

# Graphene Pellicles

Richard van Rijn

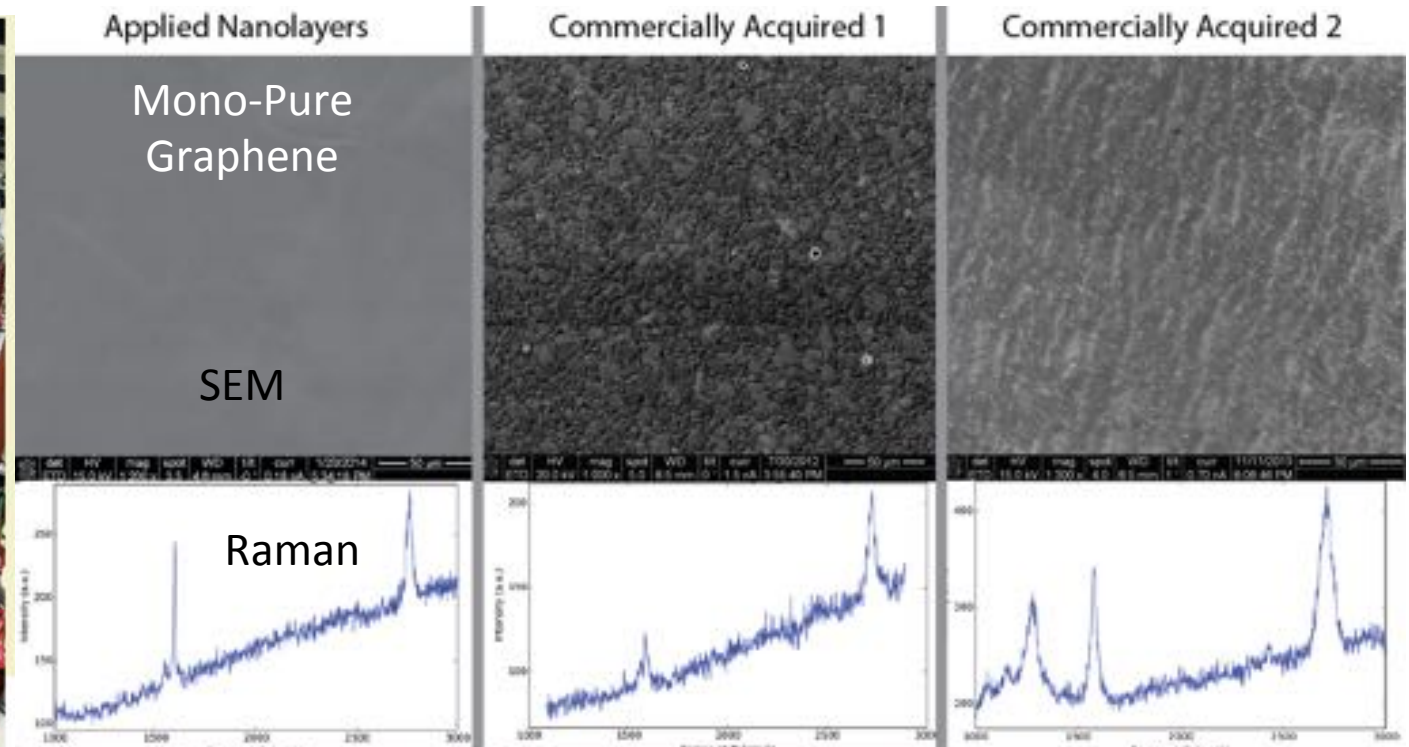
# Applied Nanolayers

- Scalable automated production of high quality graphene up to 200 mm wafer sizes by CVD
- 2DM (graphene and related materials) supplier of choice
  - Strong verifiable automated quality assurance
  - Robust high volume supply chain
  - Focus on applications and integration with CMOS
- Global 2DM device foundry

# Technology

- *Production of high quality graphene on 200 mm wafers using epitaxial metal films*
  - *Developed fully automated production platform engineered for lowest cost per cm<sup>2</sup>*
  - *Platform and method compatible with h-BN and other 2D materials*

