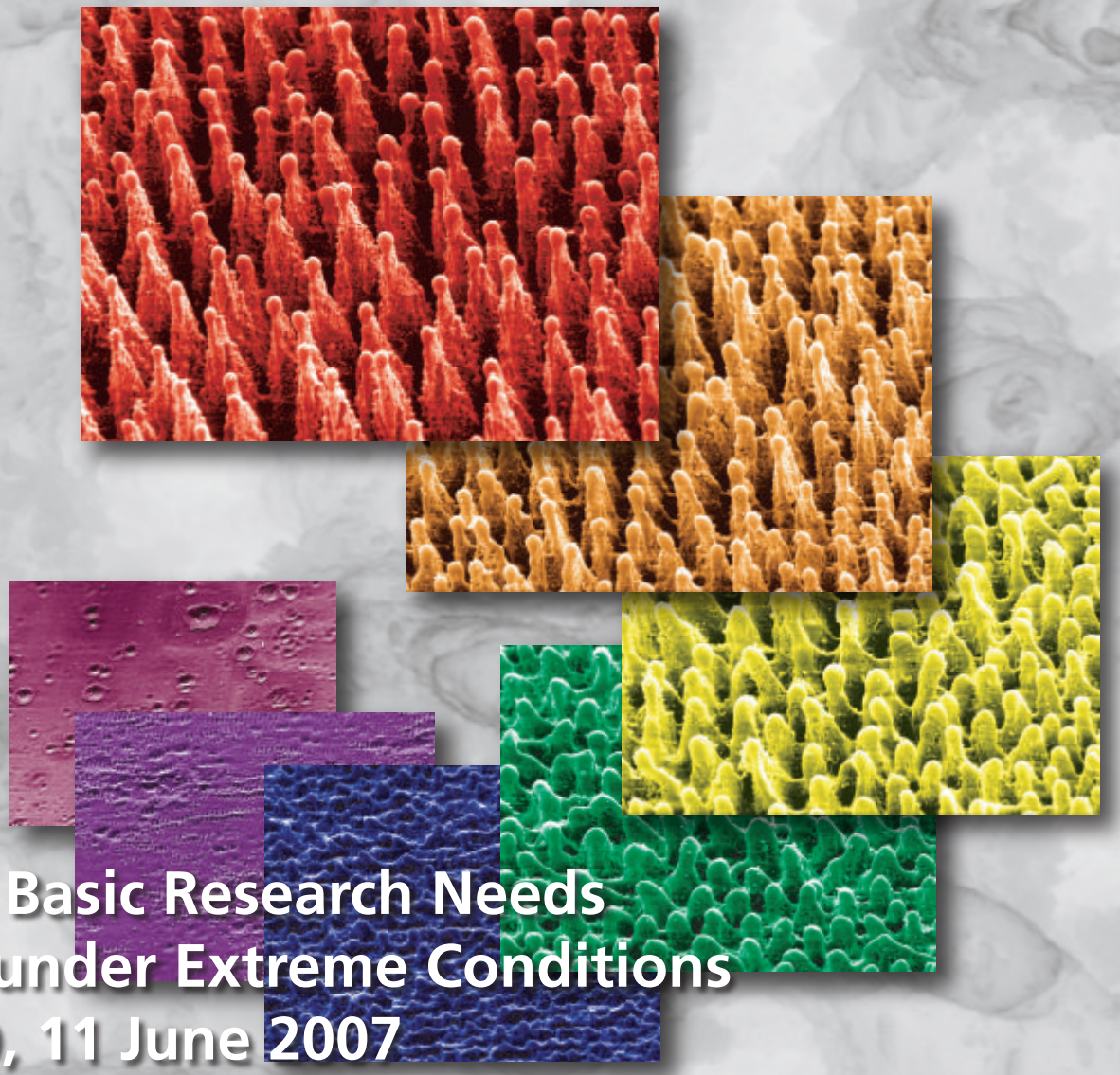
Driving atoms into materials using extreme photon fluxes



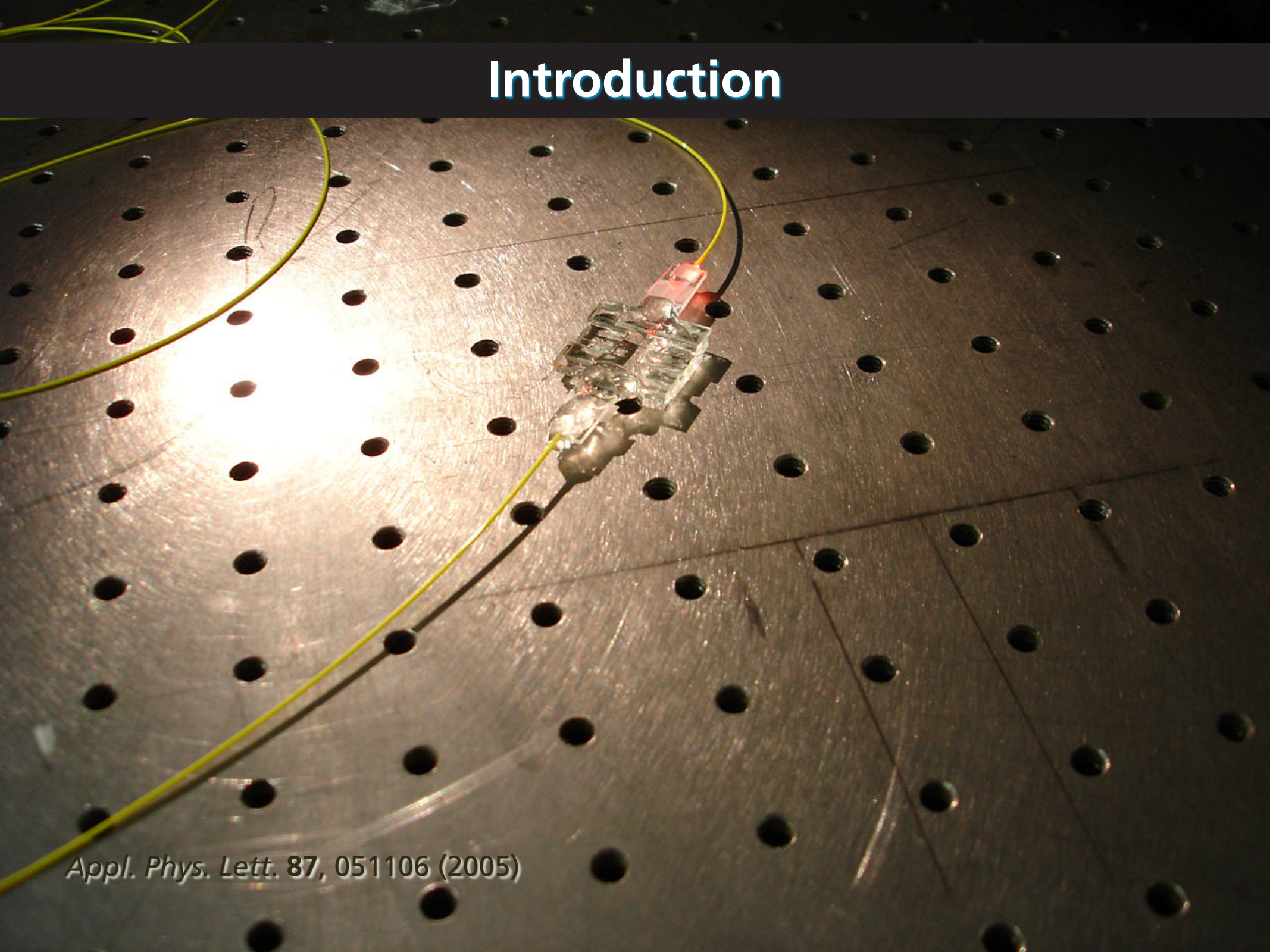
Workshop on Basic Research Needs
for Materials under Extreme Conditions
Bethesda, MD, 11 June 2007

Challenge

failing to see problem as an *opportunity*

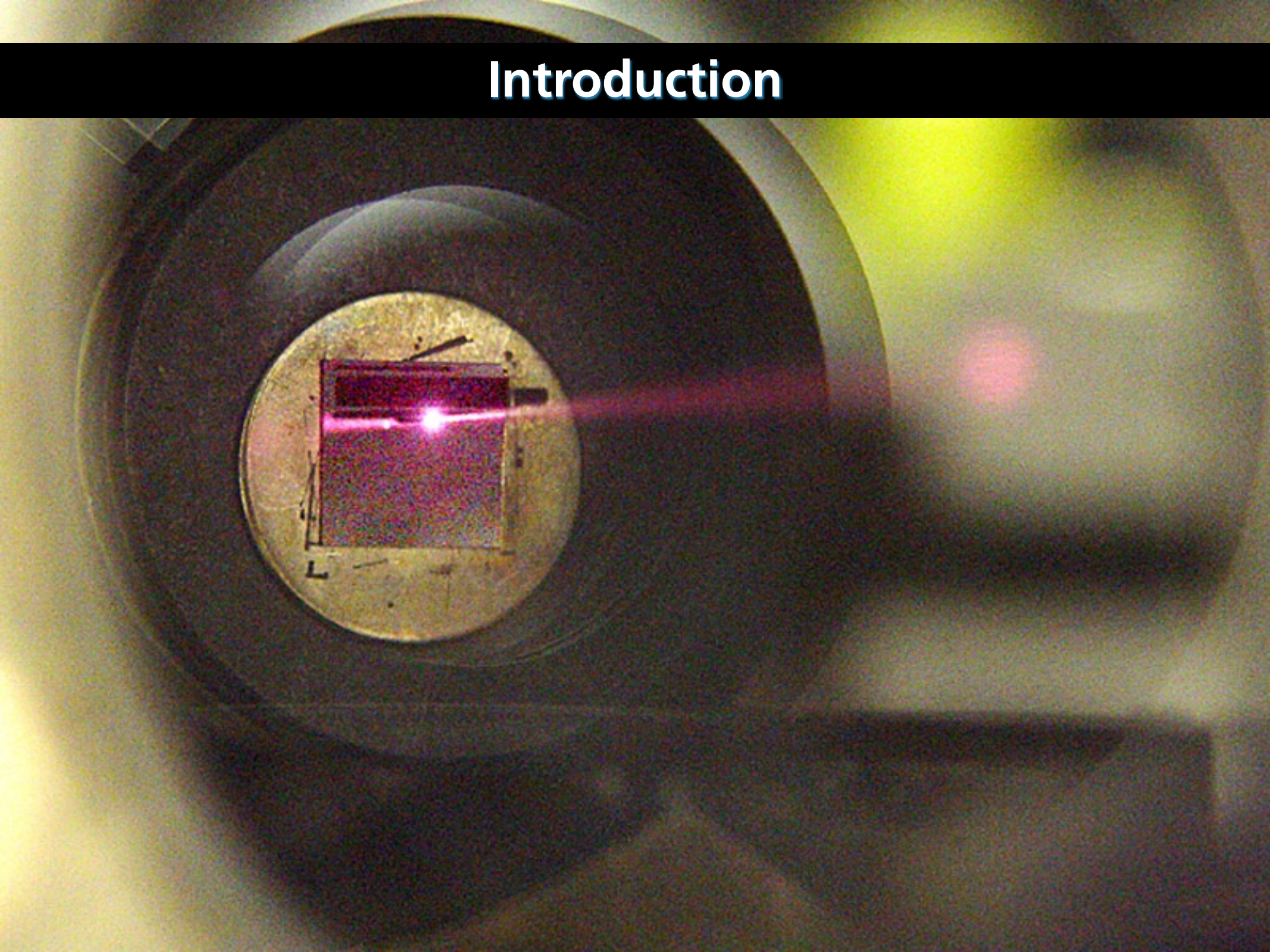
Introduction

Introduction

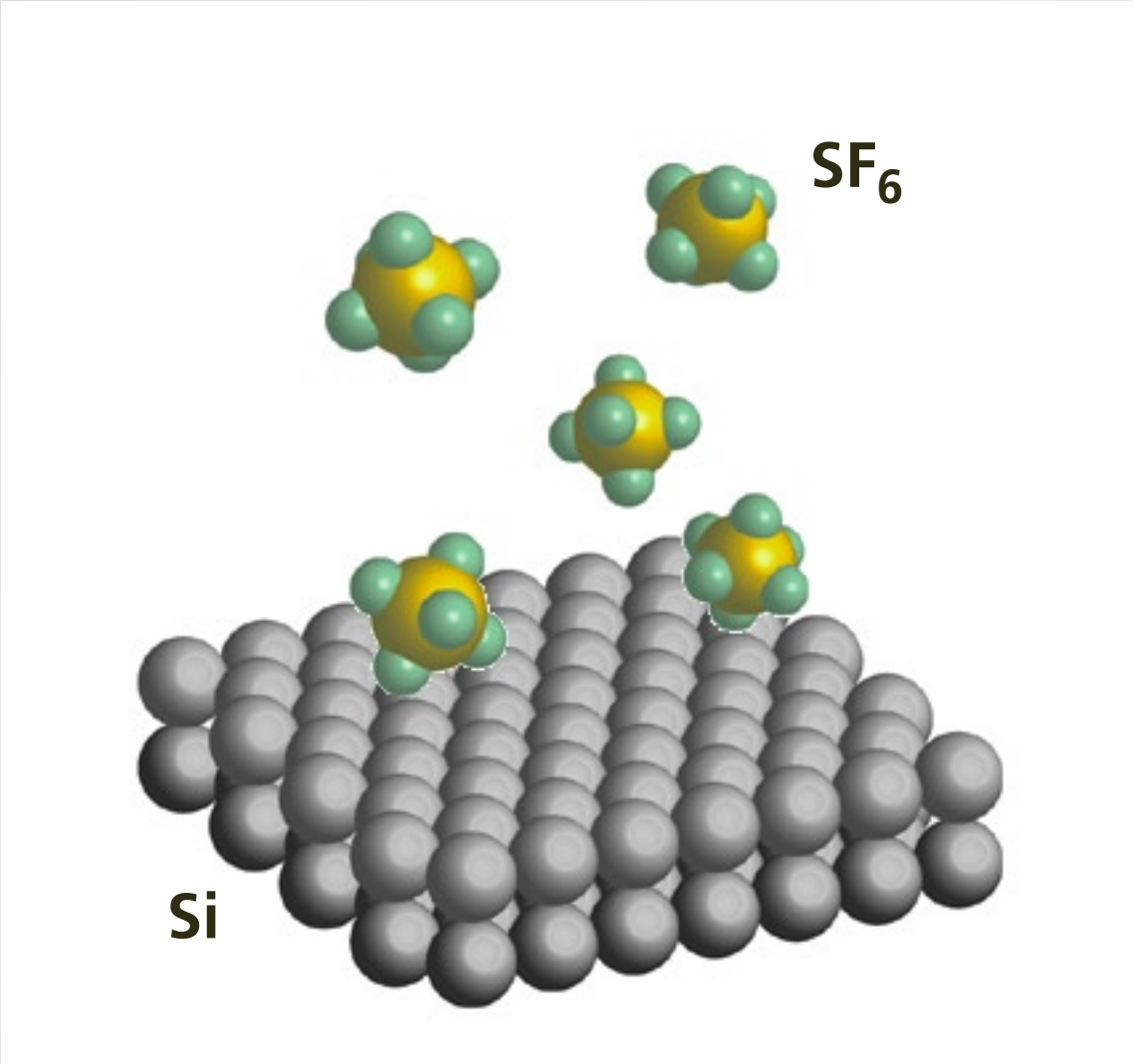


Appl. Phys. Lett. **87**, 051106 (2005)

