Crystal structure dynamics of graphite and graphene coated alkali photocathodes

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Special Equipment Requirements and Hazards

Special equipment:

- Laser pump similar to optical parametric oscillator pumped by a Ti:sapphire with known possibly adjustable cross-correlation between pump and probe. Maximum fluence ~0.5 mJ/cm2.

Hazards:

- Potential hazards include the laser of the MUED instrument. We will work with the BNL collaborators to exercise the necessary precautions, follow the defined procedures when operating these systems, and utilize the necessary personal protection equipment. Graphene and graphite is not considered a hazardous material..

Experimental time request

CY2021 Time Request

Capability	Setup Hours	Running Hours
UED Facility	16	48

Diffraction measurements of graphite with different numbers of layers, exploring different laser fluences and time delays. Estimated time: 8 hours for each material sample. (24 hours total)

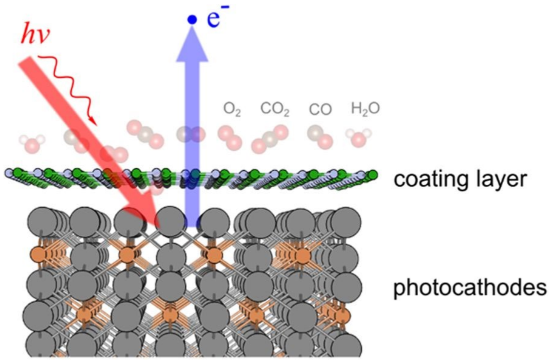
Diffraction measurements of graphene coated alkali photocathodes. Estimated time: 8 hours for each material sample. (24 hours total)

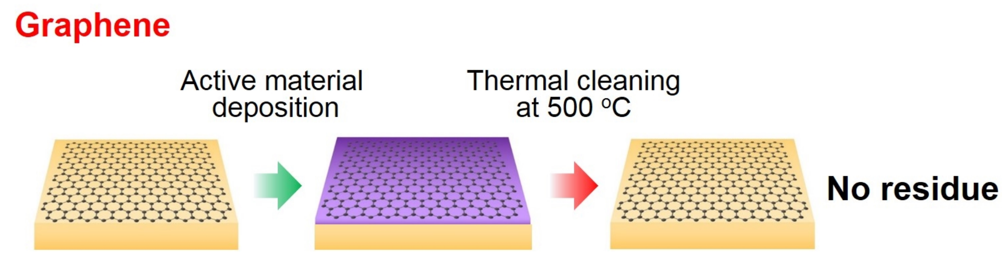
Time Estimate for Remaining Years of Experiment (including CY2021)

Capability	Setup Hours	Running Hours
UED Facility	8	24

Overview of proposal

This proposal seeks to quantify short-term crystal structure deformation of graphene and when graphene-coated alkali photocathode films or surrogates.



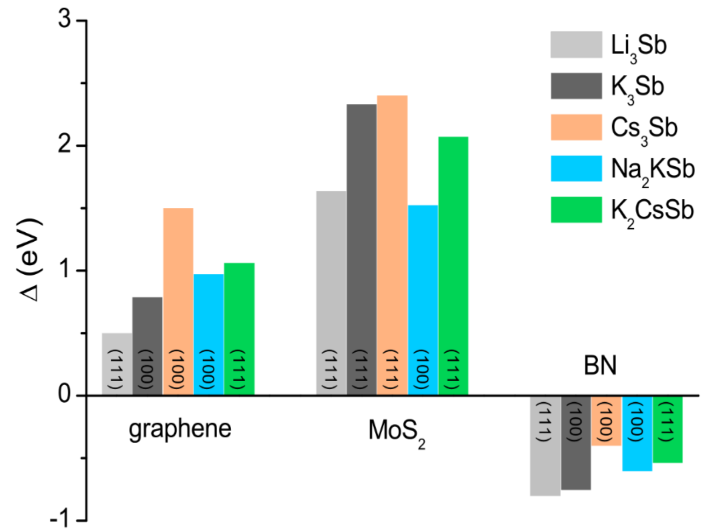


The goal of the proposed research is to characterize the crystal structure dynamics of graphite and graphene with and without alkali photocathode films. We propose to first characterize graphite with different number of layers, then focus on comparing the dynamic response of graphene-coated alkali photocathodes (~10-100nm thick, accessible with MUED). These samples quickly degrade when exposed to air so we will explore available options for transporting them to the beamline with minimum damage and/or the use of surrogate films.

