Nano-electromechanical systems (NEMS) resonator which offers the potential for extreme mass and force sensitivity, has triggered intense interest in recent years. Two-dimensional (2D) materials are attractive for use in next generation NEMS devices due to their unique physical properties (high Young’s modulus and breaking strength), flexibility and low mass. Among the family of 2D materials, graphene is the most studied one so far.

Two-dimensional (2D) materials are attractive for use in next generation NEMS devices due to their unique physical properties (high Young’s modulus and breaking strength), flexibility and low mass. Among the family of 2D materials, graphene is the most studied one so far. Nevertheless, the lack of a bandgap in graphene limits its applications that requires a semiconducting material. 2D MoS2 and WSe2, with an intrinsic bandgap, which presents excellent mechanical properties in combination with good electrical and optical quality can be an attractive alternative for graphene in NEMS application.

Low frequency graphene resonator

- The ratio of 2D band to G band is 2.7
- 2D band has a sharp symmetric peak
- The D band peak is significantly low
- Resonance was actuated with a piezoelectric disc and detected with a Laser Doppler Vibrometer (LDV)
- Resonant frequency in air ~16kHz
- Little defects in the graphene

High frequency graphene resonator

Transfer process of CVD graphene to trench

2D semiconductor FET

Fabrication process
- Poly-Si (75nm) and SiO2 (100 nm) were grown on Si substrate
- Transferred CVD graphene to the substrate with PMMA
- Patterning graphene by O2 plasma
- Deposited Cr (10 nm)/Au (100 nm) metal layers as electrodes
- Removed poly-Si underneath graphene by XeF2 vapour

Sample preparation
- Thermal growth of SiO2 (280 nm) on Si substrate and patterned SiO2 with hole arrays
- Exfoliation and transfer of 2D WSe2 onto pre-patterned substrates with a PDMS stamp

Electrical characterization
- MoS2 FET → N-type
- WSe2 FET → P-type
- As E_F increases, I_DS increases exponentially
- As I_DS of WSe2 increases, I_DS increases and saturates

Raman spectra
- In-plane mode (E_{2g}) and out-of-plane mode (A_{1g}) for 2D MoS2 and WSe2
- No other notable Raman peak belonging to other materials in the range of 100–1000 cm⁻¹
- Good signal to noise ratio of the spectra

Box chart of Young's modulus for 2D WSe2
- Number of layers ↑ → 2D elastic modulus E_{2D} ↑ linearly
- Strong interlayer interaction
- Young’s modulus (E_F-E_{2D}/t) of 2D WSe2 is independent of the number of layers (~170GPa)

Mechanical property characterization

Resonance actuation and detection
- AC voltage V_A was used to drive the graphene sheet into resonance
- Gate voltage V_G was used to adjust the static stress in graphene sheet
- Lock-in amplifier was used to extract extremely weak AC signals from noise

Forced deformation curves for suspended 2D WSe2

References