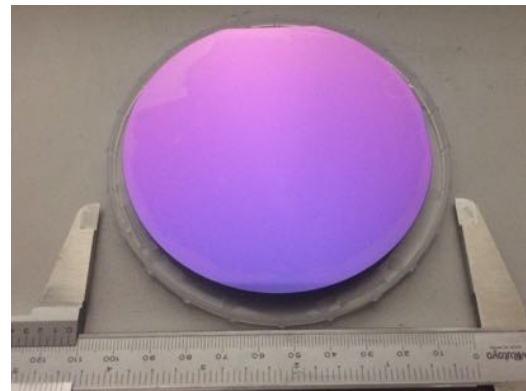
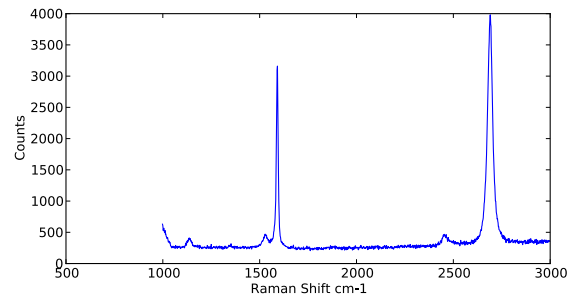
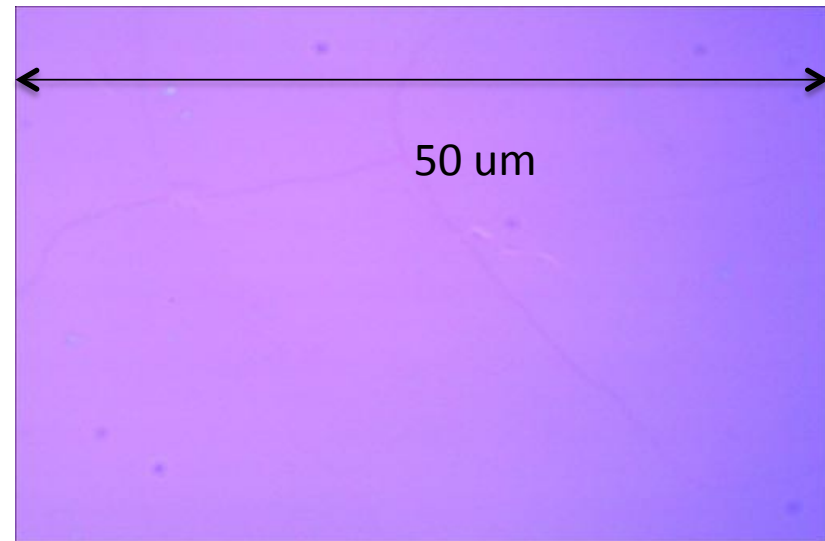
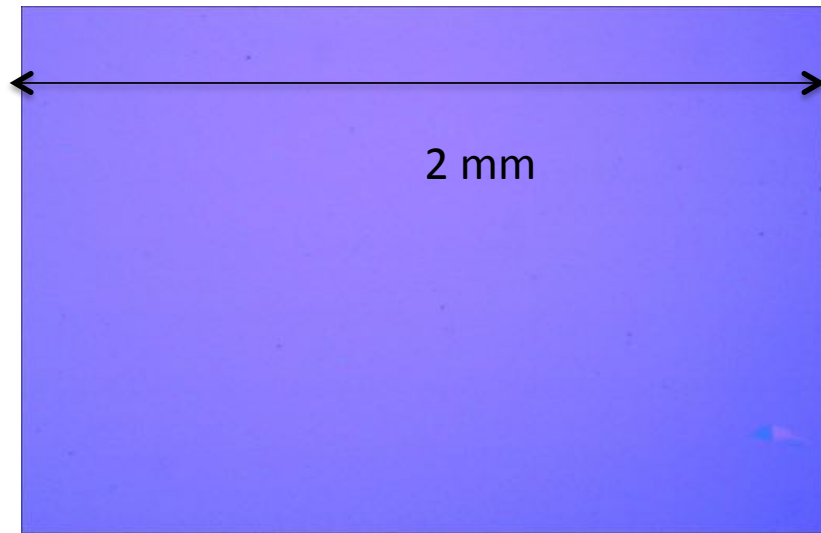
# Wafer scale graphene up to 200mm