Proposal details

- Graphene is employed to protect the surfaces of the photocathodes from contaminant gases thus enhancing their lifetime[1]. MeV ultrafast electron diffraction (MUED) is an ideal technique to **study the dynamics of the crystal structure these materials (of varying thickness)**[2] **under the mechanical deformation induced by the pump laser with high temporal resolution**.

  - Graphene has shown promise both as a coating[3] and as a substrate[4] for opto-electronic films (including photocathodes).
  - Graphene has a negative thermal expansion coefficient[5] *and* it modifies the surface charge potential at interfaces[6] (that influence transmission probabilities and work function, among others).
  - Thus, time dependent structural response of graphene (to laser-induced thermal transients) is expected to impact its function as both a substrate and a protective film, especially for photocathodes.

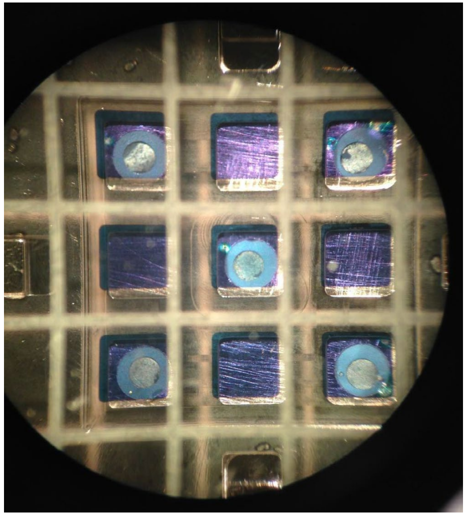


Wang, G., et al., npj 2D Materials and Applications, 2018. **2**(1): p. 17.

