Infrared absorption by conical silicon microstructures made in a variety of background gases using femtosecond-laser pulses

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CLEO, Baltimore, MD
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Harvard University
Cambridge, MA

Outline

Fabrication of conical microstructures

Optical properties of structures made in SF_6

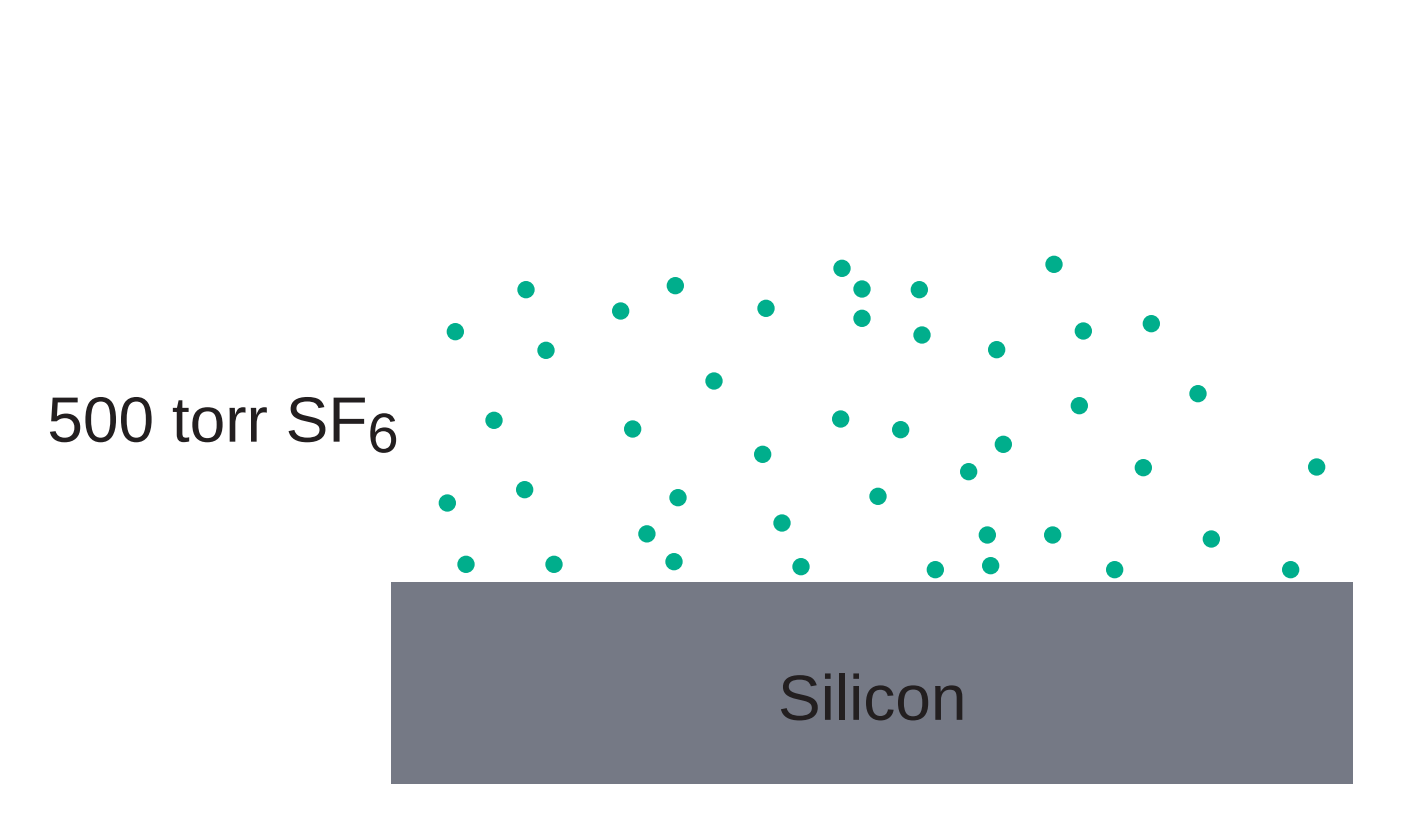
- **high absorptance**
- **explanations**

Structures made in other ambient gases

- **morphology**
- **optical and optoelectronic properties**

Microstructured silicon

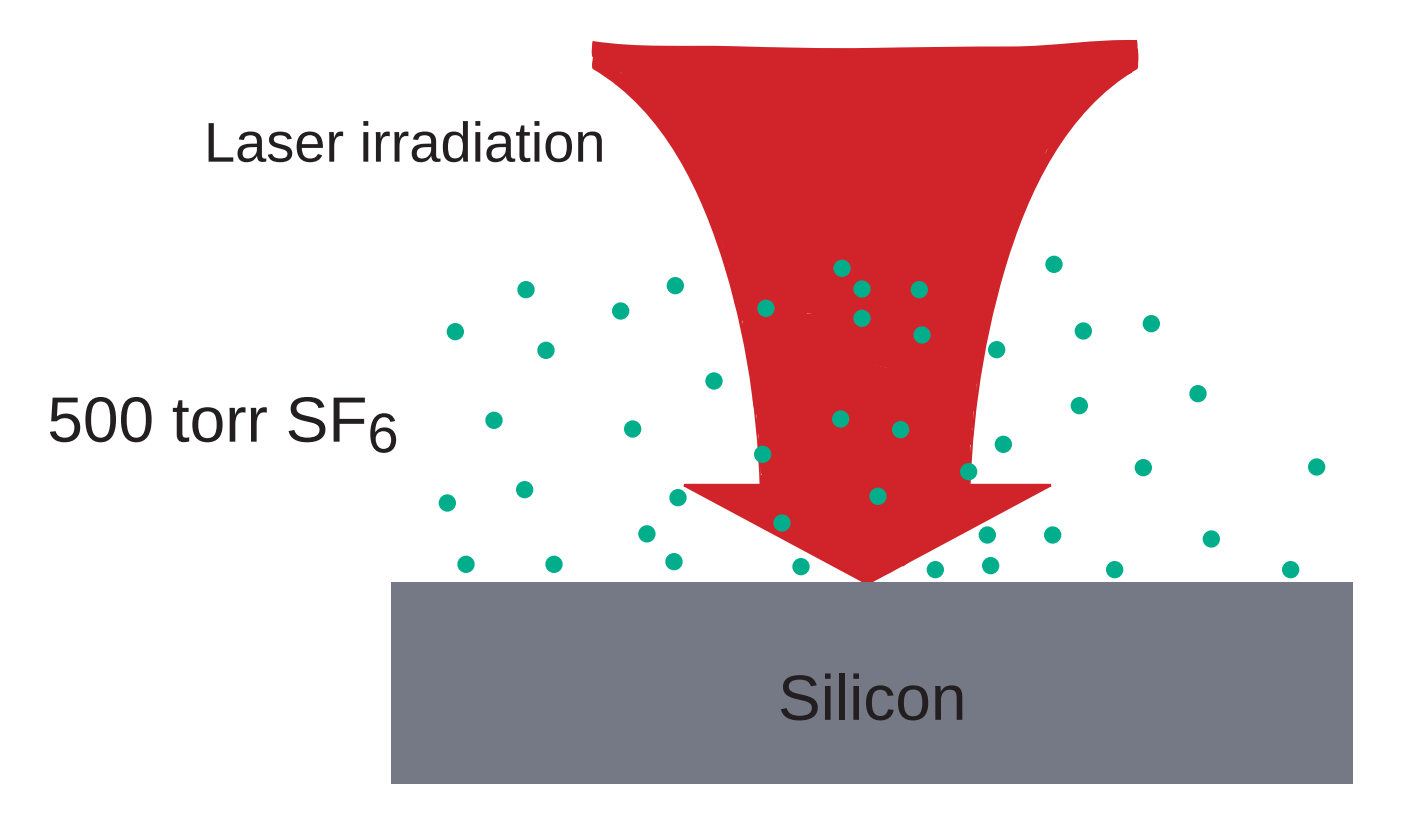
Si (111) placed in background of SF_6



Her *et al.*, *Appl. Phys. Lett.* 73, 1673 (1998)

Microstructured silicon

irradiate with 100 fs, 10 kJ/m^2 laser pulses in SF_6



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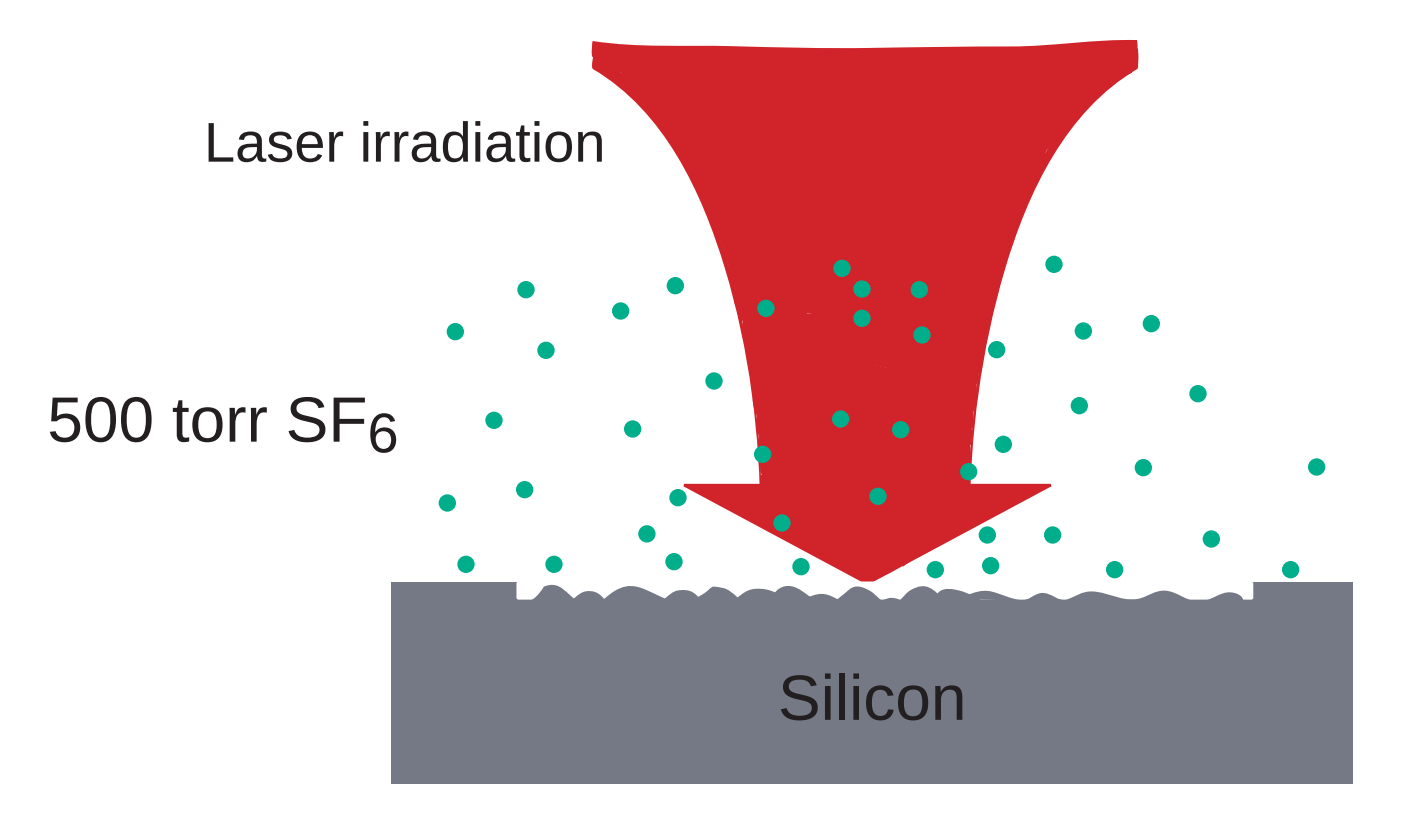

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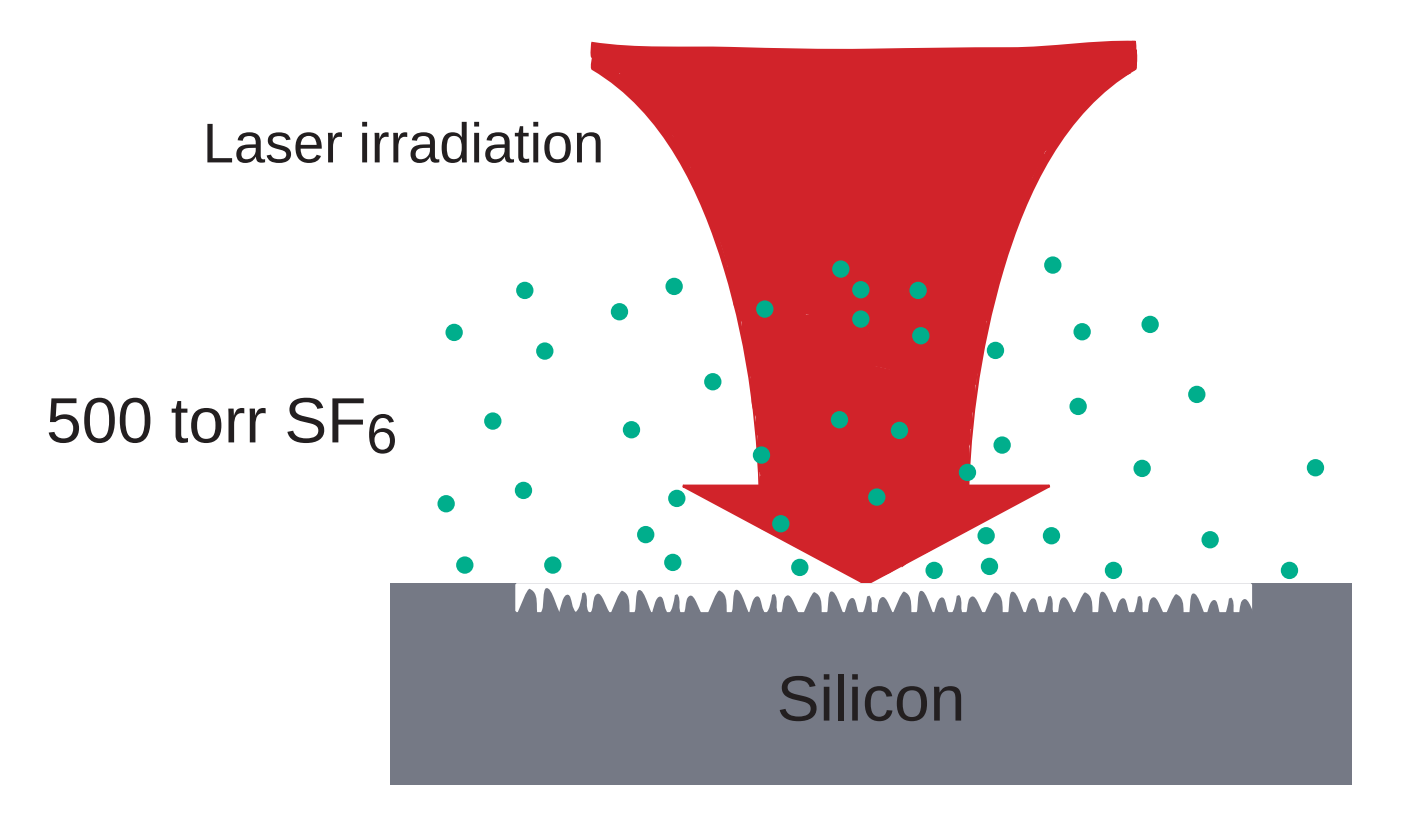

