FABRICATION AND OPTIMIZATION OF BENT FIBER PROBES

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Scanning near-field optical microscopy (SNOM) is a scanning probe technique which allows nanometer optical resolution by scanning a sub-wavelength aperture in close proximity to a sample. Among other applications, SNOM is well suited to studies of single molecules and biological samples when used as a fluorescence source because the evanescent illumination provided by the SNOM tip makes it highly surface sensitive. The cell membrane is of particular interest as protein clustering can be revealed at high resolution by fluorophores, such as GFP. [1,2]

SNOM probes can be fabricated from bent fiber optic cable. [3,4] These probes can be operated using a normal force mode and optical beam deflection (OBD) for distance regulation. This makes them compatible with many commercial atomic force microscopes (AFM) unlike the usual straight fiber probes used in combination with quartz tuning forks in a shear force mode. Normal force imaging modes are well understood in terms of the forces applied to the sample. [5,6] Thus, using a bent fiber probe, quantitative force spectroscopy can be performed simultaneously with optical measurements.

Fabrication of the bent fiber probes proceeds with a number of steps. The fibers are bent with a high frequency electric arc. The angle is controlled to the desired precision by bending in multiple stages. As with all fiber based SNOM probes it is necessary to taper the fiber to connect the core-cladding index difference waveguide to the sub-wavelength aperture. Chemical etching is used to create the tapers, making use of the meniscus, tube, and selective techniques. In addition, by employing multiple techniques it is possible to create probes (so-called 'pencil probes') combining the high reproducibility of selective etching with the overall geometry of meniscus or tube etching. [7] A thin film of aluminum is deposited on the taper by thermal evaporation in order to confine the light. A high yield of smooth, pinhole free coatings is obtained. The bent, tapered and coated fibers are glued to microfabricated silicon v-groove chips. The chips have the same dimensions as a microfabricated AFM cantilever chip allowing easy mounting in commercial instruments while the v-groove aids in positioning of the fiber. Finally, the sub-wavelength aperture is created by FIB milling. The aperture size can be controlled in 25-30 nm increments by repetitive slicing perpendicular to the axis of the fiber.

The final product is a combined AFM/SNOM probe with typical resonance frequencies in the range of 10-20 kHz, spring constant of ~200 N/m, and Q-factors of 300-400. Submersion of only the fiber tip beyond the bend and special shaping of its end-face allows the resonance characteristics of the probe to remain virtually unchanged while in fluid. [8] The high Q-factor and well defined resonance enable the possibility of using a commercial AFM in non-contact mode in fluid which usually requires custom OBD hardware to accommodate the low Q-factor of a cantilever in water. [9] Optimal parameters for the bent fiber probe (spring constant, Q-factor, resonance frequency, diameter, length) will be presented.

References:

[1] Koopman et al., FEBS Letters, **573** (2004) 6.
[2] Ianoul et al., Nature Chemical Biology, **1** (2005) 196.
[3] Muramatsu et al., Ultramicroscopy, **57** (1995) 141.
[4] Taylor et al., Proc. SPIE, **3009** (1997) 119.
[5] Sader and Jarvis, APL, **84** (2004) 1801.
[6] Lee and Jhe, PRL, **97** (2006) 036104.
[7] Mononobe and Ohtsu, Journal of Lightwave Technology, **14** (1996) 2231.
[8] Lu et al., NFO9 Poster Presentation.
[9] Fukuma and Jarvis, RSI, **77** (2006) 043701.

Figures:

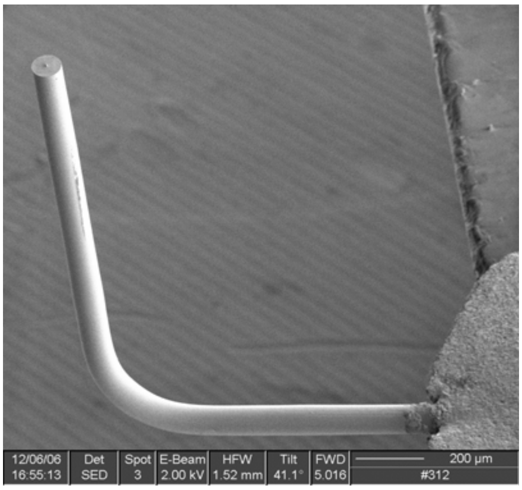

Fig. 1: An example of a probe fabricated by electric arc bending, selective etching, Al coating and FIB milling. The conical taper created by selective etching is visible on the end of the tip.

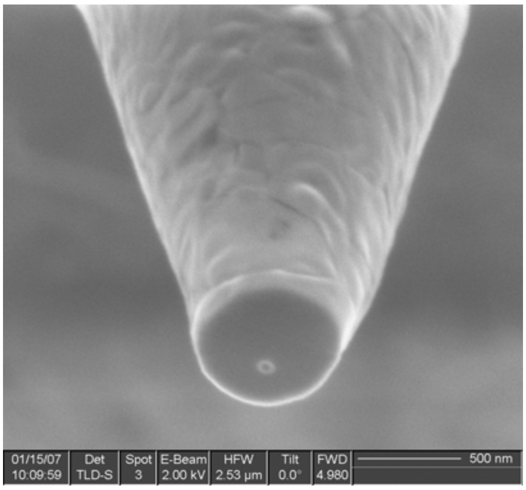

Fig. 2: An example of an aperture created at the end of the tapered fiber by FIB milling. The diameter of the aperture is 70 nm.