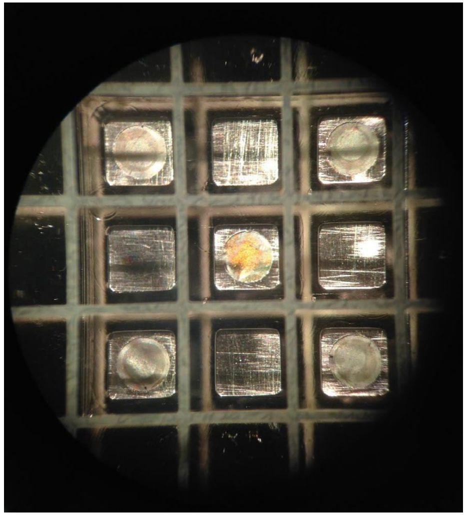
Sample synthesis and mounting options

Frame for Graphene

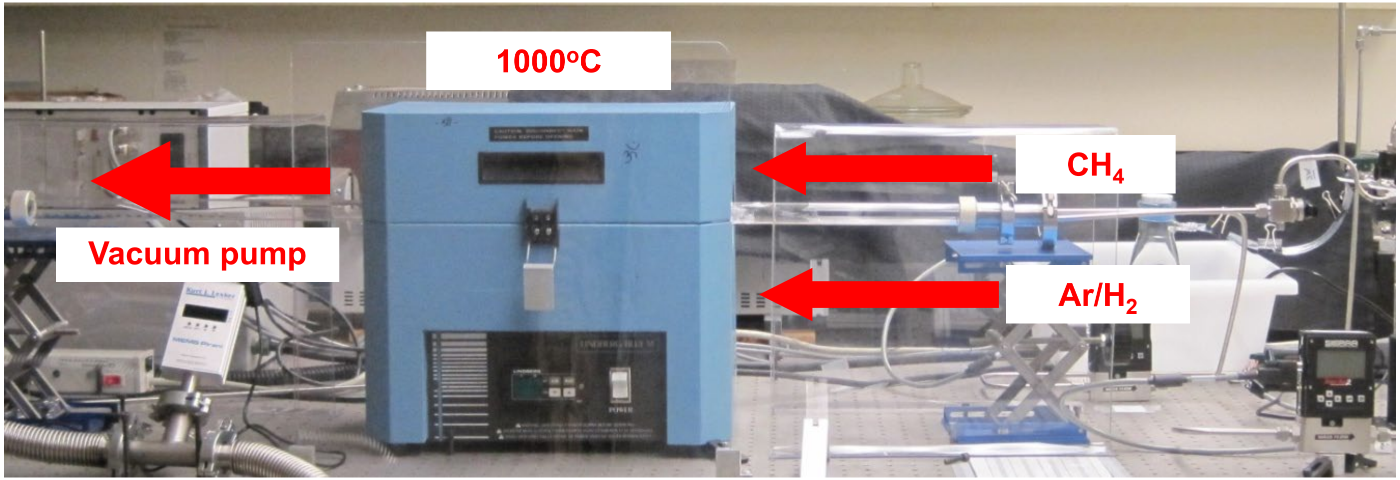
Deposited side

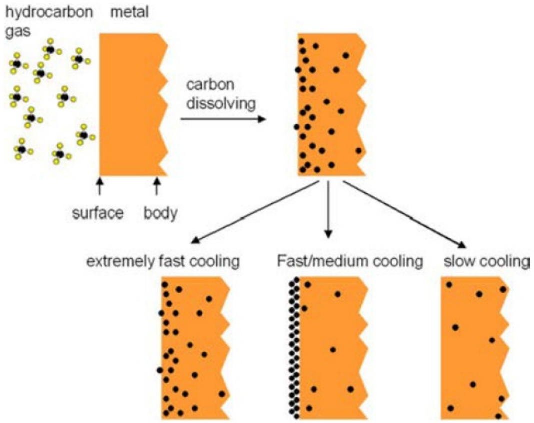


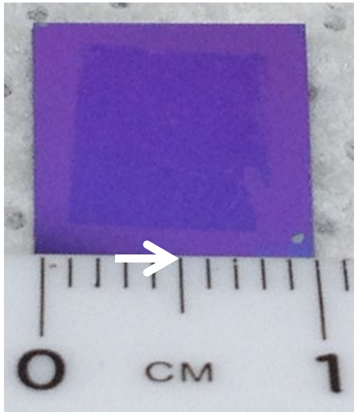
Non-deposited side



