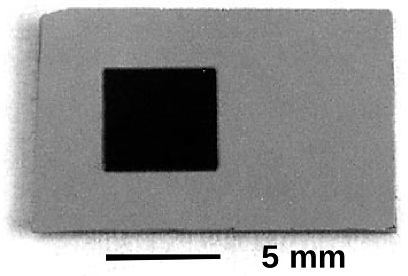
Silicon microtexturing using ultrashort laser pulses

Cynthia M. Friend and Eric Mazur

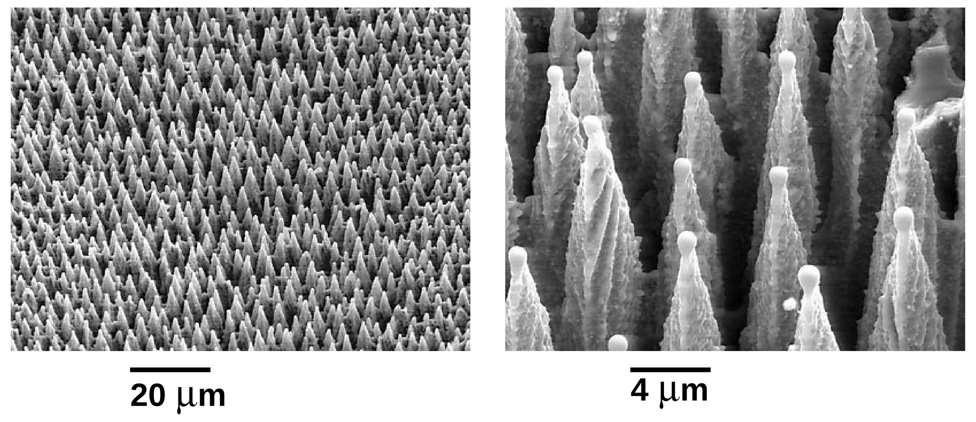
contributors: J.E. Carey, C.H. Crouch, J. Levinson, M. Sheehy, R. Younkin

Introduction

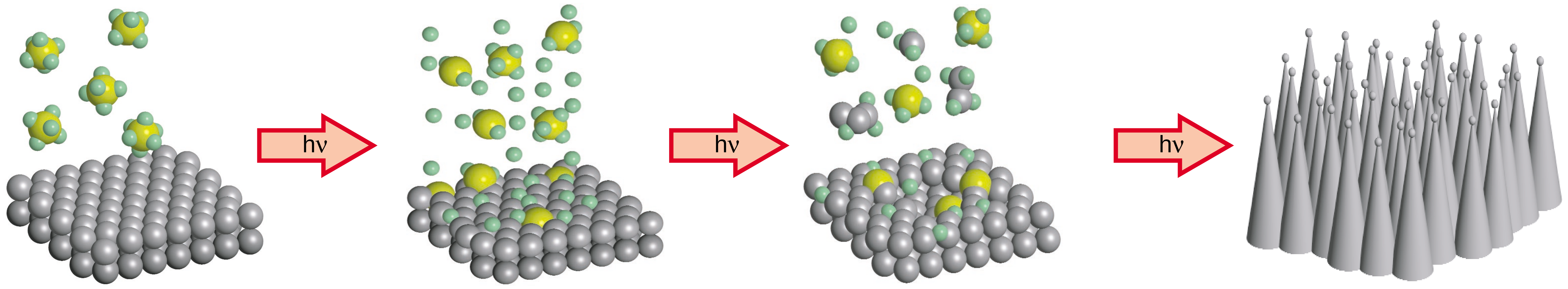
We created sharp conical microstructures in silicon by irradiating Si (111) surfaces with a train of 100-fs laser pulses in the presence of SF_6, Cl_2, N_2, or air. The textured surface appears black, with an absorptance of up to 90% for 250nm < λ < 2500 nm.



