Nano-scaled water ejection using Nanopipette with QTF-AFM for Nanolithography

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ABSTRACT

We demonstrated that the apex of nanopipette with applying electric field could be used as a nano-scaled water ejection system using AFM(Atomic Force Microscopy) System based on QTF(Quartz Tunning Fork), namely nanolithography system. The tip diameter was 100~1000 nm which was fabricated by commercial pipette puller (P-2000) and electrode on the substrate was deposited by sputter deposition. With QTF-AFM feedback system, we could make the patterning on the substrate where we want. We could control the amount of water solution with applying electric field, tip diameter, distance between tip and substrate.

Keywords: Nanopipette, Nanolithography, QTF-AFM.

1 INTRODUCTION

Nanolithography is a promising tool for manipulating individual nanostructures. There are several techniques of nanolithography such as electron beam lithography, nano imprint lithography, sidewall transfer lithography and nanolithography using scanning probe microscopy (with atomic force microscopy[1], scanning tunneling microscopy, and near-field scanning optical microscopy[2] and Dip-pen nanolithography[3].

In this letter, we present a scanning nanolithography technique by using a pulled nanopipette which was formed of nanometric aperture formed at the end of pipette. We used FM QTF-AFM feedback system[4] to control the amount of water solution which was patterned on the SiO_2 or Au plate. And we applied electric field between tip and substrate to eject the liquid solution with respectively long distance(100~500nm).

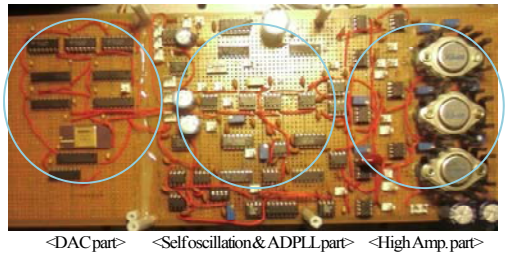
2 NANOLITHOGRAPHY WITH FM QTF-AFM SYSTEM

2.1 Fabrication

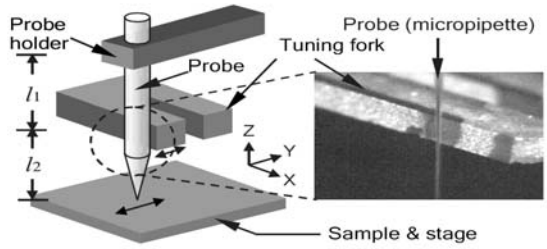
FM(Frequency Modulation) QTF-AFM consisted of self oscillation part and AD-PLL(All Digital-Phase Locked Loop) part was used to get feedback to sustain the distance between tip and sample as you see from Figure 1(a). The several hundreds of nm sized nanopipette was fabricated by pulling a quartz micropipette(out/inside diameter; 10/5mm) with inserted filament using a commercial pipette puller(P-2000, Sutter Instrument). The apex size of pulled nanopipette could be fabricated up to 100nm like Figure 1(c). The metal electrodes of Au were deposited by sputter deposition method on the SiO_2 substrate.

2.2 Experimental setup

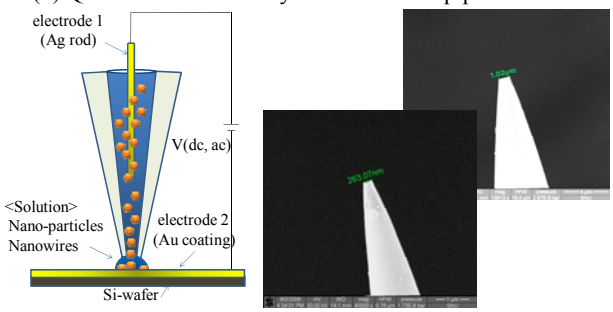
QTF-AFM system was used in this experimental setup. A resonance frequency of used quartz tunning fork was 32,768Hz and driving amplitude was about 10mV. The Nanopipette was in contact with QTF by glue like Figure 1(b). As this tip was getting closer to the sample, the signal from QTF became decreased cause of nucleation of water cluster. We used the PZT-tube which could be moved to 4um(z-direction), 20um(y-direction), 20um(x-direction).



(a) FM circuit for FM QTF-AFM system.



(b) QTF-AFM feedback system with Nanopipette.



(c) Diagram of SPM Nanolithography with Nanopipette & SEM image of Nanopipette size.

