Comparing properties of femtosecond and nanosecond laser-structured silicon

Catherine H. Crouch
James E. Carey
Jeffrey M. Warrender
Michael J. Aziz
Eric Mazur

Harvard University

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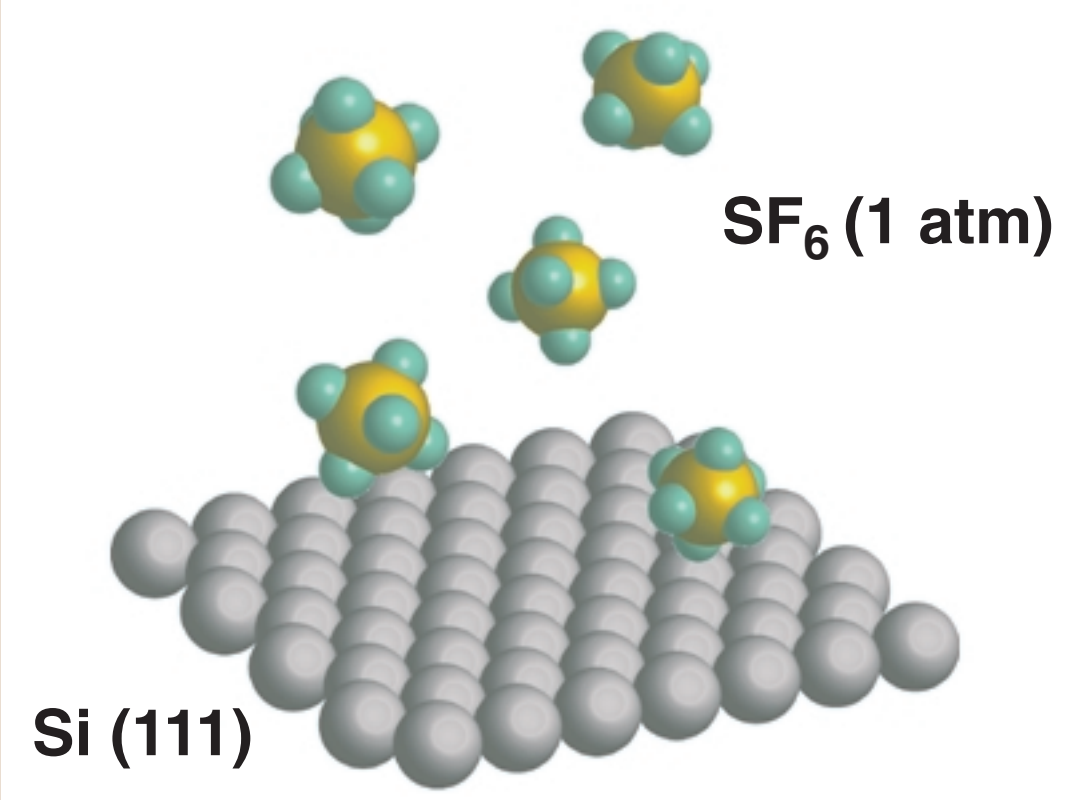
Laser-structured silicon



Irradiate surface with pulsed laser above ablation threshold

Motivation

fs pulses: Her *et al.*, APL **73**, 1673 (1998)
ns pulses: Pedraza *et al.*, APL **74**, 2322 (1999).

How do nanosecond and femtosecond compare?

