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Direct Synthesis of Graphene on Niobium Superconductors

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Background & Motivation

Why direct growth of graphene on niobium?

Graphene is a single atom thick hexagonal lattice of carbon, see Figure 1 (c). Its isolation and initial characterization in 2004 [1] generated massive interest from the scientific community because of its **unique physical and electronic properties**. Of interest to this work:

- **Ballistic electron transport.** In graphene electrons have a mean free path in the lattice that is longer than the conductor dimensions, i.e. **electrons travel without scattering** and with **little to no energy dissipation**. [2]
- **Proximity induced superconductivity.** Placed in contact with a superconducting material, **graphene also turns into a superconductor**, i.e. **electrons move without resistance**, and do not need an external voltage source to maintain a current. [3]

Creating highly electron transparent graphene-superconductor interfaces remains difficult, so ballistic conduction in this system is still not well characterized. **Direct graphene growth** on a superconductor vs transfer **promises a higher quality interface**, see Figure 1 (a & b). [4]

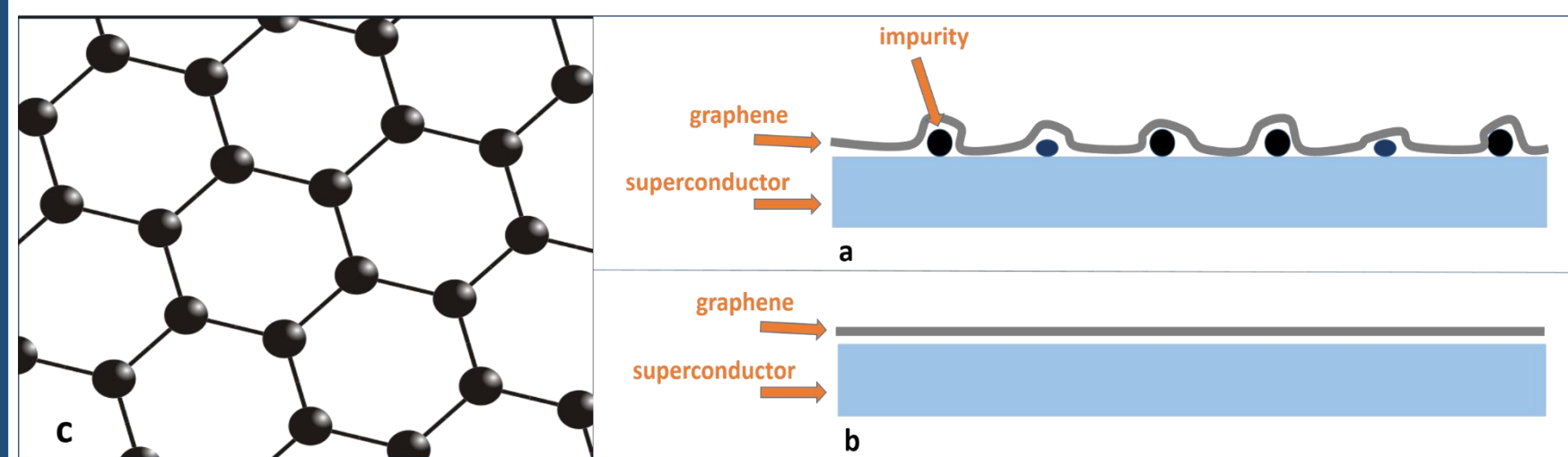


Figure 1. A cartoon of transferred graphene showing impurities trapped in the graphene-superconductor interface (a), cartoon of directly grown graphene showing a more electron transparent interface (b). An image of graphene's hexagonal structure (c).

Objective

The synthesis few-layer graphene on niobium and niobium nitride nanofilms supported on industry standard silicon dioxide wafers

Methods

- **CVD of niobium on SiO₂**
 - 200 nm niobium and niobium nitride films were deposited on silicon dioxide wafers via chemical vapor deposition (CVD).
- **Direct growth of graphene by PECVD**
 - Wafers were subjected to various growth regimes in a plasma enhanced chemical vapor deposition (PECVD) system.
- **Characterization by Raman Spectroscopy**
 - Wafers were characterized by Raman spectroscopy to see the effectiveness of the chosen growth regime.