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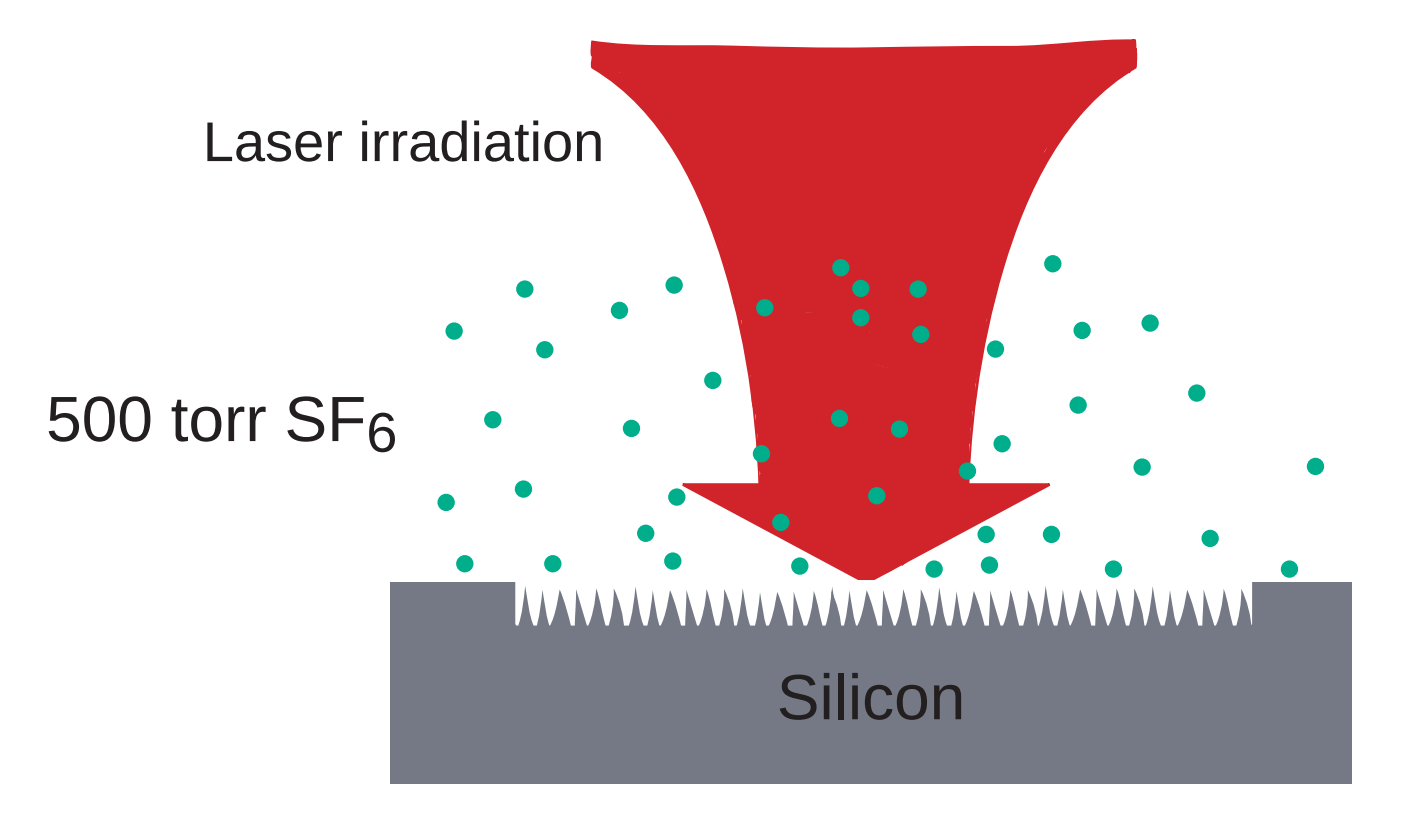
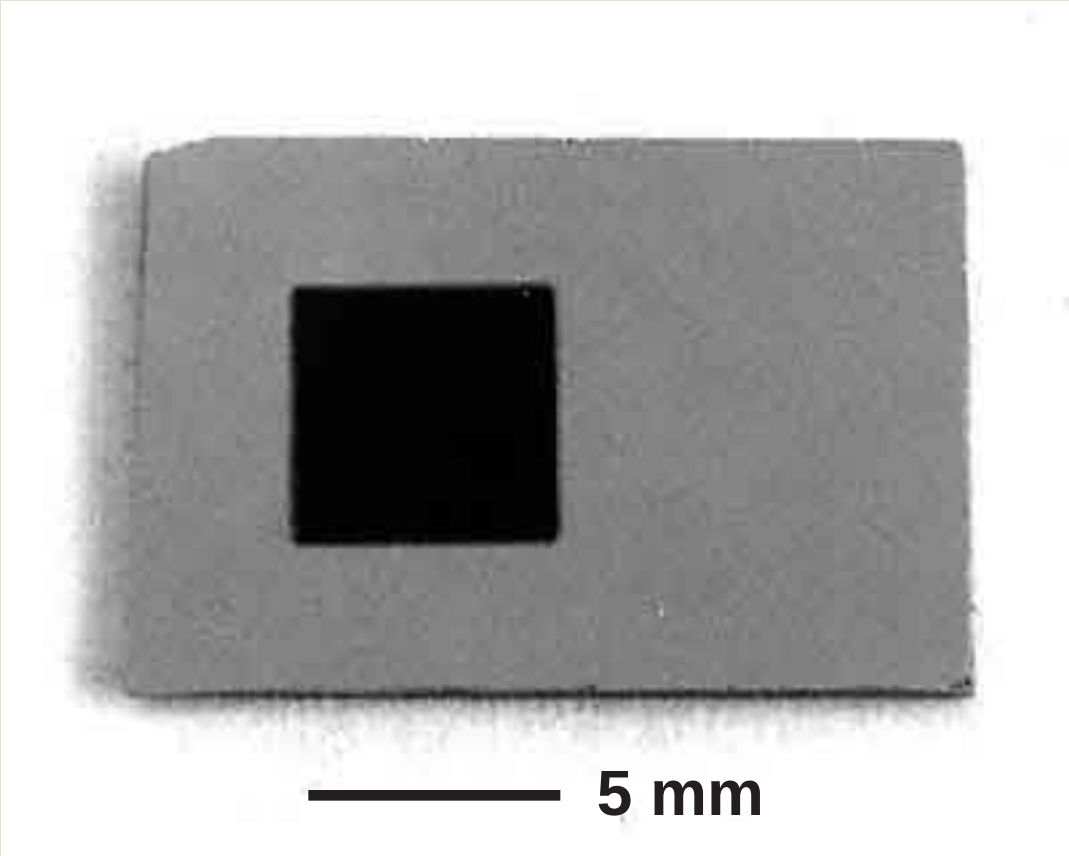
Microstructured silicon

irradiate with 100 fs, 10 kJ/m^2 laser pulses in SF_6

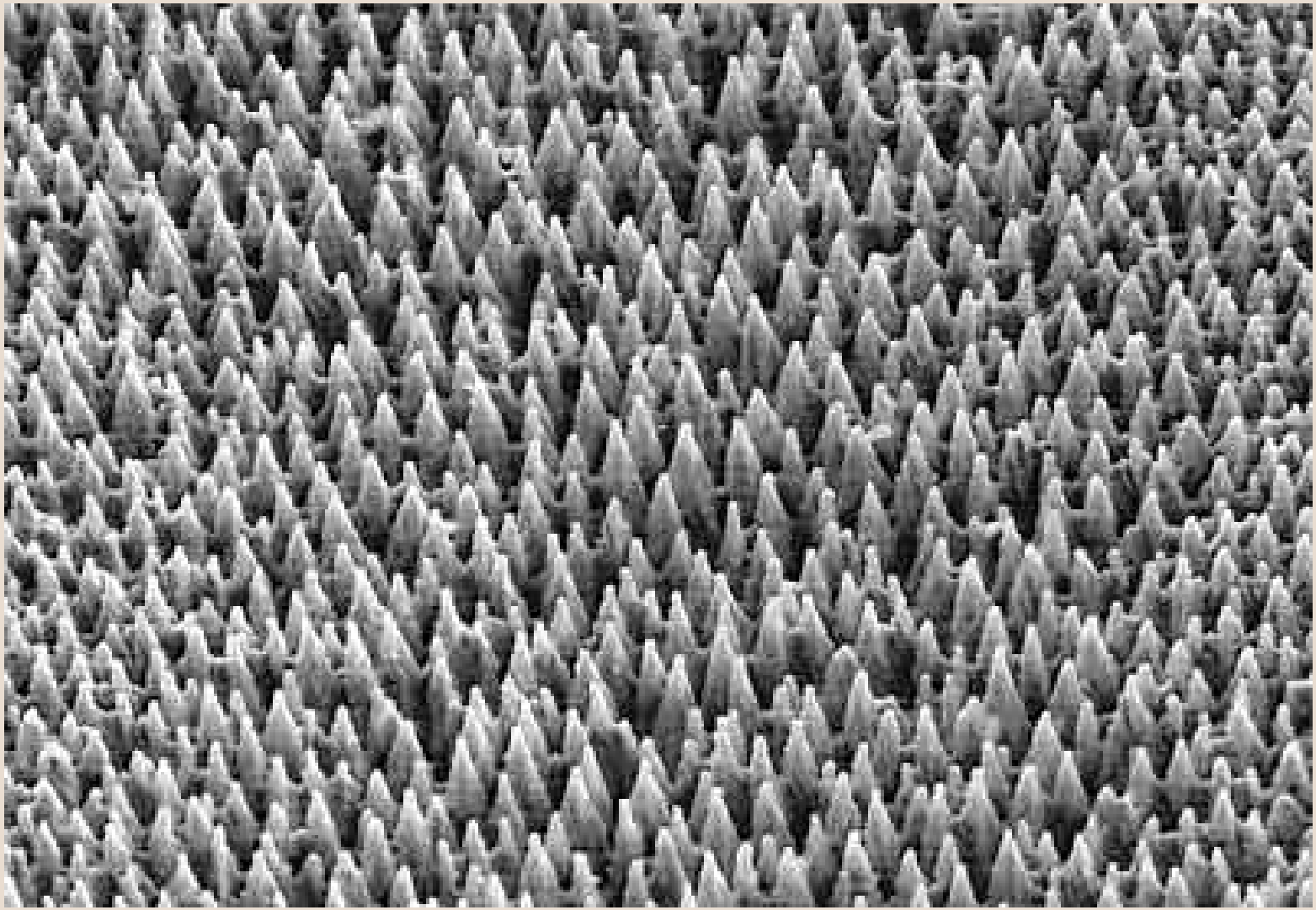


Her *et al.*, *Appl. Phys. Lett.* 73, 1673 (1998)

