermore, we examine the observation of phonon Poiseuille flow under an explicit criterion ($\kappa/G_{ballistic}$) in Fig. 1d. As the temperature increases, κ is enhanced over the ballistic case from 30 to 60 K, attributed to the hydrodynamic transport of phonons in the isotopically enriched sample. Whereas $\kappa/G_{ballistic}$ solely decreases in the natural graphite sample, which indicates the absence of phonon Poiseuille flow resulted from the sufficient momentum-destroyed isotope scattering. Supported by our theoretical calculation by solving the phonon Boltzmann transport equation (BTE), we demonstrate that the phonon Poiseuille flow can only be observed in isotopically purified graphite ribbon. This result thus orientates future progress for a deeper understanding of phonon hydrodynamics in solids.

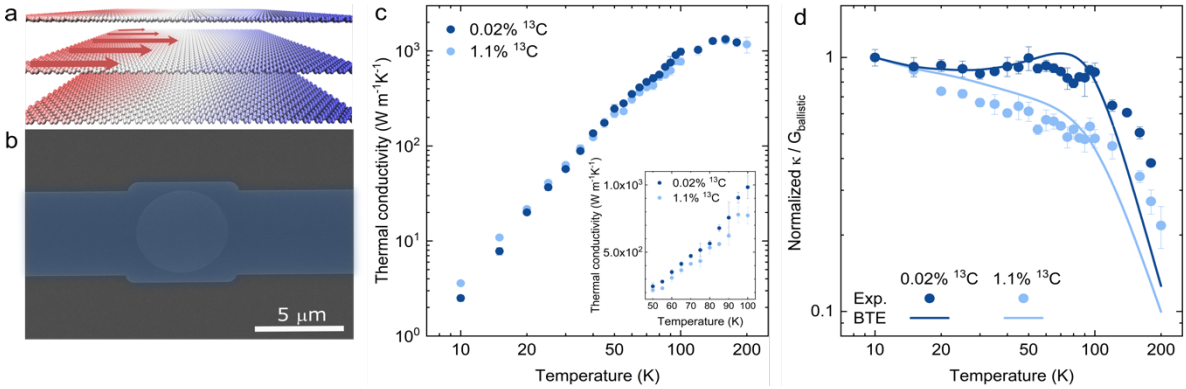


**Fig. 1** (a) Illustration of phonon Poiseuille flow in graphite. (b) SEM image of a 65-nm-thick suspended graphite ribbon (blue color). (c) Temperature-dependent thermal conductivity of isotopically enriched (dark blue) and natural (light blue) graphite ribbons. Inset: thermal conductivity from 50 to 100 K. (d) Normalized thermal conductivity over ballistic thermal conductance as a function of temperature. The increasing trend around 50 K indicates the observation of phonon Poiseuille flow for only purified graphite ribbon.

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**References** [1] Huberman, S. et al. Science **364**, 375–379 (2019). [2] Machida, Y. et al. Science **367**, 309–312 (2020).