# Technology

- Production of high quality graphene on 200 mm wafers using epitaxial metal films
  - Developed fully automated production platform engineered for lowest cost per cm<sup>2</sup>
  - Platform and method compatible with h-BN and other 2D materials
- *Wafer to wafer transfer up to 200 mm*
  - *Fully mechanical transfer*
  - *Full automation*

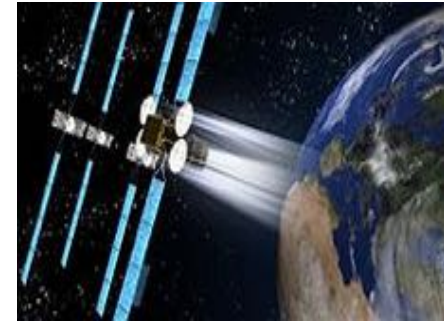
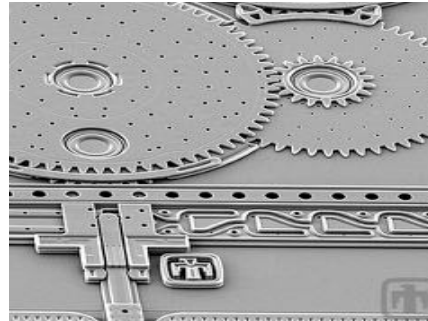
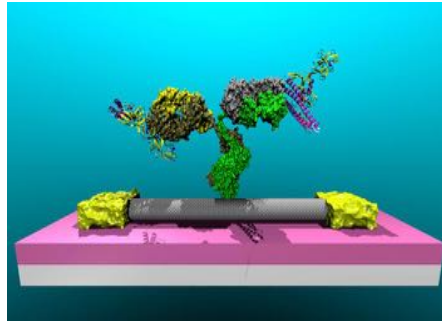
# Wafer to wafer transfer



# Technology

- Production of high quality graphene on 200 mm wafers using epitaxial metal films
  - Developed fully automated production platform engineered for lowest cost per cm<sup>2</sup>
  - Platform and method compatible with h-BN and other 2D materials
- Wafer to wafer transfer up to 200 mm
  - Fully mechanical transfer
  - Full automation
- *Automated quality control on 200 mm*
  - *Raman spectroscopy*
  - *Optical microscopy*