Outline

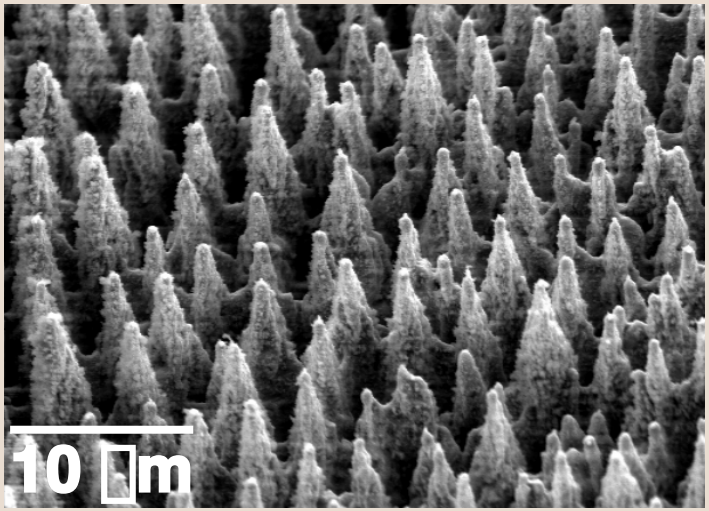
Morphology

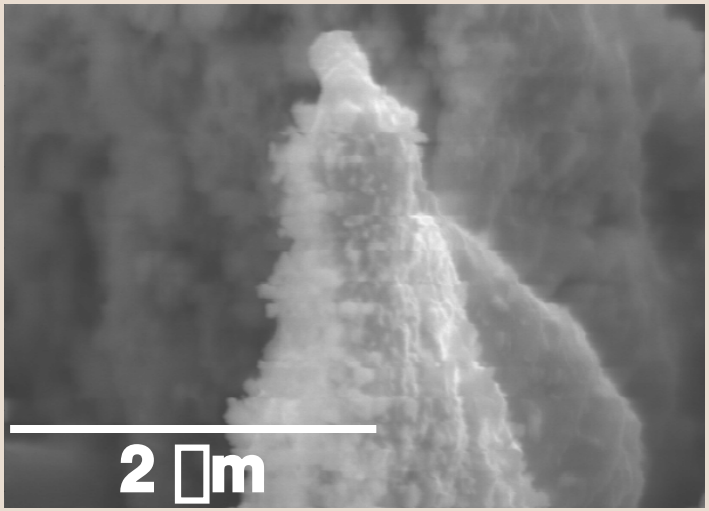
Optical properties

Chemical and structural analysis

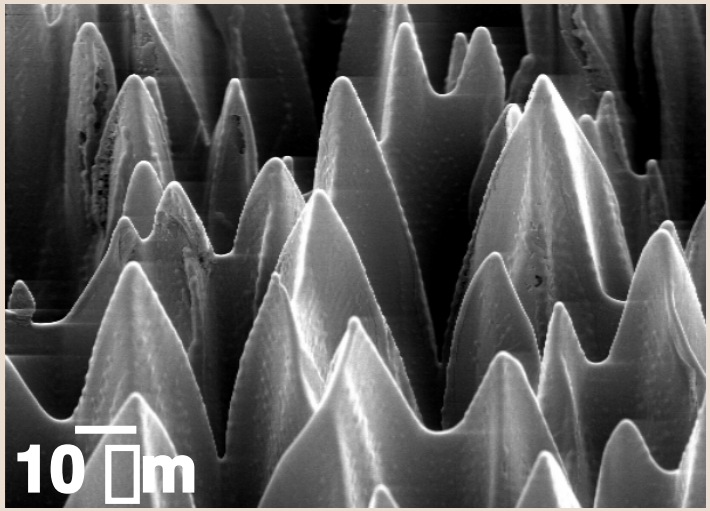
Morphology

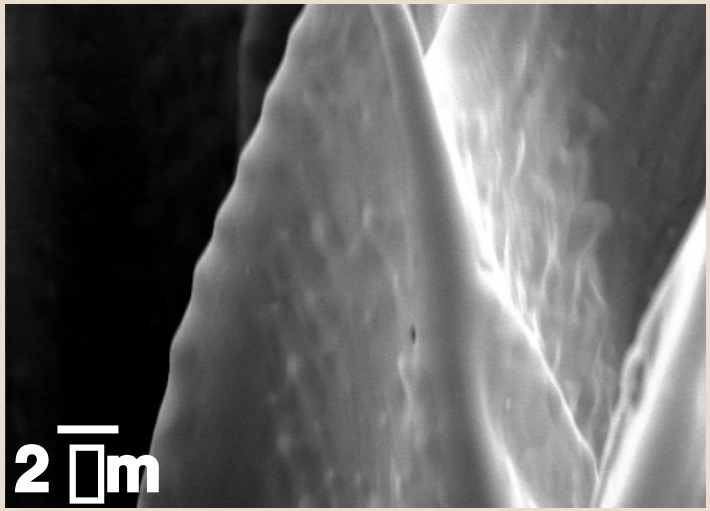
800 nm, 100 fs, 10 kJ/m^2





248 nm, 30 ns, 30 kJ/m^2

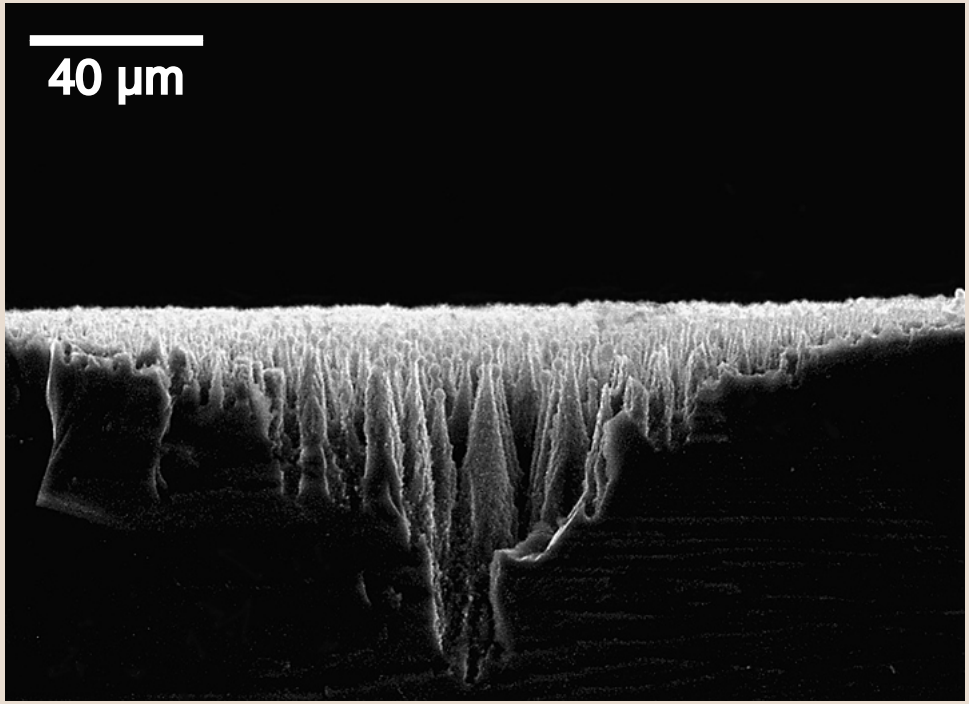