Introduction

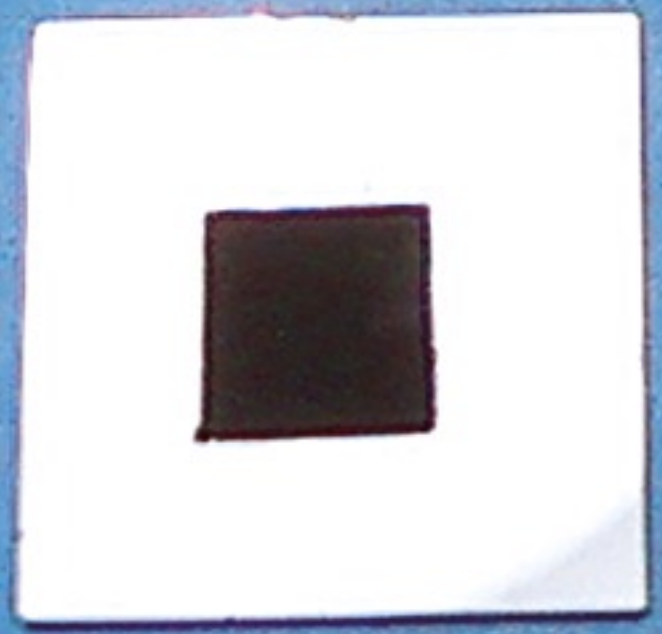


Introduction



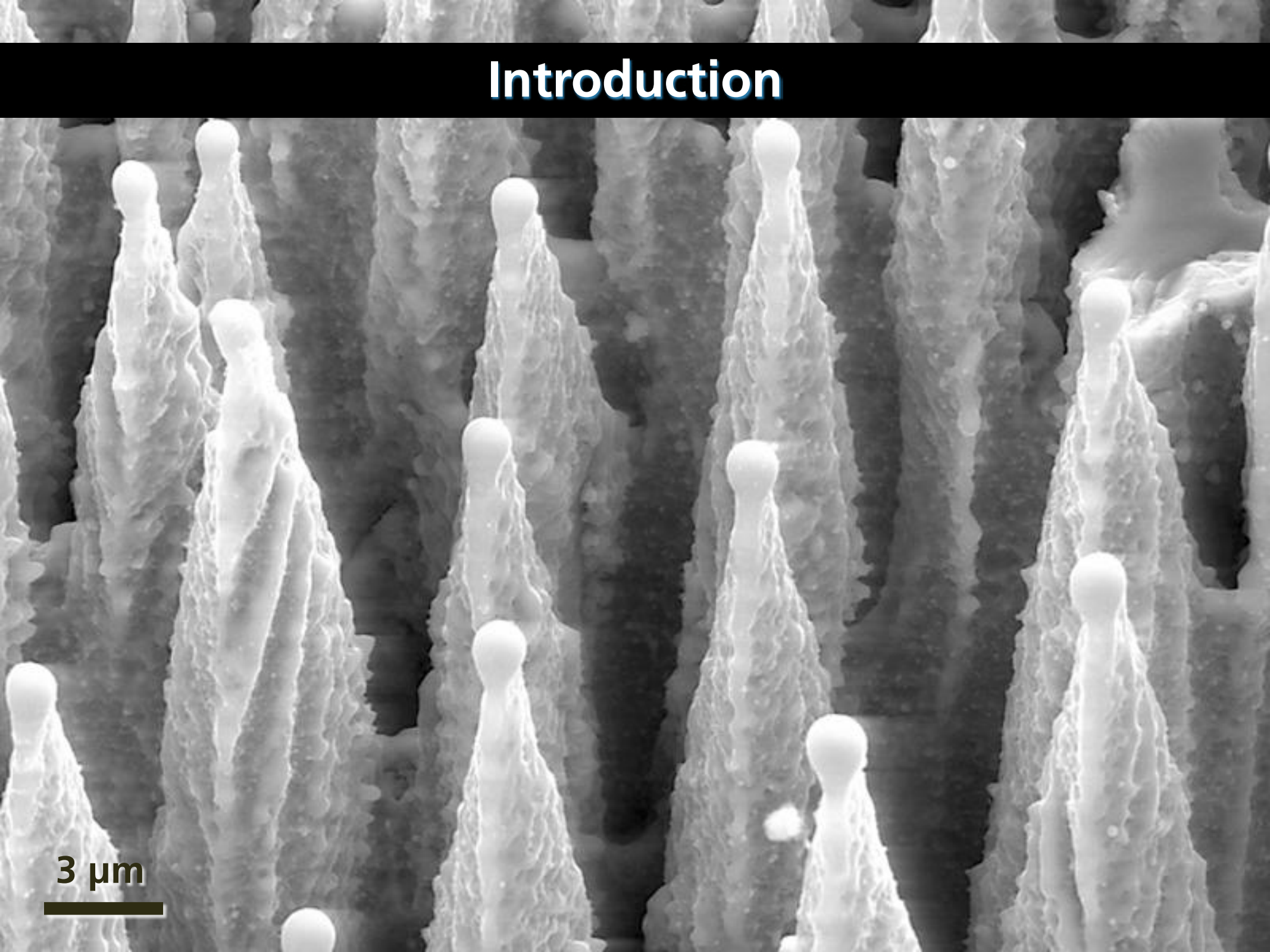
irradiate with 100-fs 10 kJ/m^2 pulses

Introduction



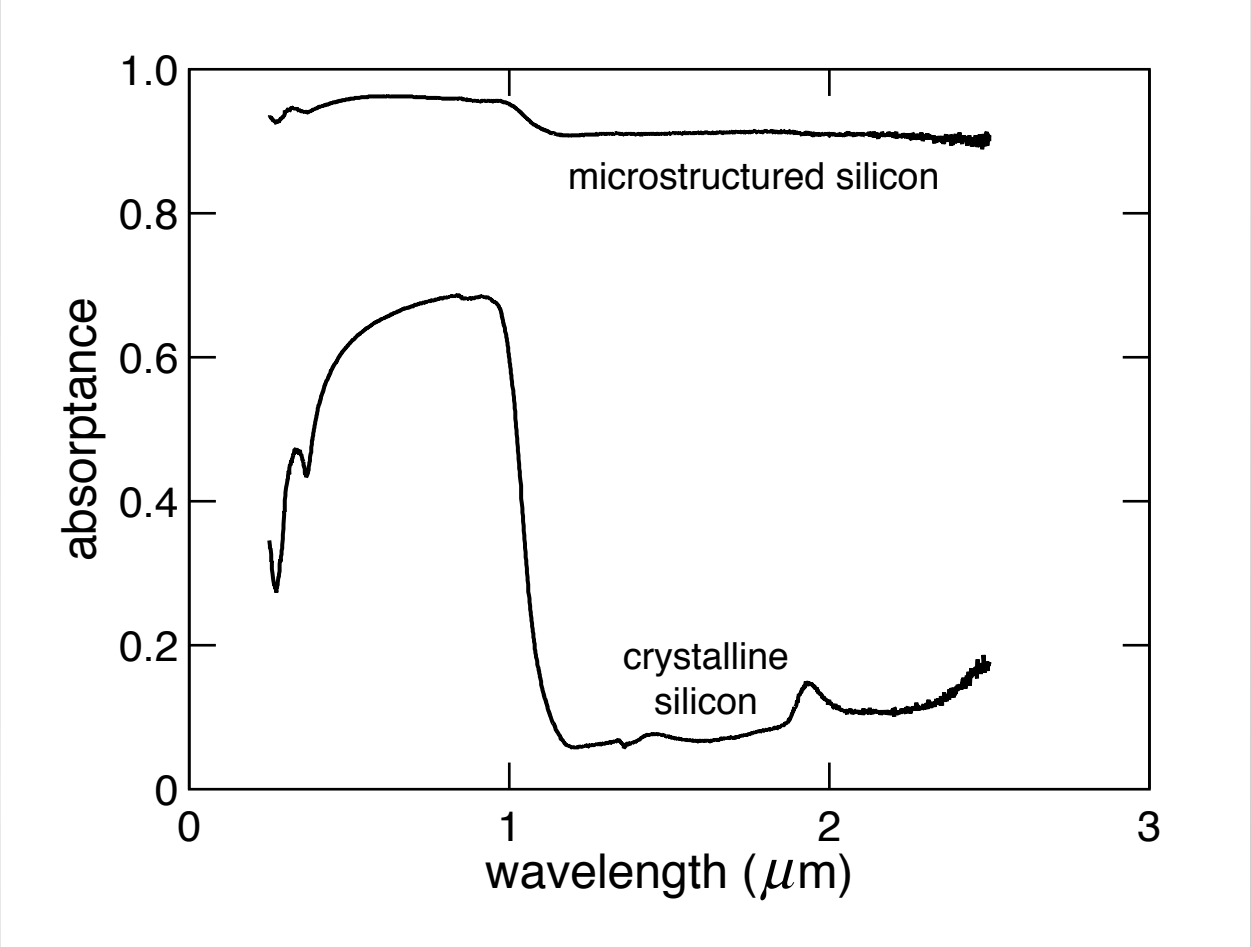
“black silicon”

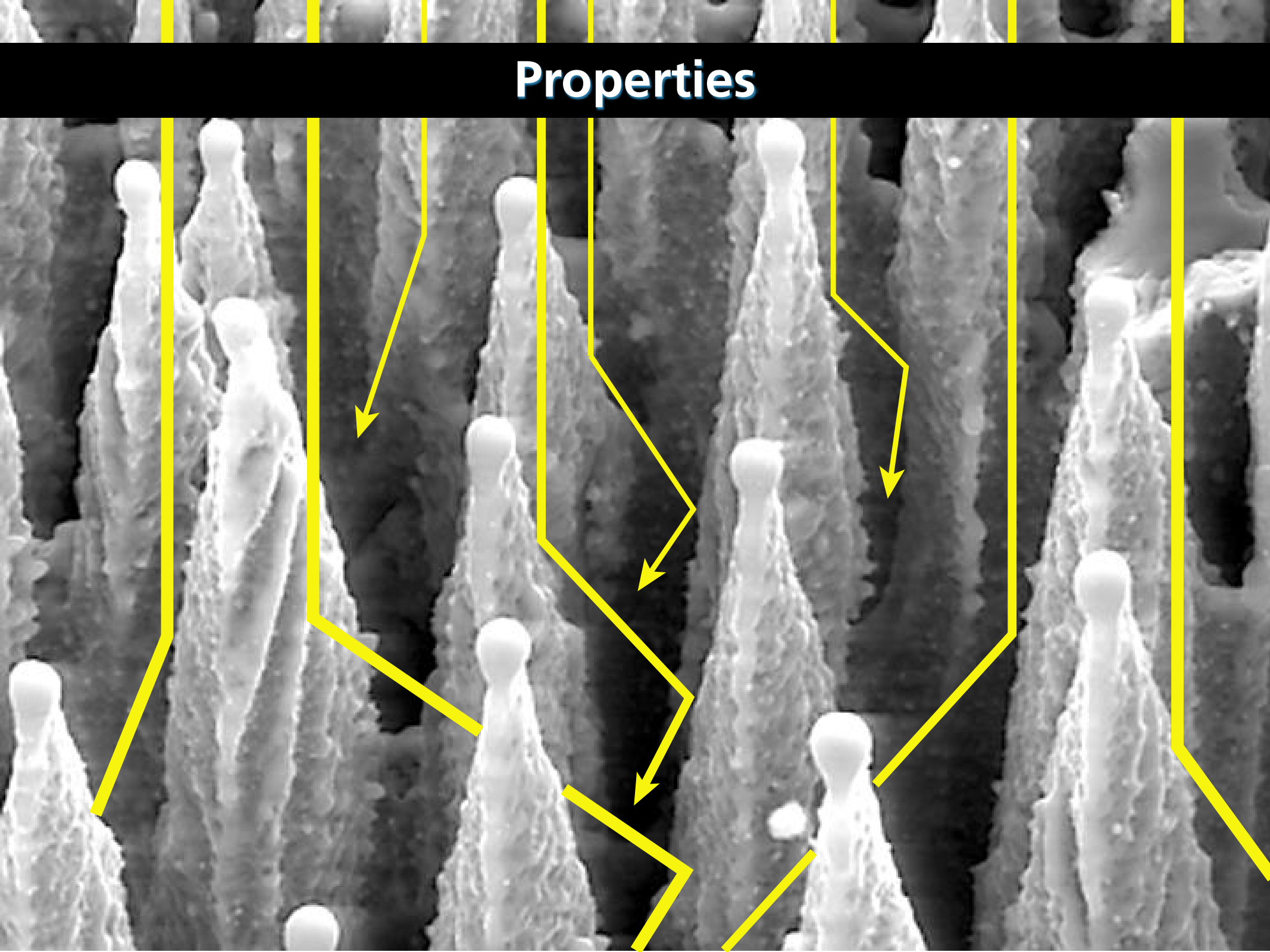
Introduction



Properties

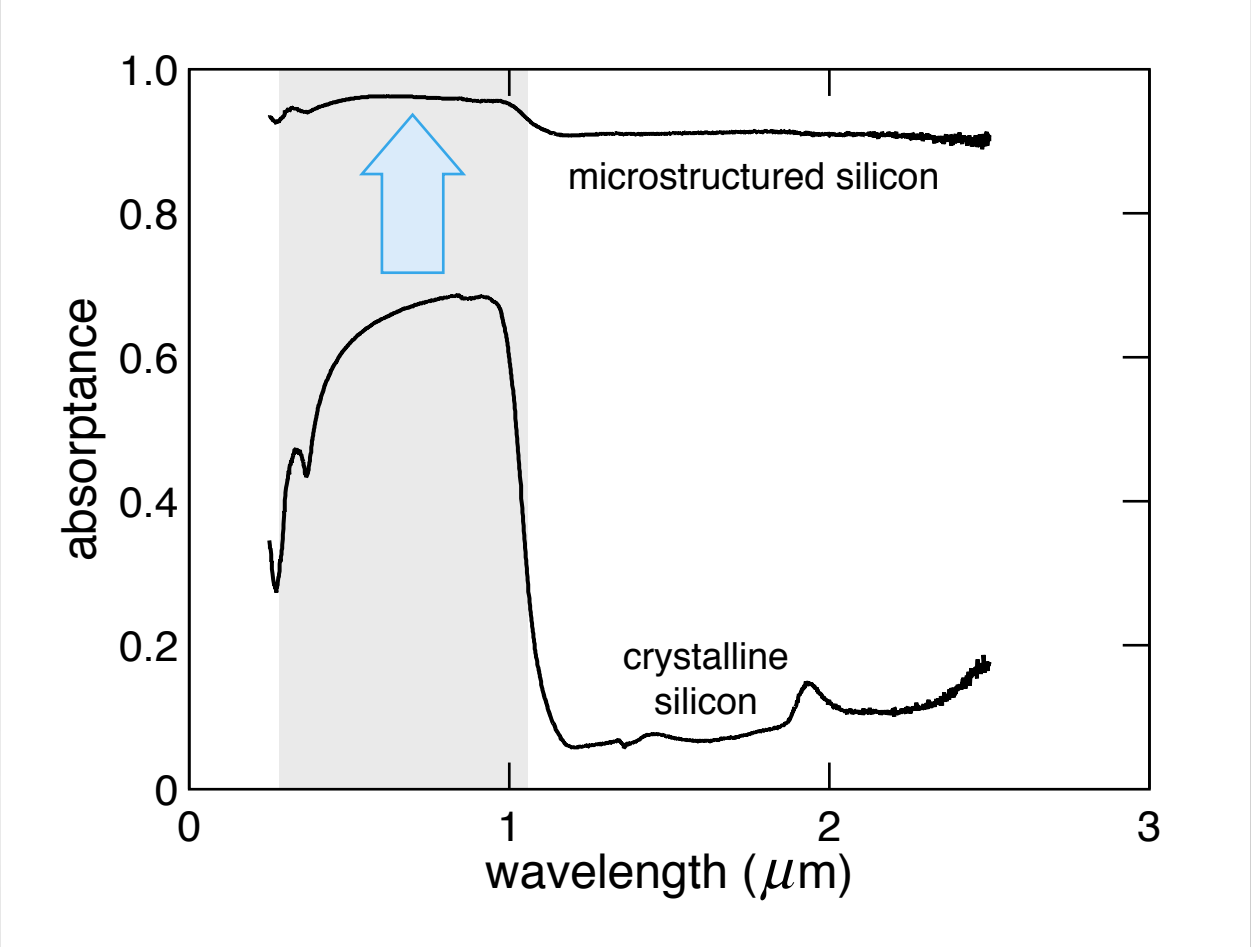
absorptance (1 – *R* – *T*)