Growths in custom PECVD system built in house

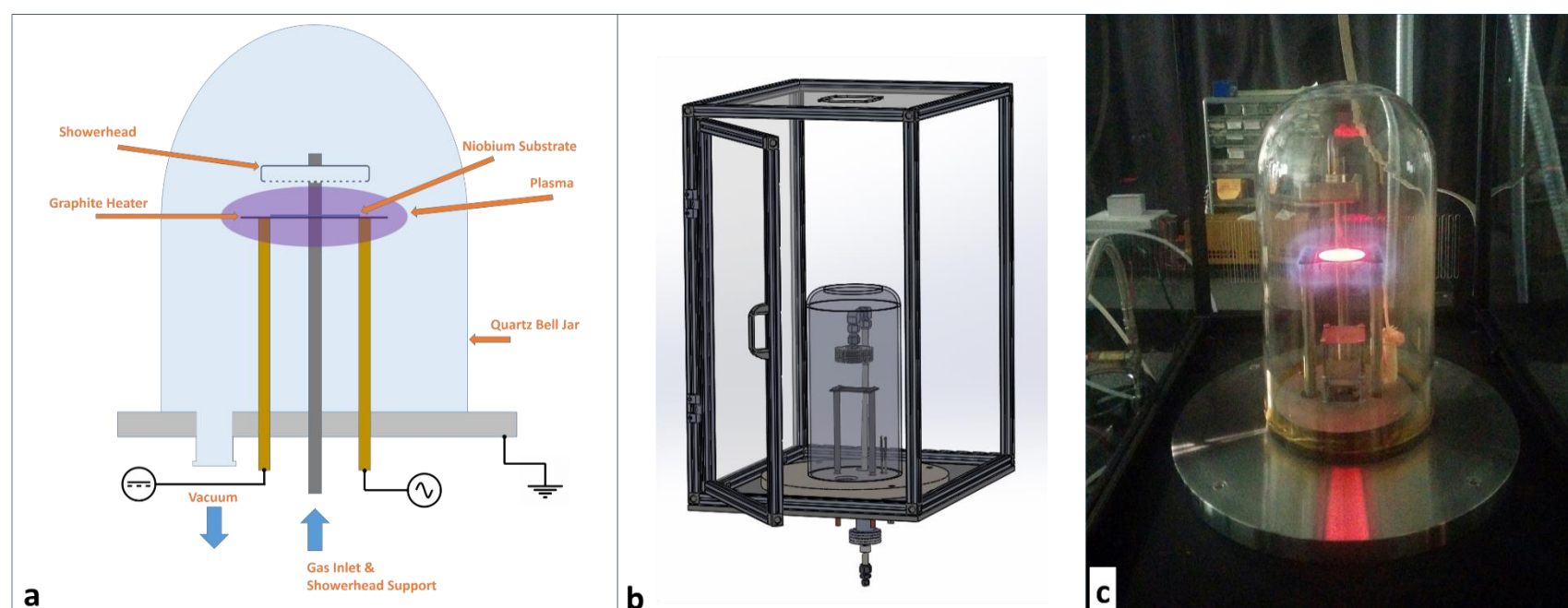


Figure 2. Schematic of PECVD vacuum chamber (a). CAD drawing of PECVD bell jar and acrylic shield (b). Photo of PECVD system with active plasma and resistive heater (c).

Growth trials were performed in a PECVD system designed and built by current research group members, see Figure 2.