# Applications



**Semiconductor**

**Biotech**

**MEMS**

**Defense & space**

EUV pellicle  
Active devices  
Sensors  
Optoelectronics  
RF

BEOL integration

Thin membranes  
Gene sensing  
Biocompatible coating  
Bio I/O

Platform substrate

Low friction layer  
Flexible membrane  
Sensing  
Lab on chip

BEOL integration

Devices & sensors  
Advanced sensing  
Solar power  
Membranes

Advanced platforms



# Graphene pellicles

**Bottom up construction** → build membrane layer by layer using wafer to wafer transfer

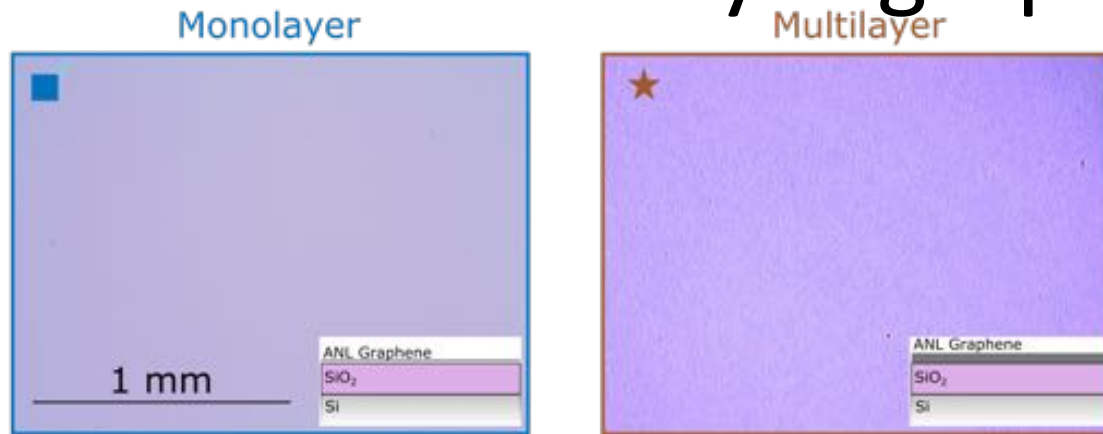
## Advantages

- Precise control over the number of layers
- Heterostructures: incorporate other layers to improve pellicle properties (h-BN)
- Control interlayer orientation
- No need to thin membrane
- Supported ANL graphene proven to be resistant to EUV + H<sub>2</sub> > 24h

## Challenge

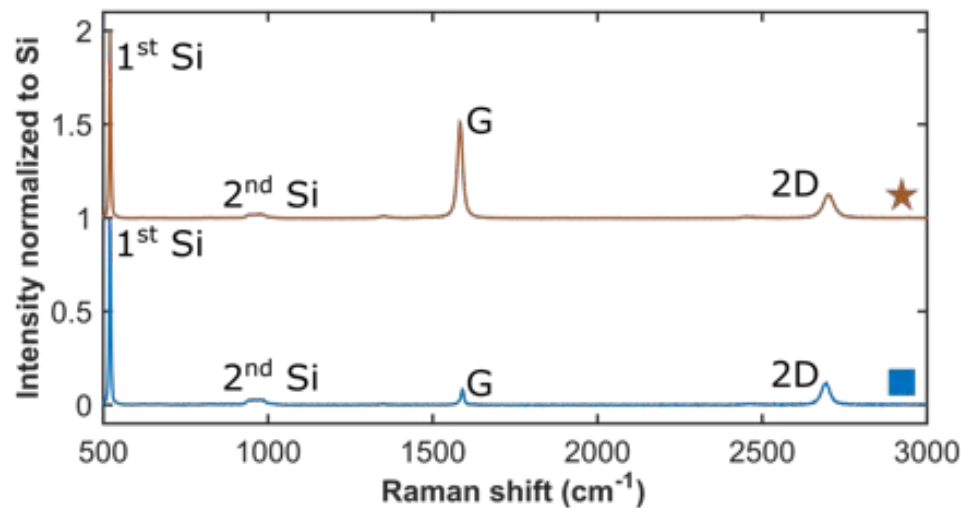
- Integration with pellicle support structure

# Raman quality control for mono and multilayer graphene

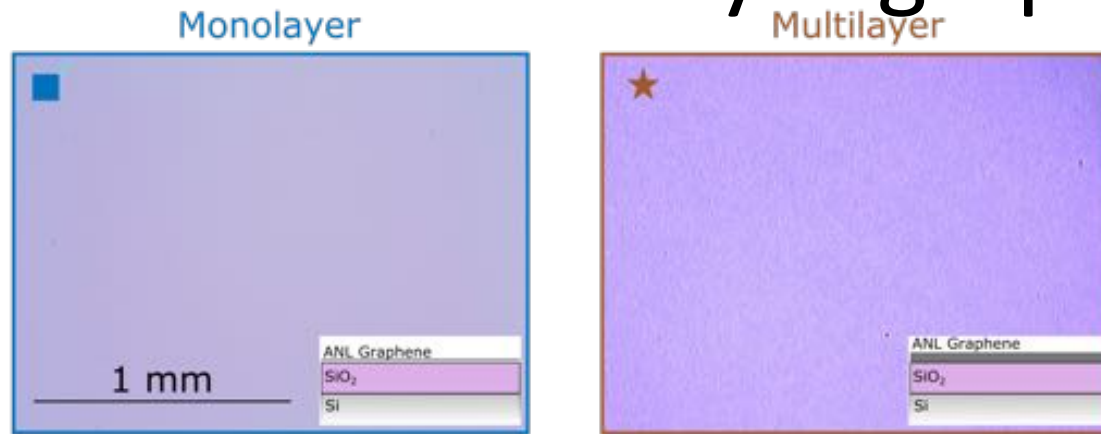


Uniform crack-free transfer on >cm-size domains for both 1L and ML.