Irradiated silicon appears black

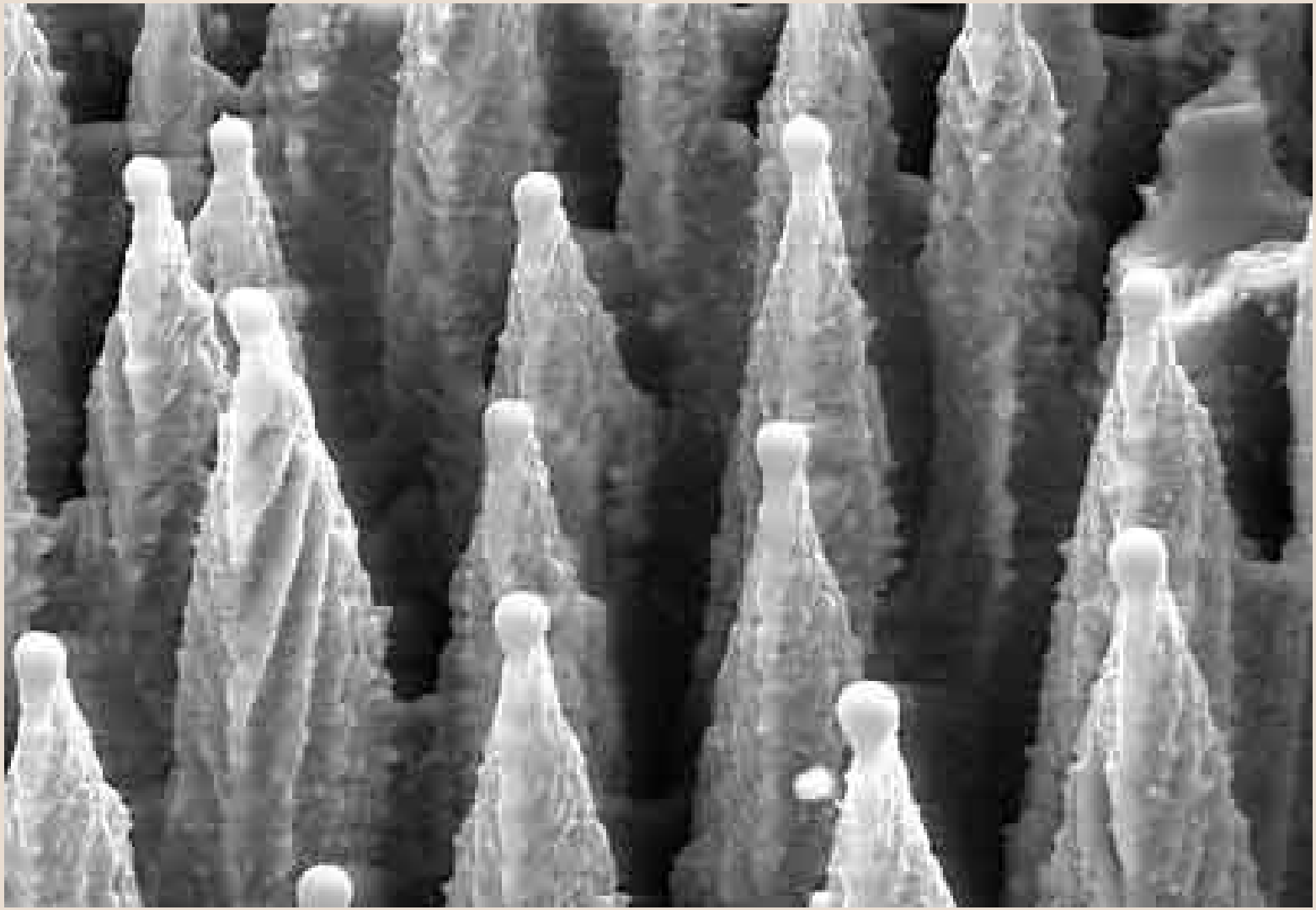


Microstructured silicon

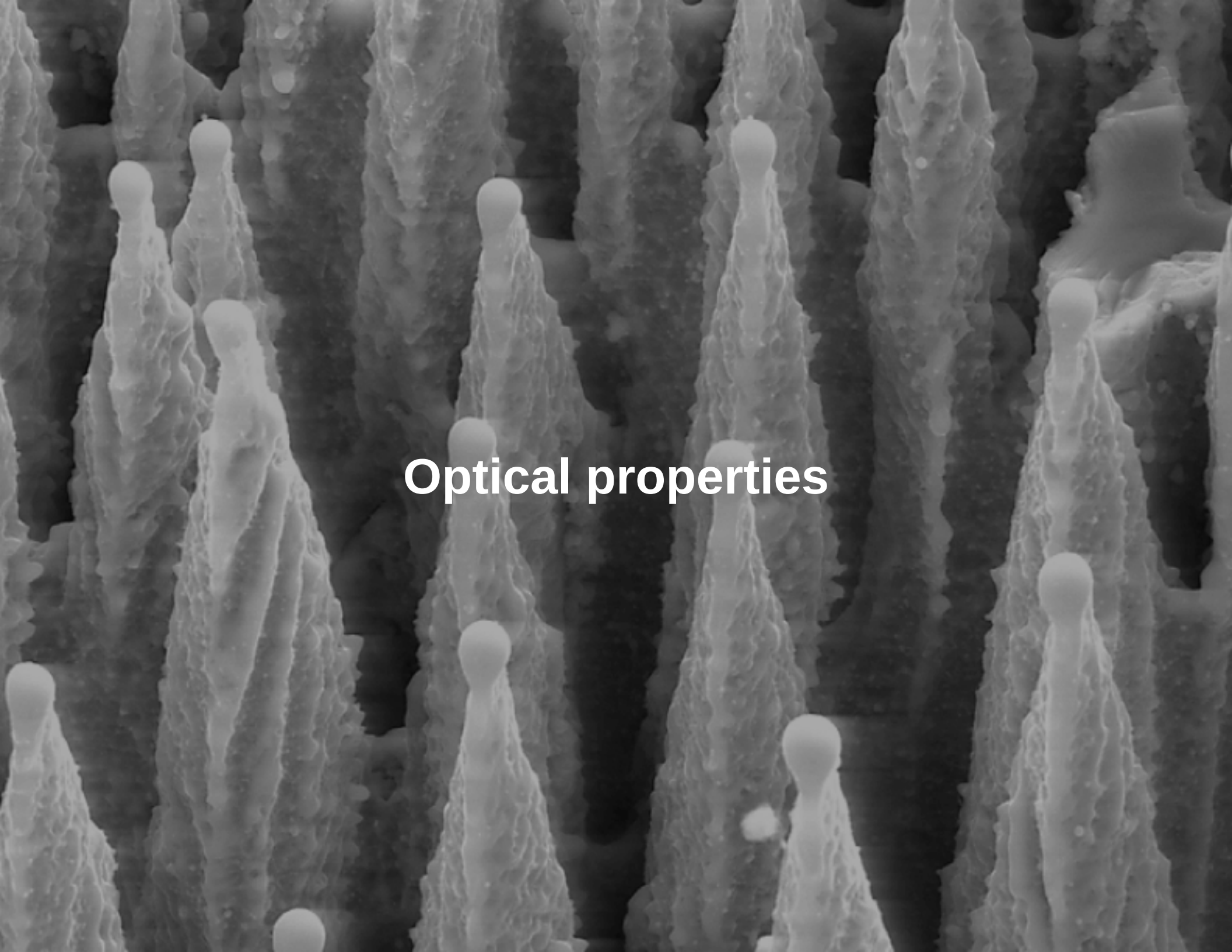


20 μm

Microstructured silicon

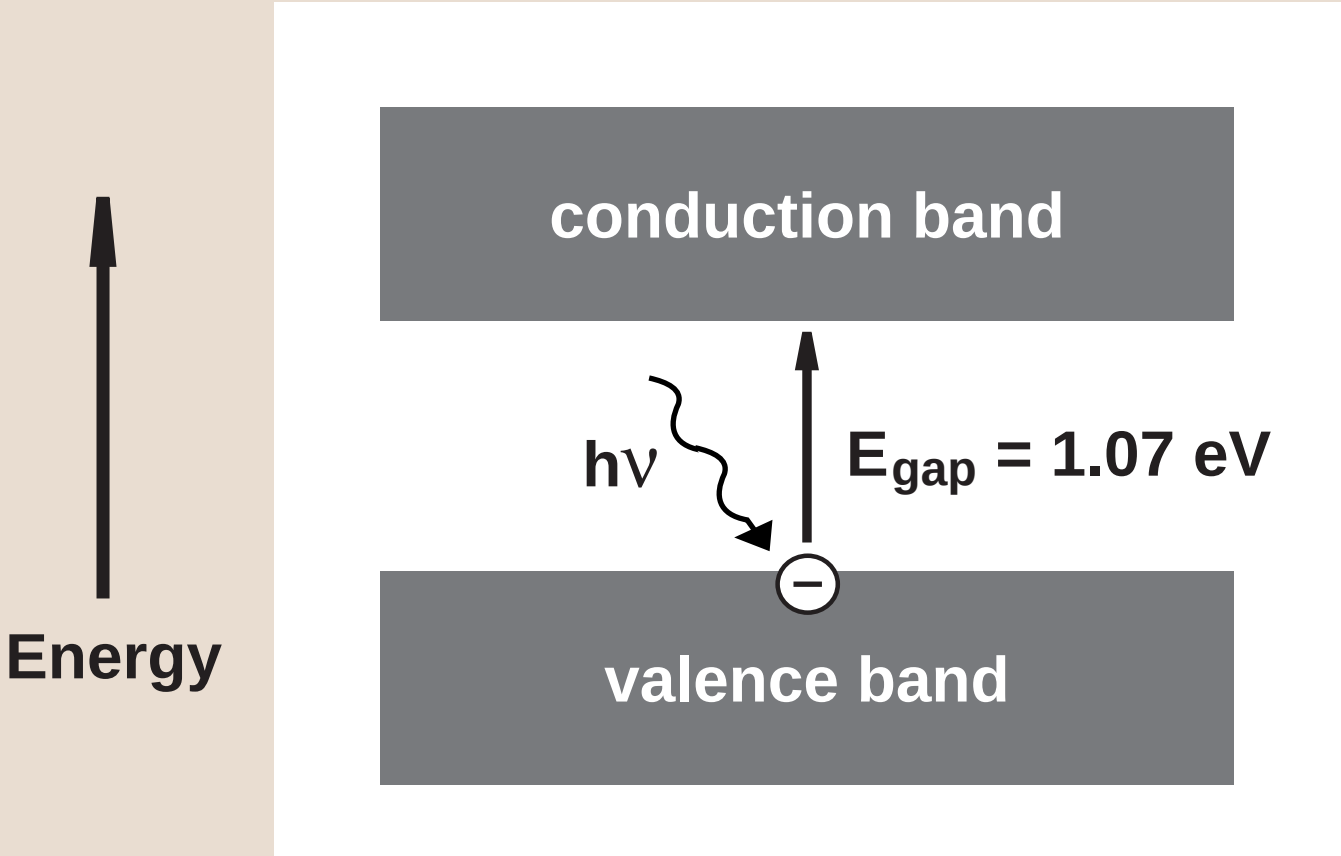


4 µm



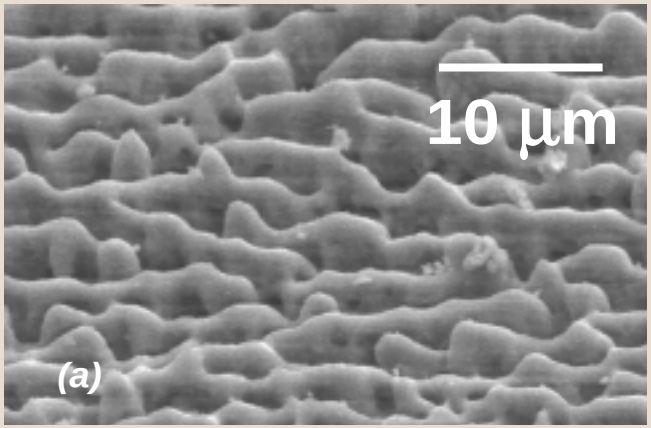
Optical properties

Ordinary silicon

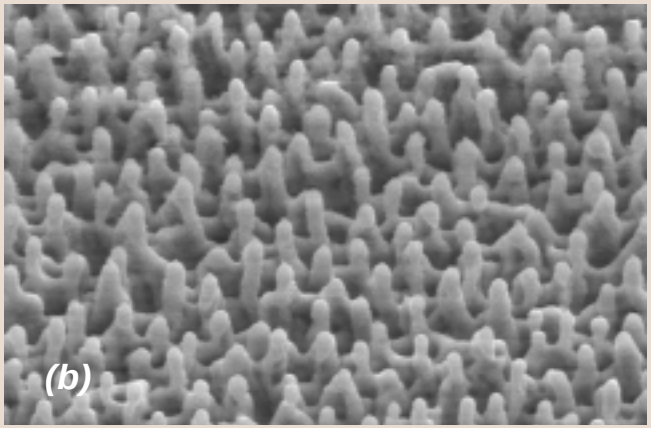


Only wavelengths < 1.1 μm are absorbed

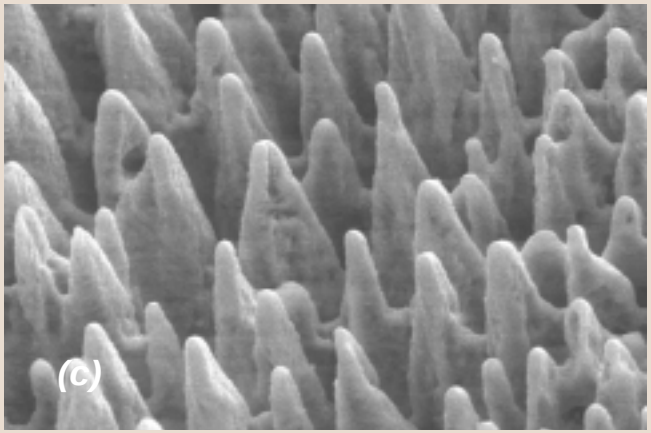
Microstructured silicon



