

NANOMETER-SCALE DEPOSITION OF PHOTO-CURING RESIN USING A SCANNING NANOPIPETTE PROBE MICROSCOPE

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INTRODUCTION

Scanning Probe Microscopes (SPMs) are well known as surface imaging techniques at nanometer scale resolution. SPM can be used not only for surface observation but also for local surface fabrication. The typical fabrication technique using SPM is directly scratching on surfaces with the probe. However in this case, high loading force must be applied between the probe and the surface, which induces some undesirable problems such as cutting particles and probe edge wearing. Therefore, other fabrication techniques are required.

Recently, we have developed novel nanometer-scale fabrication using a scanning shear-force microscope with a nanopipette probe. The nanopipette probe was used for delivering materials to any points on the substrate surface [1]. Furthermore, local metal plating was also achieved using the nanopipette probe filled with metal ionic electrolytes [2].

In this paper, we describe nanometer scale fabrication method of photo curing resin using near field optical illumination. Dot array and line pattern were sequentially fabricated on the glass substrates.

EXPERIMENTAL METHOD

Figure 1 shows a schematic diagram of a scanning shear-force microscope using a nanopipette probe for local surface fabrication. This scanning probe microscope system was constructed by us. A capillary glass tube, having 1.0 and 0.6 mm outer and inner diameters, respectively, was thermally pulled using a filament-type nanopipette puller (Narishige, PD-5). The diameter of the probe aperture was approximately 200 nm as shown in Fig. 2. The nanopipette probes could be filled with any kind of liquids for delivery and fabrication. In regard to the topographical observation of the surface, the shear-force control technique was employed. The pipette probe was fixed on a dither PZT and oscillated laterally at its resonant frequency of approximately 20 kHz with the amplitude of 1 nm. As the probe is approached to the surface, the

amplitude is damped. Thus the distance between probe and surface could be controlled.

As for the photo curing resin, liquid state photo curing resin was filled into the nanopipette probe. After deposition of the liquid state resin, the resin was cured by irradiation of light. The peak of the absorption spectrum of the photo curing resin is about 500 nm. Thus Ar⁺ laser was employed due to almost same wavelength of 488 nm. In order to avoid undesired cure of the liquid state resin inside the pipette, evanescent wave was employed on the triangle prism in total internal reflection.

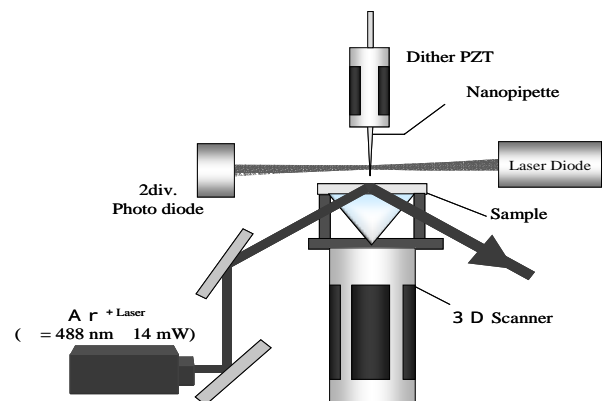


Figure 1: Experimental setup of the nanopipette probe microscope. Glass substrate is put on the triangle prism fixed on the PZT tube scanner. Ar⁺ laser (wavelength of 488 nm) is employed to cure the photo curing resin.

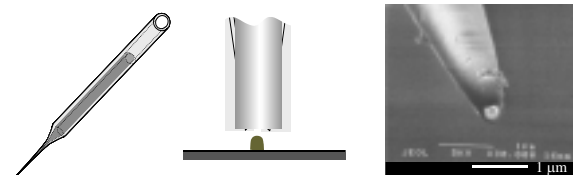


Figure 2: Nanopipette probe. The nanopipette probe was prepared by thermally pulling from the capillary glass tube.

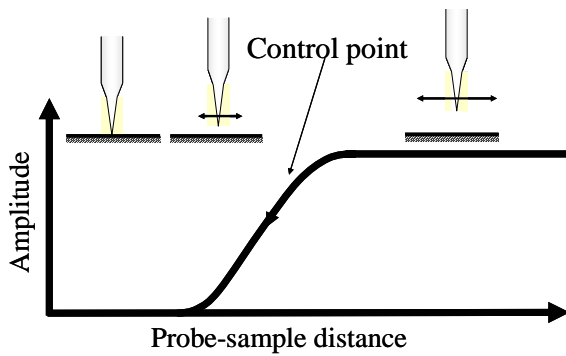


Figure 3: Shear force distance control
Nanopipette probe was oscillated laterally at its resonance frequency with amplitude of 1 nm.

