

Nano-Patterning of NaCl Using Nanopipette with QTF-AFM System

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ABSTRACT

We made nano-patterning of NaCl on the clean Au-Substrate & Mica using Nanopipette based on the QTF-AFM (Quartz Tuning Fork-Atomic Force Microscopy) nano-scaled water ejection system. The NaCl is ionized in liquid solution (we used deionized-Water) which can be easily extruded out from the hole of nanopipette, and the Na⁺ and Cl⁻ ions would be resolved and be crystallized without liquid. After filled the NaCl solution in the nanopipette, we applied electric field to eject out the solution on the clean Au-Substrate and Mica. Used nanopipette's apex diameter was 100~1000 nm which was fabricated by commercial pipette puller (P-2000). With QTF-AFM feedback system, we could sustain the distance between tip and substrate. The nano-patterned size could be controlled by the nanopipette's size and applied electric field.

Keywords: Nano-Patterning, NaCl, Nanopipette.

1 INTRODUCTION

Sodium chloride is very important to Human-Body. And we can get much of that material easily from the sea. Here, we suggest that this abundant material can be used as "Nano-Ink" on the certain substrate, and also it will be start to investigate nano-scaled NaCl. We used previous our nanolithography system which was demonstrated before Nanotech 2009. As you know, 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 at the end of pipette. We used FM QTF-AFM feedback system to control the distance between tip and substrate[4]. To monitor the amount of extracted NaCl solution, we choose the current detection technique using generally used IV converter (LF356). We can also control the patterning size with Nanopipette size and Humidity, approach time, distance, applying voltage. Used substrate was coated with Au using Commercial Metal Sputter on the SiO₂ substrate.

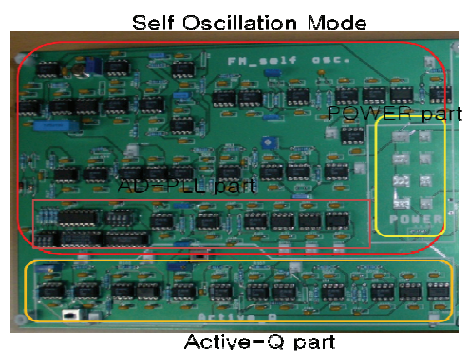
2 NANOLITHOGRAPHY WITH FM QTF-AFM SYSTEM

2.1 Fabrication

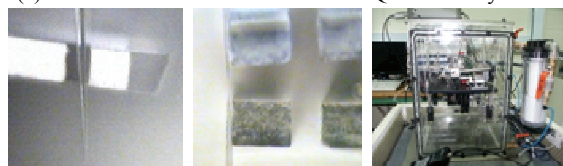
We fabricated the new version of FM (Frequency Modulation) QTF-AFM system. It shows more accurate and precise performance and high speed. The circuit was consisted of four parts, self oscillation part and AD-PLL(All Digital-Phase Locked Loop) part, Power part, and Active-Q control part. It was used to 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 using a commercial pipette puller (P-2000, Sutter Instrument). The pulled nanopipette which is filled with NaCl solution is attached to the QTF like Figure 1(b).

2.2 Experimental setup

QTF-AFM system was used in this experimental setup. A resonance frequency of used quartz tuning fork was 32,768Hz and driving amplitude was about 0.1 mV. As this tip approach to the sample, the frequency of QTF increased cause of perturbation of nucleation of water meniscus. We used the small PZT-tube which could be moved to 400nm(z-direction), 600nm(y-direction), 600nm(x-direction).



(a) New version of FM circuit for FM QTF-AFM system.



(b) Nanopipette which filled with NaCl Attached to QTF

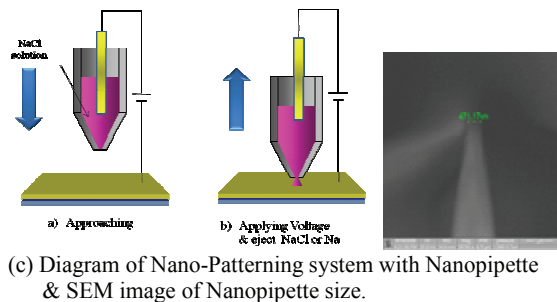


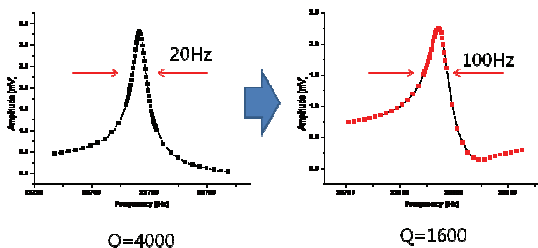
Figure 1. Experimental devices for Nano-Patterning with FM QTF-AFM system

Figure 1(c) shows diagram of proposed nano-patterning system. Before patterning, we used a capillary filament of pipette and injector to fill up the NaCl 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 of NaCl could be fabricated on the substrate by using ejection of liquid and evaporating liquid.

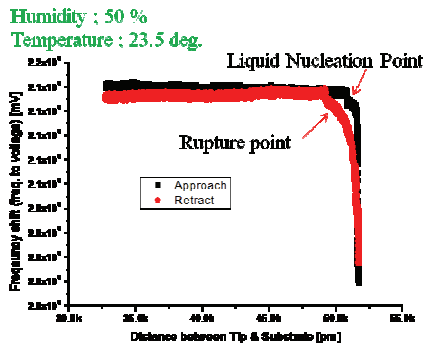
3 EXPERIMENTAL RESULTS

3.1 Nano-Patterning size Control by Nanopipette size, Humidity and etc.

To measure the distance 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(b) shows an approach curve. To control the exact size of Nano-Patterning, we used the 2-chamber system (inside - acrylic box, outside - Faraday metal cage box) to sustain the fixed Humidity and Temperature. In particular humidity is more important. At low humidity condition & small apex size of Nanopipette, the patterning size could be small. On the contrary, at high humidity condition & big apex size of nanopipette, the patterning size could be large enough. Approach time, distance, applying voltage also influence to the size of patterning. We can sustain under 10nm distance with PID feedback system. In the region of 10~20nm. Bare QTF has high Quality Factor (~4000), nanopipette attached QTF has 1500, but it is enough to detect the signal of nucleation liquid bridge, Figure 2(a)(b).



(a) Bare QTF compared to Nanopipette attached QTF



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

Figure 2. Profiles of signal for control of system.

3.2 Results of Nano-Patterning of NaCl

Figure 3 shows the experimental results. We could get a several hundred nm sized patterning of NaCl using this simple and easy method.

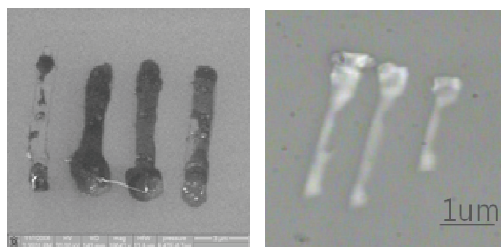


Figure 3. Experimental Results: Nano-Patterning of NaCl

4 CONCLUSION

In this paper, we demonstrated that nano-scaled water ejection system using QTF-AFM could be used as a NaCl Nano-Patterning system like “Nano-Ink”. 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-Ink system, and so on.

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