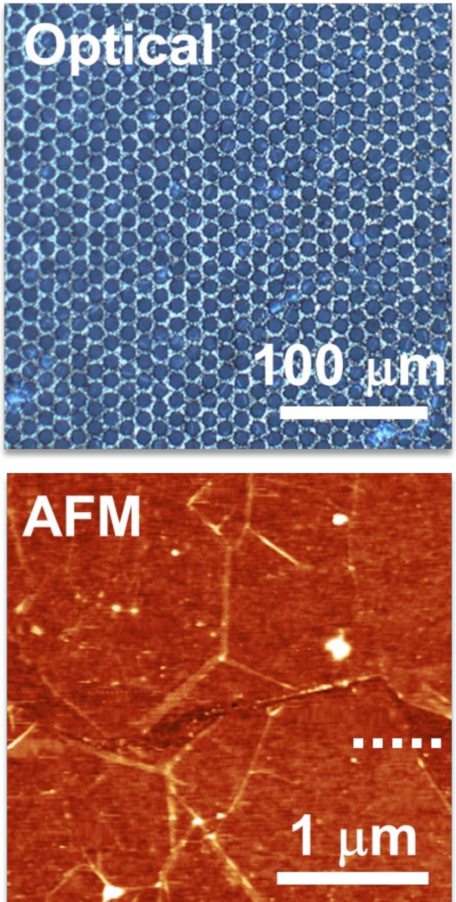
2D film/coating synthesis

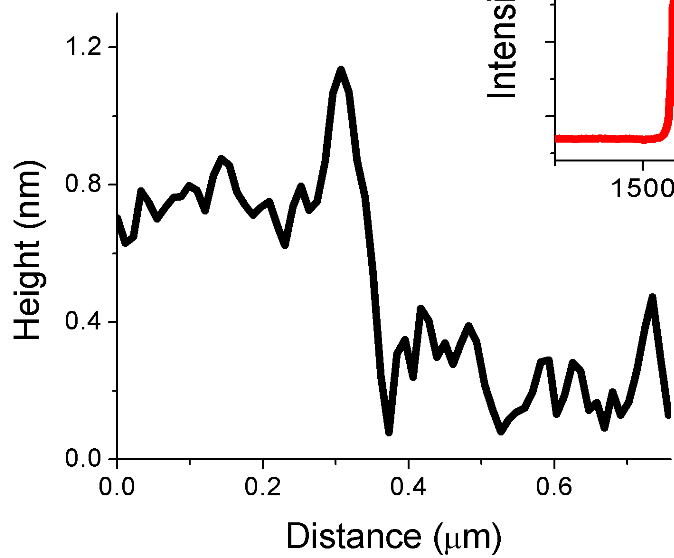


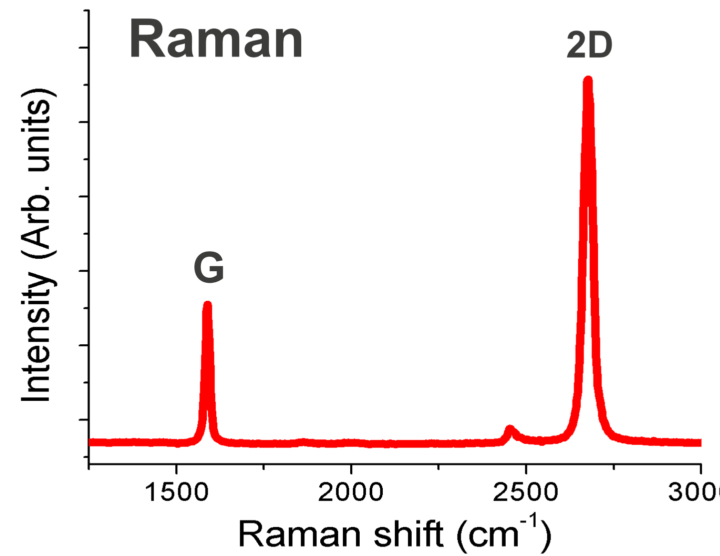




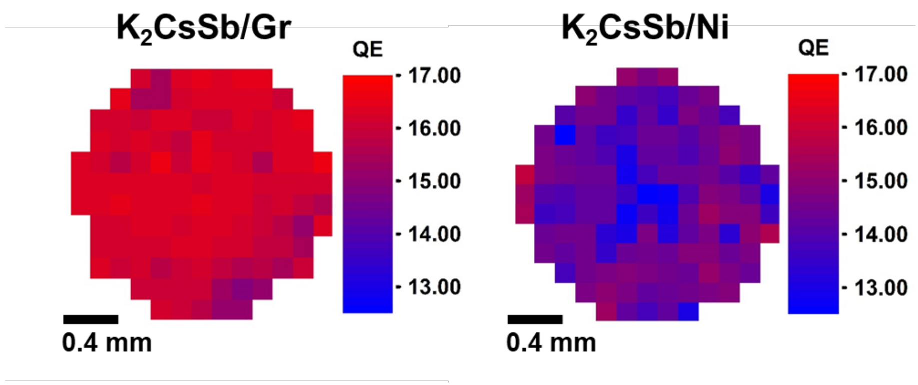
2D substrate characterization prior to MUED studies