Properties

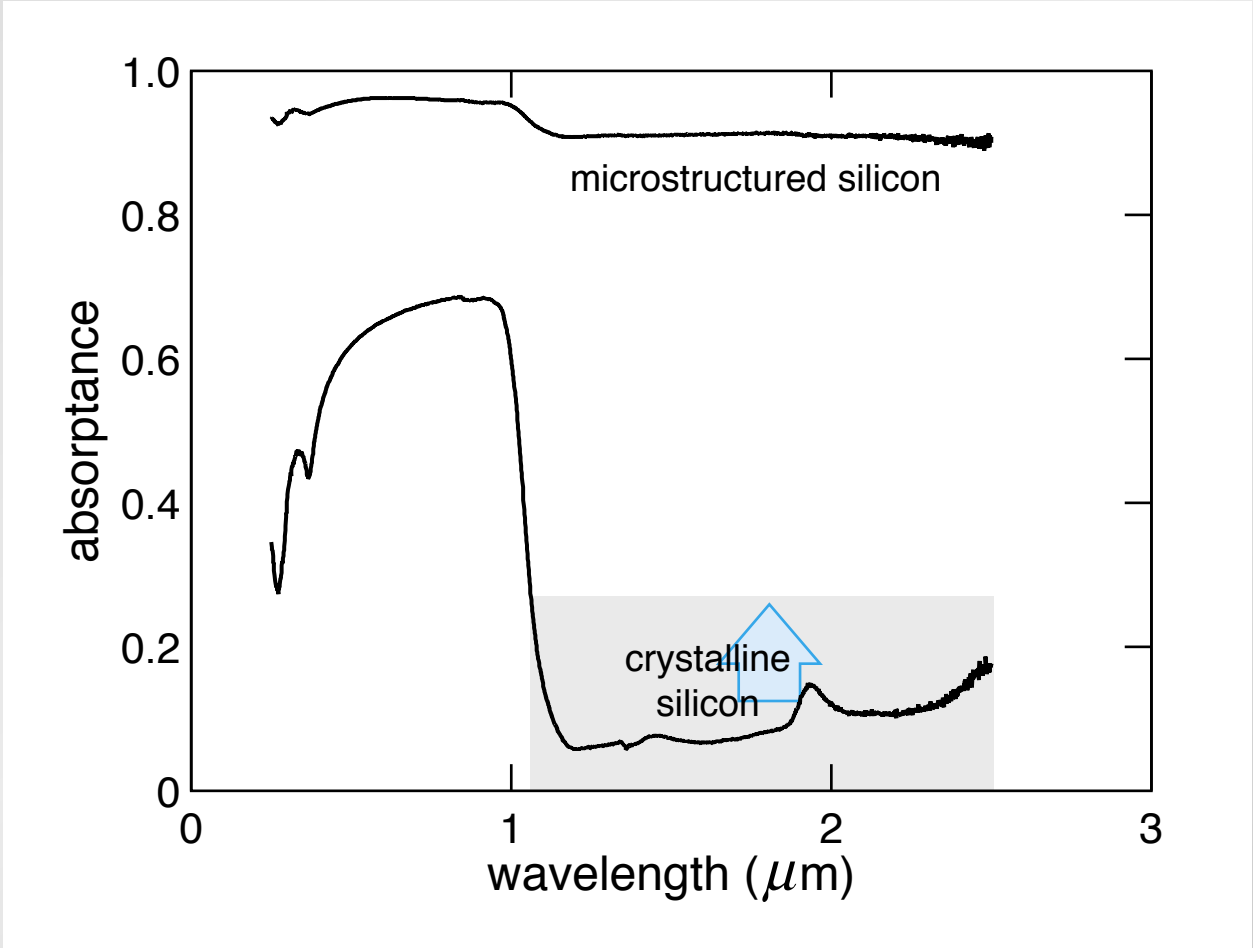
Properties

multiple reflections enhance absorption



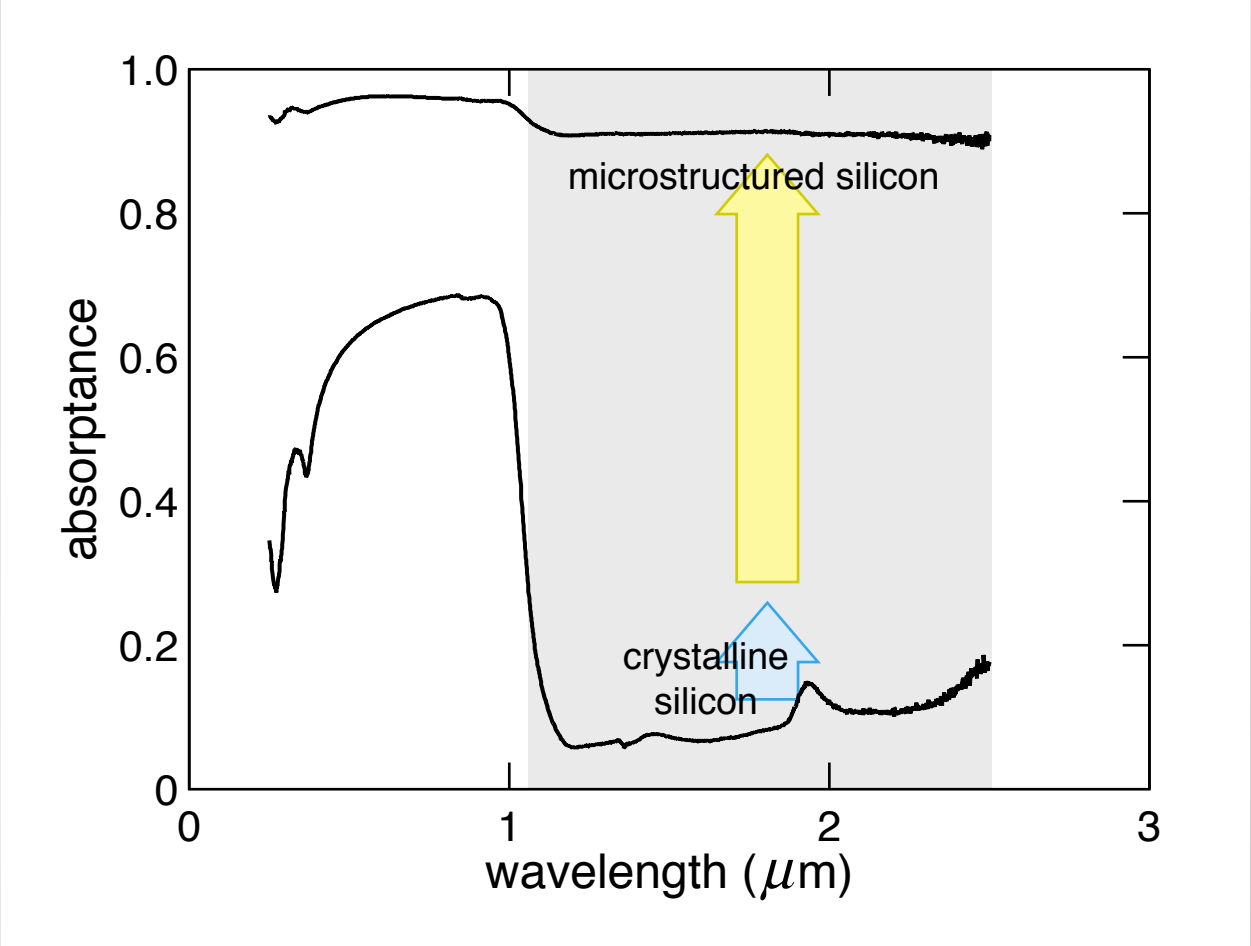
Properties

multiple reflections enhance absorption

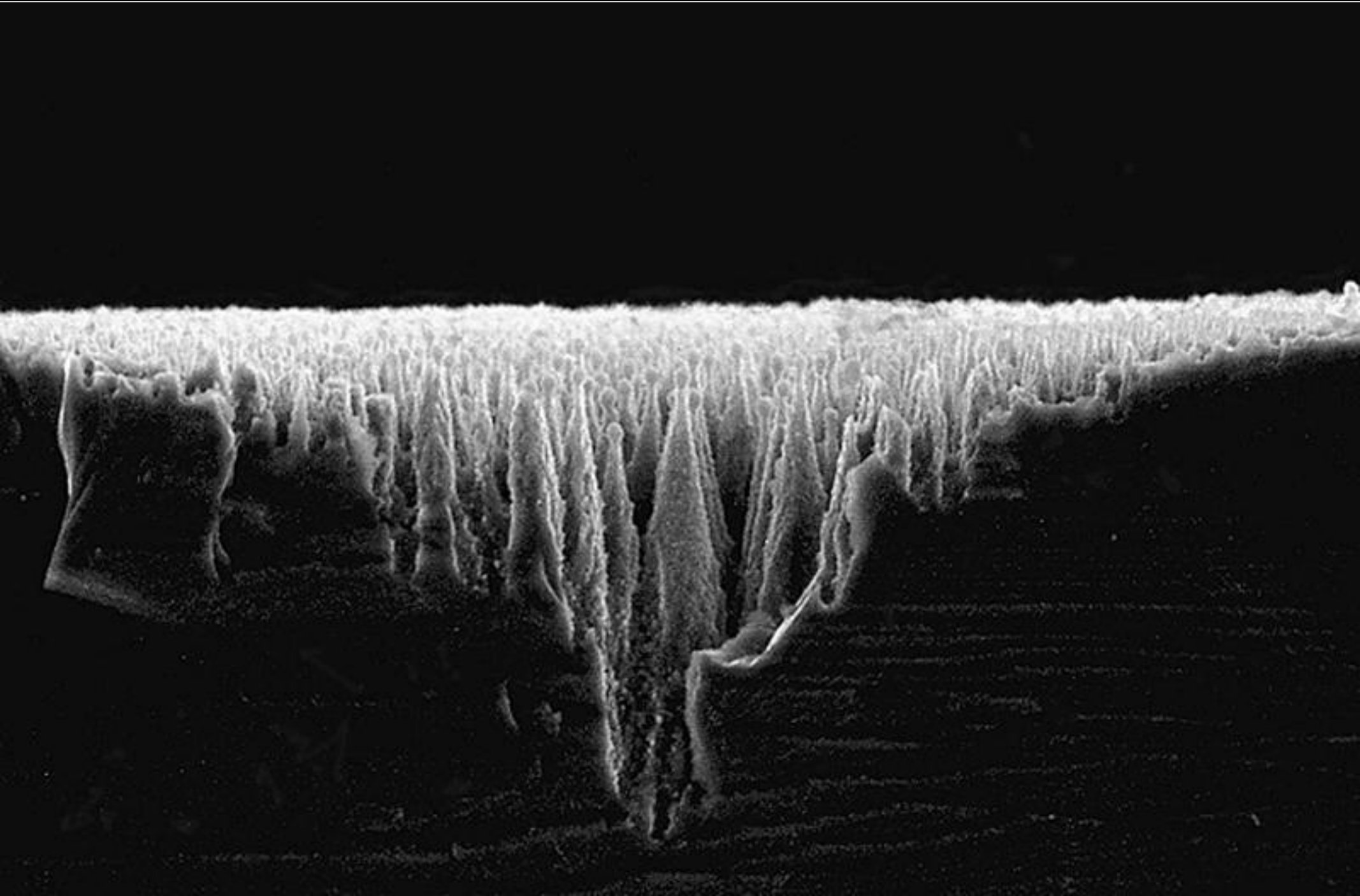


Properties

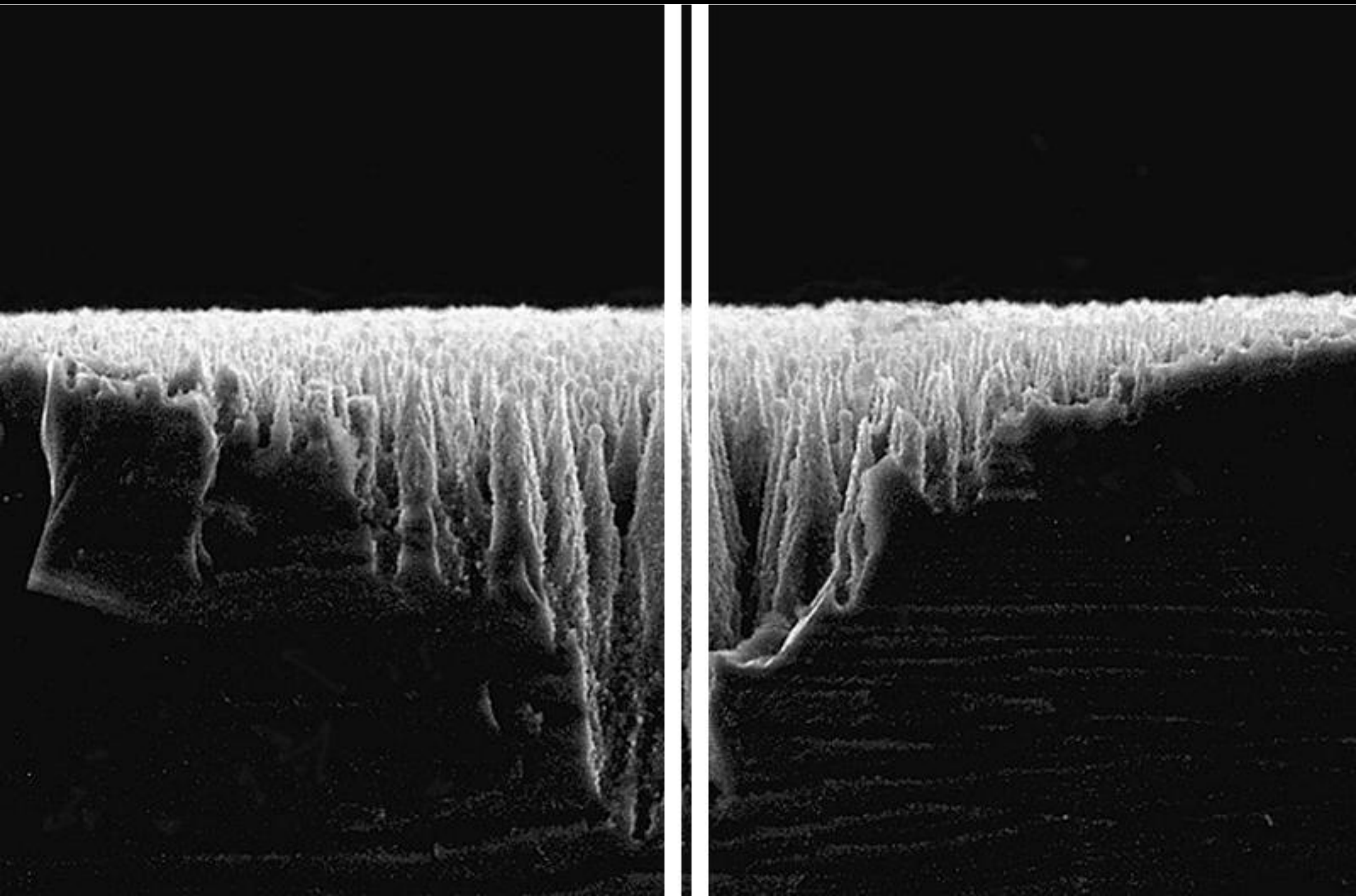
electronic band structure changes



