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

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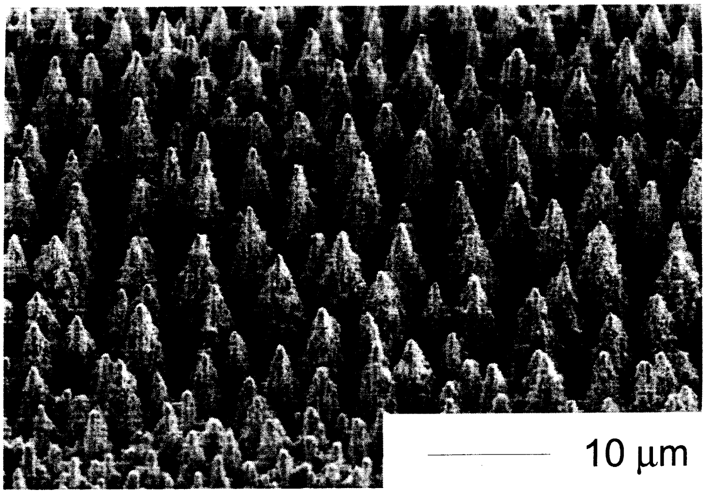
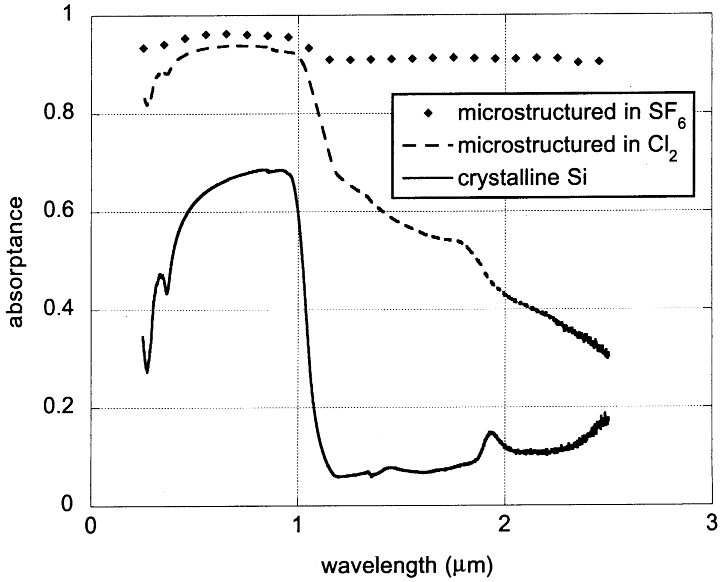
Previous work in our group has shown that novel conical microstructures are formed on the surface of silicon when it is irradiated with 100-fs laser pulses in the presence of halogen-containing gases (see Fig. 1). Structures are also formed using other background gases, such as N_2 or air, but they tend to be more blunt and irregular in shape.[1,2]

We have measured the optical properties of microstructures formed in various gases. The structures are typically 1 μm wide at the top and several μm wide at the base, with a height in the range 1–20 μm, depending on ambient gas pressure and laser fluence. For the experiments reported here, we use a background pressure of 500 torr and choose the laser parameters to give structures of roughly the same height (10–15 μm) regardless of gas species. The transmittance and reflectance of a 10×10 mm^2 area covered with these microstructures are measured using a spherical detector that integrates the transmitted or scattered light over all angles. The reflectance and transmittance are then used to calculate the absorptance of the material.

We observe a marked increase in the absorption of infrared light for patterned silicon surfaces compared with flat silicon. The effect is strongest for structures formed in the presence of SF_6: the absorptance is approximately 0.9 in the wavelength region 1.2–2.5 μm. Structures made in Cl_2 show an absorptance of 0.3–0.9 in this range (see Fig. 2) while for flat, crystalline silicon, the absorptance at these infrared wavelengths is less than 0.2. In the wavelength range 1.2–1.8 μm, surfaces structured in air or N_2 are better infrared absorbers than flat silicon, but they are much less effective than those made in the halogen-containing gases.



CFC3 Fig. 1. Scanning electron micrograph of conical silicon microstructures formed in a background gas of SF_6 upon irradiation with femtosecond laser pulses.



CFC3 Fig. 2. The dependence of the absorptance of microstructured silicon surfaces on the gas in which they were formed.

Given that the conical structures made in Cl_2 are very similar in size and overall shape to those made in SF_6, we believe their different infrared-absorption properties are due not only to the geometry of the microstructures but perhaps also to impurities introduced into the silicon or deposited on the surface of the microstructures during irradiation. For structures made in air or N_2, the shapes are sufficiently different from the cones formed in the halogen-containing gases that we expect that the geometry also influences the absorptance.

We are currently examining the dependence of the optical properties of these surfaces on the conditions in which they are made to learn more about the mechanism of formation. These experiments will help us tailor our gas parameters to optimize absorptance for surfaces that may be incorporated into devices such as solar cells or infrared detectors.

References

1. T.H. Her, R.J. Finlay, C. Wu, S. Deliwala, and E. Mazur, Appl. Phys. Lett. **73**, 1673–1675 (1998).
2. T.H. Her, R.J. Finlay, C. Wu, and E. Mazur, Appl. Phys. A **70**, 383–385 (2000).