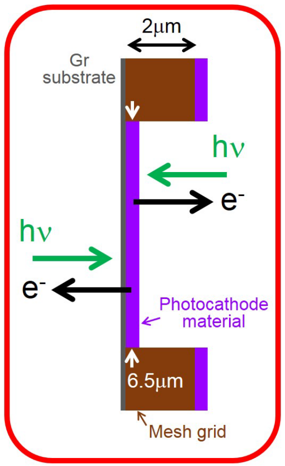


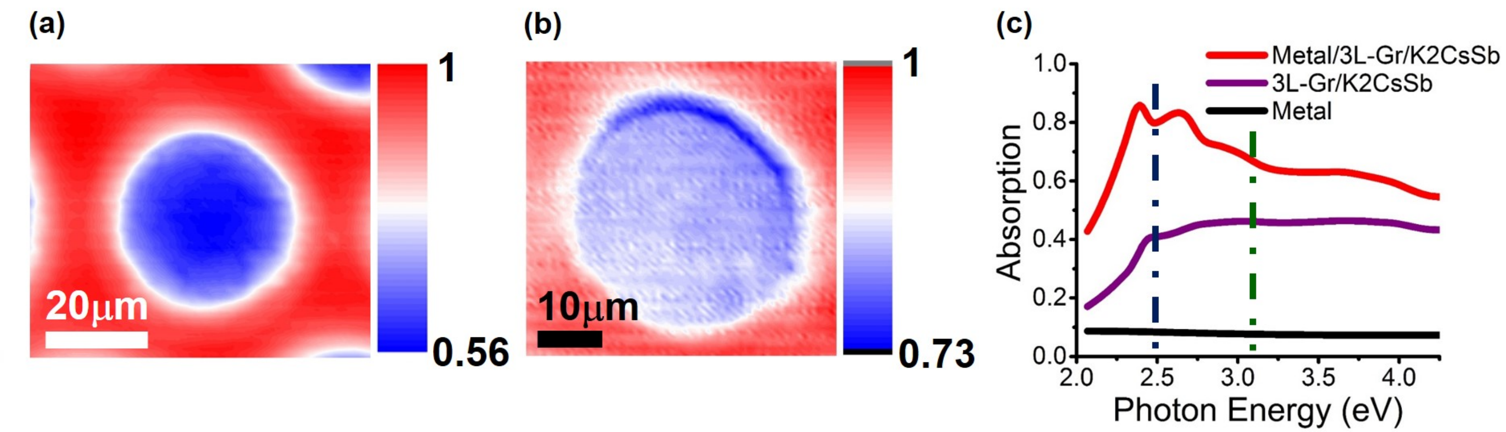




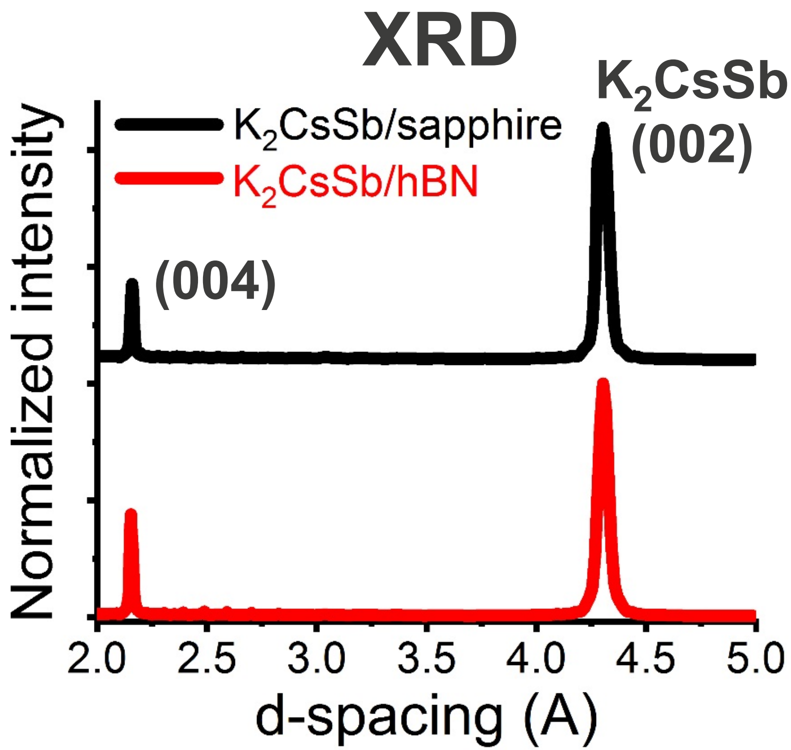
Photoemission studies of film + substrate samples



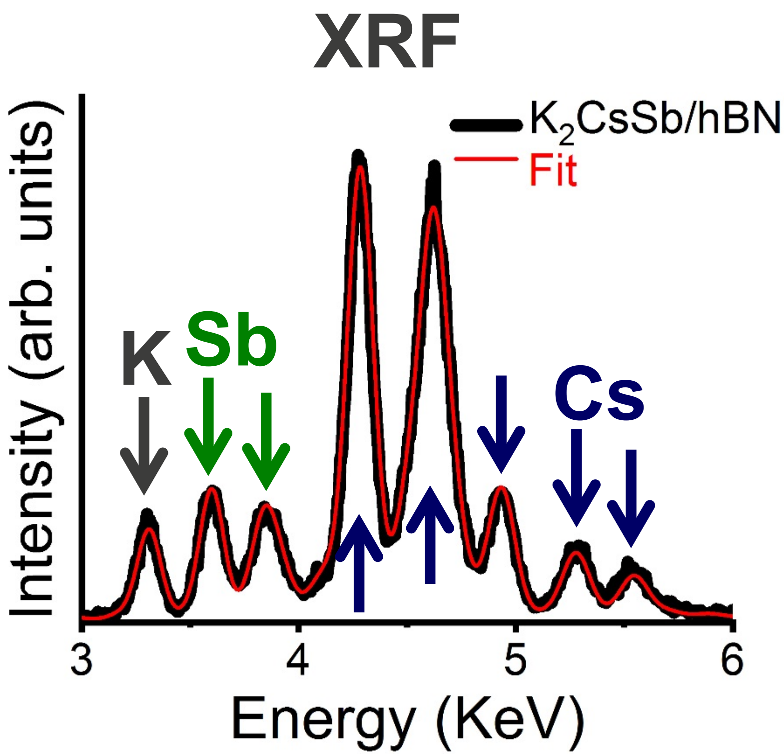




Sample characterization prior to MUED studies



Good crystallinity



$K_{1.85}Cs_{1.08}Sb$

Questions to be addressed by MUED studies

- What are the thresholds (fluence, pulse length) for onset of an observed structural response?
- What is the onset of damage (if accessible using available laser)?
- Does the response evolve with continued pump laser exposure?
- What is the effect of transient heating on defects in graphene (do we observe migration or healing)?
- What is the nature of the structural response (in-plane, out of plane) and how localized is it?
- Is the structural response in explored regimes strong enough to modulate the transmission probability of low energy electrons across the material?

Collectively, this information will enable greater understanding and application of 2D coatings to opto-electronic devices and application.

References

1. Moody, N., et al., *Graphene shield-enhancement of photosensitive surfaces and devices*. SPIE Defense + Security. Vol. 9083. 2014: SPIE.
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