Structural and chemical analysis



Structural and chemical analysis

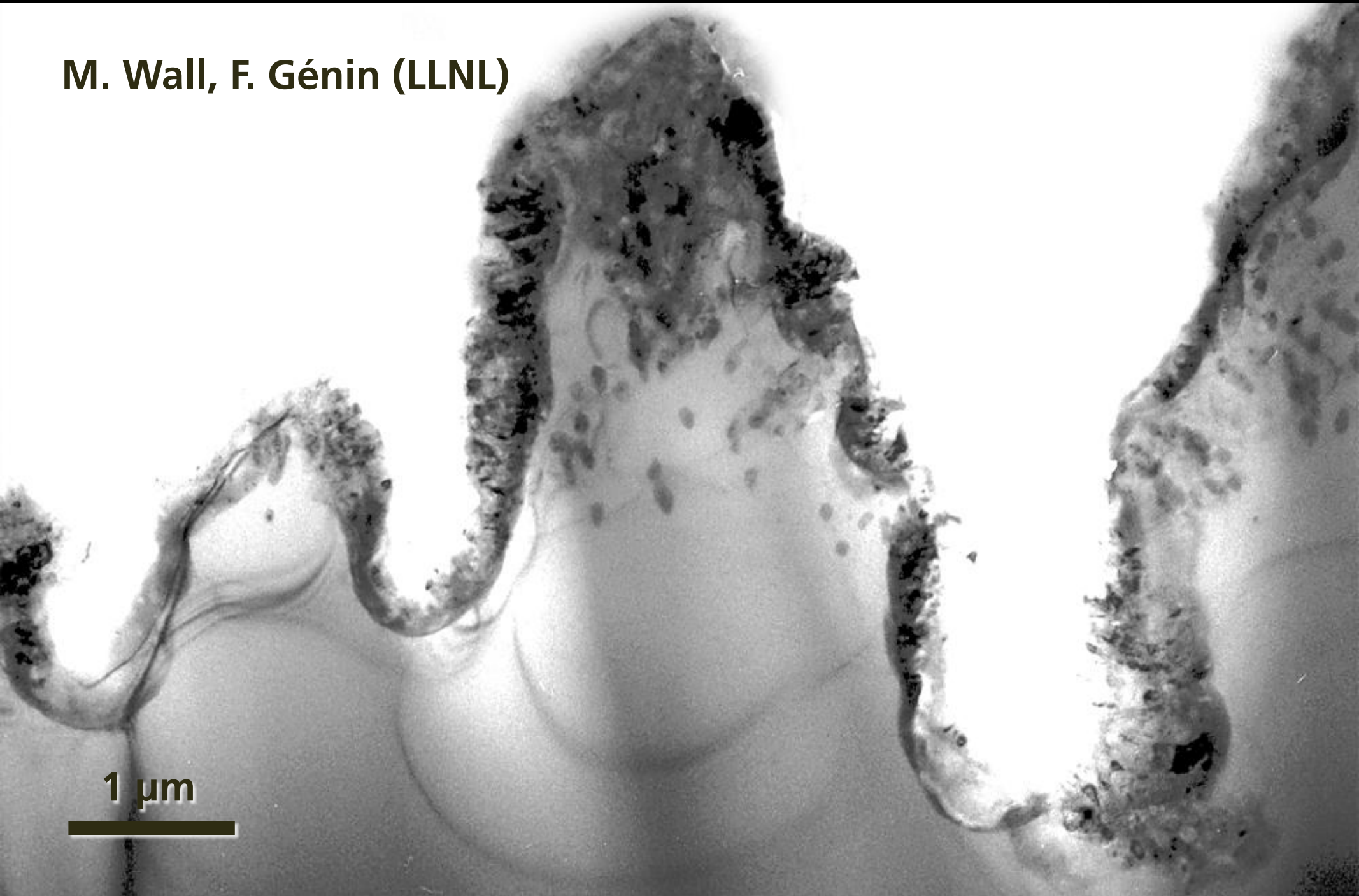


Structural and chemical analysis

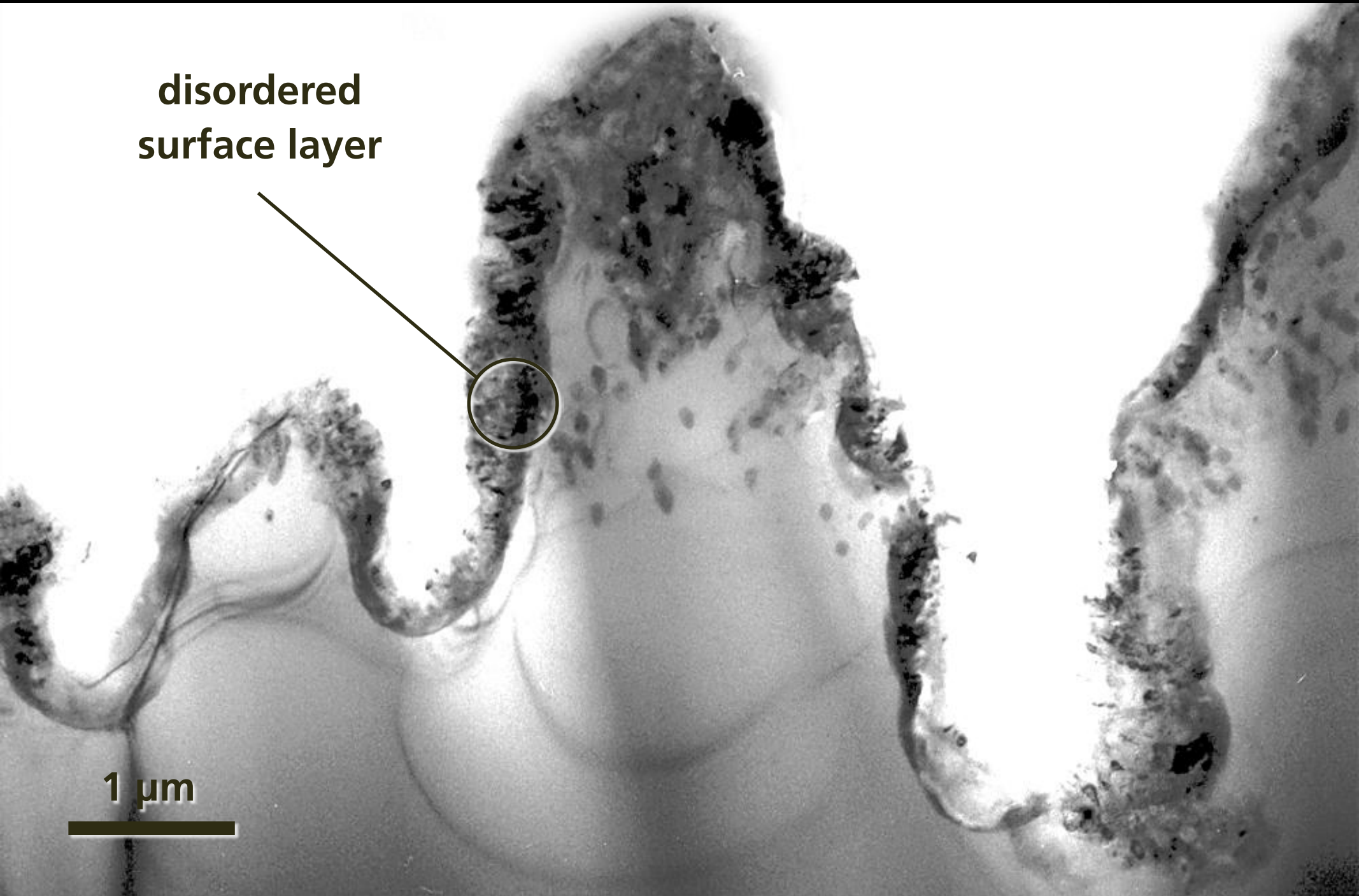
cross-sectional
Transmission Electron
Microscopy

Structural and chemical analysis

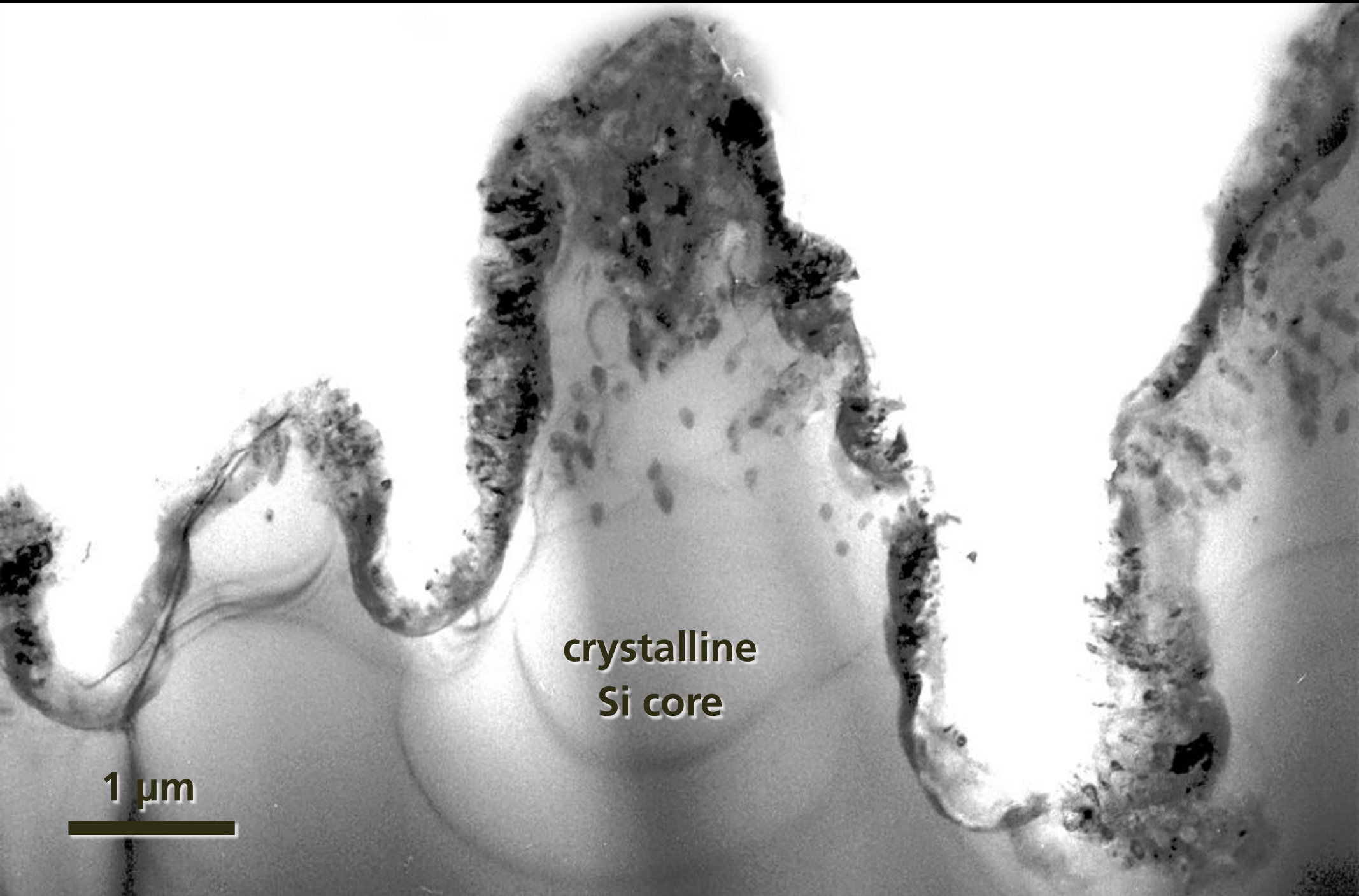
M. Wall, F. Génin (LLNL)