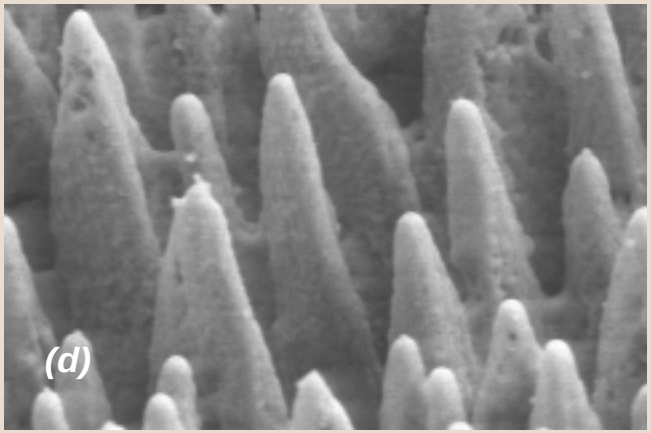
1- 2 μm



4 - 7 μm

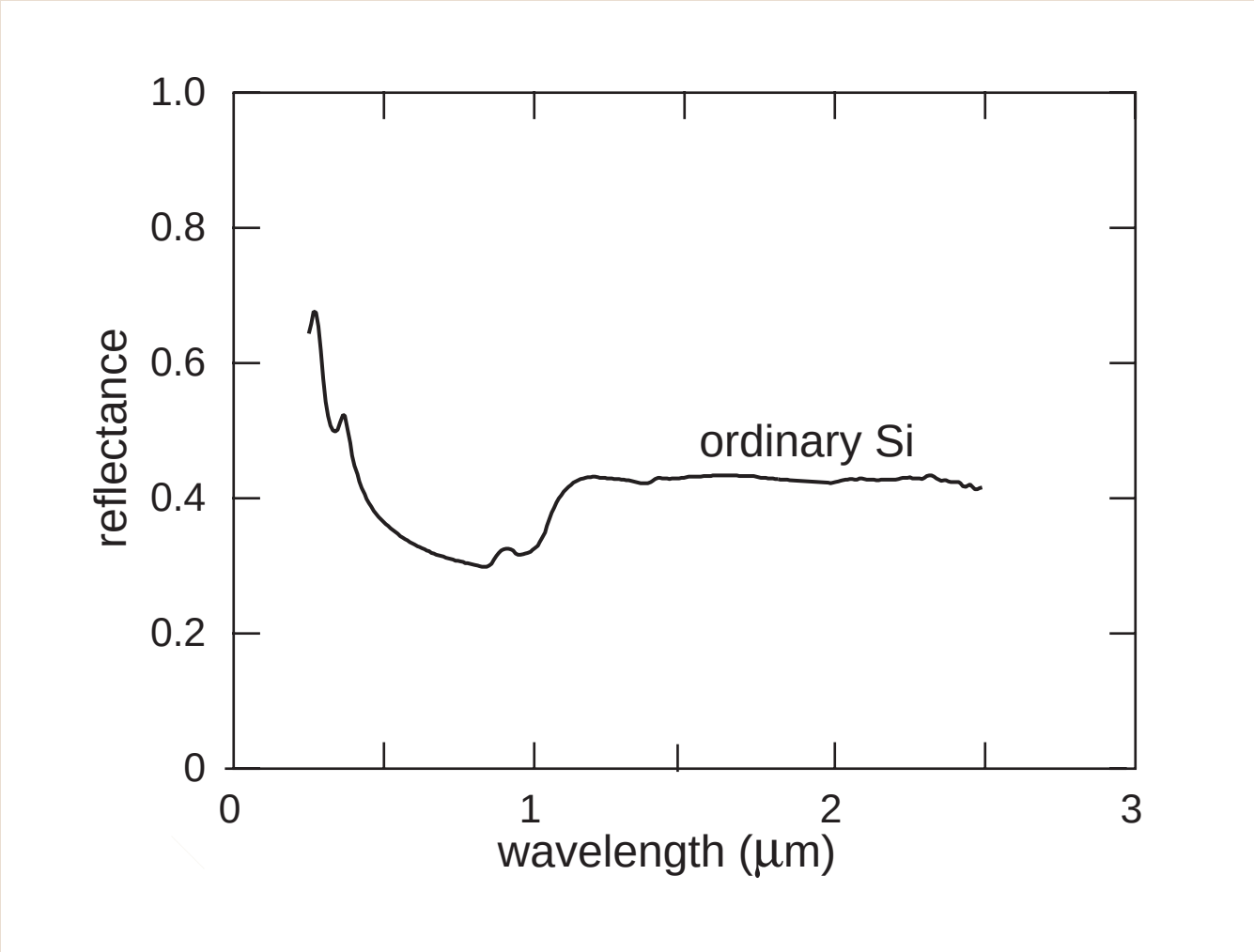


10 - 12 μm

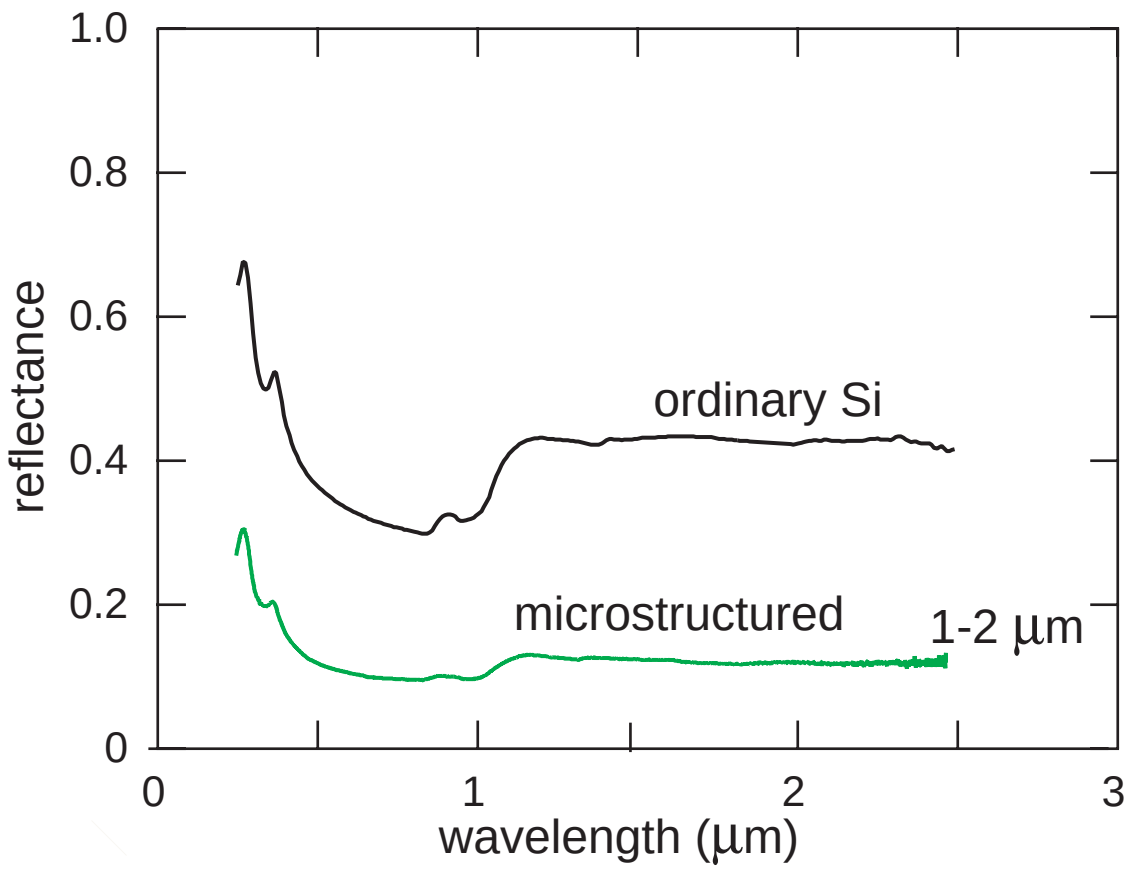


18 - 20 μm

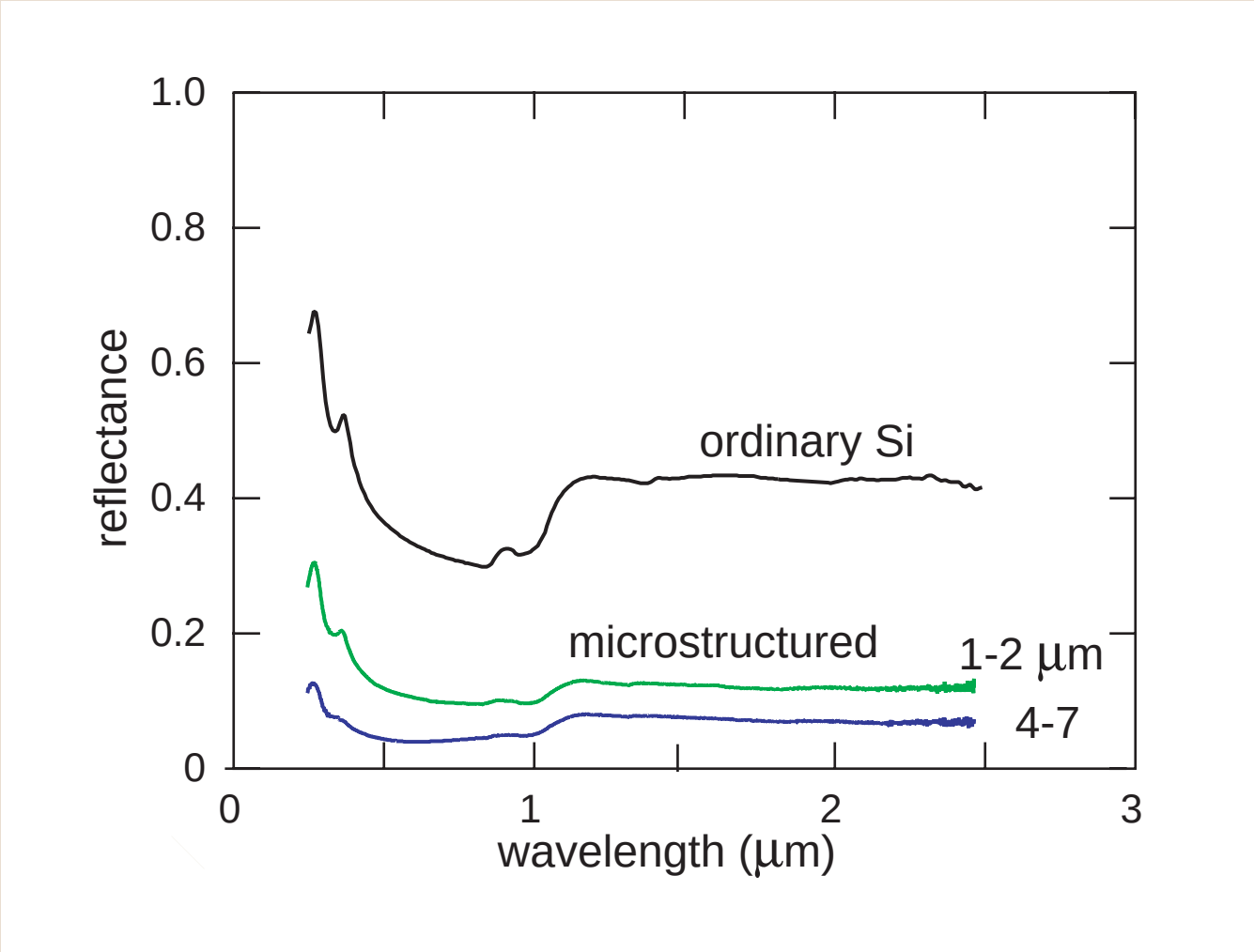
Total integrated reflectance



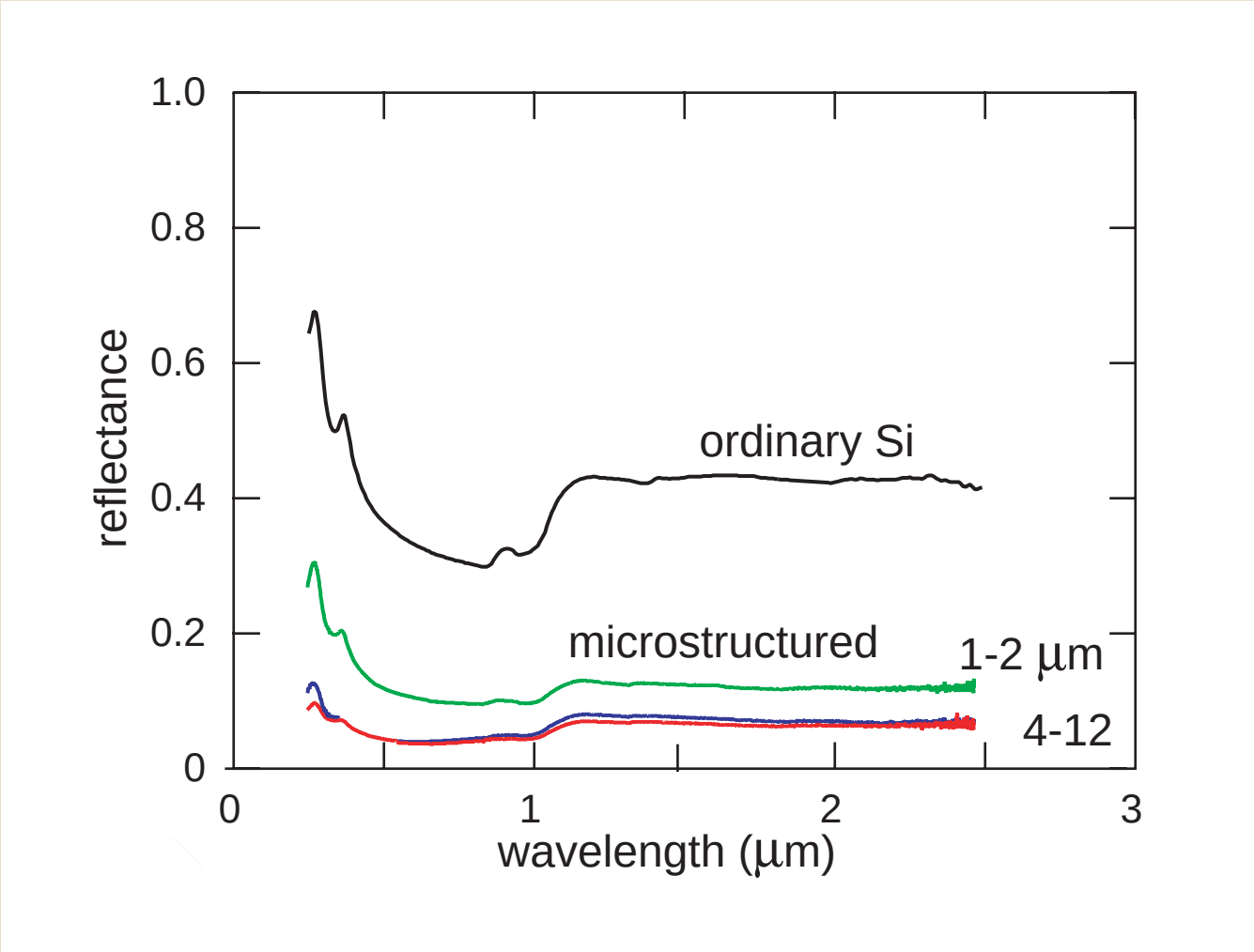
Total integrated reflectance



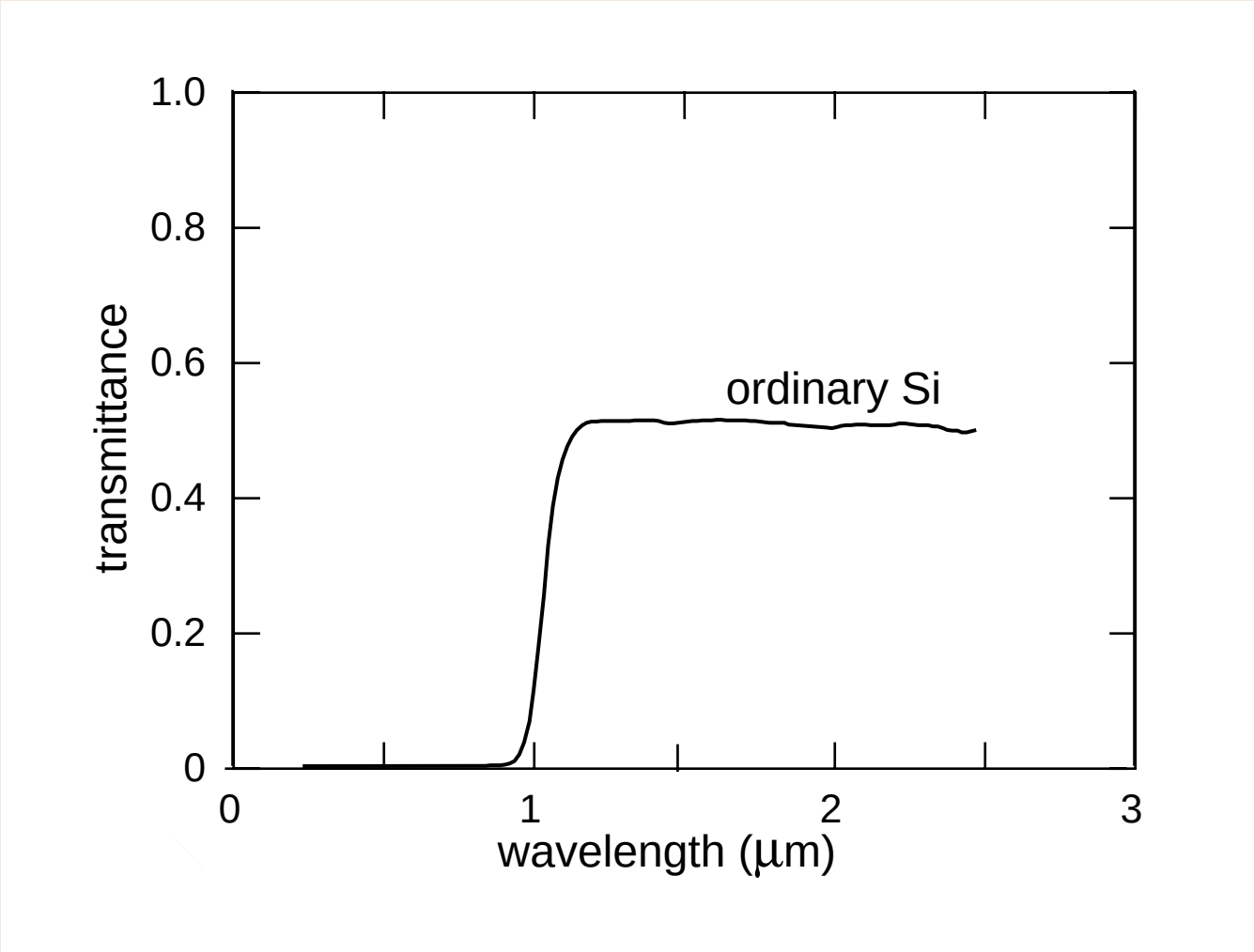
Total integrated reflectance



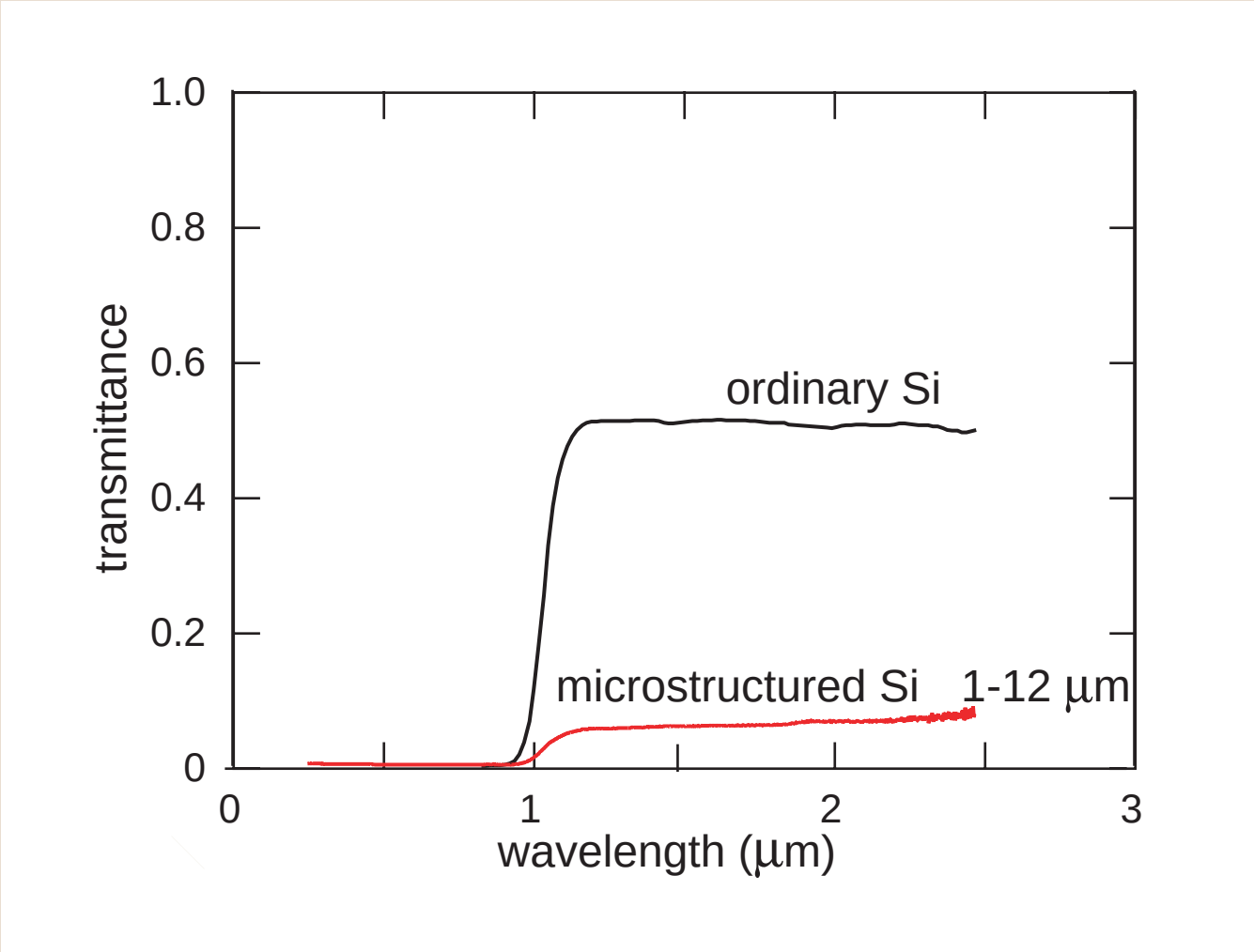
Total integrated reflectance