Stronger G peak on ML → stronger scattering → more material present.



# Raman quality control for mono and multilayer graphene

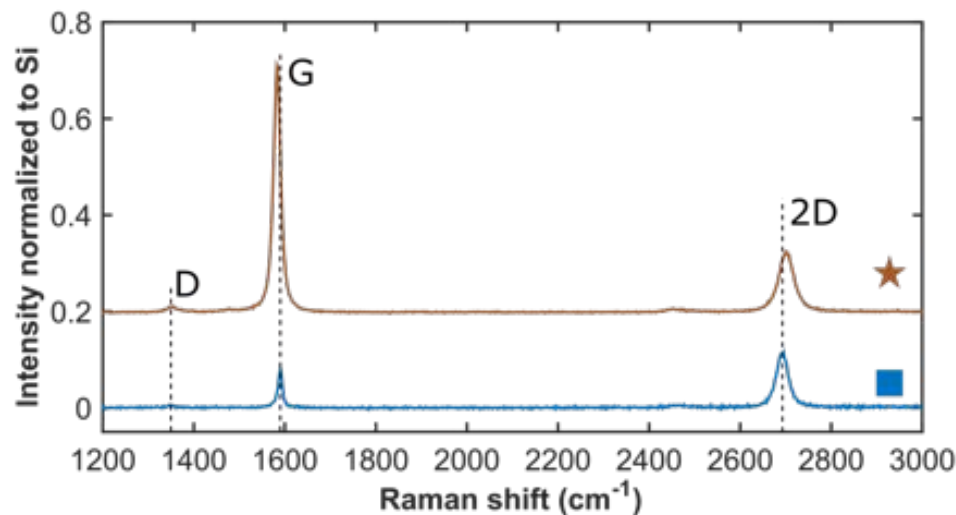


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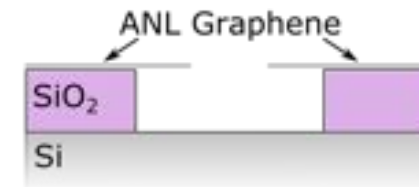
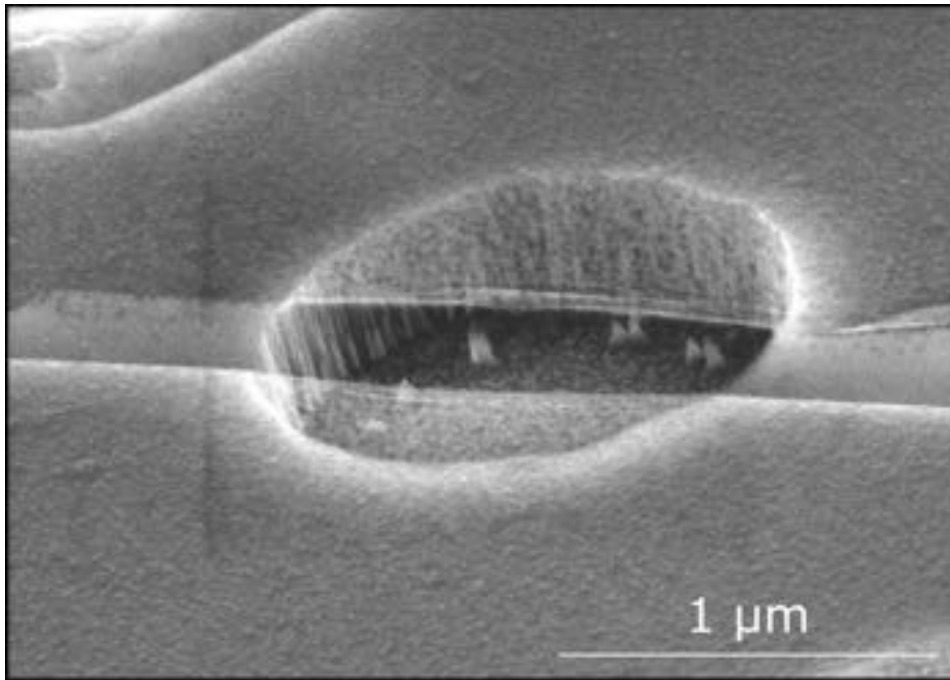
Stronger G peak on ML → stronger scattering → more material present.