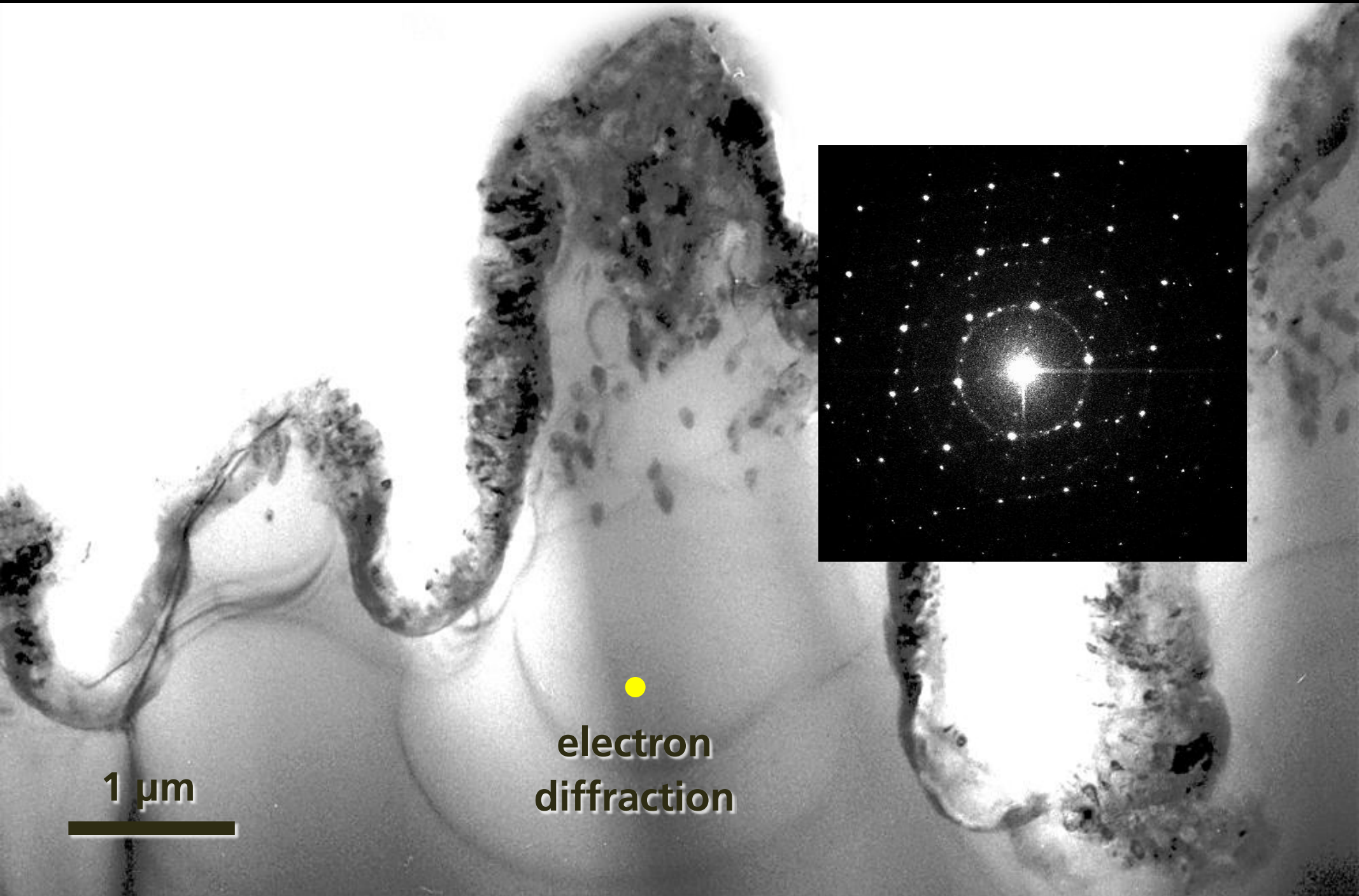
Structural and chemical analysis



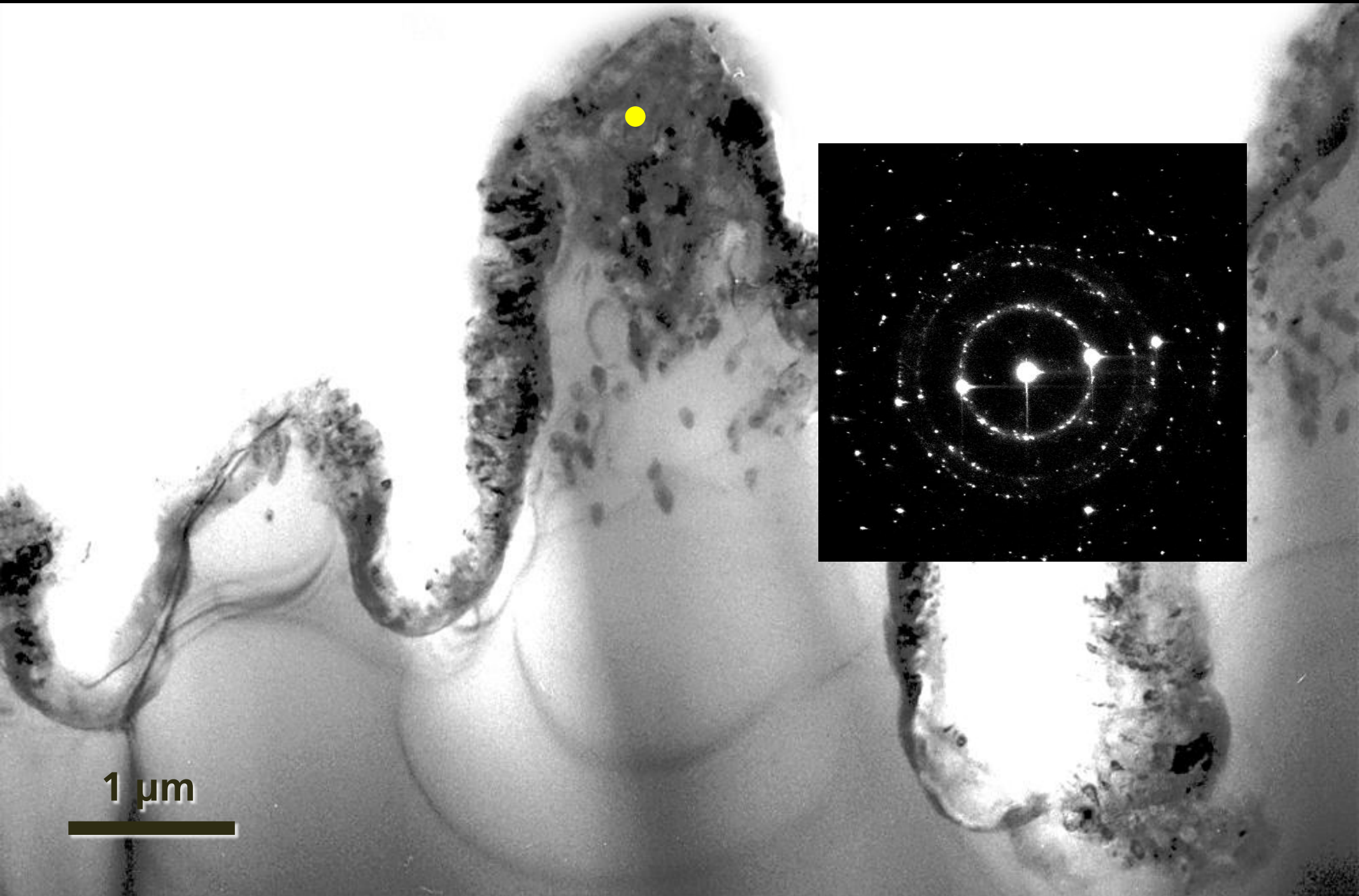
Structural and chemical analysis



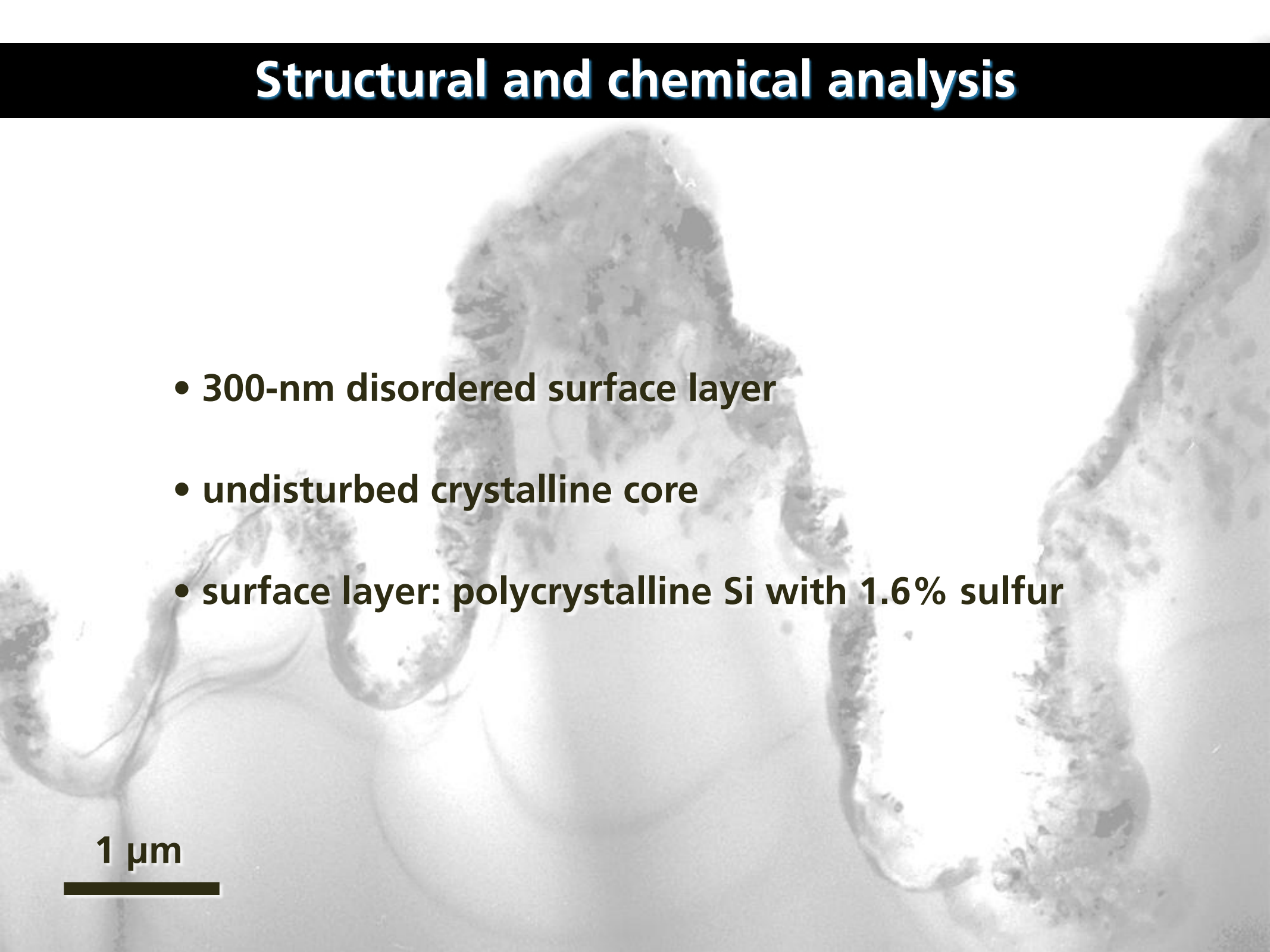
Structural and chemical analysis



Structural and chemical analysis



Structural and chemical analysis

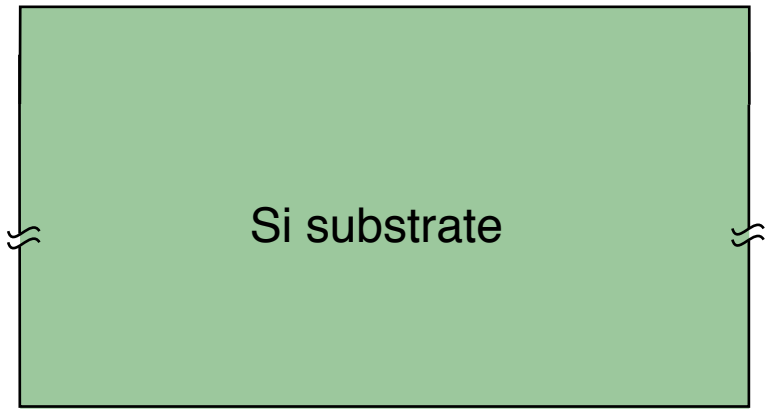


- 300-nm disordered surface layer
- undisturbed crystalline core
- surface layer: polycrystalline Si with 1.6% sulfur

1 µm

Detectors

black silicon/silicon junction



Detectors

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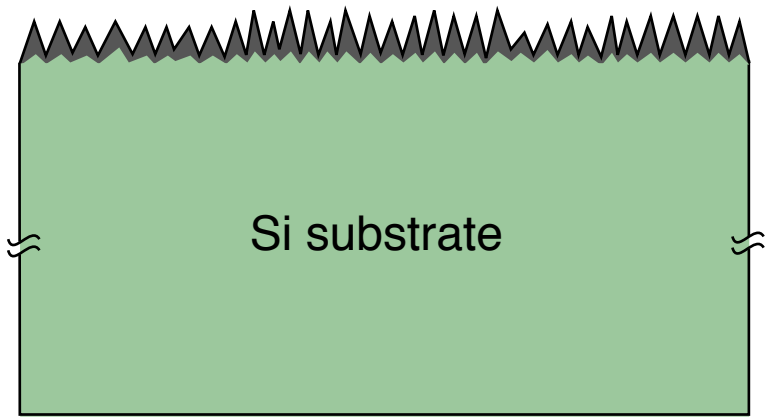

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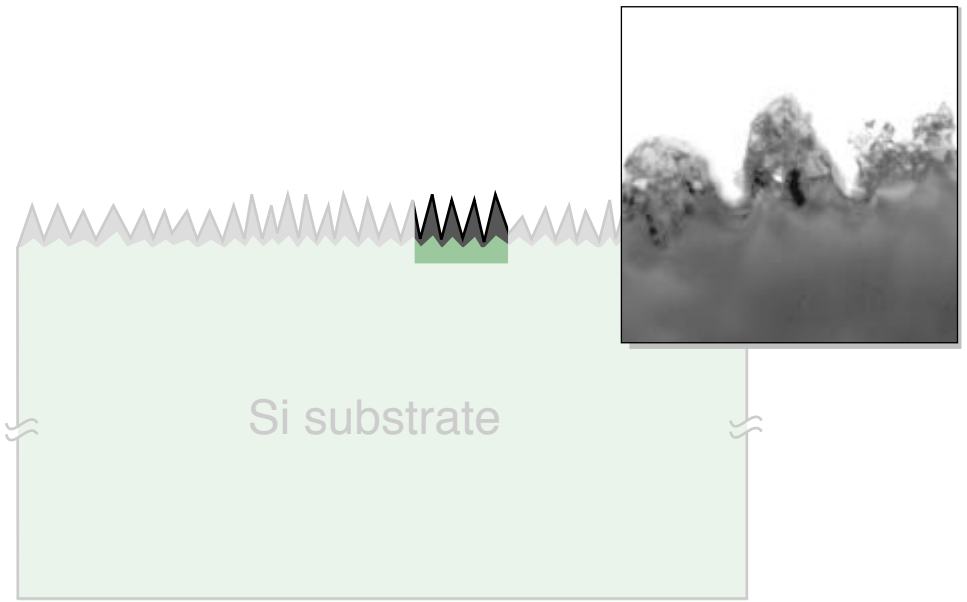

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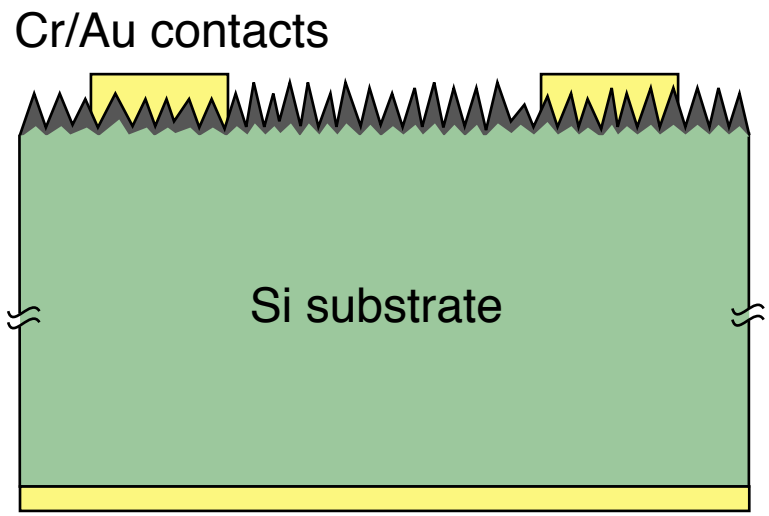
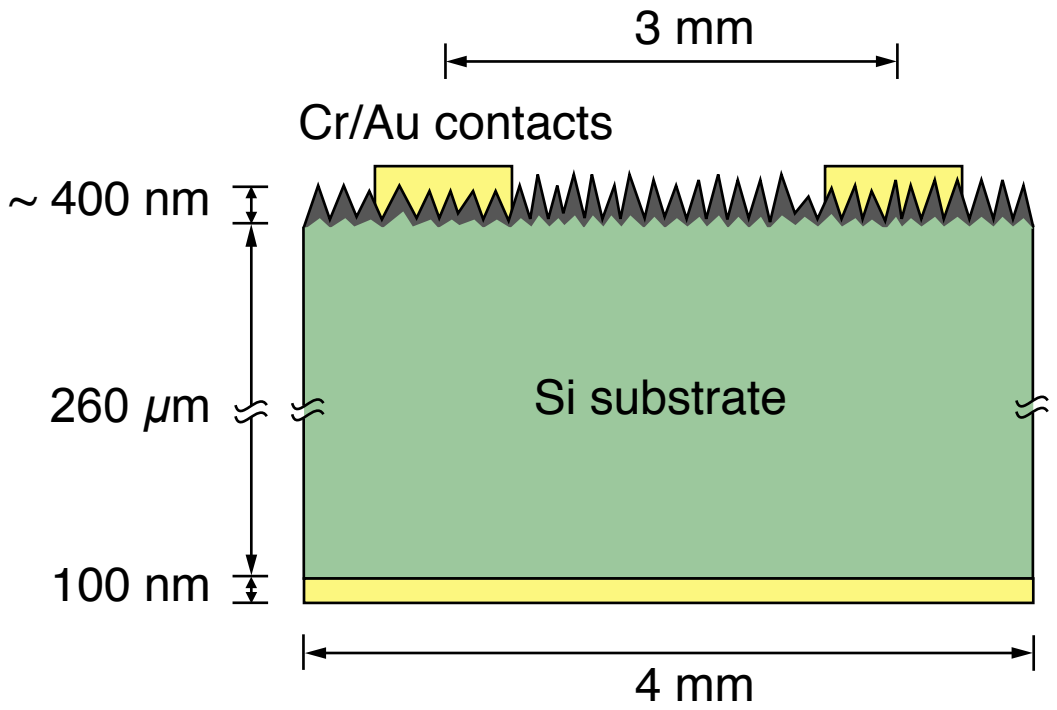