Nanosecond cones bigger, smoother

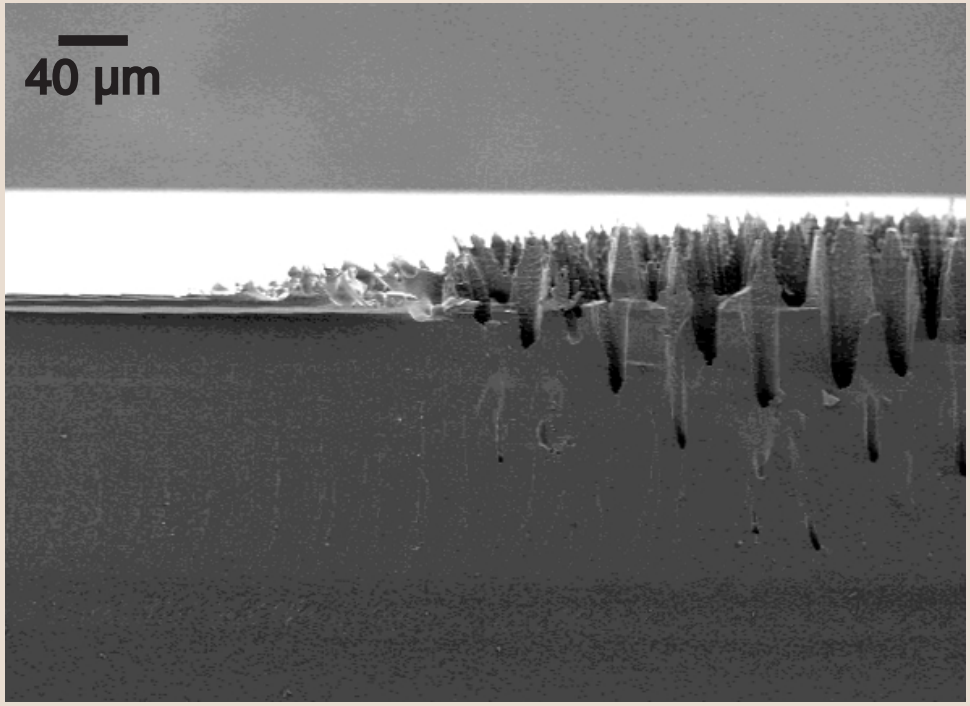
Morphology

800 nm, 100 fs, 10 kJ/m^2



fs cones etched below surface

248 nm, 30 ns, 30 kJ/m^2



ns cones grow above surface

Morphology

Nanosecond cones bigger, smoother

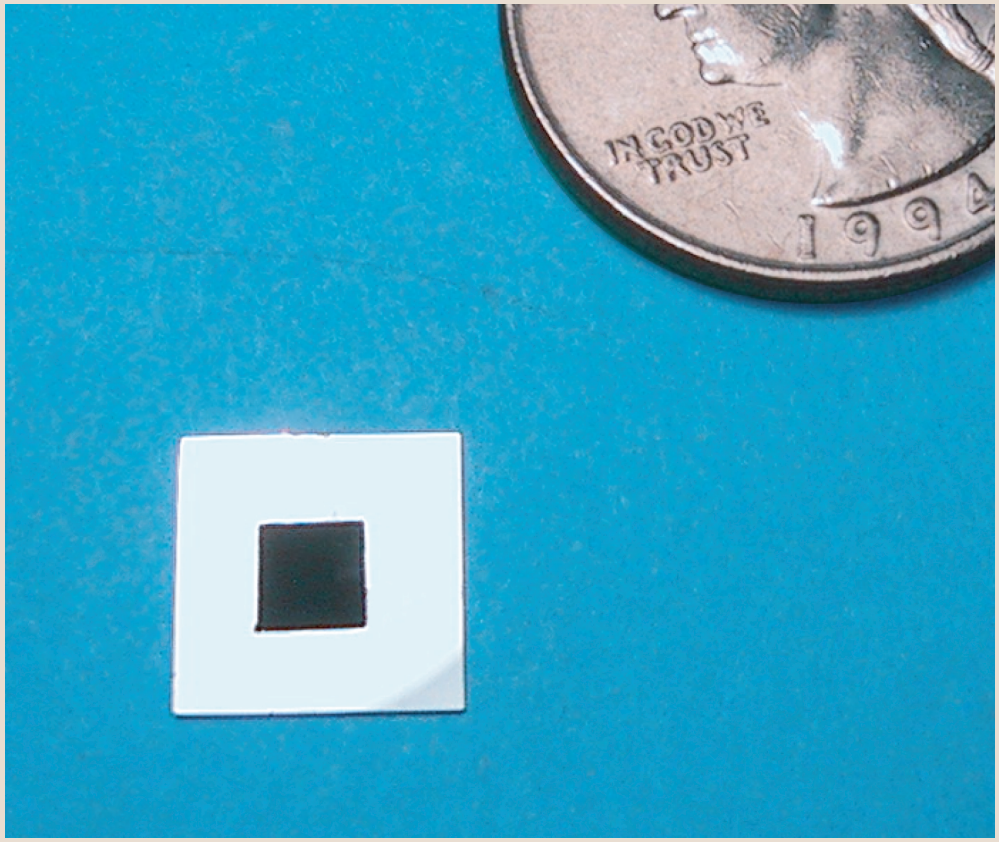
Nanosecond cones grow, femtosecond cones are etched

