Micro Bubble Removal Depending on Glass Cleanness

Akira Kawai* and Daisuke Tanaka

Department of Electrical Engineering, Nagaoka University of Technology, 1603-1 Kamitomioka, Nagaoka, Niigata 940-2188, Japan
(*Corresponding author, kawai@nagaokaut.ac.jp)

One serious problem for immersion lithography is micro bubble adhesion which is responsible for various exposure failures. In immersion lithography, it seems reasonable to suppose that organic contamination of lens surface brings about micro bubble adhesion onto them. Therefore, this study is intended as an analysis of adhesion and removal of micro bubbles on quartz surfaces by the contact angle method. We discuss the adhesion and removal behavior of micro bubble on the point of the balance model of surface energy. In the consequence, the micro bubbles are more likely to adhere to the organic contaminant on the quartz substrate. Keeping cleanliness of a lens surface is necessary in order to prevent the micro bubble adhesion.

Keywords: immersion lithography, micro bubble, removal, adhesion, surface energy

1. Introduction

In recent years, adhesion and removal control of micro or nano bubble has become important technique for the immersion lithography. Various studies with regard to adhesion and removal behavior of micro bubble in a solution have been accomplished.[1-3] It seems reasonable to suppose that the lens surface would be contaminated by the repeatable exposure procedure in mass production.

2. Experiment

In order to investigate micro bubble adhesion on a lens surface, a quartz substrate is dipped into deionized(DI) water with various inclined angles, as shown in Fig.1. The contaminated and cleaned quartz surfaces are used for the bubble capture investigation. The cleaned quartz surface was prepared by the oxygen plasma treatment. The oxygen plasma power was applied at 15W for 10s. The contaminated substrate prepared by exposing to HMDS (hexamethyldisilazane) vapor for 1h. In general, contact angle method is effective in order to analyze the removal nature of micro bubble formed on a quartz substrate. The inclined angle $\phi$, when a micro bubble was removed from a glass substrate, was measured.

3. Results and Discussion

Fig. 2 shows the photographs micro bubbles adhered on the quartz surfaces in the hang conditions. The contact angle of the cleaned quartz surface (surface energy of substrate $\gamma_s = 67.7 \, \text{mJ/m}^2$) is 3.5 degree. Meanwhile, the contact angle is 70 degree at the contaminated quartz surface ($\gamma_s = 37.0 \, \text{mJ/m}^2$). It is clearly observed that the contact angle $\theta$ on the contaminated quartz surface is larger than that on the cleaned surface. In addition, the bubble can be removed at inclined angle $10^\circ$ for the cleaned
shown in Fig. 3, the buoyancy $F_b$ acting to remove micro bubble from the quartz surface is defined. The buoyancy of bubble can be expressed as the well-known equation,

$$F_b = \frac{4}{3} \pi r^3 \rho g,$$

(1)

where $r$ is bubble diameter, $\rho$ is density of liquid [g/cm$^3$], $g$ is gravitational acceleration [m/s$^2$]. As shown in Fig.3(b), the buoyancy can be divided into the removal component: $F_b \sin \phi$ and the adhesion component of the bubble: $F_b \cos \phi$. In this regard, Figure 4 shows the simulation result for the relation between the bubble removal component and the bubble diameter. It is cleared that the removal component of buoyancy becomes smaller with the bubble diameter and inclined angle. In this way, it can be understand that the cleaned quartz surface is more sensitive to bubble adhesion. In order to achieve high quality pattern formation in immersion lithography, ultra cleanness procedure should be required.

**Conclusion**

The micro bubbles are more likely to adhere to the organic contaminate on the quartz substrate. The bubble on contaminated lens surface is less likely to remove. Keeping cleanness of a lens surface is necessary in order to prevent the micro bubble adhesion. Removal control of the micro bubble becomes important technique in micro and nano scale lithography.

**Acknowledgement**

The present work was partially supported by Grant-In-Aid for Scientific Research from Japan Society for the Promotion of Science. (Scientific research (B) 19360157)

**References**