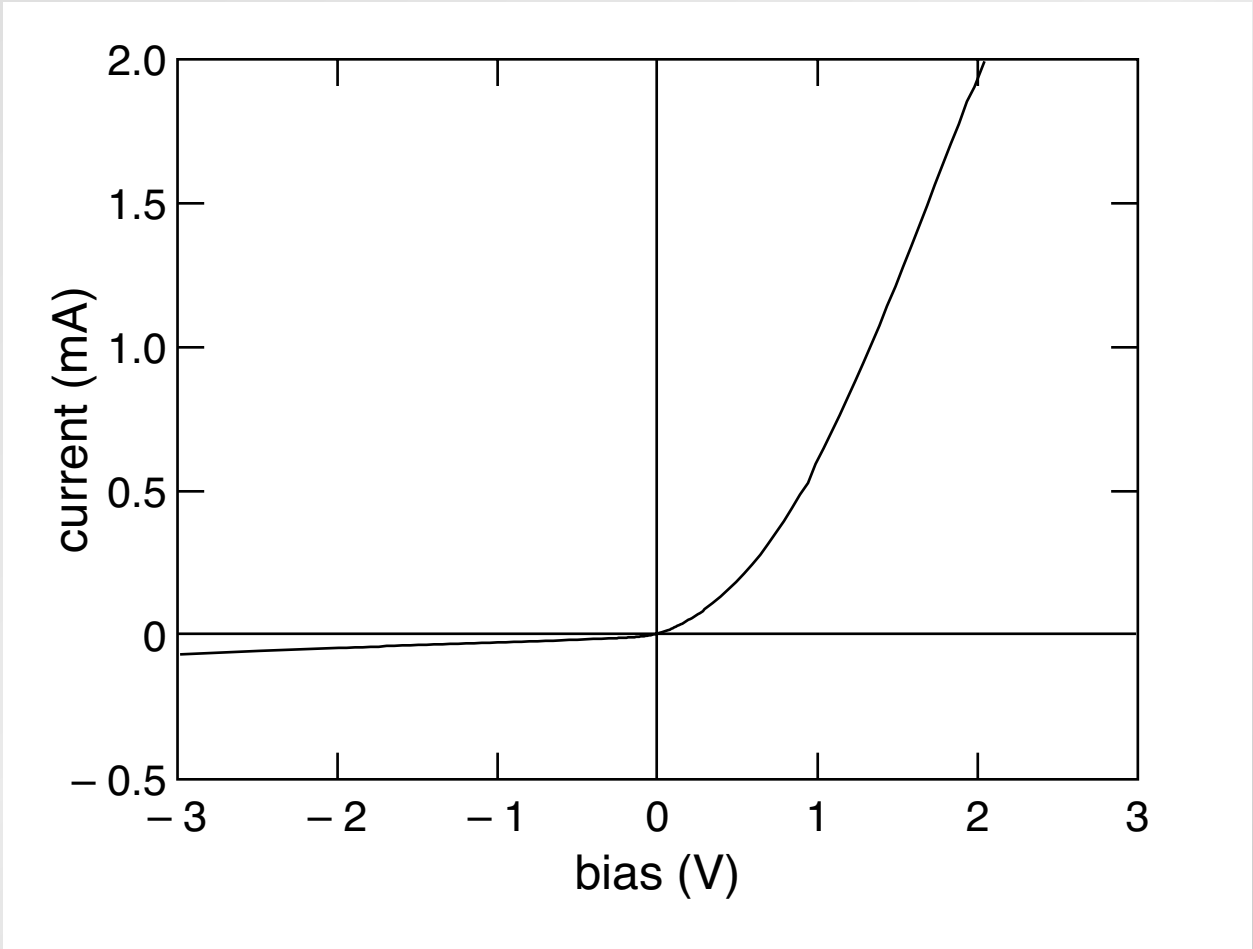
Detectors

black silicon/silicon junction



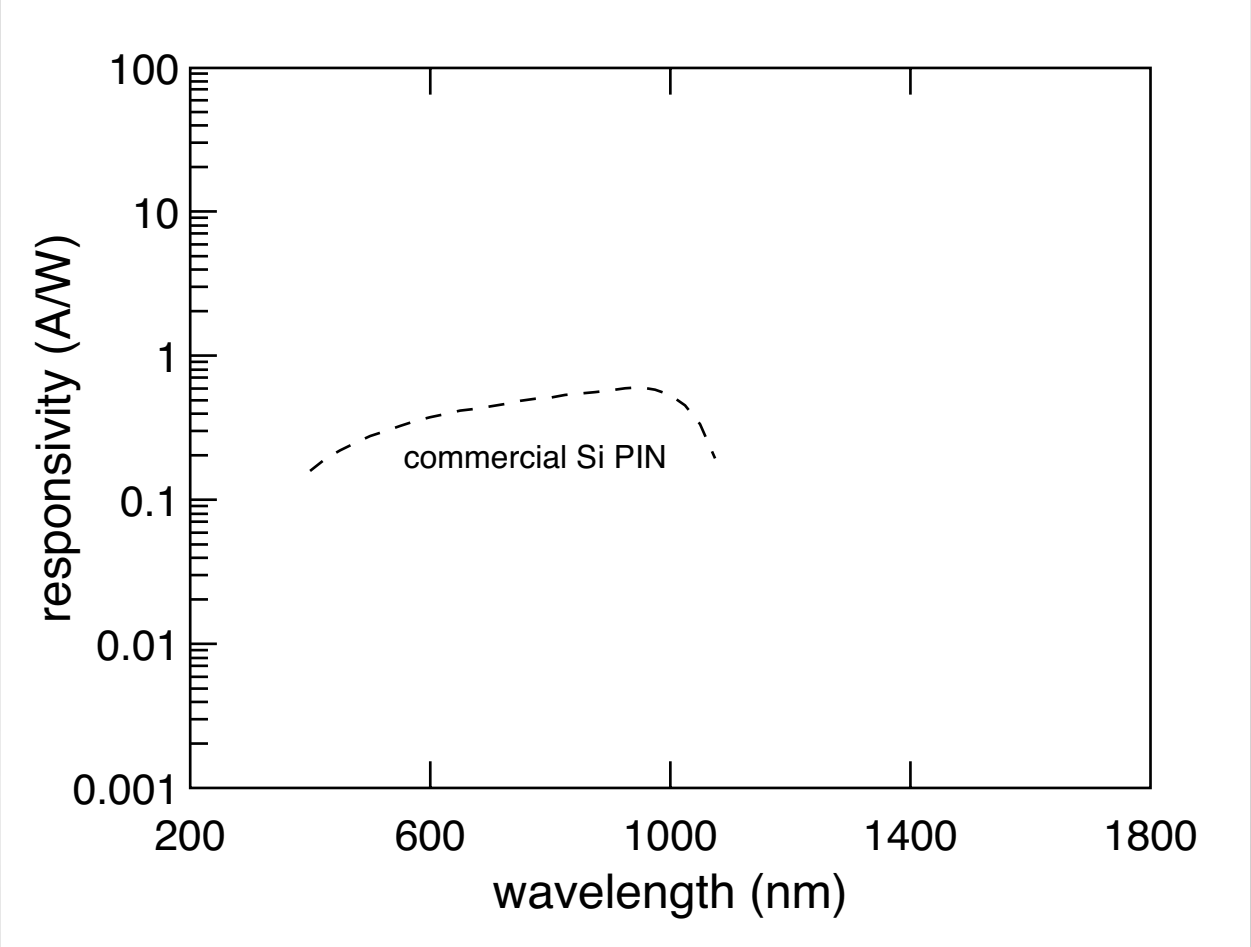
Detectors

IV characteristics



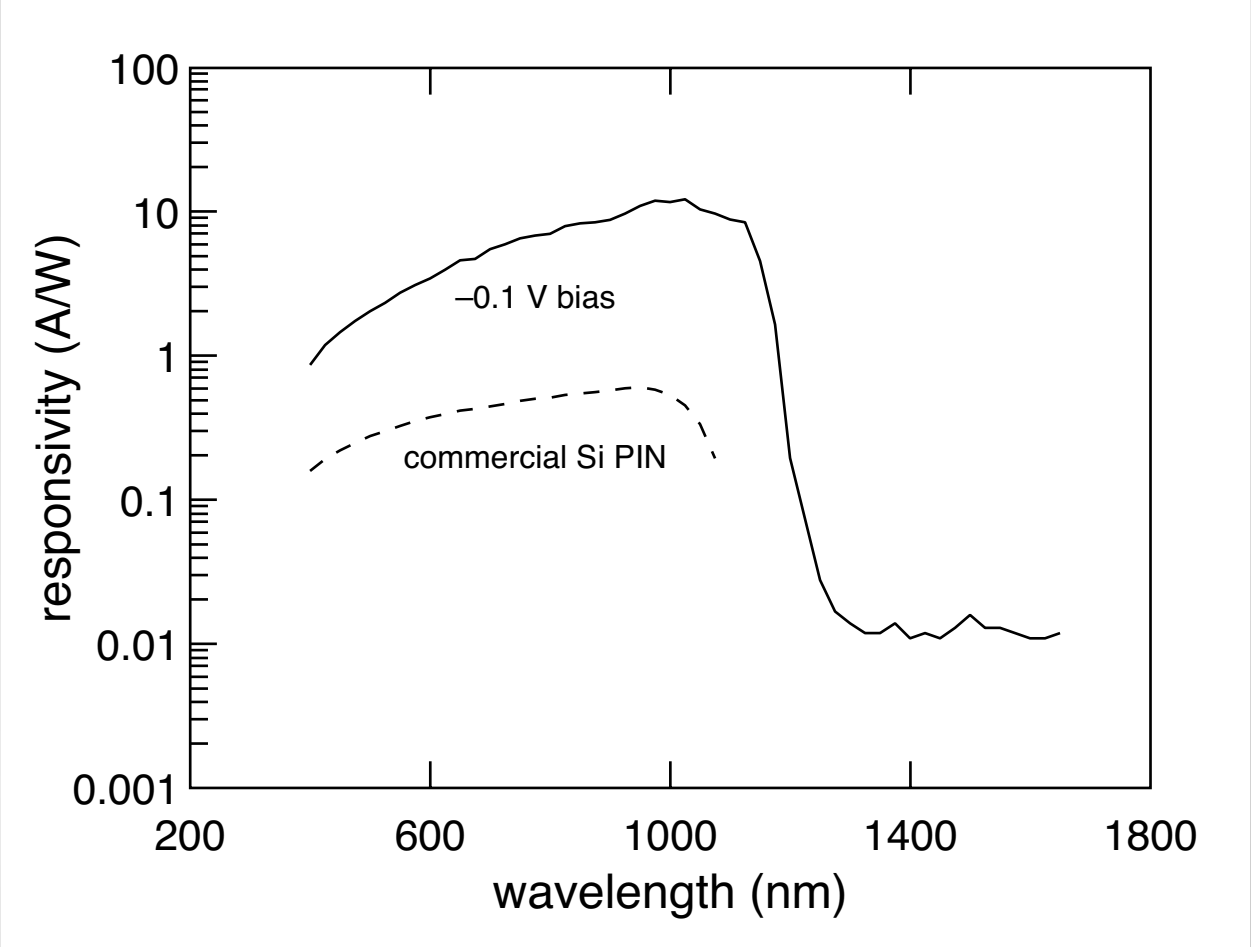
Detectors

responsivity



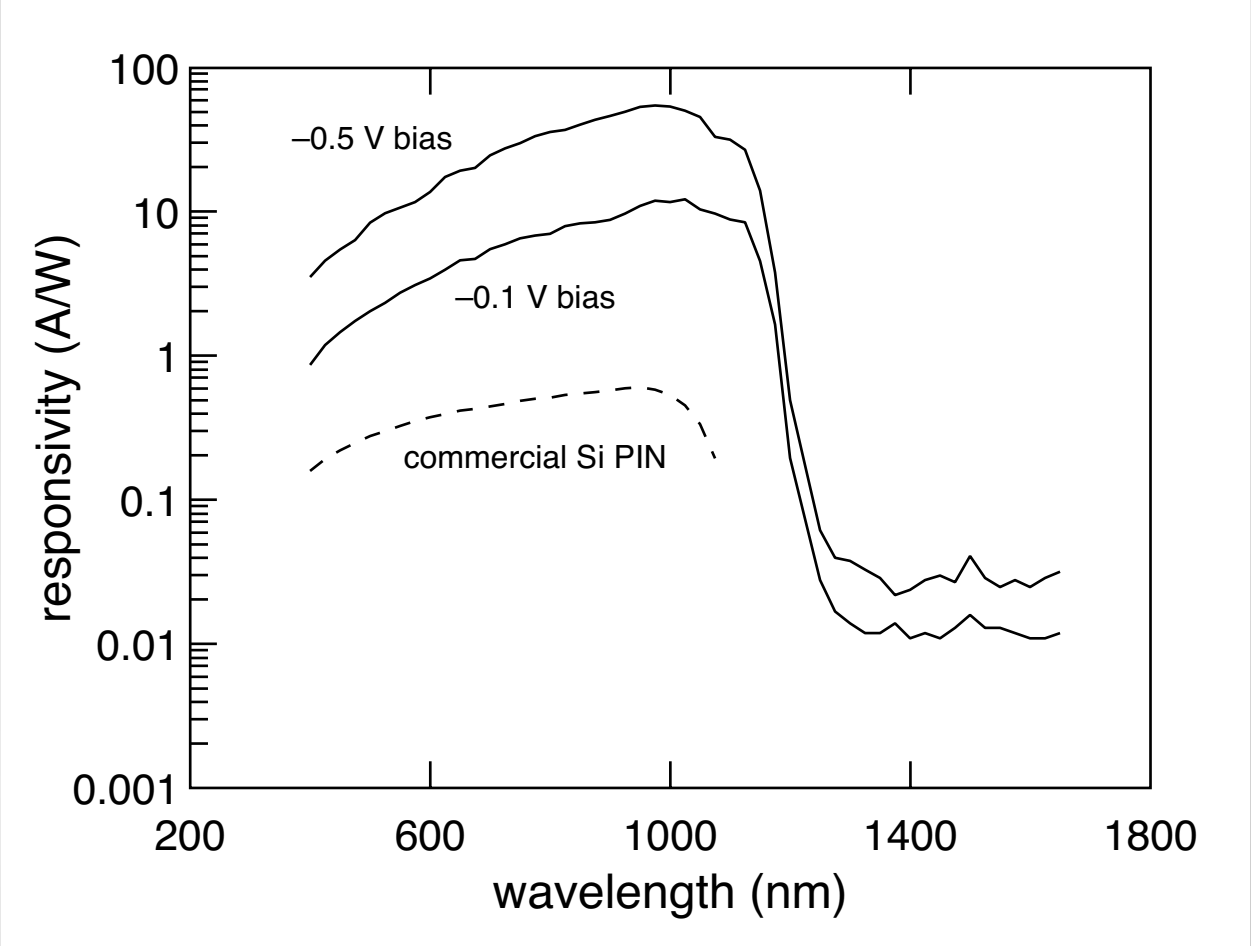
Detectors

responsivity



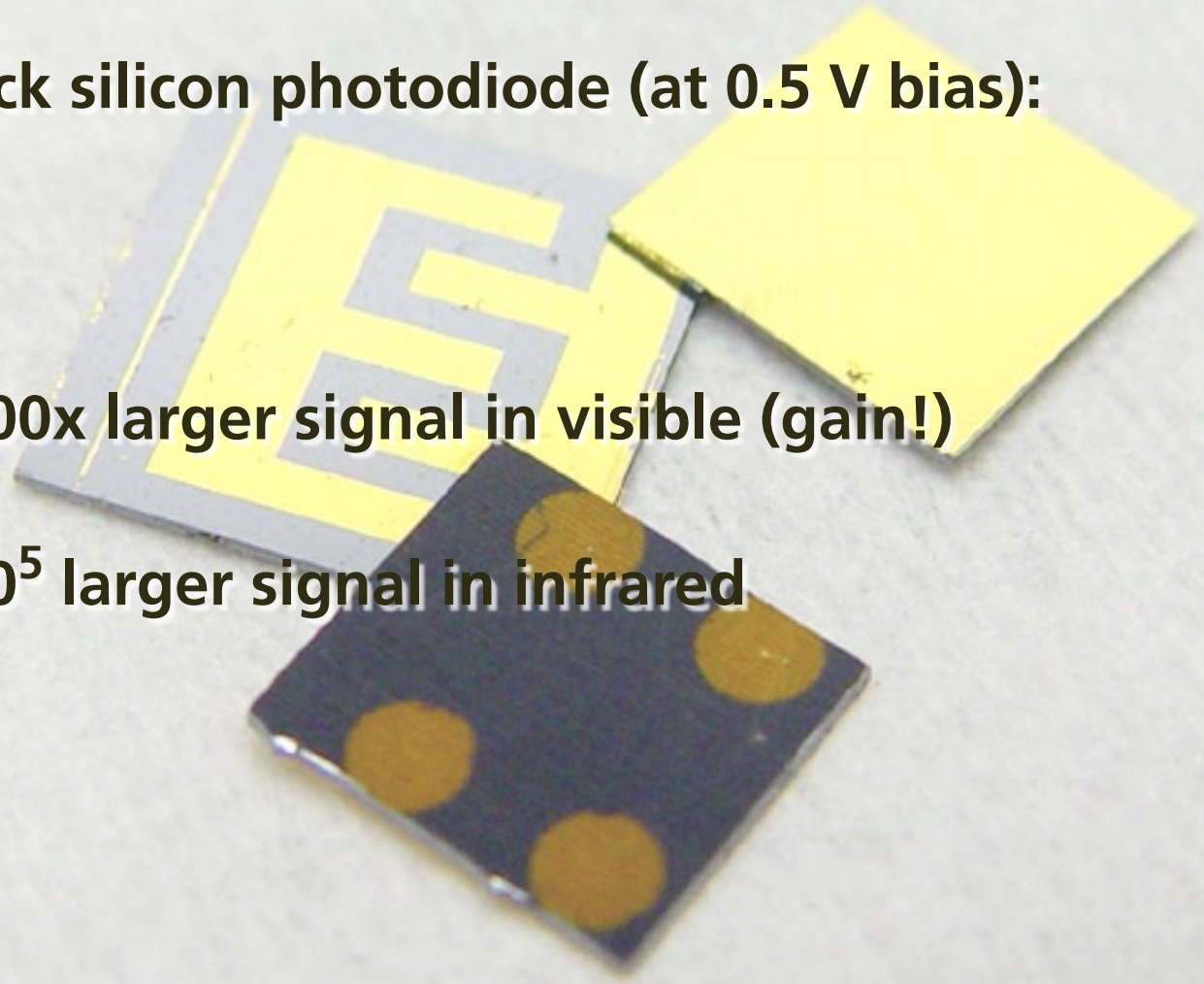
Detectors

responsivity



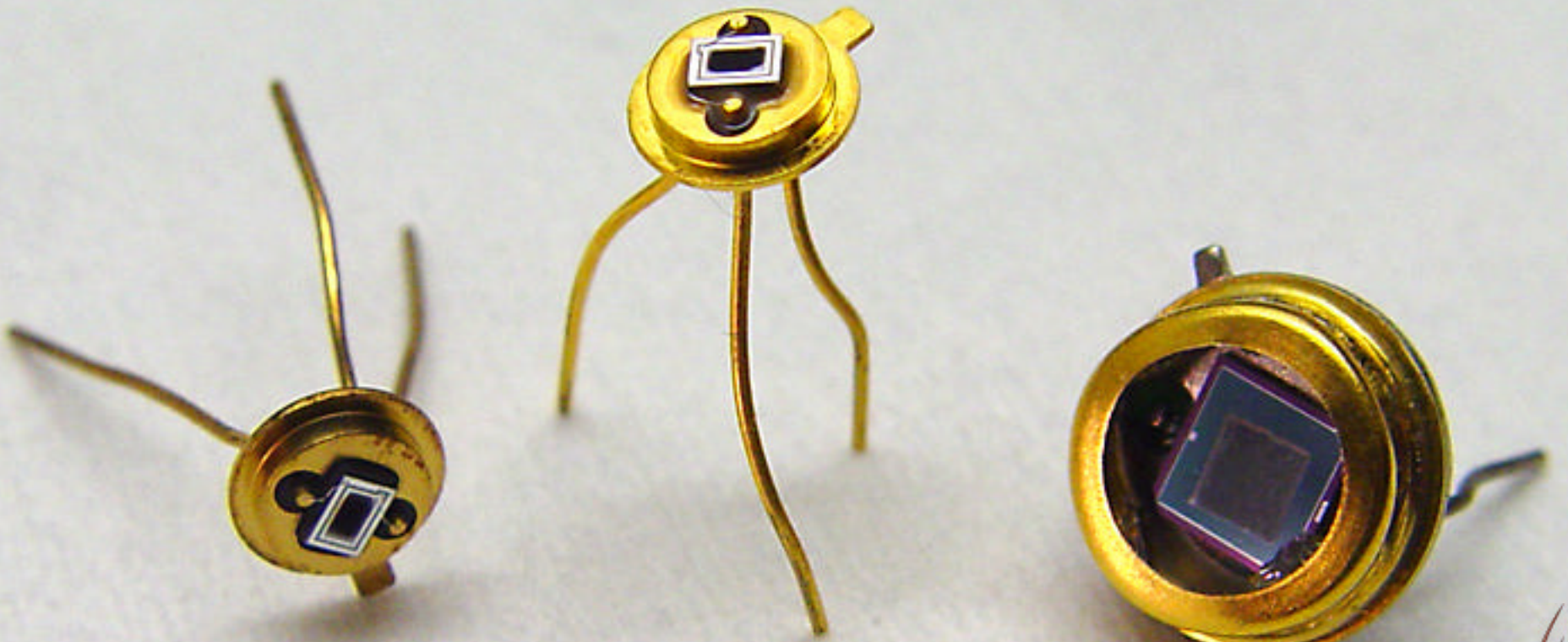
Detectors

Black silicon photodiode (at 0.5 V bias):



