Micro Bubbles formed on ArF Excimer Resist Surface detected by Tip Scanning Method

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1. Introduction

Recently, the nano-bubbles are suggested to be associated with a wide range of applications such as reduction of friction, drag in micro fluidic transportation and detergent free cleaning. The nature of nano-bubbles formed at a solid / water interface was extensively analyzed by a force measurement with a scanning probe microscope. In micro device fabrication, these bubbles adhered on a substrate affect strongly to the quality of the micro pattern in various wet processes. In this regard, the stable existence of nano-bubbles has been reported by using atomic force microscope (AFM).[1-5] In this paper, by using the AFM, the observation method of nano-bubble and removal from an ArF excimer resist surface are discussed quantitatively.

2. Experiment

As the ArF excimer resist, chemical amplified type, consisting of acrylic resin was used. The resist films were formed on a Si (100) substrate by a spinning method. The film thickness of the resists was 300nm. The pre-baking treatment was carried out at 130°C for 90s on a proximity hot plate. The resist film surface was considerably flat and no defects such as micro particle were observed. A carbonated water was used for the generation of many micro bubbles on the resist surface. A contact mode AFM was employed for micro bubble observation and the bubble images were obtained using a narrow and thin Si₃N₄ cantilever. As a tip used for the investigation, a conical tip mounted on the cantilever was used. Two spring constants, 0.082 and 0.396N/m, of the cantilever were used. The curvature radius of tip apex was 8nm. The surfaces of the cantilever and tip apex were hydrophilic by a treatment in the plasma reactor for 3s before use. The height and diffraction images of bubbles were obtained simultaneously. Normally, a suitable driving set position was selected to give a -0.977nm with scanning force of 0.052nN. In addition, the removal behavior of micro bubble was also observed with the AFM.

3. Results and Discussion

The micro bubbles were easily generated on the resist surface as shown in Fig.1. The diameter of the bubble used for investigation was about 800μm.

![Cantilever](image)

Fig.1 Optical microscope image of micro bubbles adhered on the ArF resist surface in a liquid. The AFM cantilever can be adjusted onto the top of bubble.
Fig. 2 AFM image of top region of micro bubble adhered on the resist surface in a liquid.

Then, the AFM cantilever was set on the micro bubble with the optical microscope, and the top area of micro bubble was imaged clearly as shown in Fig. 2. It can be considered the AFM tip detects the gas/liquid interface during the imaging.[6] Figures 3a to 3e show a series of AFM images in the removal process of the micro bubble after dipping into the liquid. The volume of micro bubble decreased spontaneously with lapse of time. This is because that the bubbles dissolved due to the diffusion of the inert gas into the liquid. In Fig. 3(e), the bubble of 10μm diameter still remained after 5 hour passed. In addition, the slight deformation of micro bubbles could be observed. This deformation is caused by the contact with the AFM tip during image scanning procedure with the scanning force was 0.052nN. We can fairly state that the adhesion force of micro bubbles is considerably small compared with those of nano-scale resist patterns on various substrates.[7] This removal method of micro bubble will contribute to a development of wet MEMS (micro electronic mechanical system) for operating in a liquid.

4. Conclusion
The observation and removal method of micro bubbles from ArF excimer resist surface are demonstrated experimentally. The imaging of the gas/liquid interface of micro bubble is successfully conducted. The round image of the micro bubble could be observed with the AFM. It is also clarified that the micro bubble could be easily deformed by scanning the AFM tip with a lower force.

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