Morphology

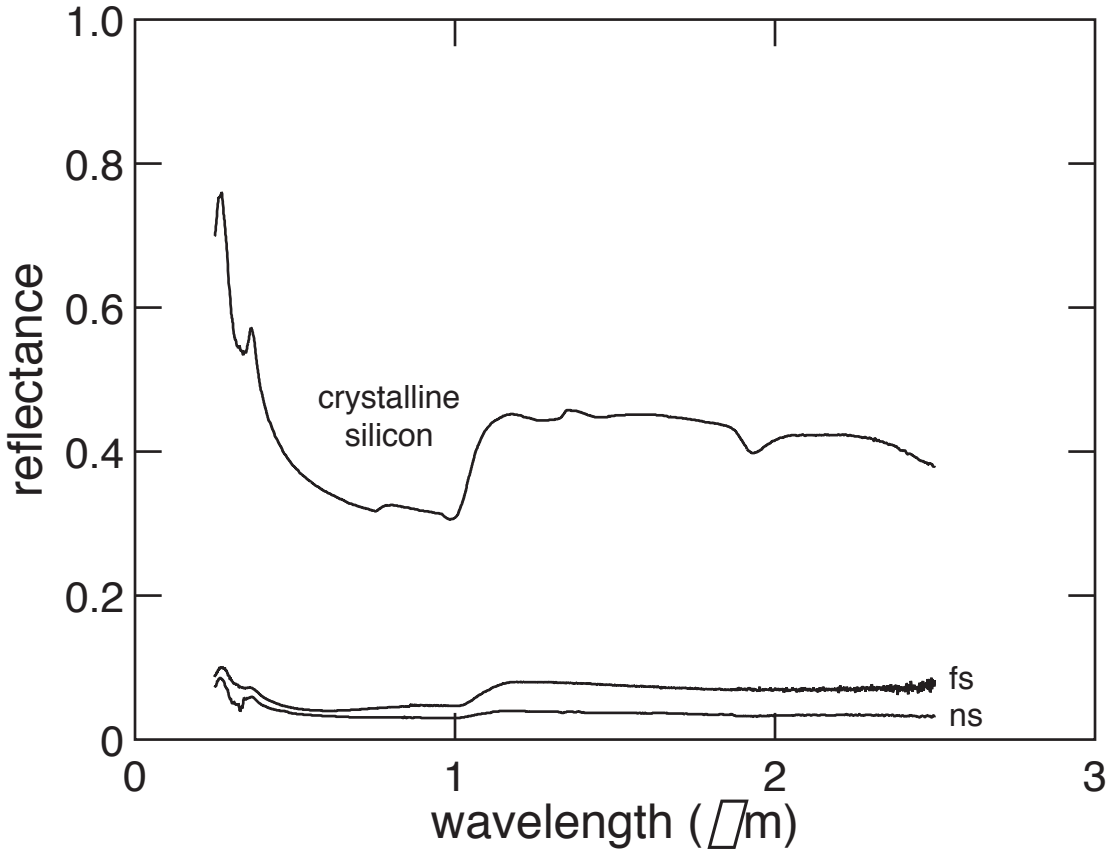
Very different morphology!

How do optical properties compare?