Results

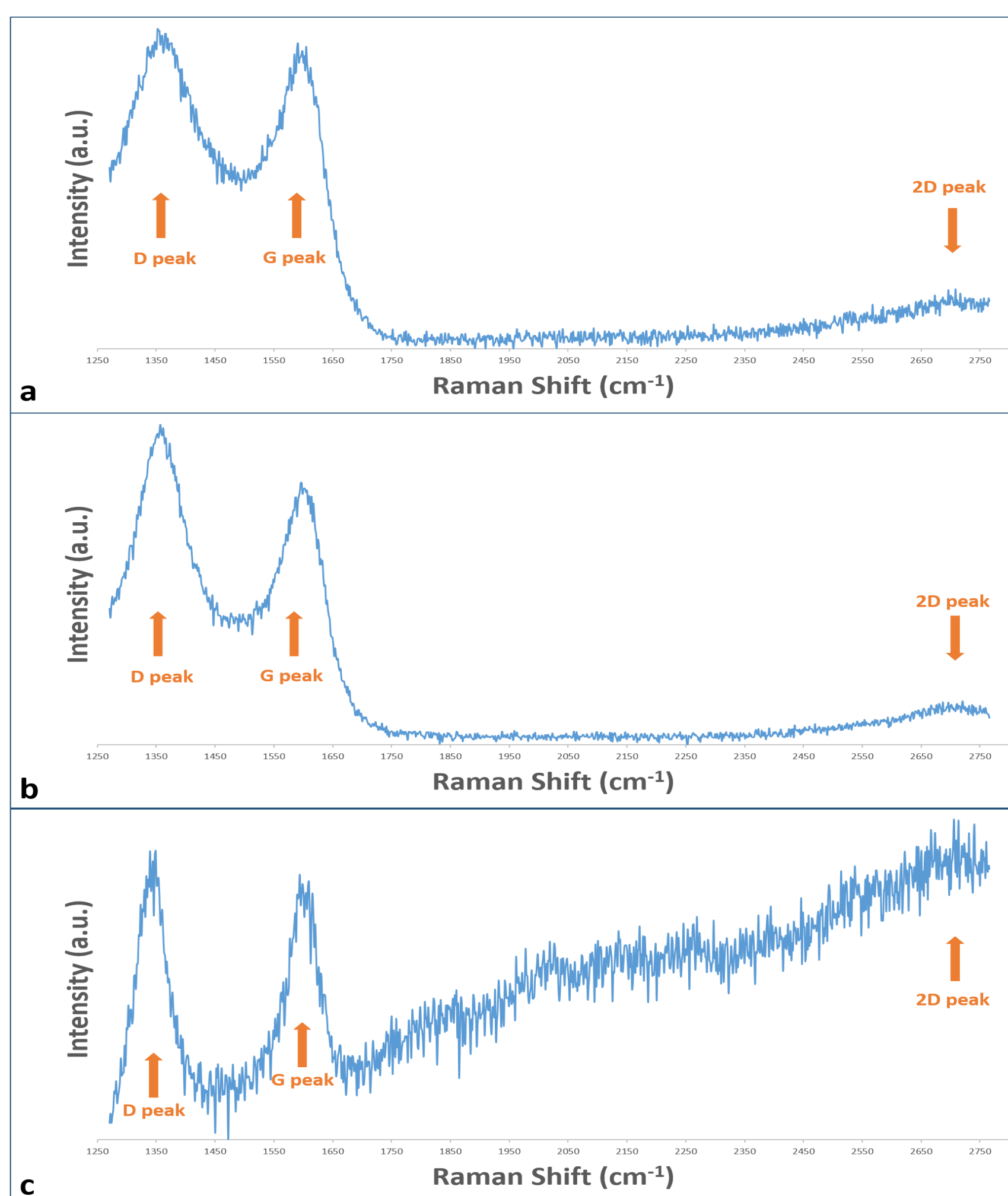


Figure 3. Raman spectra of graphitic films grown on niobium (a) and niobium nitride (b) at 1000° C with a hydrogen-acetylene plasma. Spectrum of graphitic film grown on niobium at 1100° C with acetylene only and no plasma (c).

Discussion

What do these results mean?

- We have demonstrated that both **niobium** and **niobium nitride can self-catalyze the dehydrogenation of acetylene gas** both with and without a plasma. This is shown by the presence of D, G, and 2D peaks in the Raman spectra, Figure 3.
- The progression of the 2D to G peak ratio as we moved from a plasma regime Figure 3 (a & b), to a non plasma regime Figure 3 (c), shows we are **moving to more graphene like films in our results**. Figure 4 is a reference for the peak ratios we are aiming for.

