Dot Pattern Collapse due to Laplace Force Analyzed by Dynamical Meniscus Model

Akira Kawai and Kenta Suzuki

Department of Electrical Engineering, Nagaoka University of Technology
1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
E-mail: kawai@nagaokaut.ac.jp

Keywords: Laplace force, surface energy, water meniscus, dot pattern, local wetting, pattern collapse, pattern development

1. Introduction
It is well known that Laplace force acting on micro patterns affects strongly to the resist pattern collapse phenomena. In this regard, Tanaka et al. analyzed the micro pattern collapse model theoretically.[1] They also mentioned that the dot patterns, in lattice array, collapse in the direction of array center. We also observed the dot pattern collapse as shown in Fig.1. As shown in Fig.1, the ArF excimer resist pattern of 195 nm diameter and 640 nm height collapsed during the pattern drying procedure. The pattern also collapsed toward the array center. Moreover, a certain resist residue can be observed at the each collapsed position. However, it is difficult to carry out the in-situ monitoring of the pattern collapse. Therefore, in this paper, in order to analyze the pattern collapse in visible, some minute pillars made of nylon fiber are used as the dot pattern array. By this method, we can observe the air gap formation at the vicinity of pattern bottom.[2] It was clearly observed that the water meniscus enters from the both side edges of the parallel film pattern.

Fig.1 AFM image of dot resist pattern collapse due to Laplace force. (ArF excimer resist)

2. Experiment
In this study, in order to visualize the meniscus shape in the drying stage, some transparent micro pillars made by nylon fiber were arranged as shown in Fig.2. The pattern height and diameter of the each pillar were 11.4 and 0.3 mm, respectively. The distance between two pillars was 0.3 mm. The micro pillars were adhered on the glass substrate by the adhesives. As a wetting liquid, de-ionized (DI) water was used. The sample was exposed to the air during the water drying after dipping the test patterns into the liquid. The water meniscus image can be recorded using the video recorder until the end of the drying of the DI-water.

Fig.2 Schematic diagram of micro pillars fabricated on glass substrate.
3. Results and Discussion

Figure 3 shows a series of photographs in drying stage of the meniscus among the micro pillars. In Fig.3, it is clearly observed that the air gap at the bottom of the pillars. Then, the water remained at the top region of the pillars. The micro pillars collapsed in the direction of array center. The same result is obtained in the AFM observation as shown in Fig.1. In this regard, in the practical lithography, Figure 4 explains the residue formation due to stress concentration. By the stress concentration at the pattern bottom, a certain resist residue as shown in Fig.1 can be observed. The meniscus formed at the vicinity of pillar bottom affects strongly pattern collapse and its deformation.

Fig.3 Drying of water meniscus in micro pillar arrays.

Fig.4 Pattern collapse and residue formation due to Laplace force.

4. Conclusion

The water meniscus formation between fiber pillars is discussed on the point of pattern collapse and residue formation. The pillars collapsed in the direction of the array center. In the drying process of the practical resist development, it is fairly certain that an air gap must enter from bottom pattern. The air gap at the vicinity of pattern bottom affects strongly pattern collapse and residue formation.

Acknowledgement

The authors gratefully acknowledge helpful discussions with Mr. A. Ishikawa. This present work was partially supported by Grant-in-Aid for Scientific Research from Japan Society for the Promotion of Science. (Scientific Research (B) 16360171) The present work was also supported by Grant-in-Aid for Scientific Research, Ministry of Education, Culture, Sports, Science and Technology. (Exploratory research, 16656105) This work was also partially supported by TOKYO OHKA FOUNDATION FOR THE PROMOTION OF SCIENCE AND TECHNOLOGY.

References