- Microstructures are typically 10—15 µm high, depending on formation conditions, with a 1-µm tip diameter
- Structures formed through interplay between optical excitation and surface chemistry

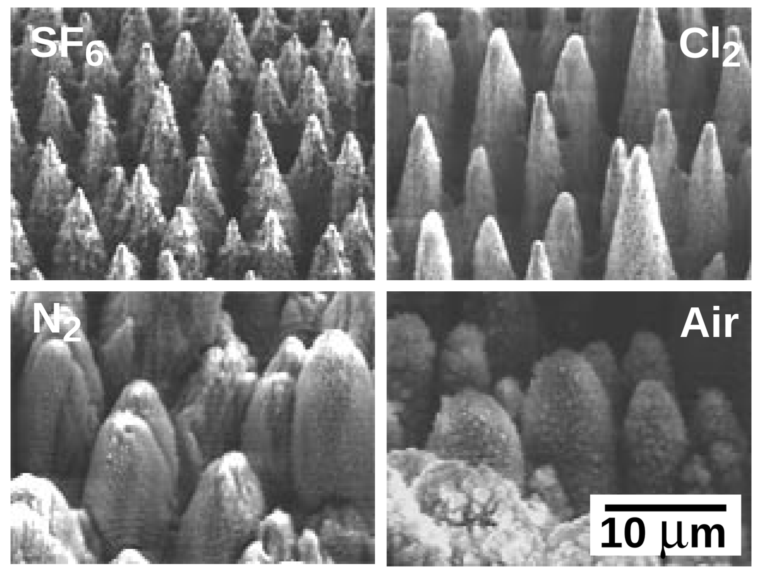


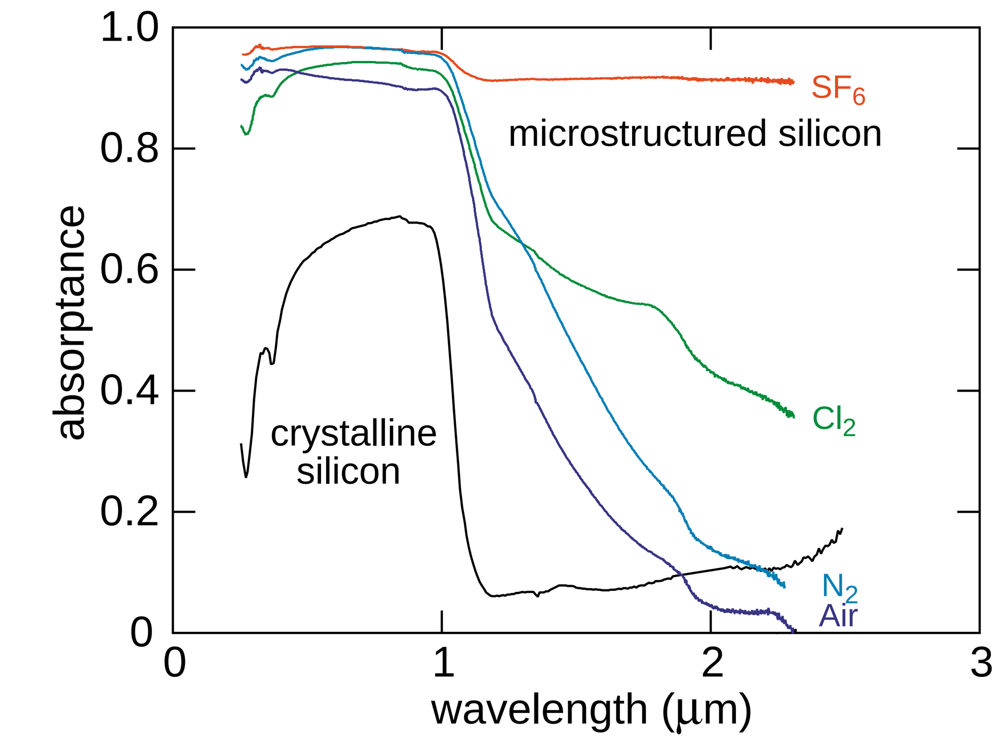
Upon irradiation, volatile compounds of silicon and fluorine are formed on the substrate surface. Removal of these compounds etches the surface.



Role of background gas

The morphology and optical absorption of the microstructures depend on ambient gas used during formation.