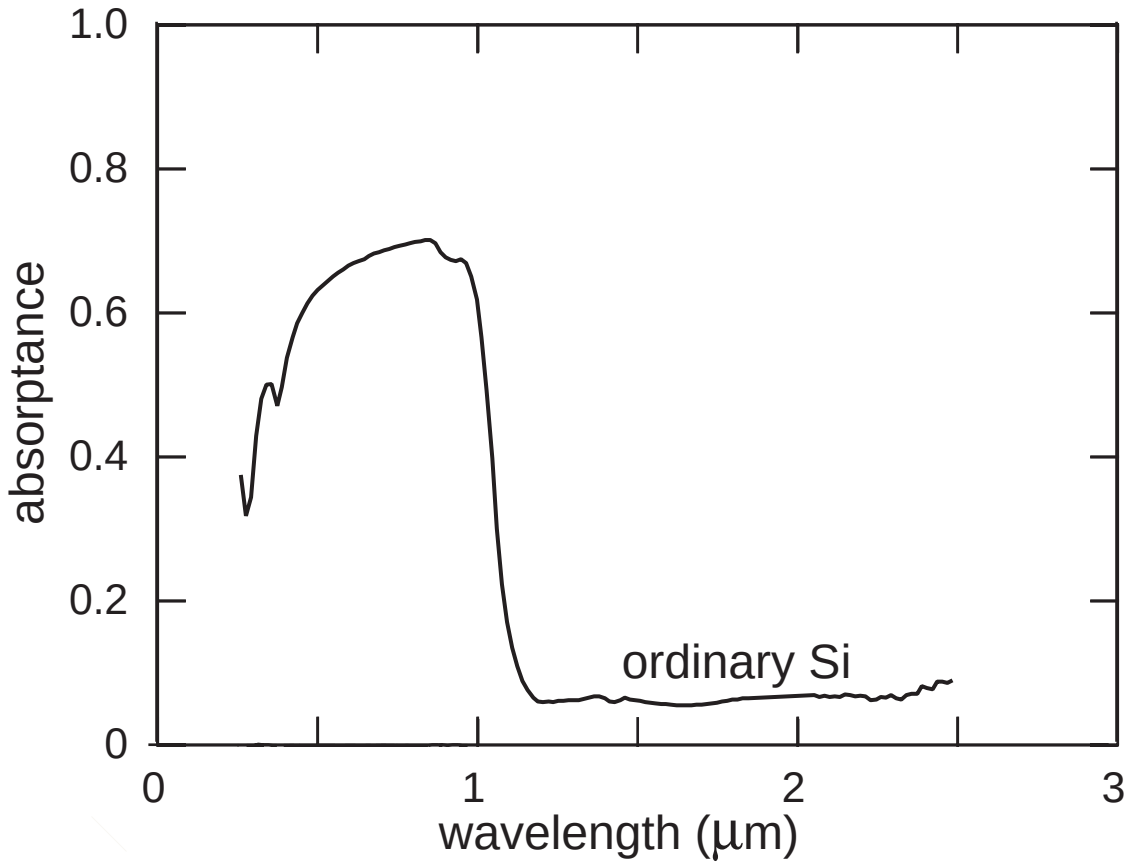
Total integrated transmittance



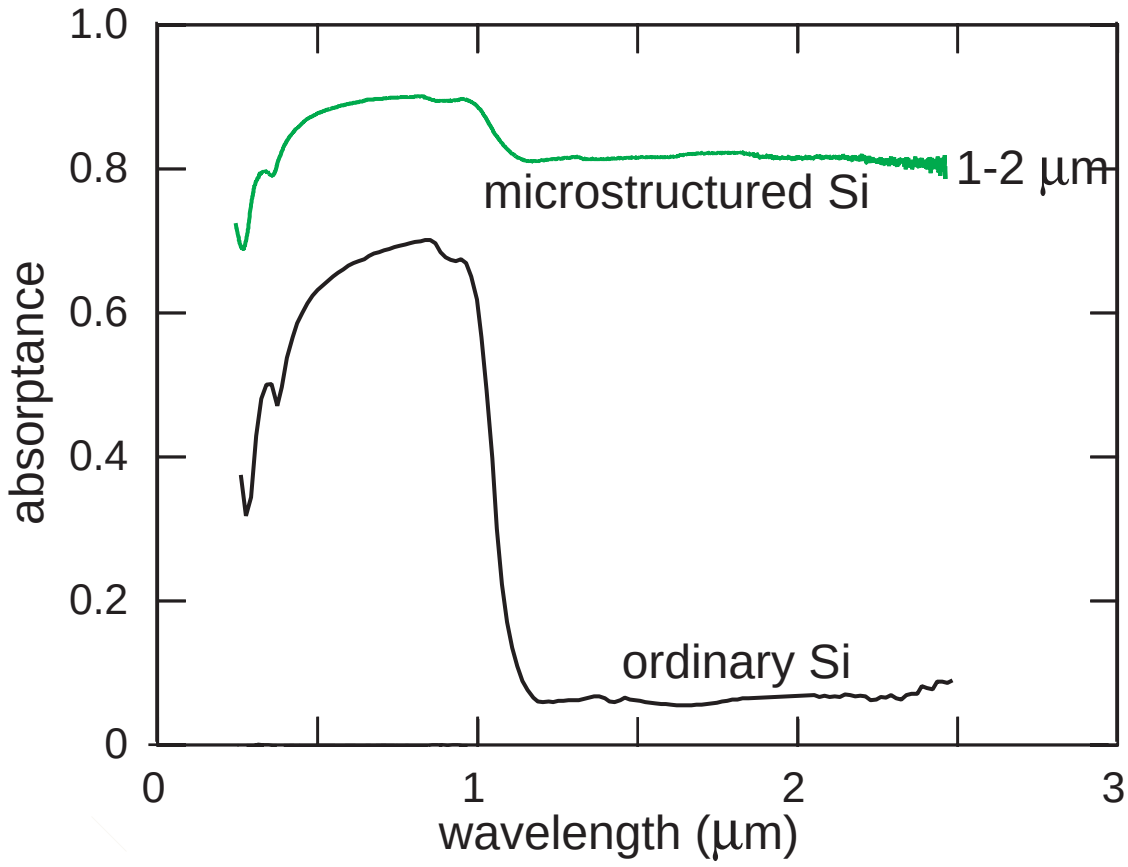
Total integrated transmittance



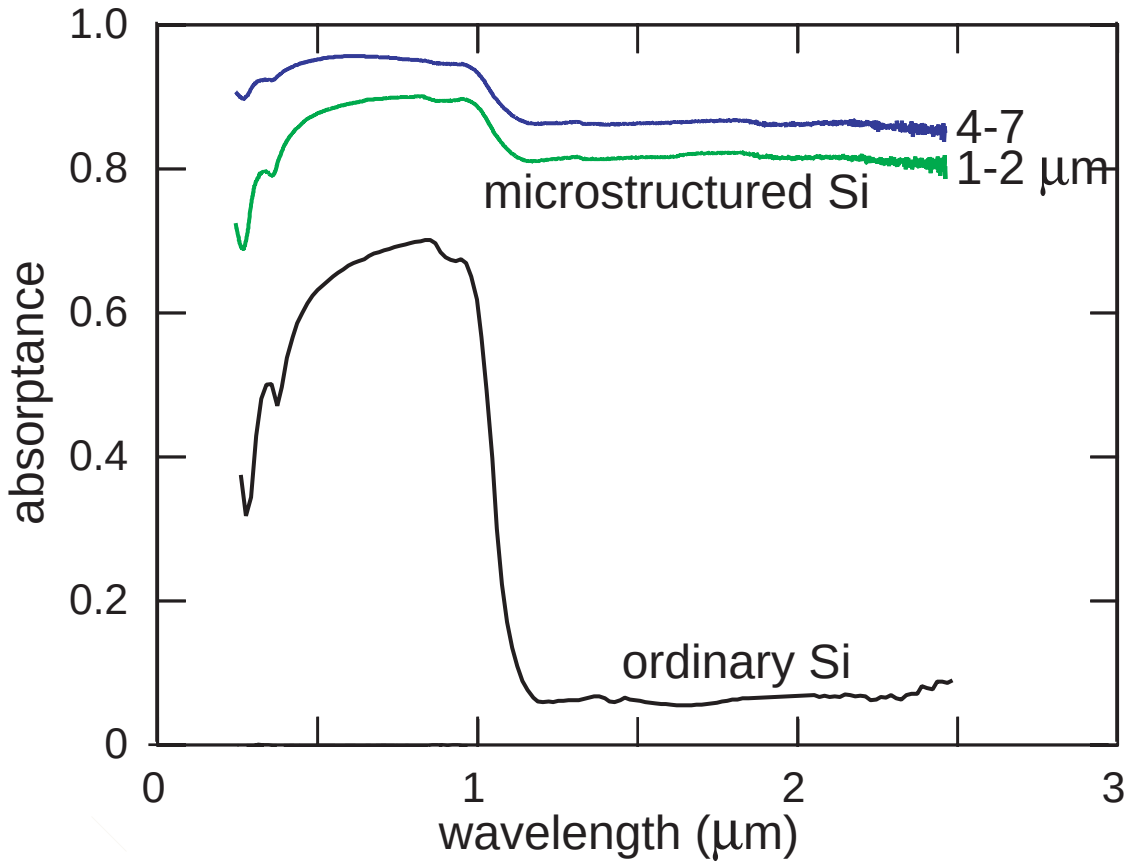
Total integrated absorptance



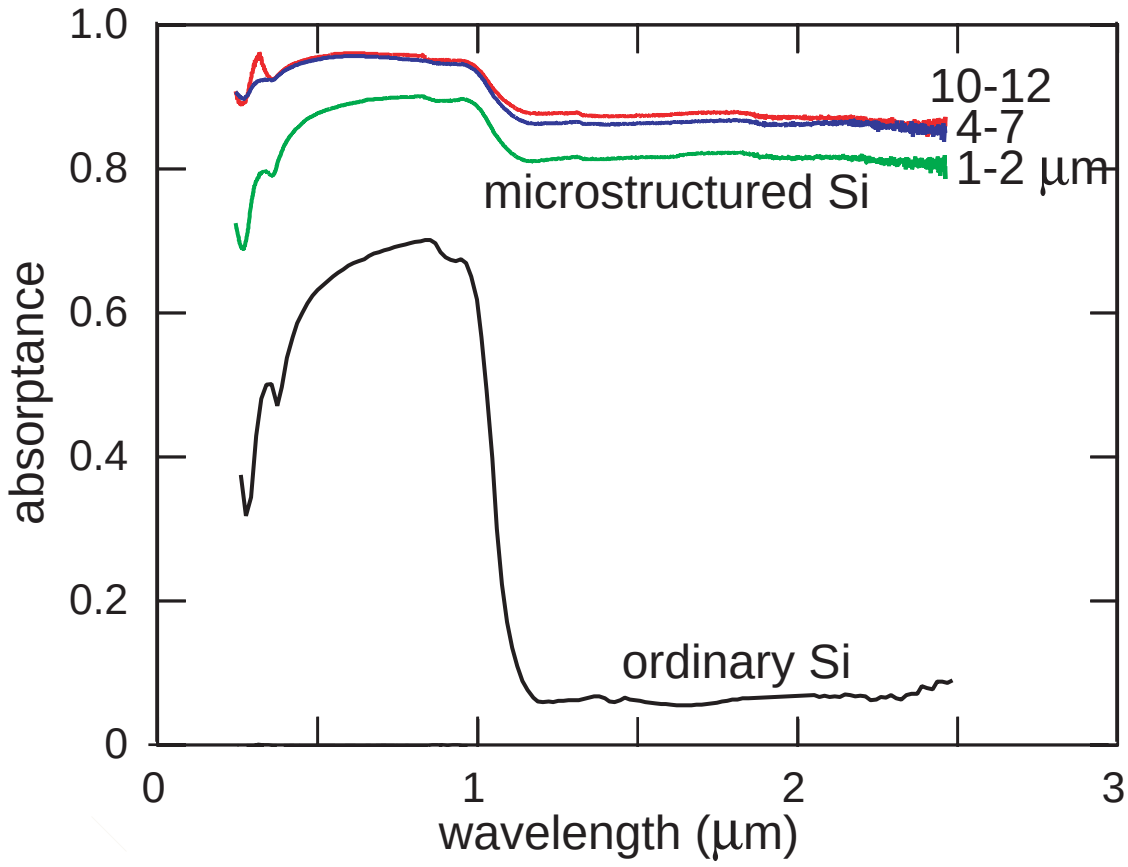
Total integrated absorptance



Total integrated absorptance



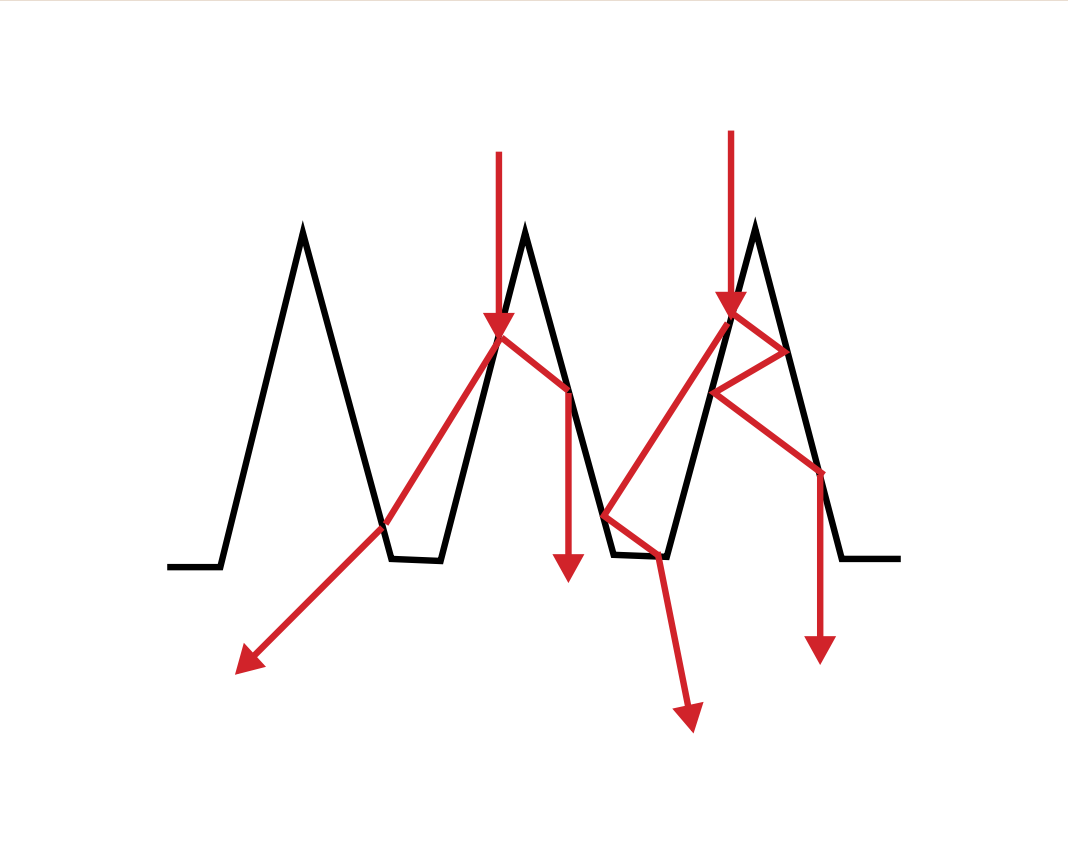
Total integrated absorptance



What causes the absorption?

Why such high absorptance?

