Electroless Nickel Plating under Ultrasonic Irradiation And Its Application to a Scanning Near-Field Optical Microscopy Probe

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Recently, a scanning near-field optical microscope (SNOM) employing shear-force feedback technique, which provides simultaneous topographic and SNOM imaging, has been widely applied nanometric optical imaging and local spectroscopy. To develop a high resolution SNOM / shear-force microscopy, we have proposed a new type of probe tip having a metal film those thickness gradually decreases to a few tens of nanometers toward the apex. [1] To realize such probes, we have developed a method based on electroless nickel plating under ultrasonic irradiation. In this paper, we present a plating method of fabricating a SNOM probe with a nickel film those thickness gradually decreases to a few tens of nanometers toward the apex.

Figure 1(a) shows schematic design of the probe. Here, the body and portions with fiber diameters of more than the optical wavelength have fairly thick thicknesses in comparison to the skin depth. θ is the cone angle of the tapered fiber. **Figure 1(b)** represents the magnified apex region of the probe. The term of d_s and t_s are defined as the fiber diameter and radial thickness in the same cross-section, respectively. And, t_a is the thickness of metal covering the apex.

The method involves tapering an optical fiber and electroless nickel plating with ultrasonic agitation. Firstly, a GeO_2-doped fiber with a core diameter of 2μm and an index difference of 2% was etched in buffered HF. The obtained probe has a conical tapered core protruding from the flat clad end with a diameter of 25μm. The cone angle of θ=20° and the apex diameter less than 10nm. Next, we plated the tapered probe under 1MHz ultrasonic irradiation by plating unit as shown in Fig. 1(c). Here, since the transducers radiates directional ultrasonic waves, the ultrasonic energy is strongly confined within the region indicated by the dotted rectangular. The total area of transducers and total electric input power were and 126mm × 110mm and 300W, respectively. The distance h between the transducers and probe tip is 220 mm.

Figures 2(a) and **2(b)** show scanning electron micrographs of the magnified top regions of the nickel-coated probes under ultrasonic irradiation and without additional agitation, respectively. Here, the white lines represent the cross-sectional profiles of the tapered fibers with a cone angle of 20°. In **(a)**, the radial thickness of the nickel film increases from an estimated value of t_a=20nm toward the foot of the protruded core and converses to 400nm. In **(b)**, the probe tip is entirely coated with nickel. These results indicate the size-dependence effect of electroless nickel plating is caused by ultrasonic agitation. This probe with a small tip diameter and metal film is effective in high resolution SNOM / shear-force microscopy.

In summary, we found that size-dependence effect of electroless nickel plating is induced by ultrasonic irradiation. By applying this plating to a tapered fiber, we succeeded in fabricating a nickel-coated SNOM probe those nickel thickness decreases from 400nm to 40nm toward the apex.

Reference

[1] S. Mononobe, Y. Saito, M. Ohtsu, and H. Honma, *Jpn. J. Appl. Phys.* **43**, Part 1, No. 5B, (2004).

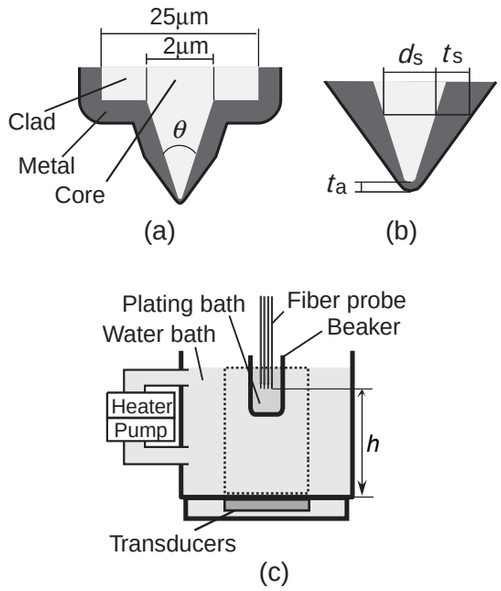

Fig. 1. (a) Schematic design of the near-field optical fiber probe having a metal film whose thickness gradually decreases toward the apex. (b) Schematic explanation of electroless plating unit with an ultrasonic generator.

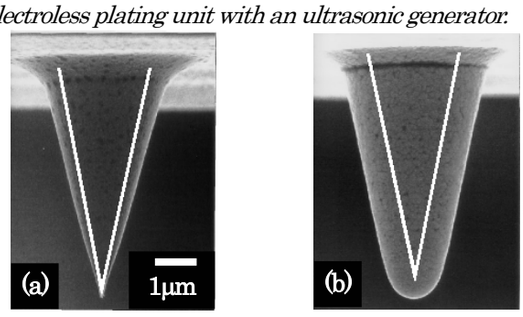

Fig. 2. SEM images of magnified top regions of the fabricated probes by electroless plating (a) under 1MHz-ultrasonic irradiation and (b) without additional agitation.