- **100x larger signal in visible (gain!)**
- **10^5 larger signal in infrared**

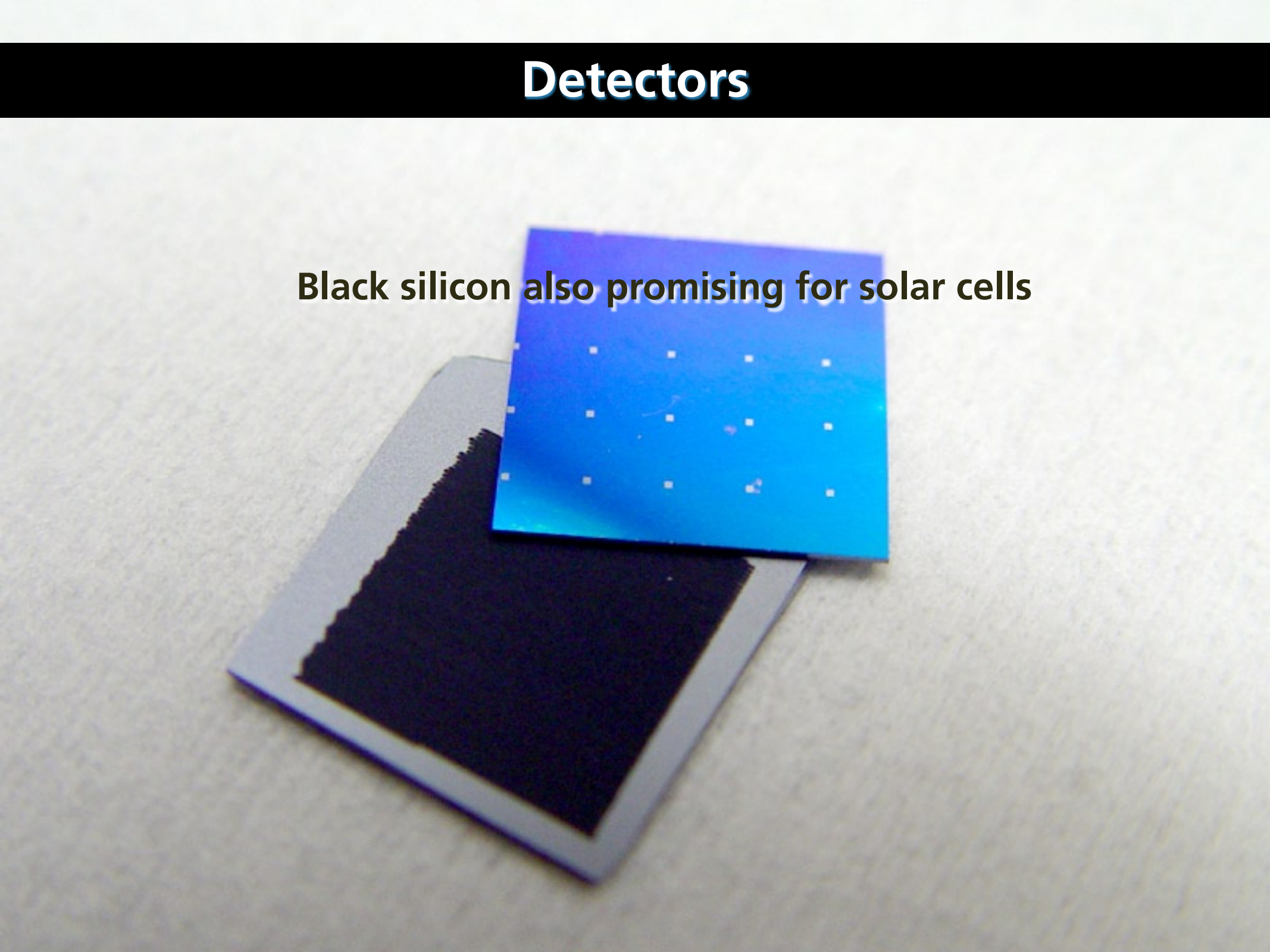
Detectors



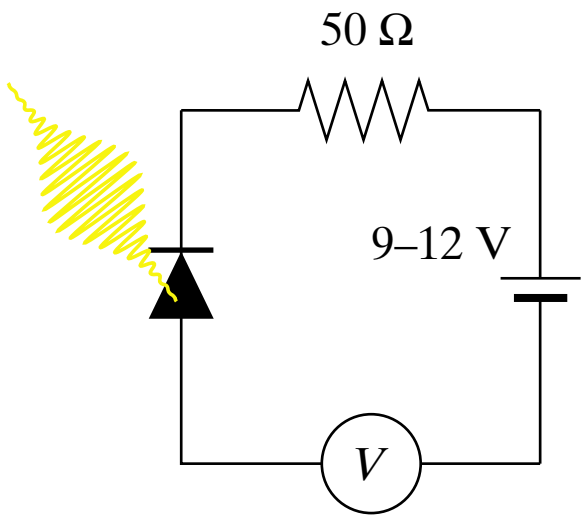
SiOnyx

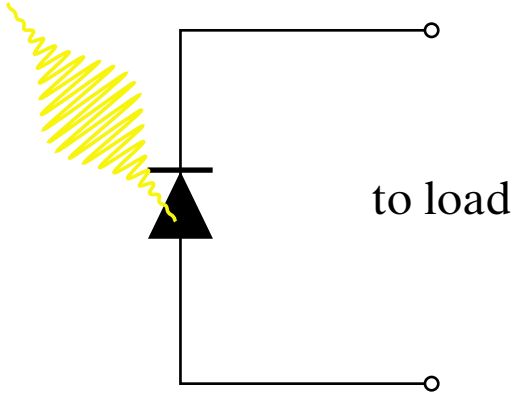
Detectors

Black silicon also promising for solar cells



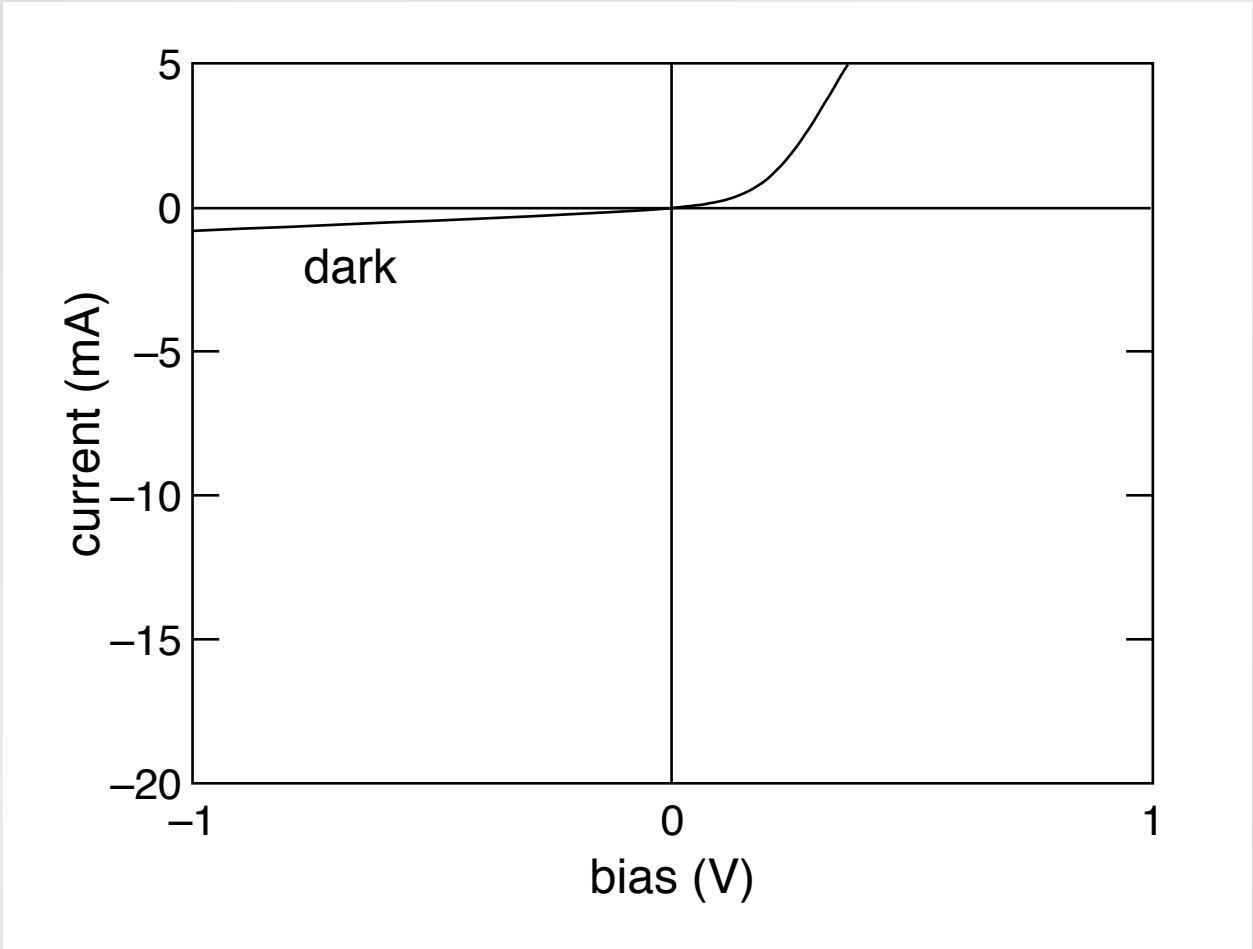
Detectors





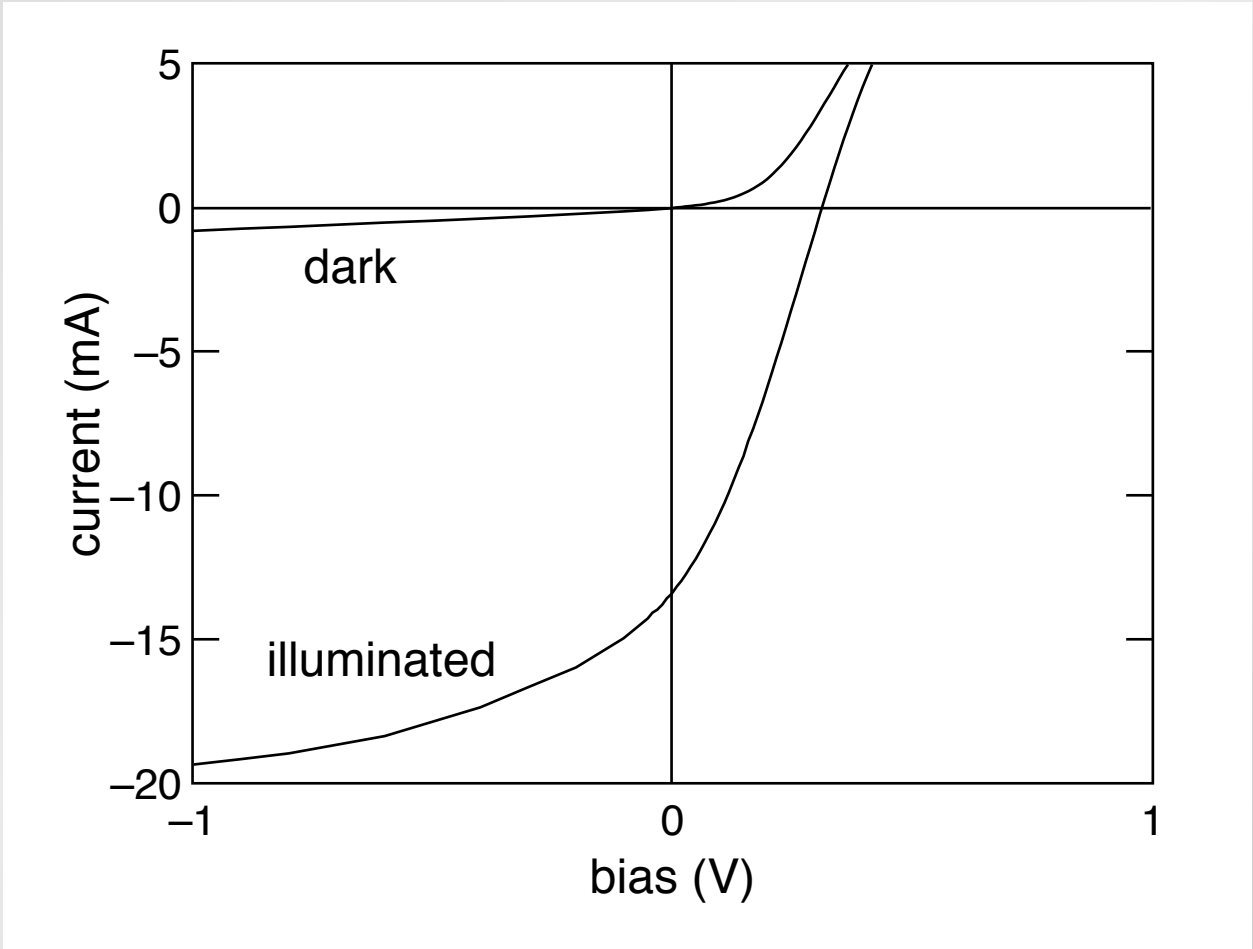
Detectors

IV characteristics



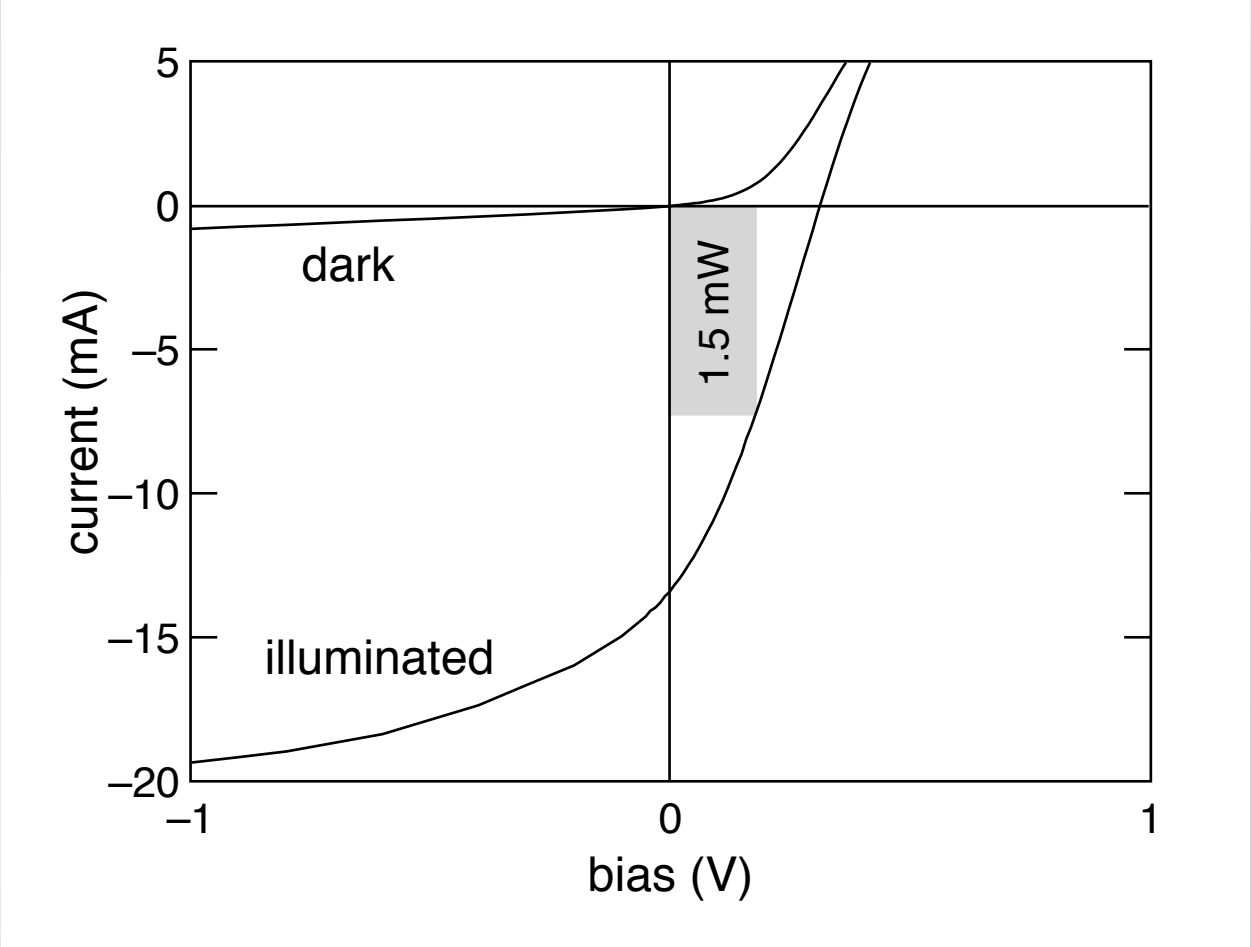
Detectors

IV characteristics



Detectors

IV characteristics



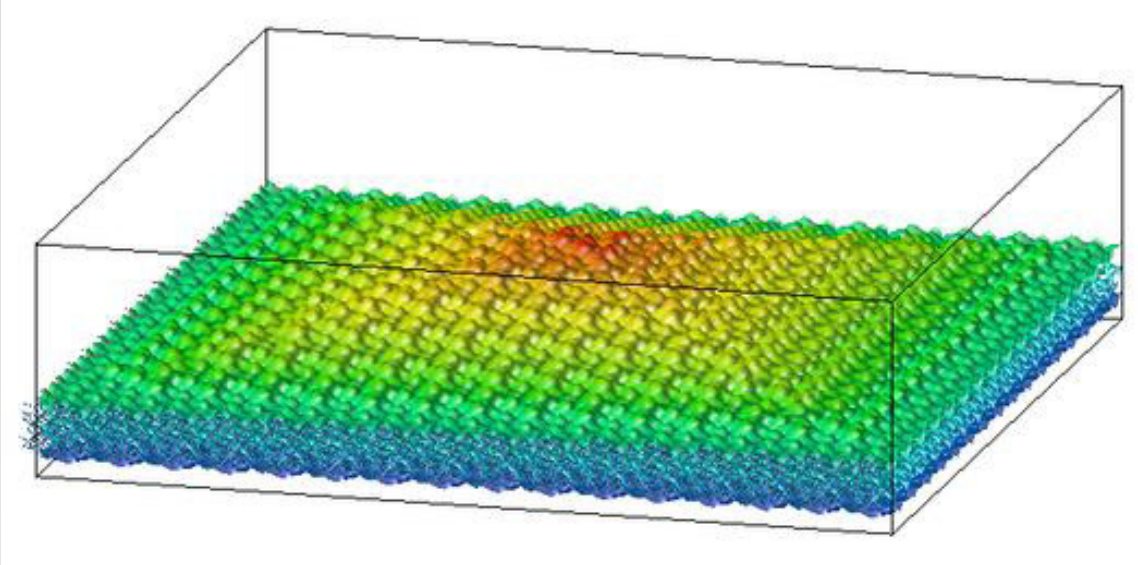