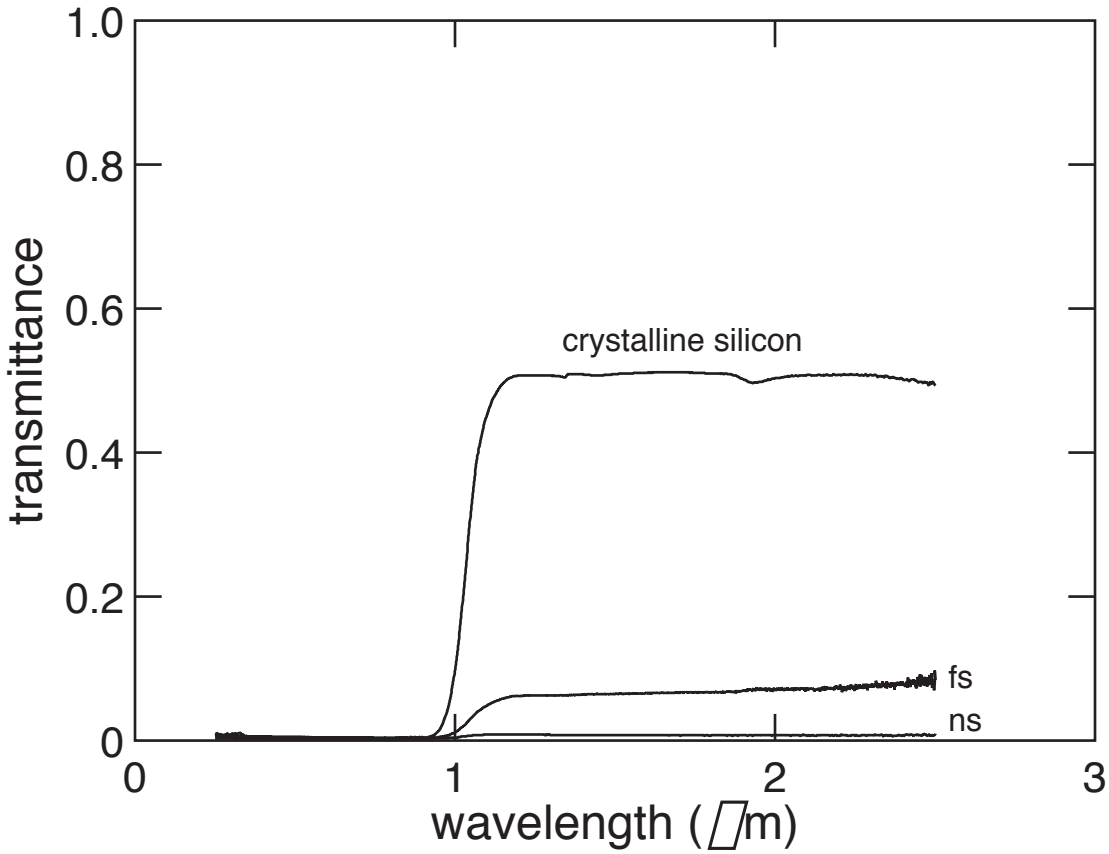
Optical properties



reflectance

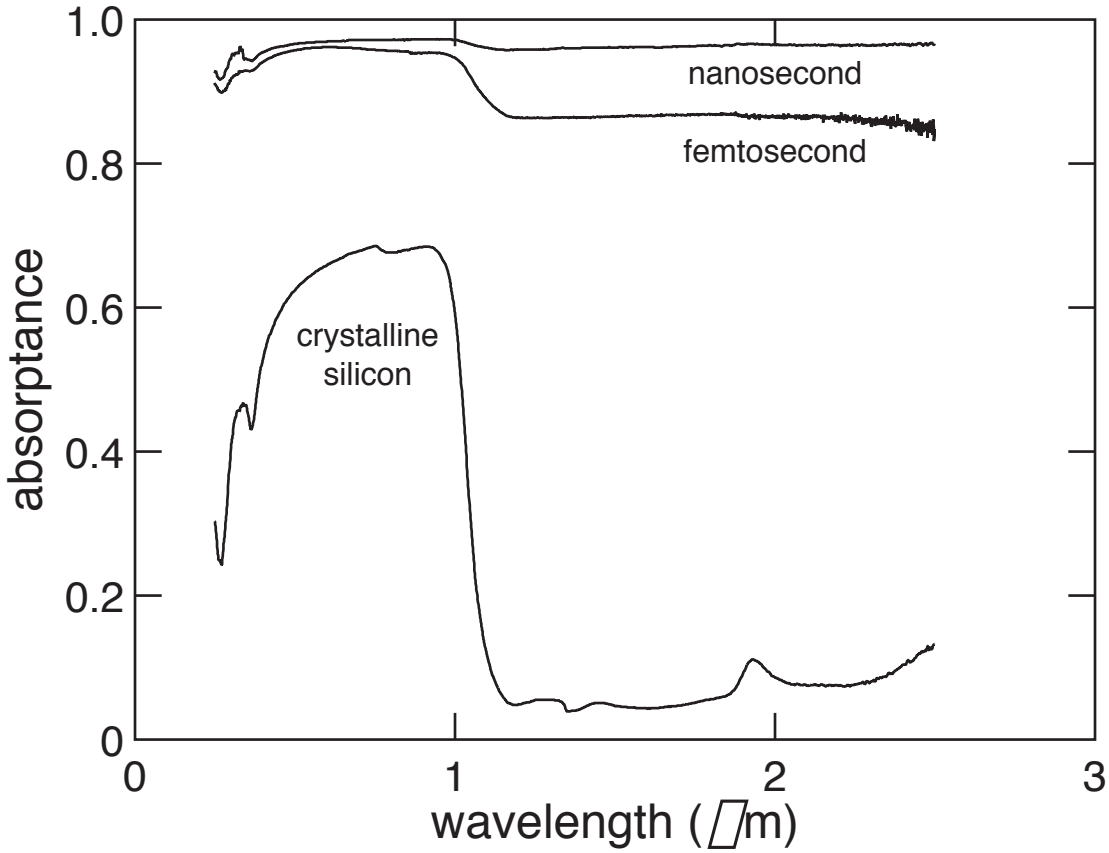


transmittance



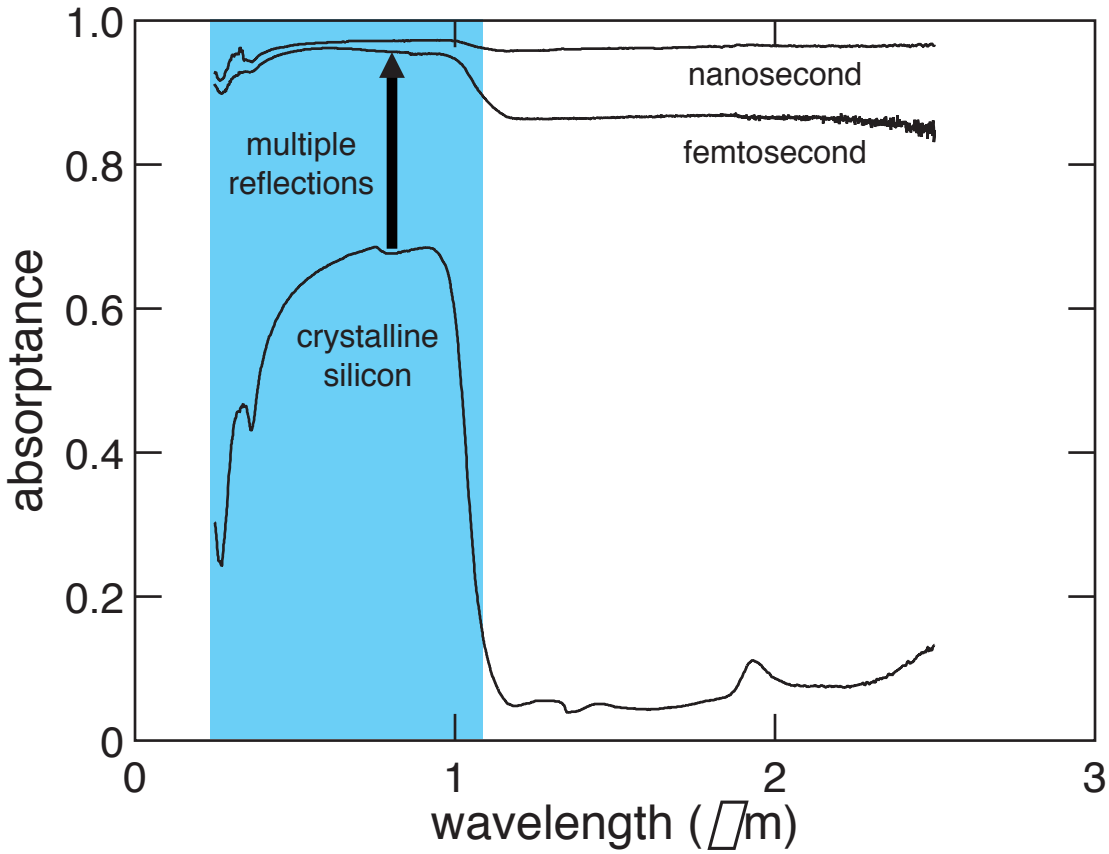
Optical properties

absorptance



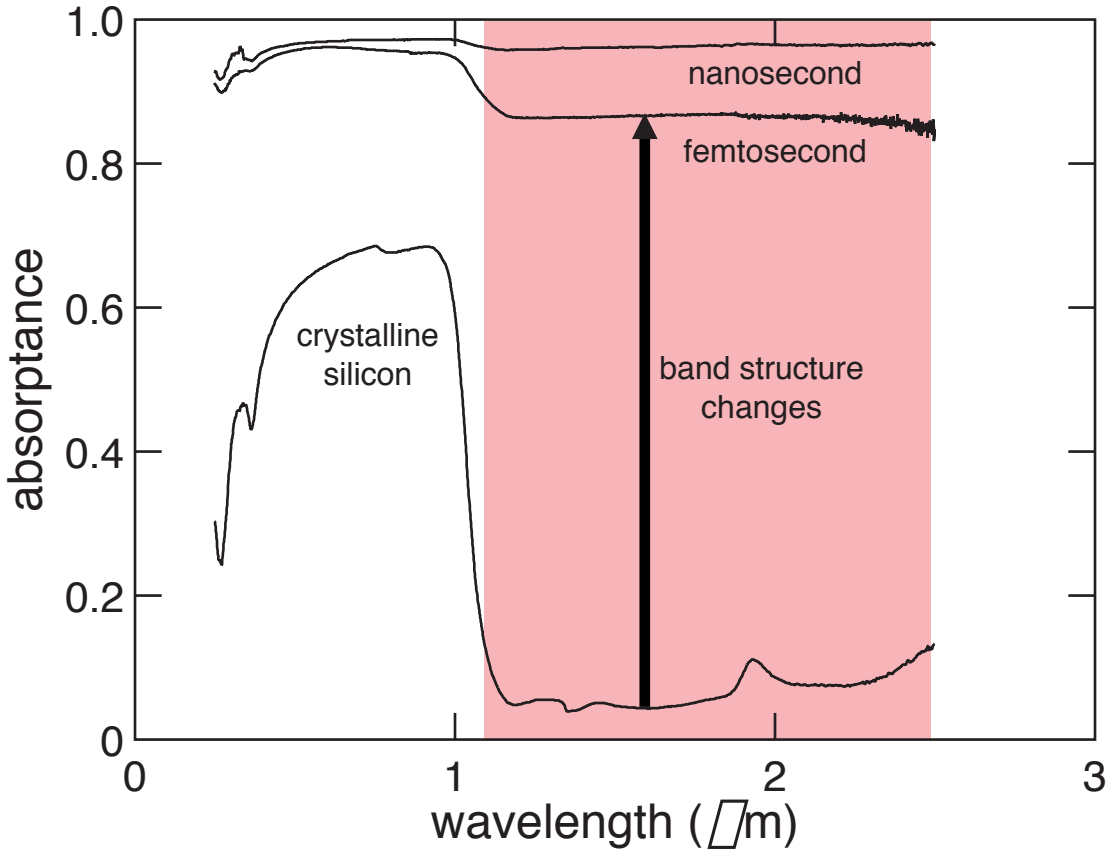
Optical properties