EXPERIMENTAL RESULTS

Figure 3 show the dot deposited by this method. Figure 3(a) shows the dot before laser illumination. Liquid state dot could not be observed due to dragging by the probe during scanning. On the other hand, Figure 3(b) shows dot structure after laser illumination. As shown in this figure, clear dot structure could be observed. Thus, the dot structure was cured by photochemical reaction. In general, intensity of such evanescent illumination is not strong. However, in our experiment, with respect to the incident beam of 14 mW power, the exposure time about 1 sec was enough to cure it.

The amount of deposition can be controlled by changing deposition time. Figure 4(a) shows the smallest dot in our experiment. Figure 4(b) shows the cross-sectional profile. The height and width of the dot are 10 nm and 180 nm, respectively. Figure 4 (c) shows the dot array of the photo curing resin deposition. The dot array was sequentially fabricated during surface scanning by varying the probe-surface distance under shear-force control. Figure 4(b) shows cross-sectional profile. High reproducibility can be confirmed.

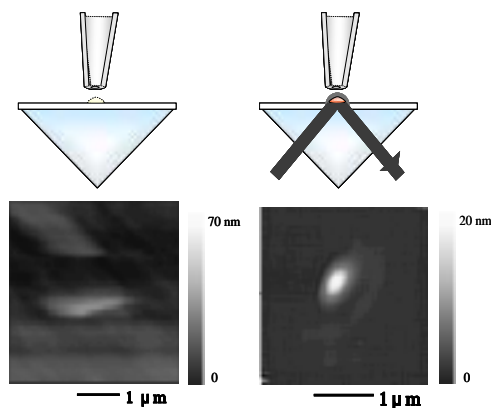


Figure 3: Dot structures before curing and after curing.
(a) Dot without laser illumination. (b) Dot structure with laser illumination.

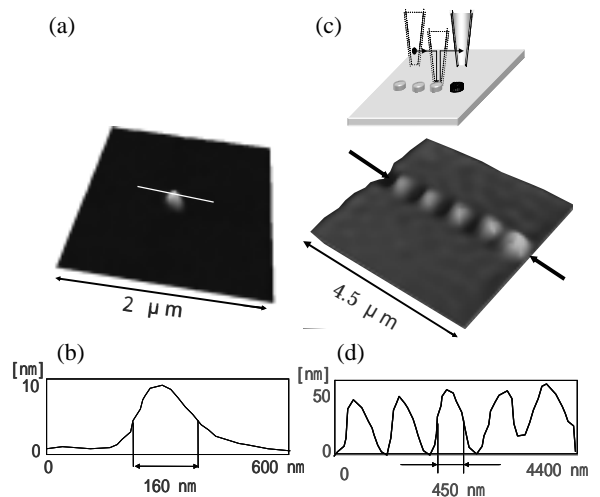


Figure 4: (a) Smallest dot deposited by this method.
(b) Cross-sectional profile of the dots structure. (c) Dot array (d) Cross-sectional profile of the line patterns.

CONCLUSION

Novel fabrication techniques of local surfaces were performed using a scanning probe microscope with various liquids filled nanopipette probes. Liquid state photo curing resin was successfully deposited on the substrate, then, the liquid resin could be cured with evanescent wave light generated by total internal reflection configuration in triangle prism attached under sample holder. Dot array structures could be realized. These fabrication techniques might be conceivable for many fields such as precision engineering and biological manipulations.

REFERENCES

1. F Iwata, Y Sumiya, S Nagami and A Sasaki "Submicrometer-scale fabrication of polycarbonate surface using a scanning micropipette probe microscope", *Nanotechnology* 15 (2004) 422.
2. F Iwata, Y Sumiya, S Nagami and A Sasaki "Nanometer-scale metal plating using a scanning shear-force microscope with an electrolyte-filled micropipette probe", *Jpn. J. Appl. Phys* 43 (2004) 4482.