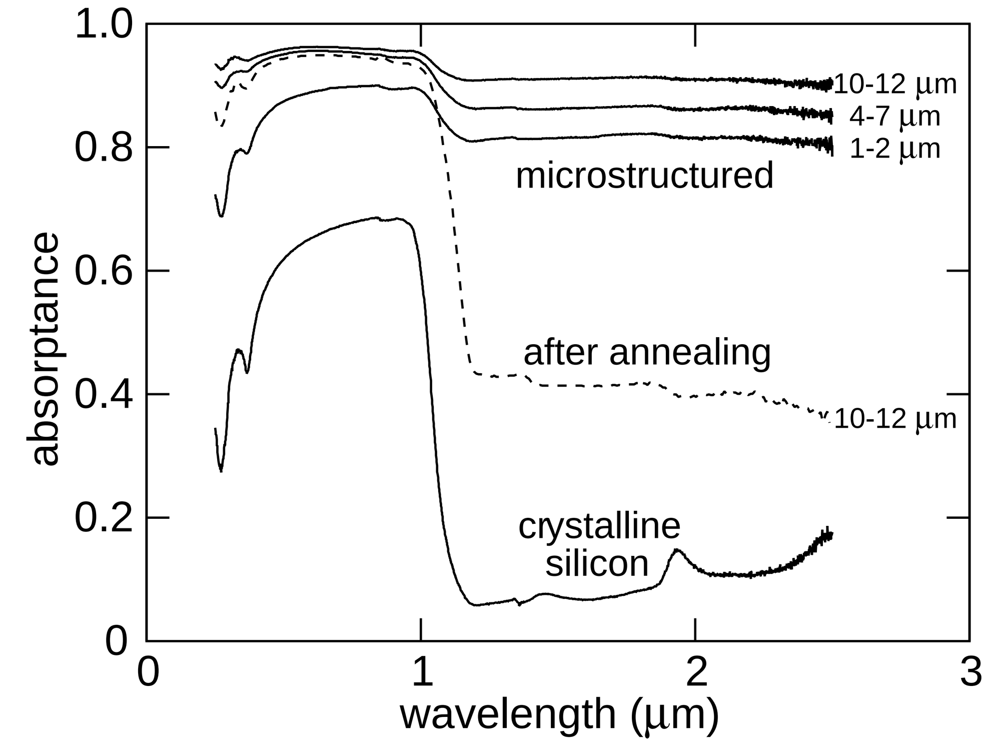


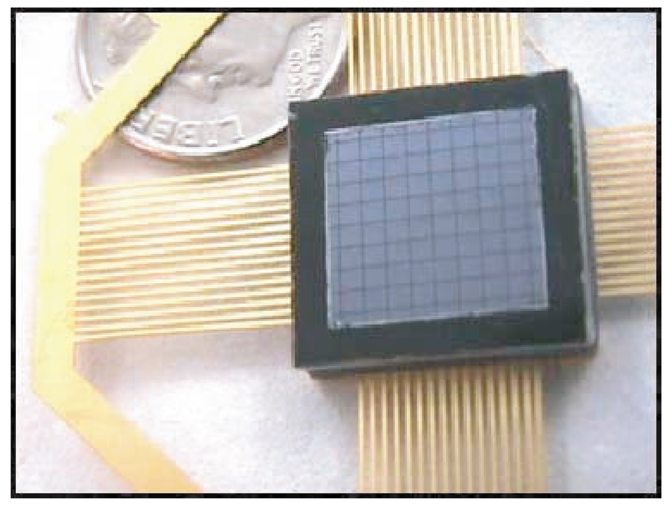
Structures produced in SF_6 show highest absorptance, especially in the infrared

Infrared absorption

Compared to flat silicon, microstructured silicon exhibits

- Increased optical absorptance in visible
- Absorption below the bandgap of Si (largest for tallest microsctructures)

