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Octadecyltrichlorosilane (OTS) Langmuir-Blodgett (LB) film was used as a resist layer for nanofabrication with AFM tips. Features with linewidth of 30nm have been achieved. Threshold forces for lithography were found to be 400nN for OTS monolayer and 800nN for mica substrate respectively. The OTS film is shown to have nice mechanical stability and wearability for AFM lithography.

Keywords: AFM; Nanolithography; OTS; LB film

INTRODUCTION

Nanoscale patterning can be done by scratching and indenting sample surface with a tip of atomic force microscope (AFM)[1]. A suitable resist is usually necessary for such AFM-based mechanical nanofabrication. In addition to the polymers conventionally used in microfabrication such as PMMA[2] and Polycarbonate[3], Langmuir-Blodgett (LB) films have been frequently employed as the resist layers because of their well-controlled and ultrathin structures[1,4-7]. Up to now, AFM lithography has been done on the LB films of arachidic acid[4,5], 22-tricosenoic acid[4,6], diynoic acid[4] and behenic acid[7] etc.. The main problem with these LB resists comes from their low mechanical stability. Scanning of the AFM tip on the film surface often destroys the film structure and even sweeps the film away. The molecules swept out of the film often contaminate the tip and the fabricated

patterns. In this paper, we report our recent efforts on using octadecyltrichlorosilane (OTS) LB film as the resist layer for AFM lithography. Our results indicate that the lateral intermolecular polymerization[8,9] has effectively improved the mechanical stability and wearability of the OTS LB film, which makes it possible to fabricate nanometer scale patterns using AFM tips.

EXPERIMENTAL

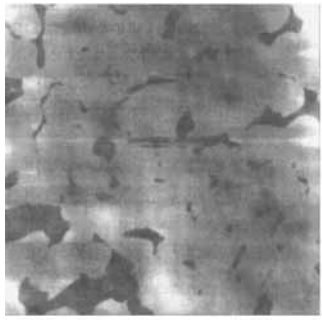
Octadecyltrichlorosilane ($Cl_3SiC_{18}H_{37}$, OTS, 95%) was obtained from Aldrich and used as received. Benzene of analytical grade was refluxed with P_2O_5 for 6 hours and distilled in dry nitrogen to remove trace water before use.

OTS was added to benzene solvent with a dry injector in nitrogen to avoid the reaction with moisture and oxygen[8]. The solution was spread on a pure water surface at 293K. The measurement of surface pressure-area isotherms and deposition of monolayers were carried out with a FACE Langmuir-Blodgett trough (Kyowa Interface Science Co., Japan). To allow the intermolecular polymerization, the OTS monolayer on water was pressed to and kept at a pressure of 25mN/m for 30 min.. Then it was transferred onto mica substrate by vertical dipping method.

A Nanoscope III Scanning Probe Microscope (SPM) (Digital Instruments, DI) with our home-made nanofabrication controlling system was used for lithography and imaging. A "hard" sharpened Si tip with a spring constant of 40N/m and tip radius of 5-10nm was used in this work. Experiments were done in contact mode at room temperature in air. The relative humidity was 40%-70%.

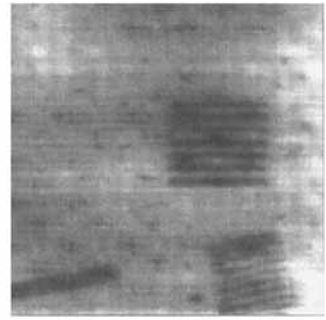
RESULTS AND DISCUSSION

Topographic AFM image of the OTS monolayer on mica was recorded at a load below 50nN, at which no discernible damage on the film by tip scanning was observed. As shown in Fig. 1, the OTS film is not uniform in large area, which is composed of lots of domains. Measuring the depth of the hole defects formed between domains, we estimated the thickness of OTS monolayer to be 1.8±0.2nm, which is a reasonable value, considering the fully extended length of OTS molecule, 2.3nm, and its slightly tilted orientation. Lithography was conducted by scanning AFM tip on the OTS monolayer at a high load from 100nN up to 2500nN. The scanning rate was kept at 2μm/s. Fig. 2 shows the topographic AFM image of the written lines. The linewidth, determined from cross section, is 50nm and the average height is 1.6nm. The minimal linewidth obtained was 30nm.



(10μm × 10μm)

Fig. 1 Topographic image of the OTS monolayer on mica before modification.



(3μm × 3μm)

Fig. 2 AFM image of lines fabricated by scanning the tip at a speed of 2μm/s and a load of 700nN. The linewidth is 50nm.

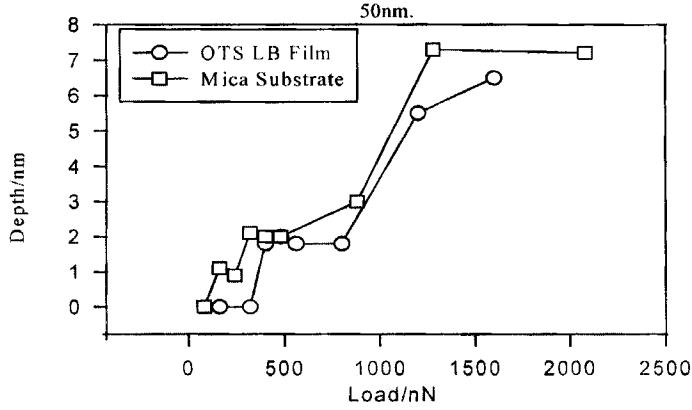


Fig. 3 Indented depth as a function of load for OTS LB film and bare mica

The threshold force for mechanical machining was studied by scanning small squares of 500nm×500nm on the OTS film at different applied forces. The relationship between the depths of the resulting hollow squares and the exerted load is shown in Fig. 3. When the load was lower than 400nN, no change of the OTS film could be observed. However in the range from 400 to 800nN, the film was found to be removed by the AFM tip, forming hollow squares with a depth of 1.8nm, equal to the height of the monolayer. When further increasing the load over 1200nN, deeper holes were created,

suggesting that the mica substrate has been damaged too. For comparison, Fig. 3 is also shown the relationship between the indented depths and the load on a bare mica. At a load above 100nN, the created depths showed a stepwise increase with the step length being 1nm, in nice agreement with the interplanner distance between two (0 0 1) faces of mica.

We noted that the OTS LB film shows a much higher threshold force for mechanical writing as compared with the fatty acid monolayers reported by other groups,[4-7] which were more easily removed by AFM tip at a load above 30nN. In our experiments, the topographic image of the written areas showed no change even after two hours of scanning at a load of 100nN. The high resistance of the OTS LB film can be attributed to the cross-linking Si-O-Si bonds between OTS molecules.[8] Such linkages may prevent the tip from penetrating into the monolayer and make the film more difficult to be destroyed.

In addition, during the lithography process, we did not observe any contamination on the AFM tip and the created patterns by removed film molecules. More detailed studies are in progress.

Acknowledgments

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