Microstructure shape can increase absorption



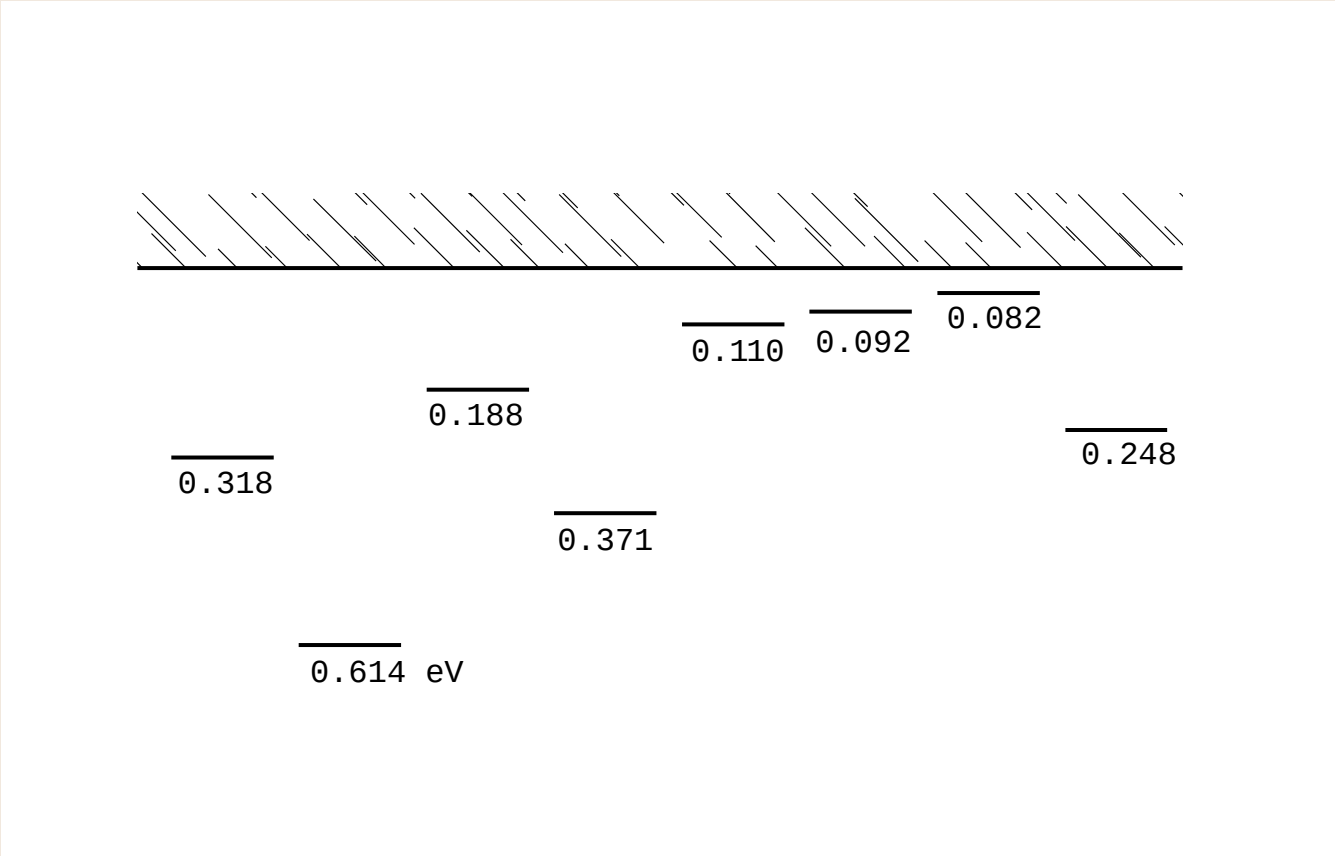
Why such high absorptance?

Secondary ion mass spectrometry

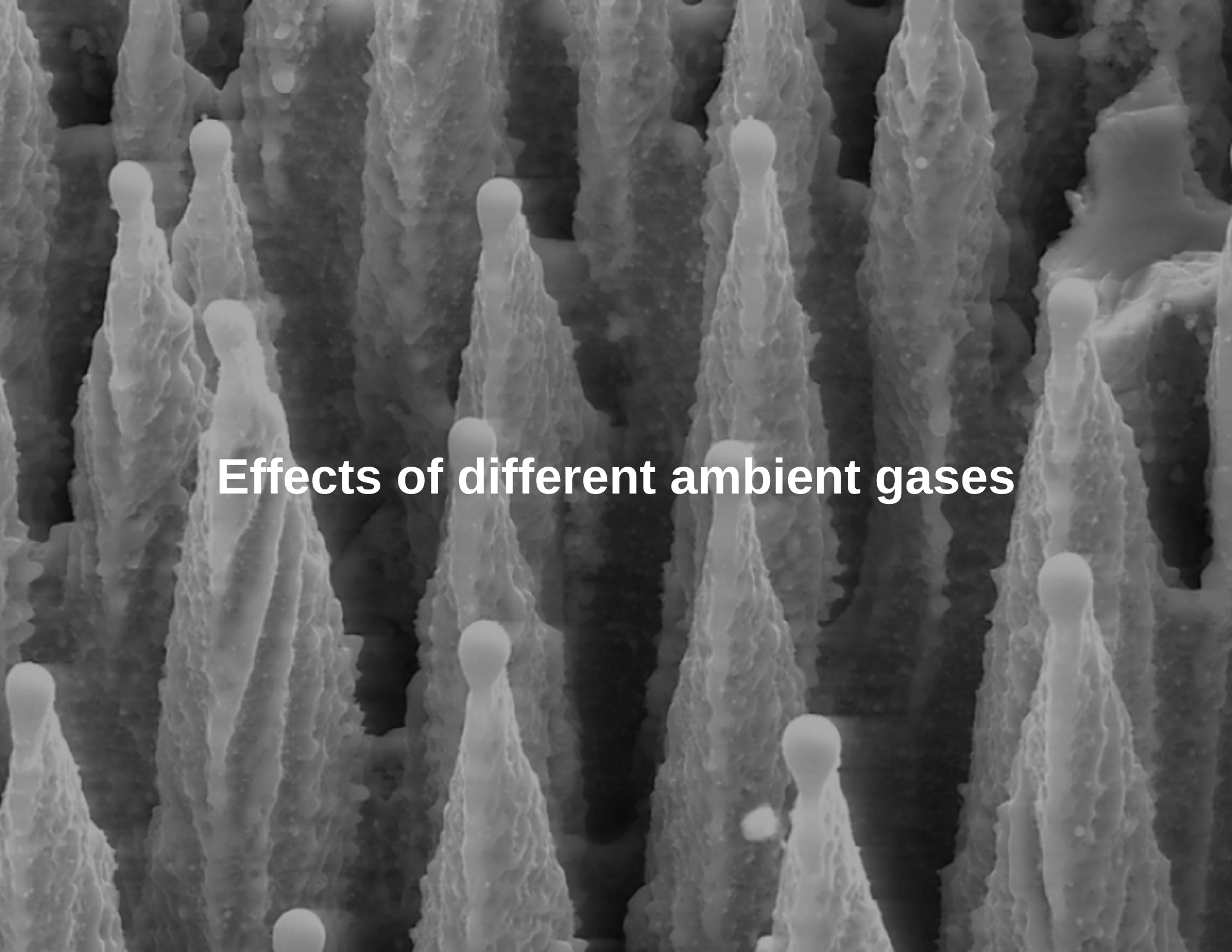
- **High concentration of sulfur (~ 10^{20} cm^{-3})**
- **Fluorine (~ 10^{17} cm^{-3})**

Why such high absorptance?