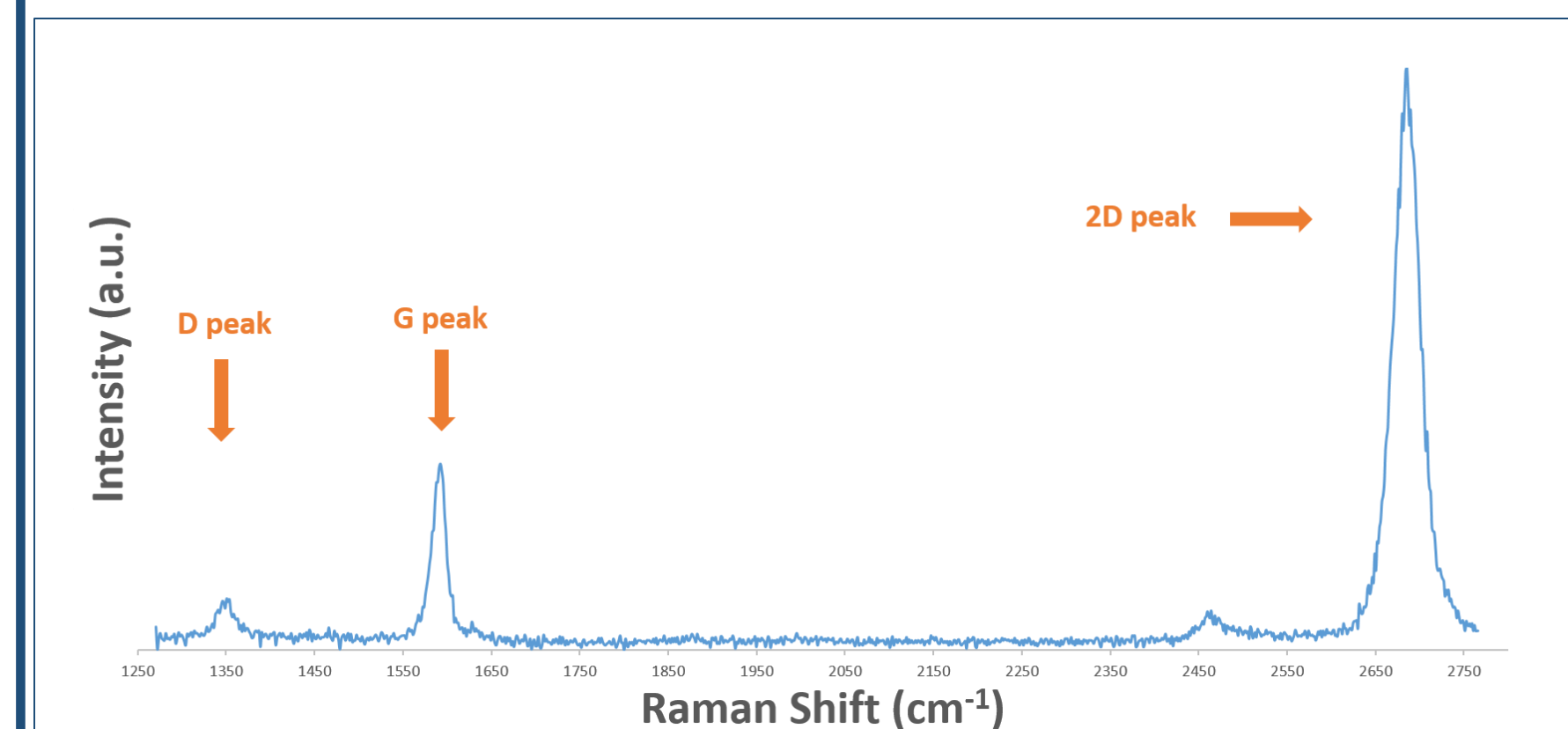


Figure 4. Raman spectrum of monolayer graphene grown on 1.5 micron copper film in our lab.

Conclusions / Future Work

- Based on the progression of our results so far, **direct growth of graphene on niobium and niobium nitride appears possible**.
- Next steps are to transfer currently grown films to a bare SiO₂ wafer and obtain Raman spectra from this known substrate. This will rule out the possibility of interference of the graphene signal by the niobium substrate.

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