Detectors

Black silicon solar cell (preliminary):

- 2–3% efficiency
- photocurrent generated in thin layer

Needs

Understanding the resulting properties



full DFT code for very large numbers of atoms

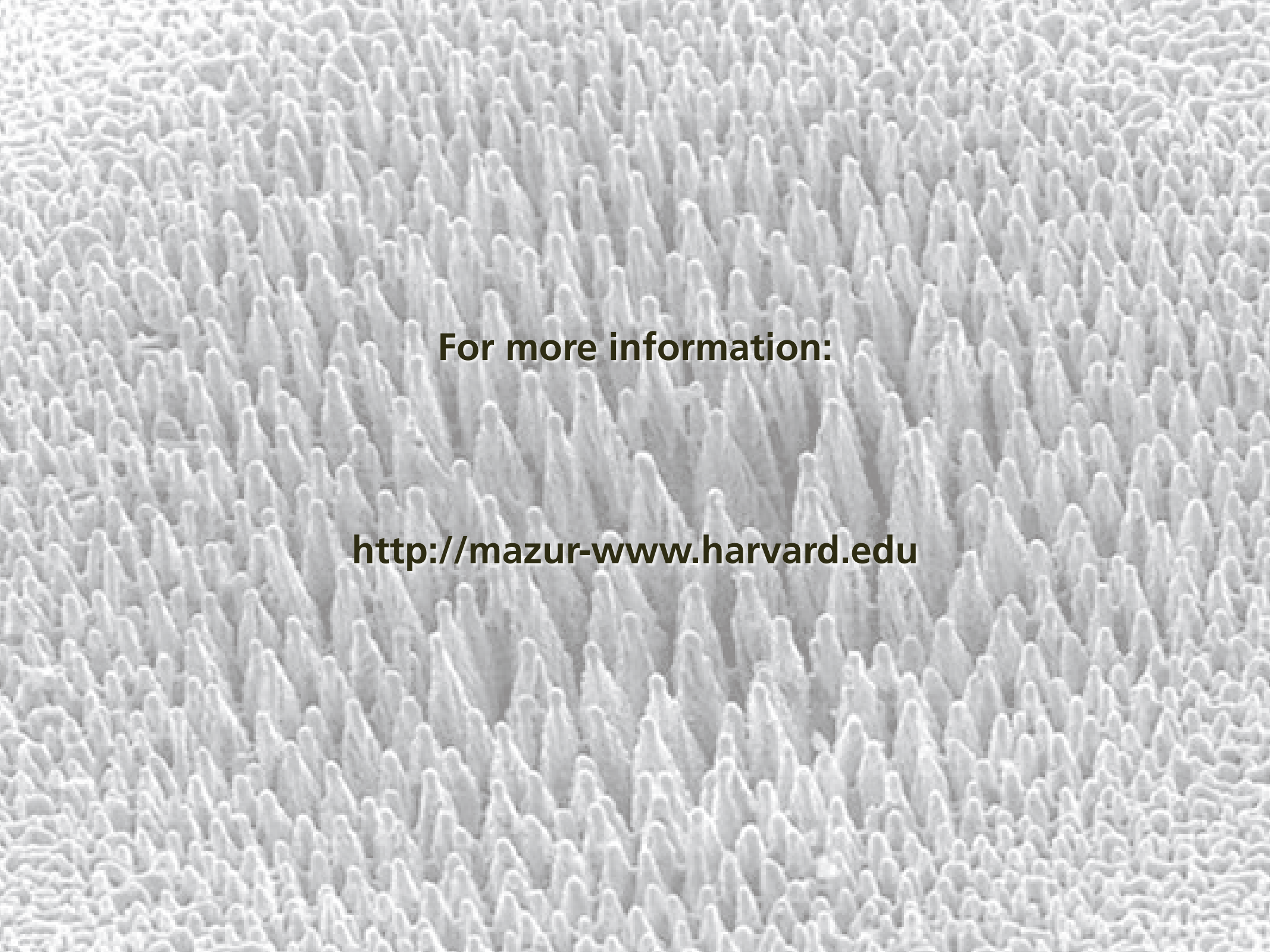
(CONQUEST beta: www.conquest.ucl.ac.uk)

Needs

- develop tools to model embedding process
- develop tools to model properties of resulting materials
- explore heavily doped materials and their properties

Conclusion

High photon flux doping: new class of materials!


For more information:
http://mazur-www.harvard.edu