

## Micromachined solid immersion lenses and optical antennas for scanning near-field optical microscopy

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*The optical microscope is a powerful and ubiquitous measurement and observation tool in science, medicine and industry. In spite of this, however, the resolving power of the optical microscope is fundamentally limited by diffraction, since conventional microscopes are unable to focus light to dimensions smaller than roughly half a wavelength. We have demonstrated two methods to overcome this limitation based on micromachined Solid Immersion Lenses (SILs) and optical antennas.*

In the first method, the Solid Immersion Lens (SIL), light is focussed in a high refractive index lens held close to the sample. Silicon nitride SILs with diameters of  $\sim 7$  micron integrated with atomic force microscope cantilevers were fabricated by surface micromachining. An SEM of an array of these devices is shown as Figure 1a. A scanning optical microscope based on the micromachined SILs and operating in reflection and transmission modes at a wavelength of 400nm was developed. The full width at half maximum spot size of the SIL-based microscope was measured to be  $\sim 130$ nm, which is  $\sim 1.9$  times better than the spot size without the SIL (256nm).

The second method used antennas operating at optical wavelengths to enhance the optical fields in regions whose dimensions are much smaller than the wavelength. We carried out a numerical study based on the finite difference time domain (FDTD) technique, showing that the optical intensity is enhanced by three orders of magnitude in a region whose dimensions are less than  $\sim \lambda/40$ . Antennas operating at infrared wavelengths ( $\sim 2$ -10 micron) were fabricated by electron-beam lithography. Far-field measurements on the optical antennas were carried out and found to be in good agreement with FDTD calculations. An SEM of an antenna operating at  $\sim 10$   $\mu\text{m}$  is shown as Figure 1b.

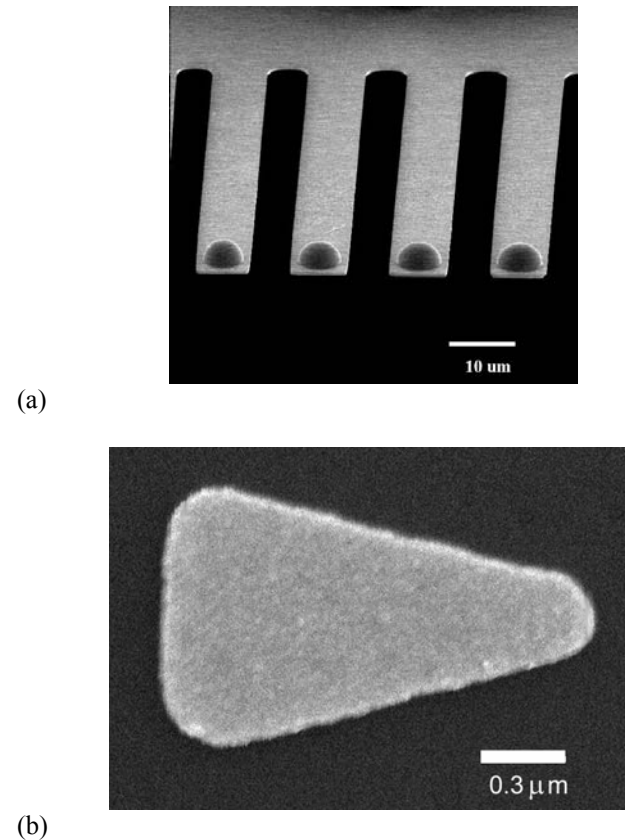


Figure 1. (a). SEM of silicon nitride micromachined lenses (SILs) on AFM cantilevers, with a tip opposite each lens (not visible in this SEM). (b). SEM of optical antenna