Negligible D peak → low defect density also on ML

Small change width G/2D peak → negligible interaction between layers.

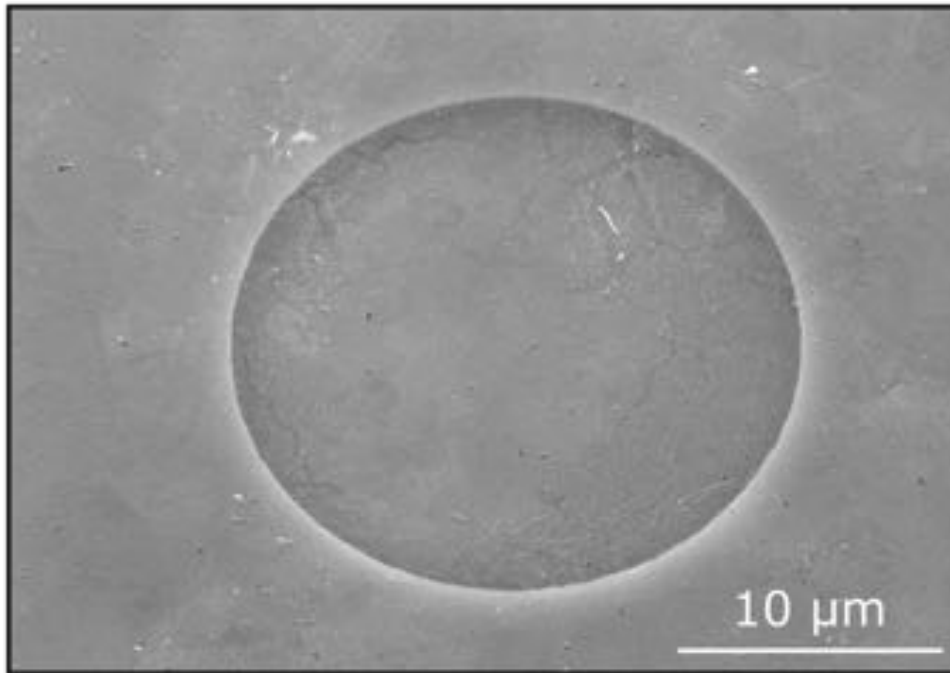


# Suspended single-layer graphene drums over cavities



SEM of single layer graphene suspended over a 1 μm diameter hole on SiO<sub>2</sub>