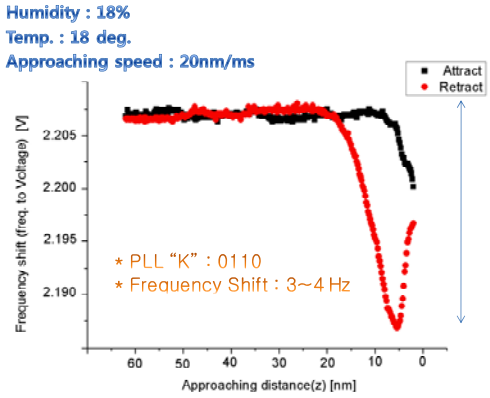
Figure 1. Experimental devices for Nanolithography with FM QTF-AFM system

Figure 1(c) shows diagram of proposed nanolithography system. Before patterning, we used a capillary filament of pipette and injector to fill up the liquid solution in the nanopipette. For nano-scaled patterning we used liquid droplet by electro ink jet ejection method with keeping distance Applying electric field, we could measure low level output current using Op-Amp(LF356, IV converter). Nano-scaled patterning could be fabricated on the substrate by using ejection of liquid of the nanoparticle and nanowire solution.

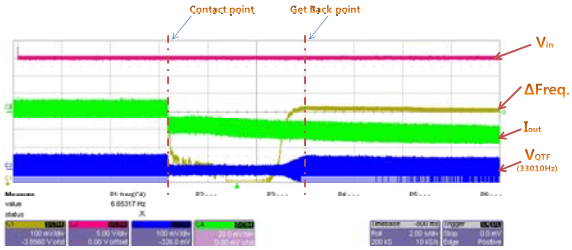
3 EXPERIMENTAL RESULTS

3.1 Control of Distance between tip&sample

To measure the pure force of surface tension of water bridge between tip and sample, we engage to shear mode QTF-AFM system which was acted like shear motion of vertical side to the substrate. Figure 2(a) shows an approach curve. We can control the distance between tip an d sample by feedback of output signal of QTF. In the region of 10~20nm, QTF's signal was getting decreased. And we can keep the distance by feedback at the certain point of signal level. As you see in the Figure 2(b), Frequency signal of QTF was decreased at the contact point and the current was changed. And signal would be recovered at the get back point. With high static electricity at the end of pipette, a current would be suddenly increased by forming of electron channel.



(a) Approach curve with nanopipette of FM QTF-AFM.



(b) Current profile by applying electric field.

Figure 2. Profiles of signal for control of distance.

3.2 Results of Nanolithography with solution

Figure 3 shows the experimental results. We could get a several hundred nm sized patterning with certain materials like nanoparticles and nanowires. Using this simple and easy method of patterning, we could get nano-scaled patternings.

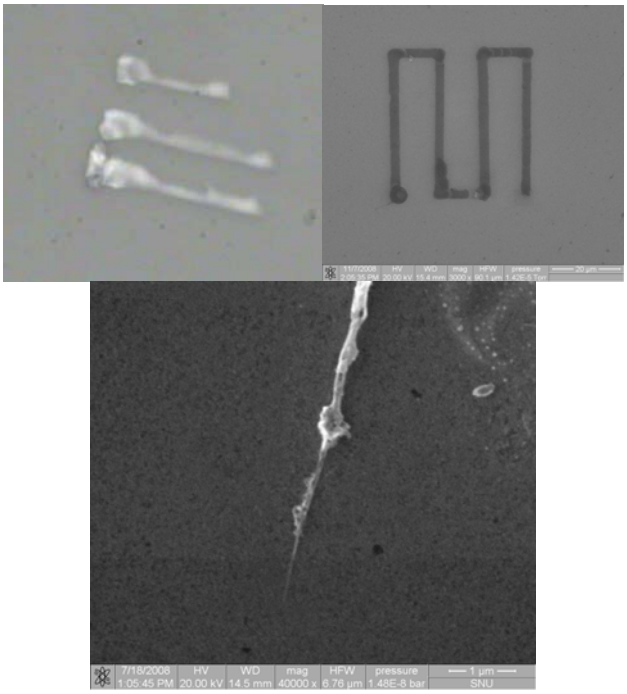


Figure 3. Experimental Results: Nano-scaled patternings of Nanoparticles and Nanowires

4 CONCLUSION

In this paper, we demonstrated that the apex of nanopipette with applying electric field could be used as a nano-scaled water ejection system using QTF-AFM nanolithography system. We have to progress further more small and more stable work about nano-patterning. We expect that this system could be used in researching of nano-patterning of a variety of liquid solution in Nano-Bio system, and so on.

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