absorptance



Optical properties

absorptance



What produces the below-band gap absorption?

Previous work with fs pulses:

ambient species incorporated into cones at surface

sulfur required for below-band gap absorption

Younkin *et al.*, to appear in J. Appl. Phys.

Ns and fs cone composition similar

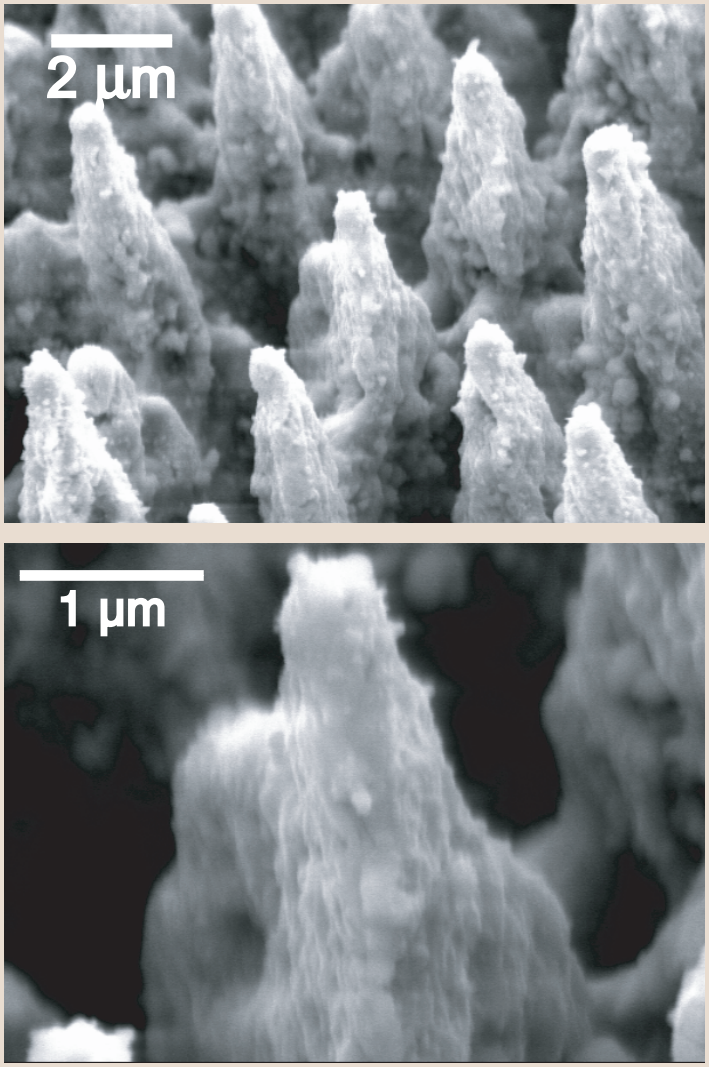
roughly 1% sulfur in surface layer (ion channeling, EDX, ToF SIMS)

sulfur content decreases significantly on annealing

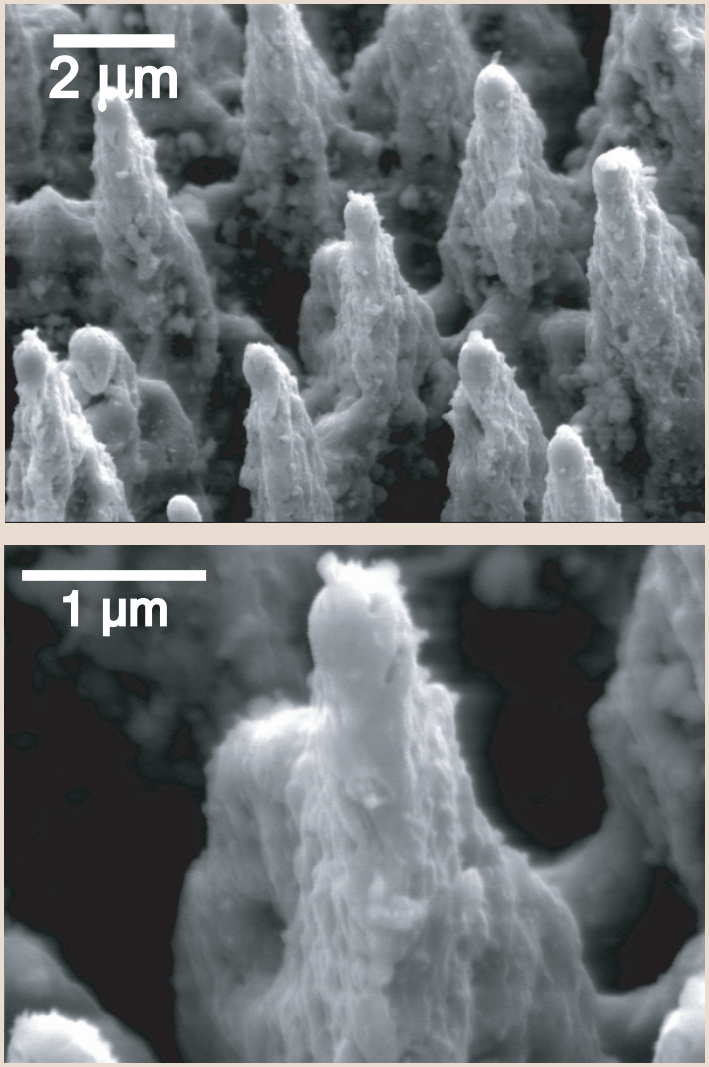
also high fluorine content (ToF SIMS)