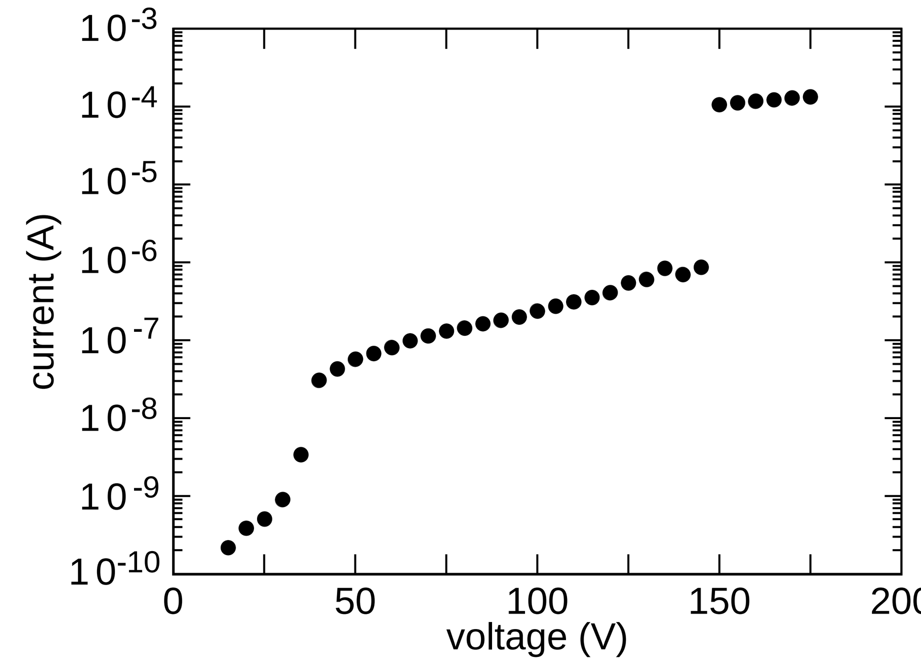


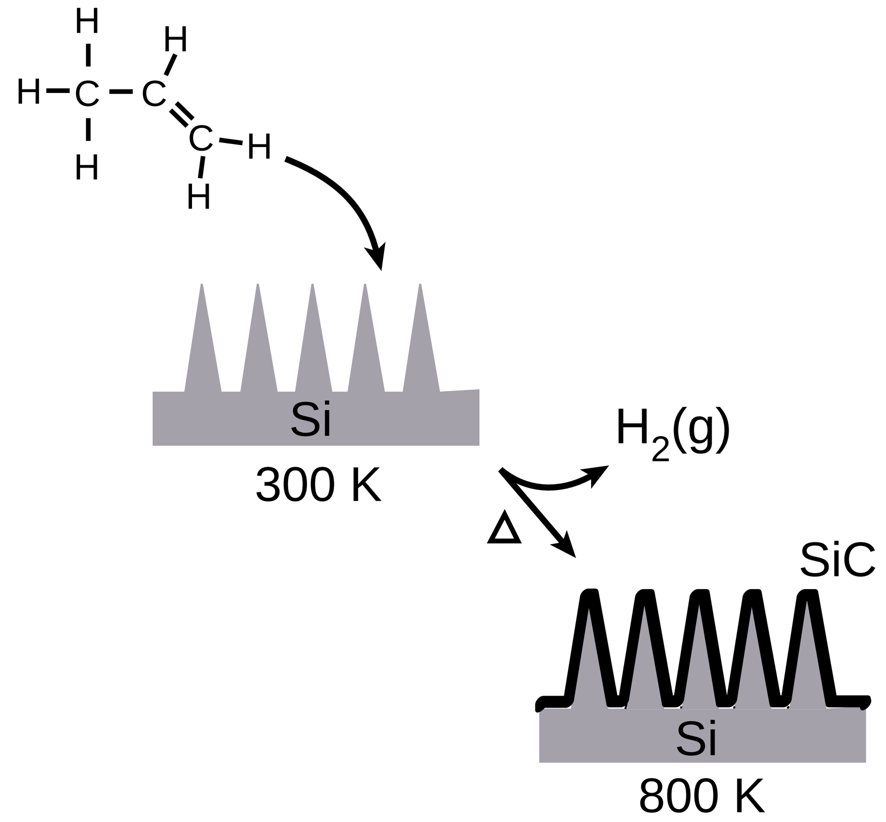


Avalanche photodetectors (left) patterned with microstructures show substantially increased photocurrent at λ = 1.3 µm relative to ordinary APDs

Applications and future work

- Microstructures show field emission (right) comparable to that of carbon nanotubes
- Microstructures formed in air produce strong photoluminescence in the visible





- Functionalization of surface to improve properties (e.g., chemical reactivity, field emission, etc.)
- Temperature-programmed reaction spectrometry for study of composition and thermal stability of surface layer