# Suspended multi-layer graphene drums over cavities

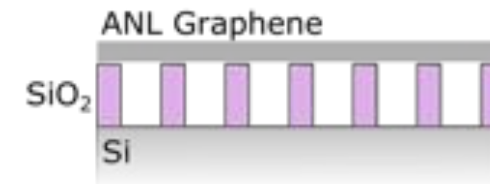
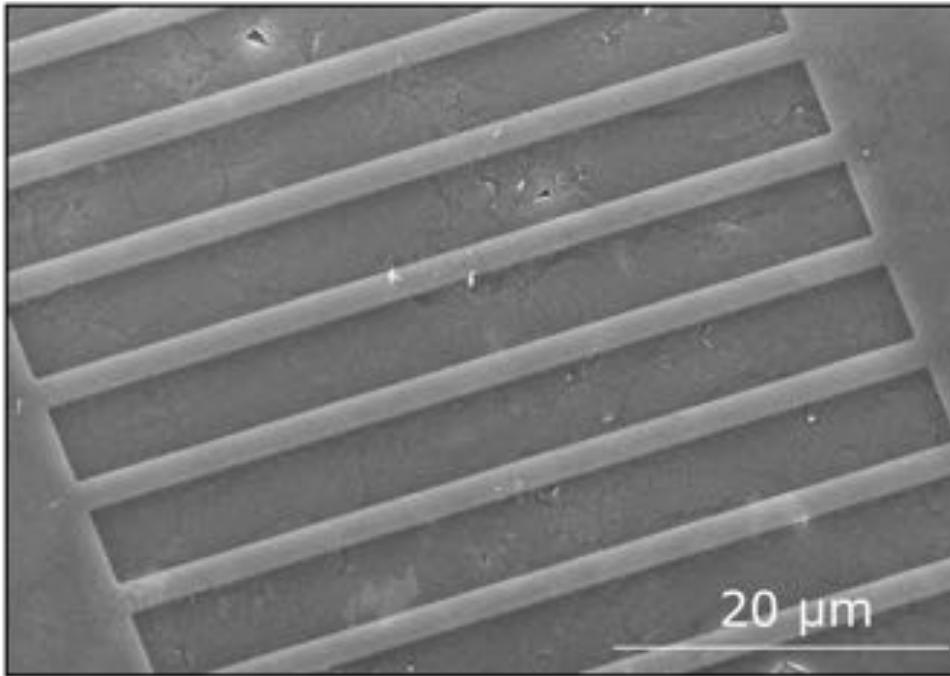


ANL Graphene



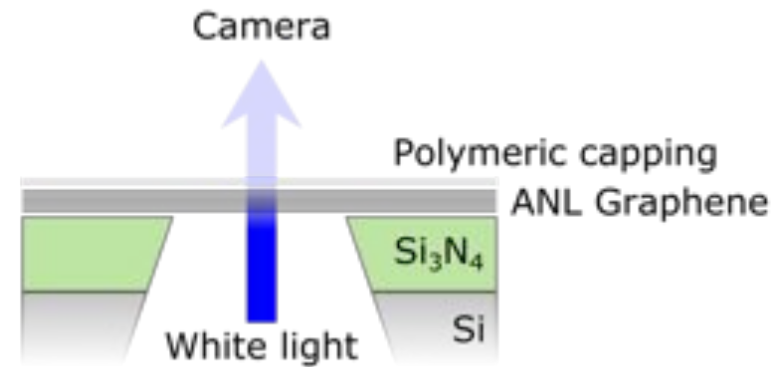
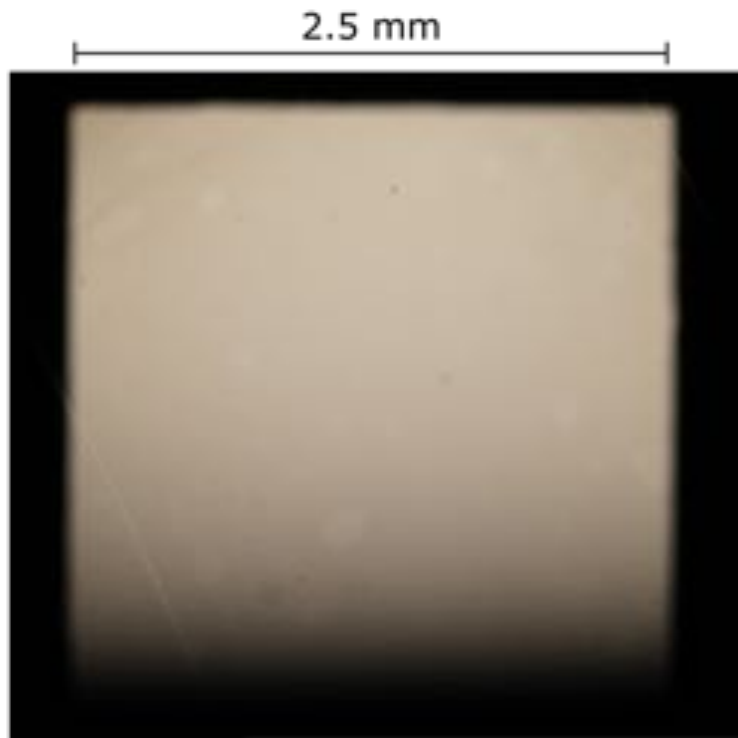
SEM of multilayer graphene suspended over a 20 μm diameter hole on SiO<sub>2</sub>

