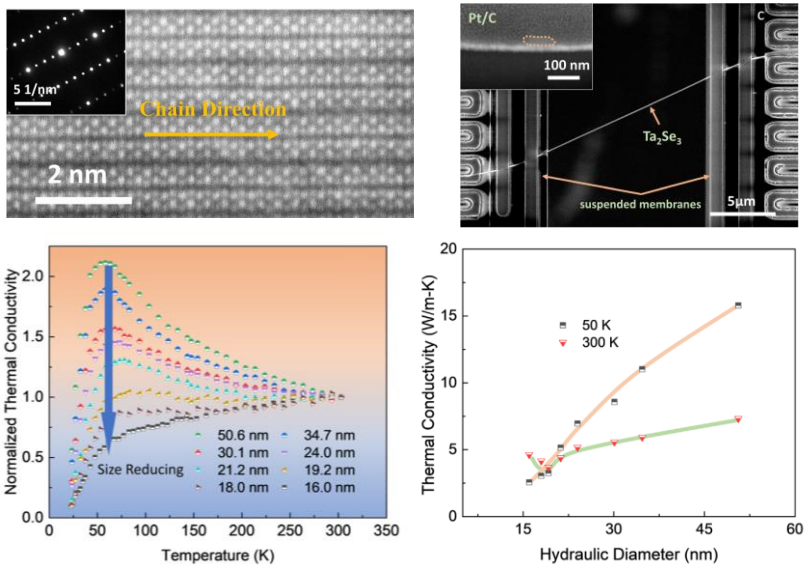
Elastic stiffening induces one-dimensional phonons in thin Ta_2Se_3 nanowires

Z. Pan and Deyu Li (Vanderbilt University); K. Wang (Penn State);
S. H. Lee and Z. Q. Mao (2DCC, Penn State)

Project Summary: Confined transport of energy carriers in low-dimensional materials could induce unusual phenomena, leading to properties promising for various applications. In the past, extensive efforts have been carried out to explore and understand thermal transport through a plethora of two-dimensional (2D) materials, while experimental studies of one-dimensional (1D) transport have been largely limited to earlier studies of thermal transport through single-walled carbon or boron nitride nanotubes. Only very recently, attempts to probe thermal transport in quasi-1D van der Waals (vdW) crystal nanowires have been made, which reveal interesting observations. Recently, Prof. Deyu Li's group at Vanderbilt University experimentally demonstrated 1D phonon-mediated thermal transport in Ta_2Se_3 nanowires, which is enabled by a phonon stiffening effect. This conclusion is based on diameter dependent thermal conductivity measurement of the nanowires, with the diameter ranging from ~15 to ~50 nm. Normally the thermal conductivity of (3D) phonons in nanowires would reduce with decreasing diameter. However, in the case of Ta_2Se_3 nanowires, an unusual increasing trend was found when the diameter is below a certain value (~20 nm) at 300 K. This non-monotonic trend is absent at 50 K. This can only be explained by 1D phonon in the thin nanowires at 300K. The detailed findings are published in *Appl. Phys. Lett*. **120**, 062201 (2022).

2DCC Role: This research resulted from a close collaboration between 2DCC and the external user, Prof. Deyu Li. The nanowires of Ta_2Se_3 used for this study were obtained from microexfoliation of bulk Ta_2Se_3 crystals grown using a chemical vapor transport method at the 2DCC Bulk Growth facility.



(Top left) An HRTEM image of a Ta_2Se_3 nanowire showing the well-aligned molecular chains. Inset: selected area electron diffraction pattern. (Top right) A SEM image of the measurement device with a Ta_2Se_3 nanowire placed between the two suspended membranes. (Bottom) Normalized thermal conductivity κ/κ_{300K} of different diameter Ta_2Se_3 nanowires. Thermal conductivity of Ta_2Se_3 nanowires at 300 and 50 K.