Analysis

before annealing

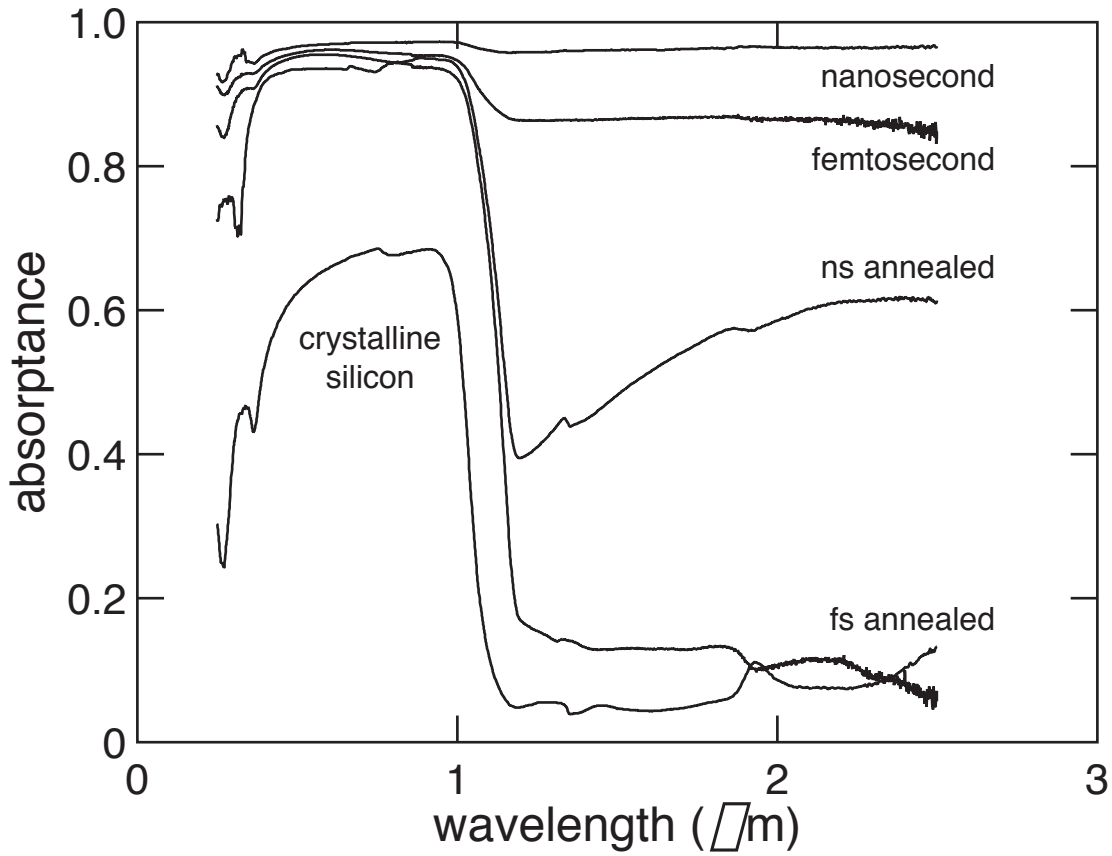


after annealing



Optical properties

absorptance



Structural analysis

Ion channeling:

- **both ns and fs cones crystalline with high defect density**
- **fs cones show much greater disorder**
- **annealing reduces disorder somewhat**

cross-sectional TEM of fs cones:

- **disordered surface layer ~500 nm thick, crystalline core**
- **surface layer includes nanoparticles and nanopores**

Conclusions

Femtosecond vs. nanosecond:

- **Optical properties virtually identical**
- **Composition and structure similar**
- **Morphology vastly different!**

Conclusions

Fs and ns laser structuring both:

- **produce below-band gap absorption**
- **incorporate sulfur**
- **form crystalline cones with surface defects**

Both below-band gap absorption and sulfur content decrease after annealing

Acknowledgements

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For a copy of this talk and additional information:

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