Sulfur adds states in Si band gap

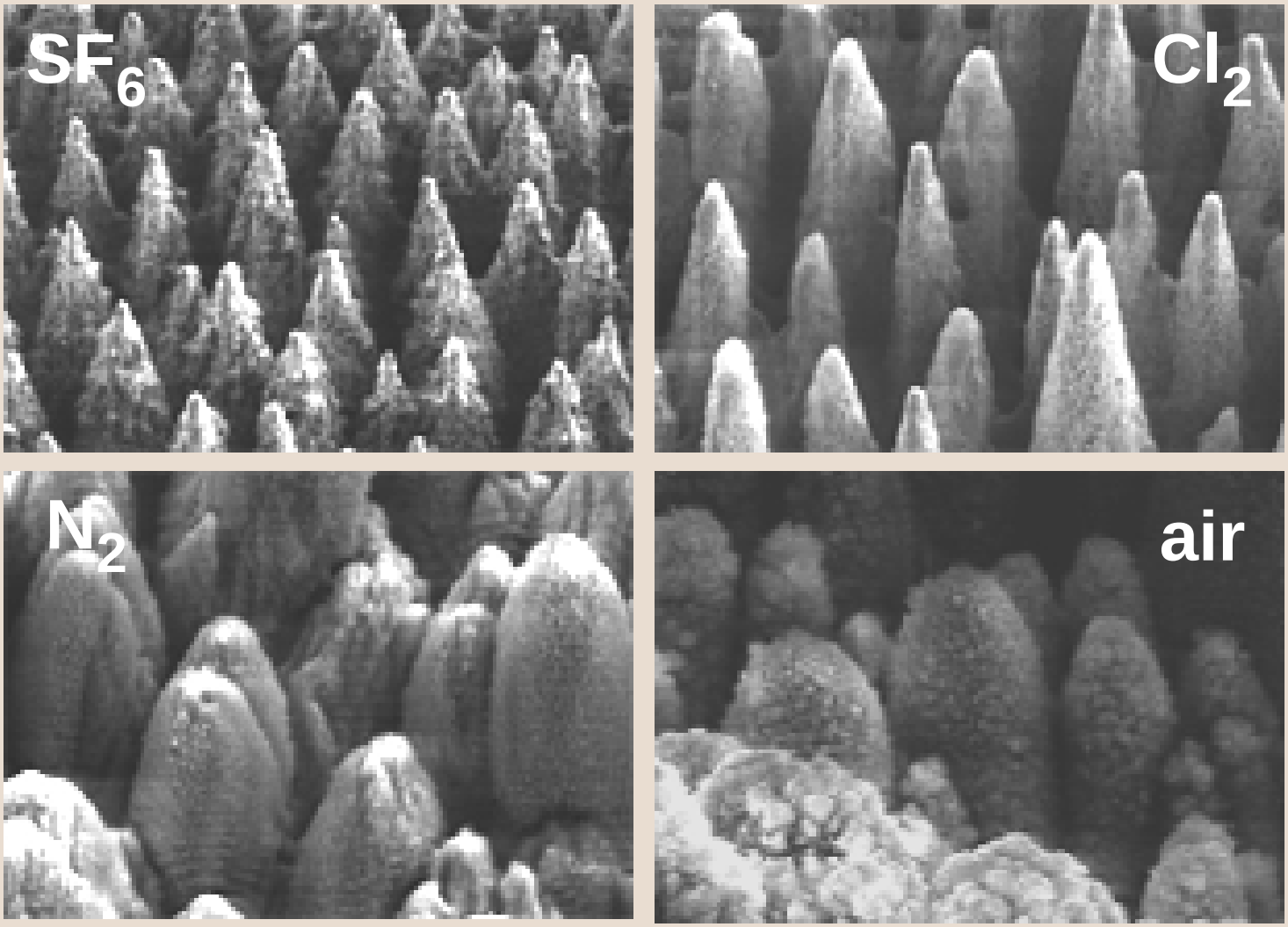


States in gap allow subgap absorption



Effects of different ambient gases

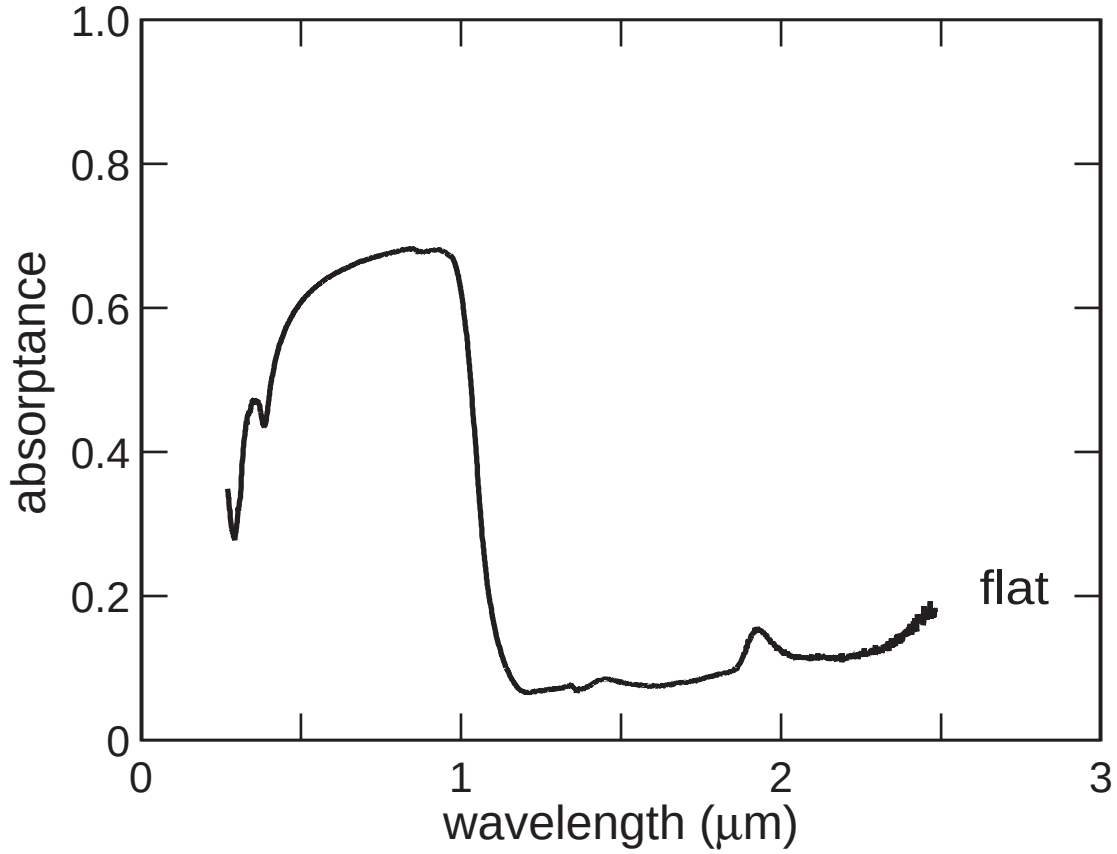
Different ambient gases



10 µm

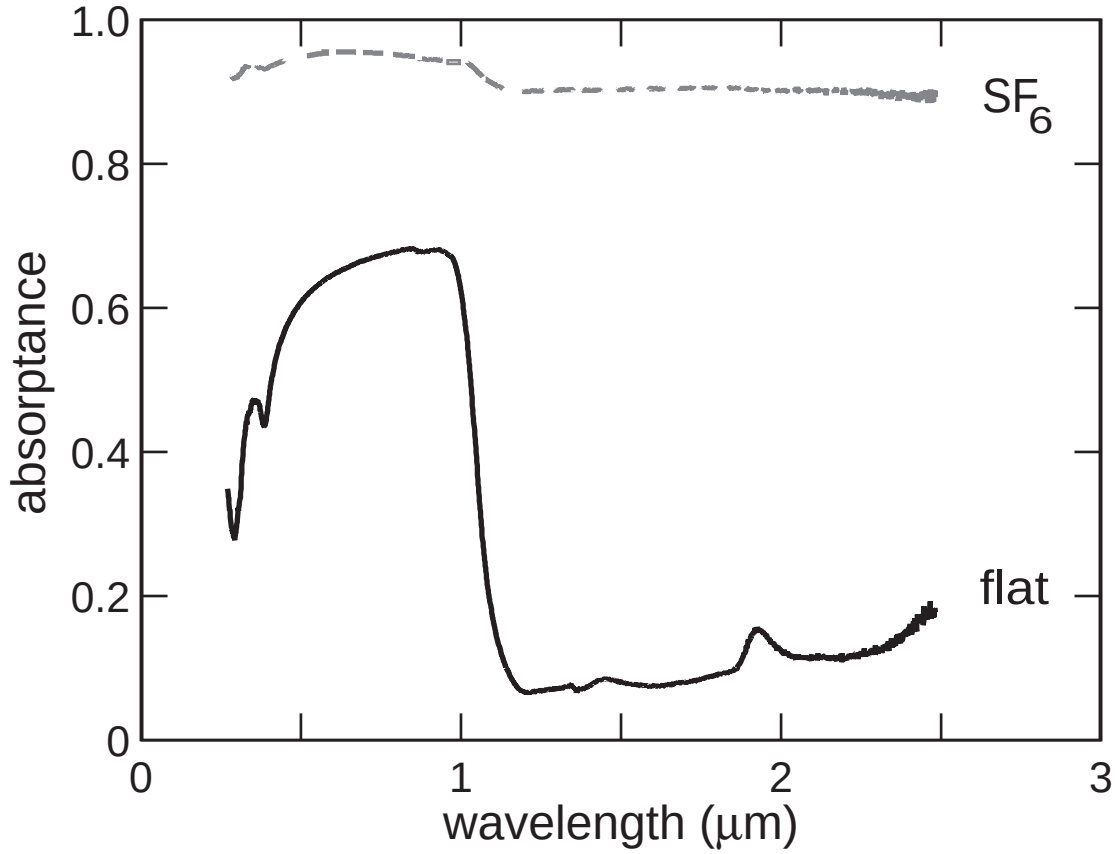
Different ambient gases

Absorptance



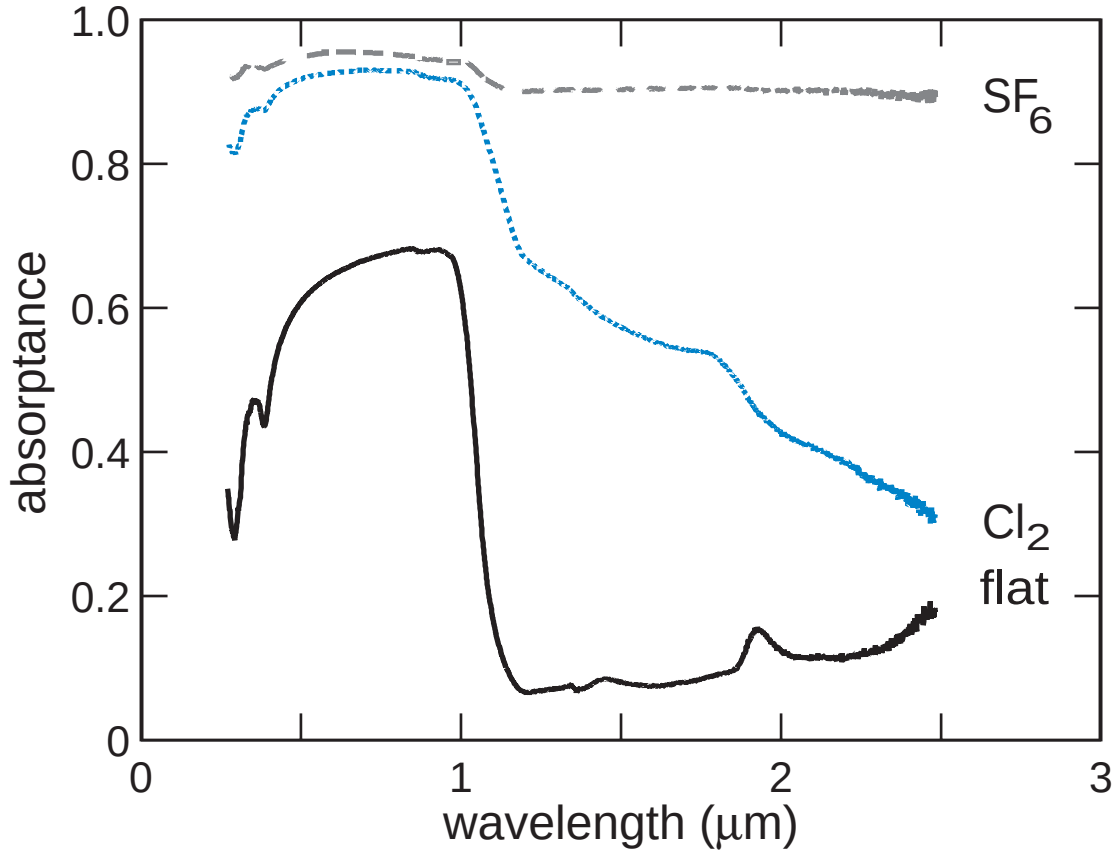
Different ambient gases

Absorptance



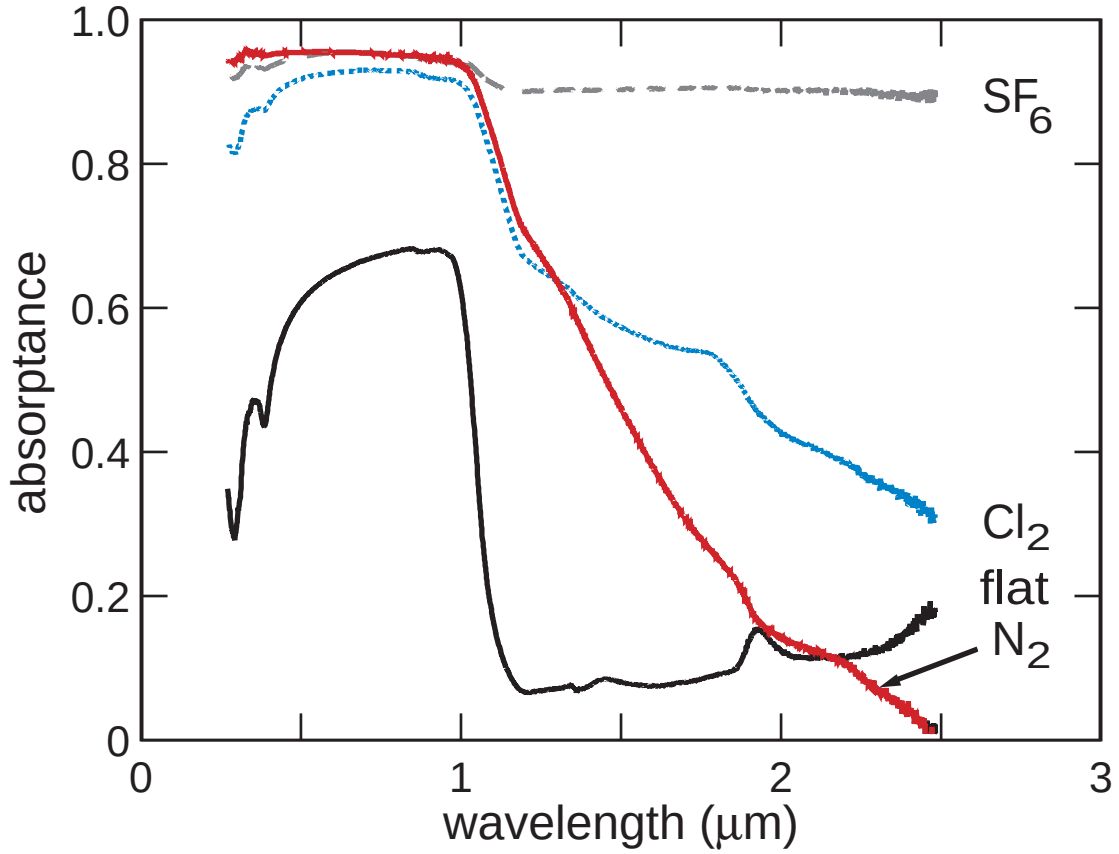
Different ambient gases

Absorptance



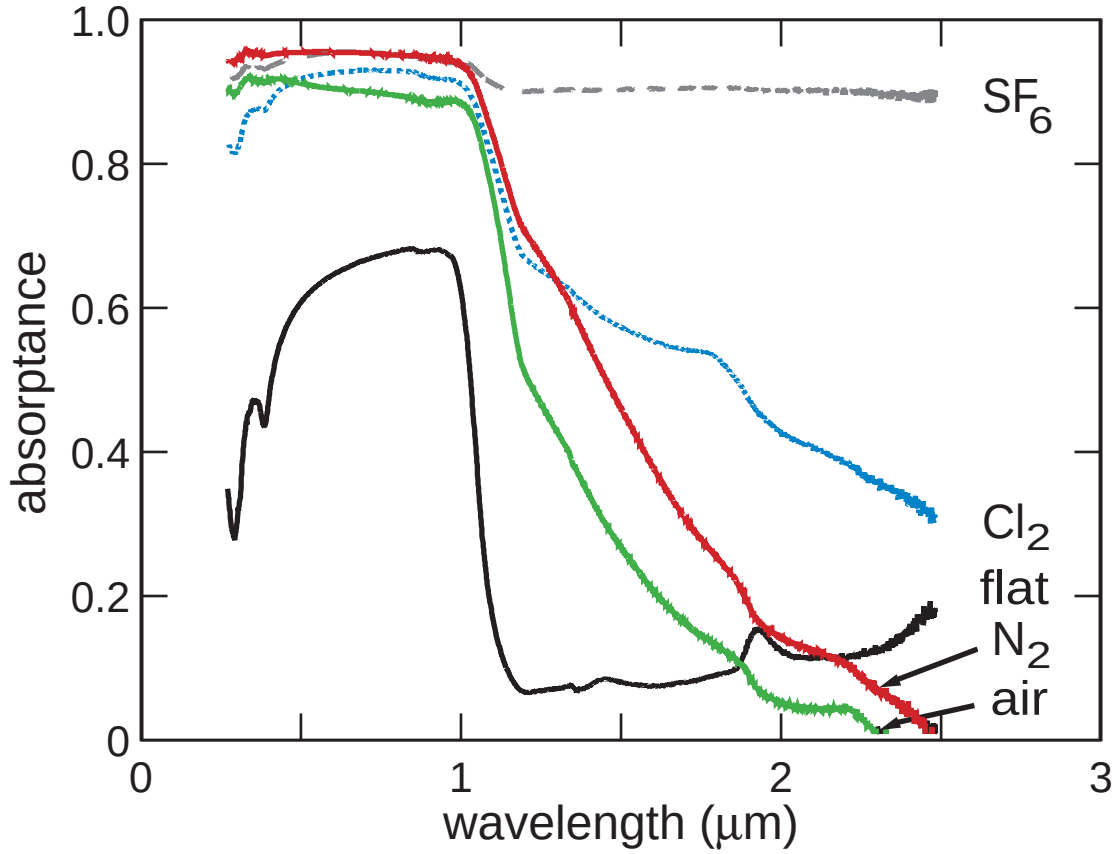
Different ambient gases

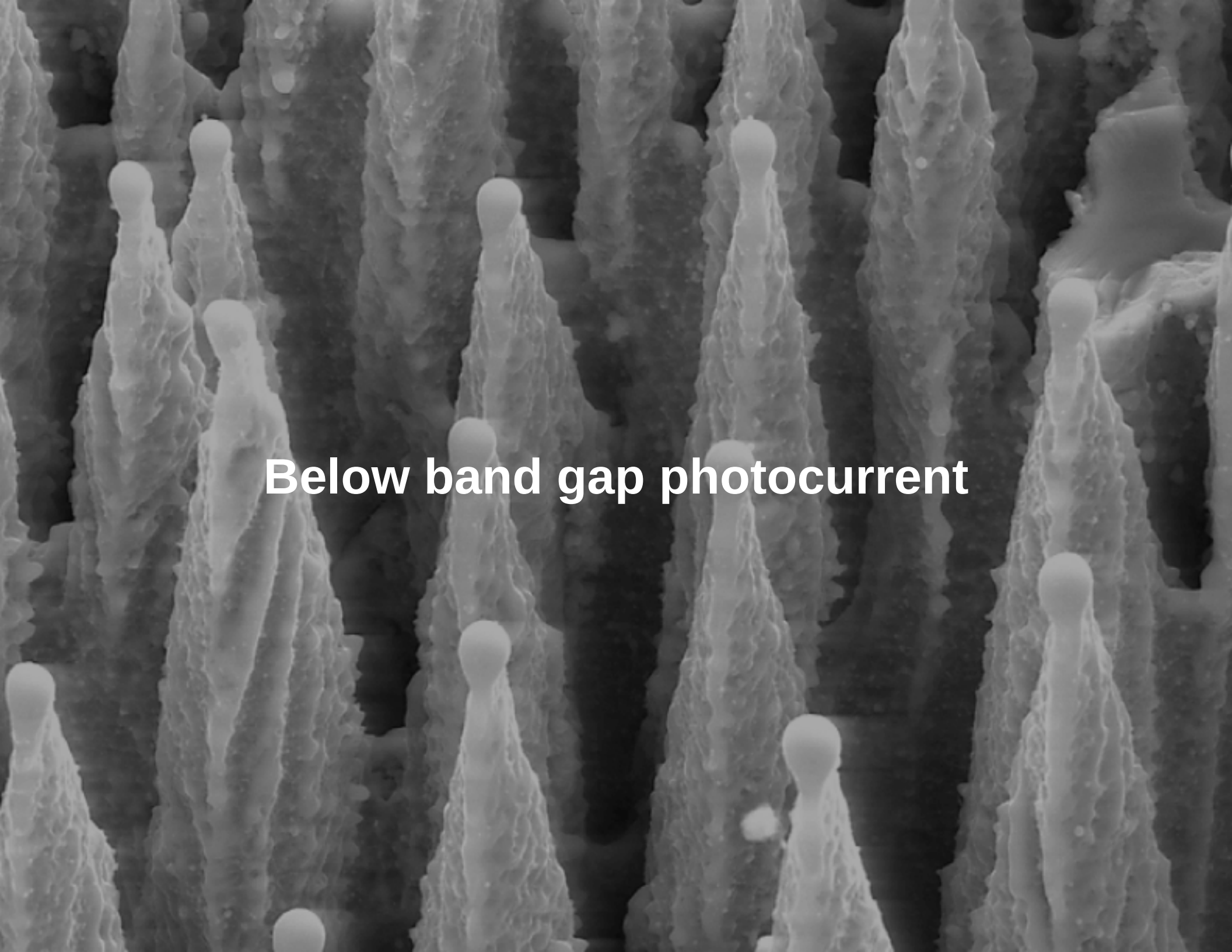
Absorptance



Different ambient gases

Absorptance

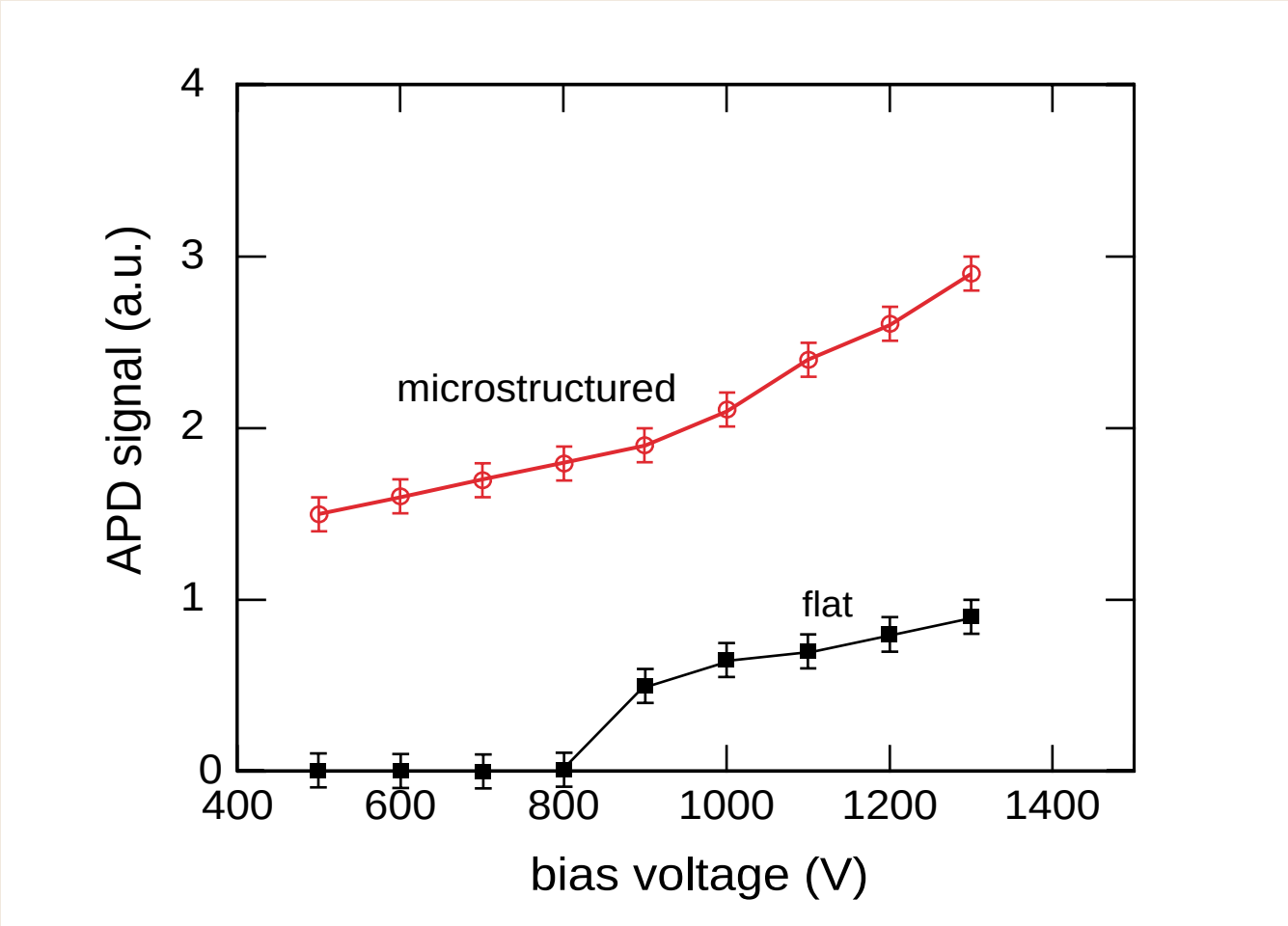




Below band gap photocurrent

Below band gap photocurrent

Avalanche photodiode response at 1.3 μm



Radiation Monitoring Devices, Watertown MA 02472

Conclusions

- Up to 90% infrared absorption
  → increased infrared photocurrent
- Absorption dependent on ambient gas
- Applications in infrared photodetectors, silicon solar cells, other possible devices