# Suspended multi-layer graphene drums over meshes



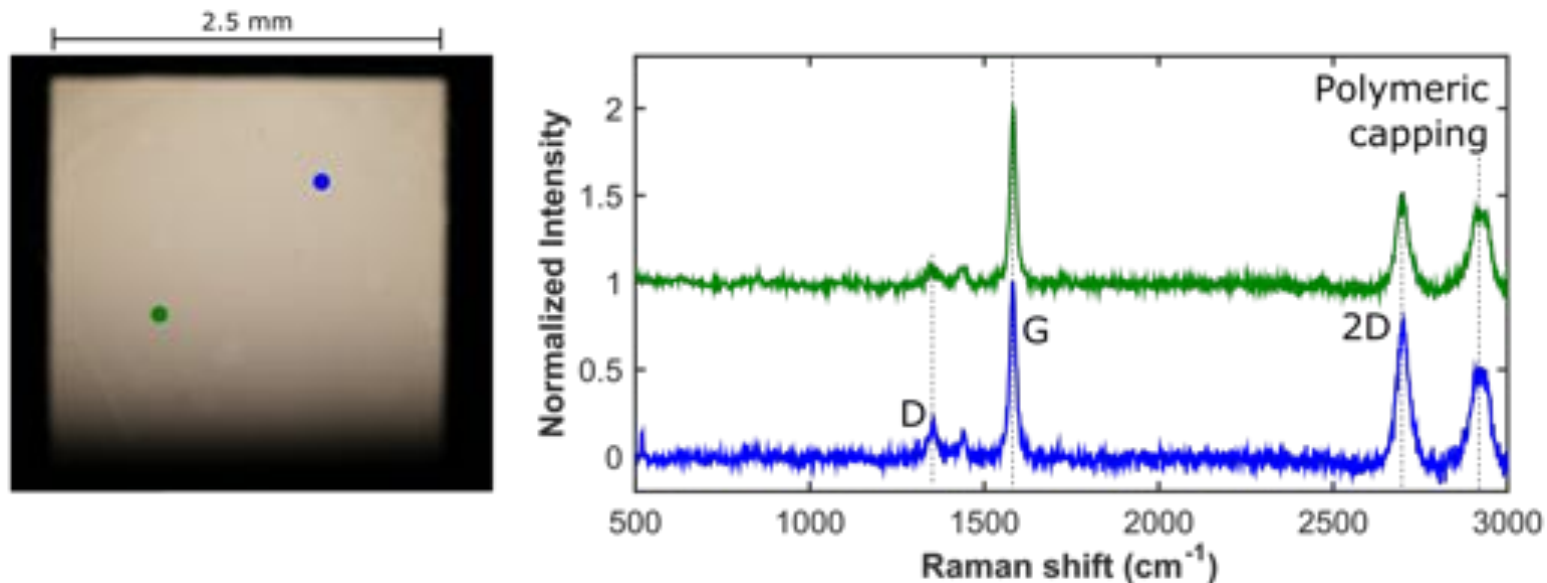
SEM of multilayer graphene suspended over a mesh

# Suspended multi-layer graphene over 2.5 mm window



Transmission  
microscopy of  
multilayer graphene  
suspended over a  
frame

# Suspended multi-layer graphene over 2.5 mm window



Raman data at two points over the suspended membrane

Clear G and 2D peak → graphene is present

G > 2D → multilayer graphene

Small D peak → low defect density



# Next steps

- Increase membrane to full size (ANL)
- Incorporate other materials (ANL)
  
- Frame integration (with partners)
- Membrane characterization (with partners)

# Thank you

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