Acknowledgements

R.M. Farrell, P. Gothoskar, A. Karger,
Radiation Monitoring Devices, Watertown, MA

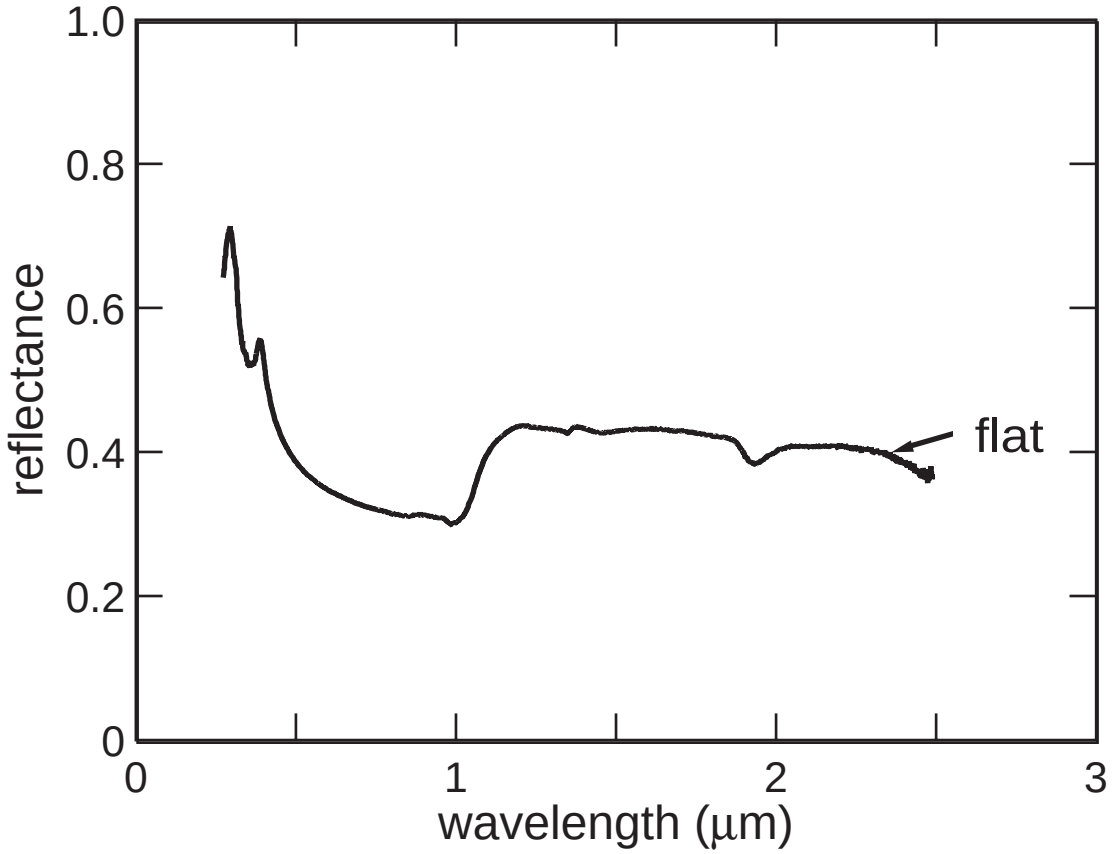
Li Zhao, Fudan University, Shanghai, China

funding: NSF, ARO

for more information, see:
Appl. Phys. Lett. 78, 1850 (2001).
http://mazur-www.harvard.edu

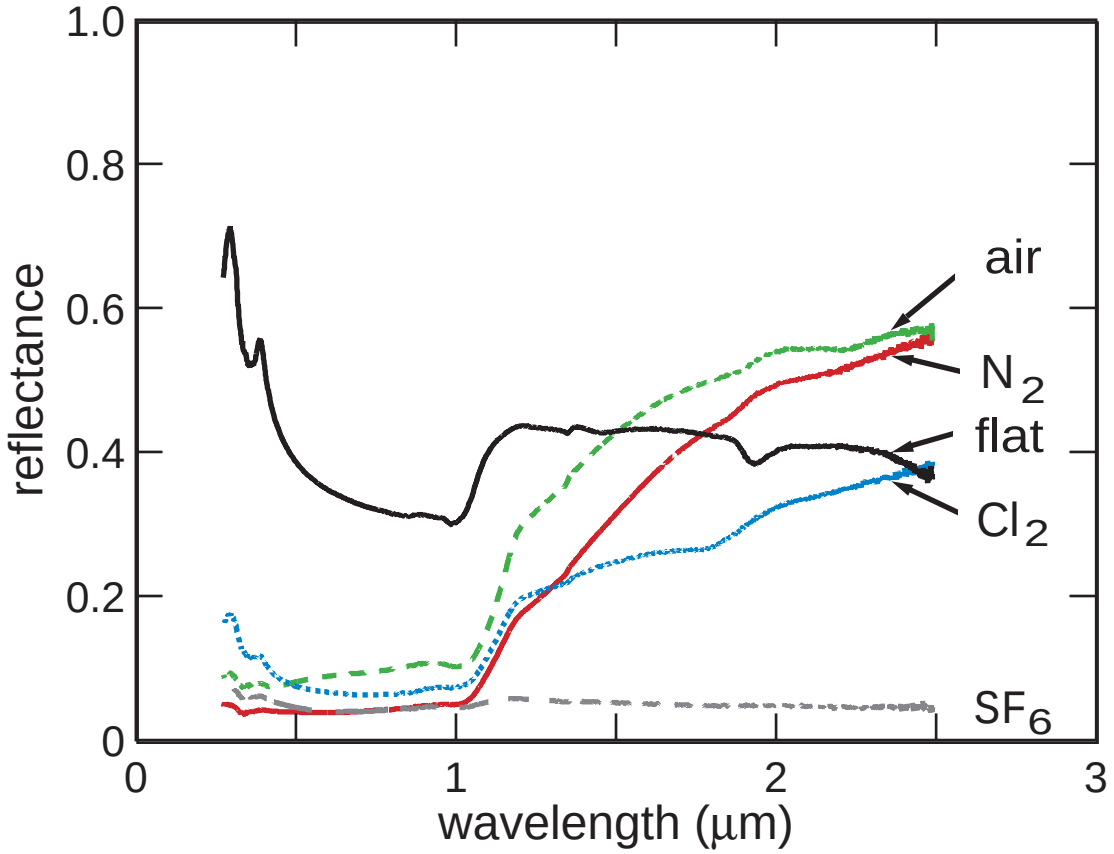
Different ambient gases

Reflectance



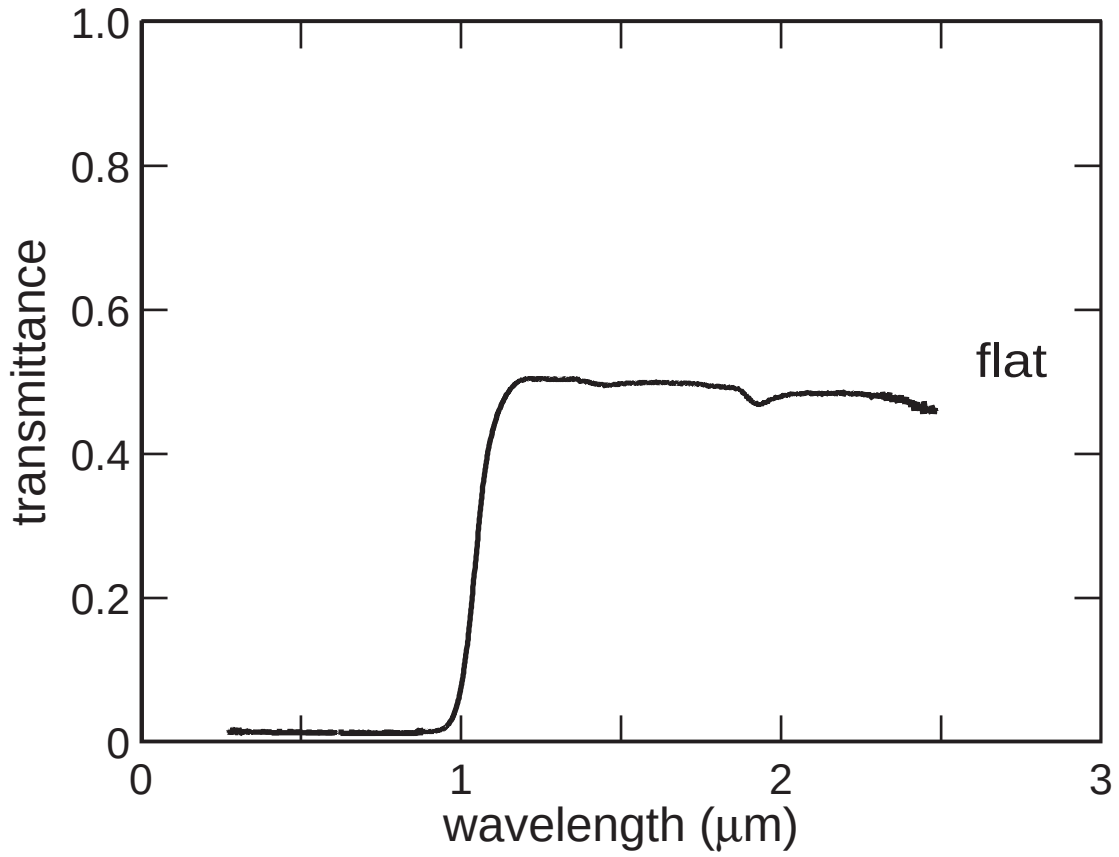
Different ambient gases

Reflectance



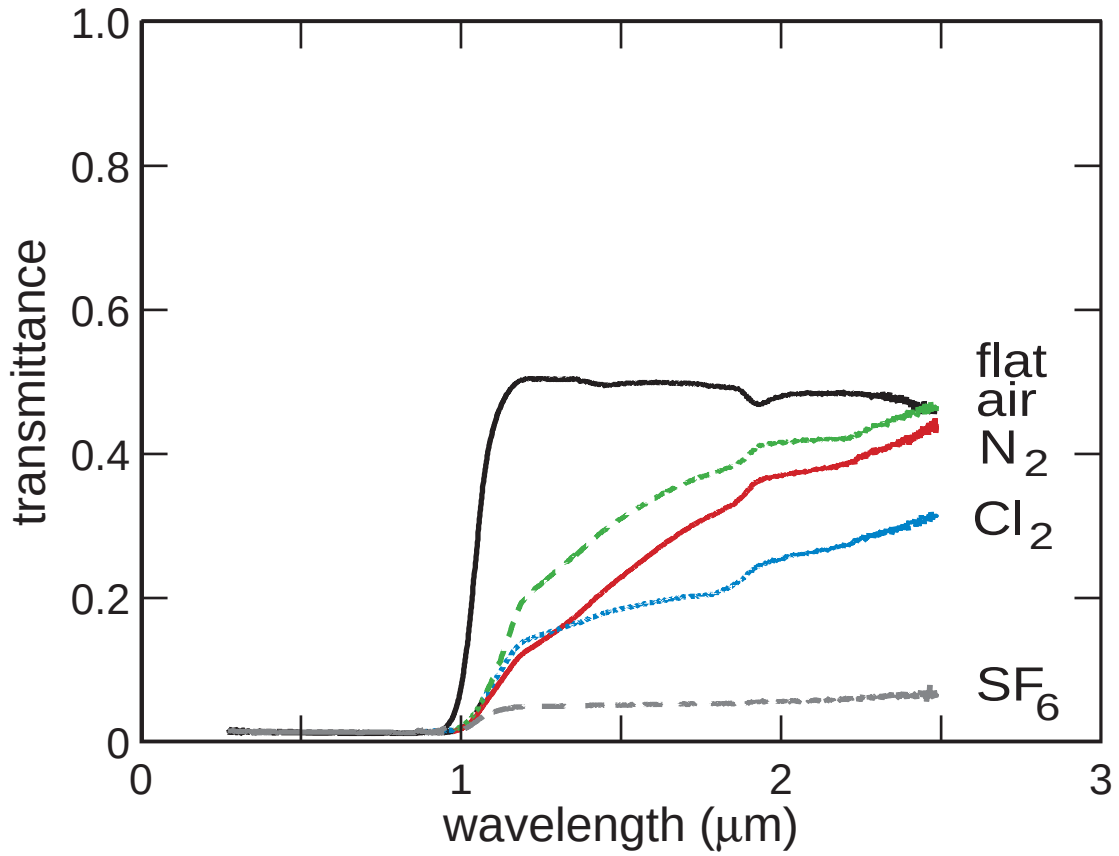
Different ambient gases

Transmittance



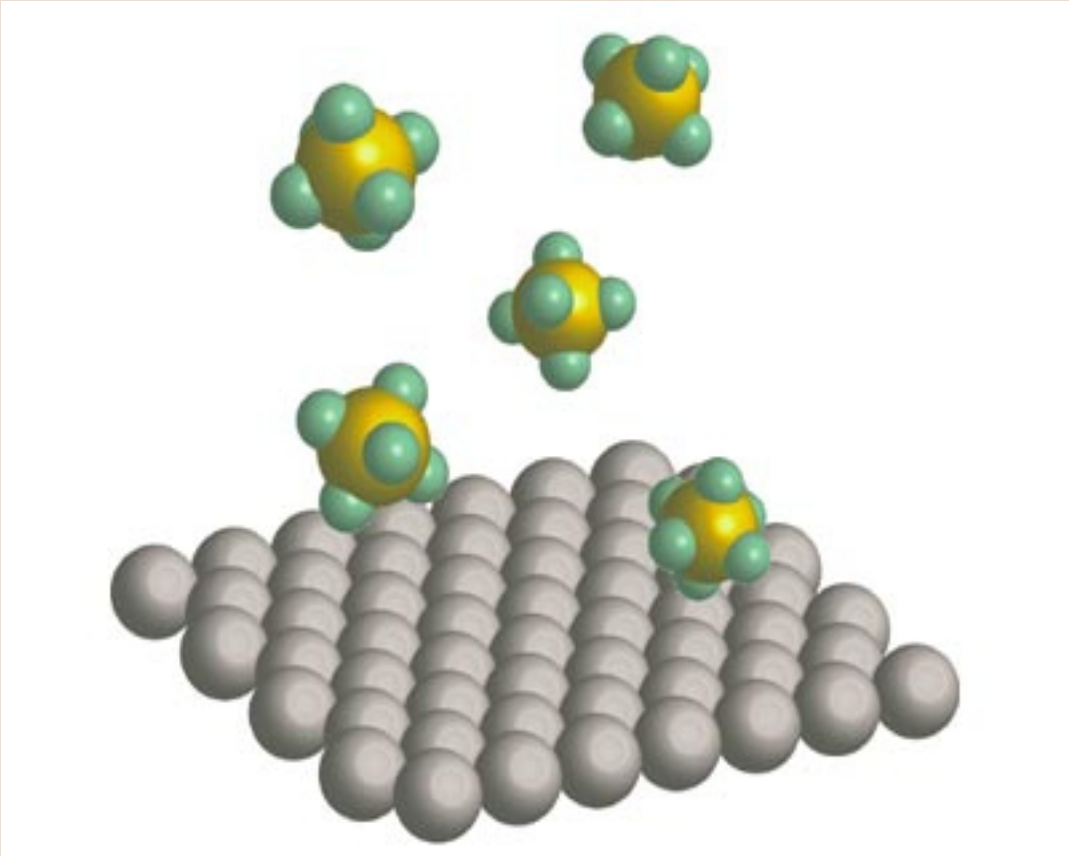
Different ambient gases

Transmittance



Microstructured silicon

irradiate with 100 fs, 10 kJ/m^2 laser pulses in SF_6



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