Characterization of Resist Micro Pattern Adhesion by Applying Ultrasonic Vibration

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An improvement of resist pattern adhesion has been recognized as one important problem that needs to be solved in micro device fabrication. Dry film resist (DFR) patterns in circle shape are fabricated on glass substrates for the adhesion test. By applying ultrasonic vibration on a edge of DFR pattern in deionized (DI) water, the time until peeling occurred is measured. The DFR pattern can be peeled from a glass substrate under the ultrasonic vibration at 25 kHz. The water intrusion model into the DFR/glass interface is employed in order to discuss the adhesion behavior.

Keywords: dry film resist, ultrasonic vibration, peeling strength, surface energy, water intrusion

1. Introduction

In recent years, various resist materials have been widely employed for fabricating micro device component such as micro channel structure in MEMS (micro electro mechanical systems) [1-2]. As increasing integration density of micro devices, adhesion improvement of micro resist pattern has been recognized as one important problem to be solved because of pattern peeling during development process. Meanwhile, in general, the ultrasonic vibration is utilized as a useful technique to remove a micro condensed matter which is adhering on a substrate surface. In this study, we analyze adhesion property of micro resist pattern quantitatively under the ultrasonic vibration. By the combination of surface energy analysis, the intrusion nature of DI water into dry film resist (DFR)/glass interface under ultrasonic vibration can be clarified.

2. Experiment

2.1 Circular pattern fabrication

As the resist material, negative type DFR

Table 1 Condition of micro resist pattern.

<table>
<thead>
<tr>
<th>Process</th>
<th>DFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFR Film</td>
<td>laminating</td>
</tr>
<tr>
<td>Pre bake</td>
<td>70°C/1min</td>
</tr>
<tr>
<td>Exposure (λ=365nm)</td>
<td>2.5sec</td>
</tr>
<tr>
<td>Development</td>
<td>1wt% Na2CO3 /70sec</td>
</tr>
<tr>
<td>Post Bake</td>
<td>80°C/5min</td>
</tr>
<tr>
<td>Pattern diameter</td>
<td>72μm ~ 3.45mm</td>
</tr>
</tbody>
</table>

Fig. 1 Photographs of circular mask pattern.
film of 23μm thickness made by Nippon Synthetic Chemical Industry Co., Ltd. was used. As a substrate material, slide glass plates (20×20×1mm) were used. Figure 1 shows photographs of photo mask plates which were used for the exposure of the circular patterns. The photo masks were designed in a series of various size circle patterns. Table 1 summarizes photo lithography condition of DFR pattern.

2.2 Ultrasonic vibration system

The DFR pattern was peeled by using an ultrasonic vibration system (SF-60) made by SONOTEC Co., Ltd. As the probe, a stainless needle tube (outer diameter of 700μm, inner diameter of 400μm) was used. Figure 2 shows a photograph of the ultrasonic vibration system. The system was mounted on a bonding tester (PTR-1100 RHESCA Co., Ltd.). Ultrasonic oscillation frequency was fixed at 25 kHz. Figure 3 shows a peeling sequence of the DFR patterns.

2.3 Water intrusion analysis

In order to analyze the adhesion mechanism of a DFR pattern in DI-water, a contact angle on the DFR and the glass substrates were measured by using the contact angle meter. The test liquids were DI-water (γ / γd / γp = 72.8 / 21.8 / 51.0 mJ/m²) and diiodomethane (γd/γp = 50.8/48.3/2.50 mJ/m²) of which dispersion and polar components were well known. The test liquids were dropped on to the sample surfaces. Then, after 1 minute exposure time to air, the contact angles were precisely measured. Generally surface free energy γ of a condensed matter reflects strongly its cohesive energy (dispersion) and number of surface groups (polar). [3-5] Surface energy γ of matter is defined as a sum of two components, London dispersion γd and Keesom polar γp, based on van der Waals interaction as follows.

\[ γ = γd + γp \] (1)

Figure 4 shows a schematic diagram of intrusion model of DI-water into DFR/glass interface. Hence, the adhesion energy \( W_{12} \) between phase1 (glass substrate) and phase2 (DFR) is represented by the following equation.

\[ W_{12} = 2\left( \sqrt{γ_{12}^{d}} \cdot \sqrt{γ_{2}^{d}} + \sqrt{γ_{1}^{p}} \cdot \sqrt{γ_{2}^{p}} \right) \] (2)

The intrusion energy \( W_{1} \) of liquid into interface of DFR / glass can be defined as Eq. (3).

\[ DI \text{ water (3)} \]

Fig.4 Schematic diagram of intrusion of DI-water into DFR/glass interface.


\[ W_f = W_{13} + W_{23} - 2\gamma_L \]  \text{[mJ/m}^2\text{]} \quad (3)

The spreading coefficient \( S\text{[mJ/m}^2\text{]} \) of a liquid into the interface between two surface can be determined as the following equation.

\[ -S = W_{12} - W_f \]  \text{[mJ/m}^2\text{]} \quad (4)

We can discuss the intrusion nature of liquid thermodynamically as follows.

\( S \leq 0 \): Poor adhesion  
(DI water can intrude into the interface)

\( S > 0 \): Good adhesion  
(DI water cannot intrude)

By the combination of the ultrasonic vibration test with surface energy analysis, we can clarify the peeling nature of micro DFR pattern in a liquid.

3. Results and Discussion

3.1 Peeling of DFR pattern in air

Figure 5 shows a microscope photograph of a series of DFR patterns before or after peeling. Figure 6 shows a photograph of pattern peeling during ultrasonic vibration in air. The apex of probe is contact with the pattern edge. In Fig.5, the DFR patterns of (f) and (g) can be perfectly peeled by applying ultrasonic vibration. However, the larger patterns couldn’t be peeled. The slight destruction of DFR pattern can be observed at the contact position of the ultrasonic probe. It is cleared that the DFR pattern less than 265\( \mu \text{m} \) diameter can be peeled in air.

3.2 Peeling of DFR in DI-water

The peeling nature of DFR pattern in DI-water under ultrasonic vibration is characterized. Figure 7 shows photographs of the DFR pattern in DI-water before or after ultrasonic vibration test. Figure 8 shows a photograph of pattern peeling during ultrasonic vibration in DI-water. Some micro bubbles are adhered on the DFR pattern. It is clearly observed that the DFR pattern can be
peeled easily in DI-water. The size of peeled pattern is larger than that in air. As shown in Fig.9, the DFR patterns less than 850μm diameter are easily peeled. No correlation between the pattern size and the applying time of ultrasonic vibration can be observed.

3.3 Spreading coefficient analysis

Figure 10 shows a schematic diagram of water intrusion mechanism of glass/DFR interface. Figure 11 shows the two components map of the surface energy of DFR, glass substrate and DI-water. Circlel model as shown in Fig.11 is derived from eqs. (3) and (4).[5] In the case of the DFR/glass interface, the point of DI-water is positioned at outer of the circle. In this case, the spreading coefficient S of DI-water can be estimated to be $S=14.7\text{mJ/m}^2$. When the S value is larger than zero, DI-water cannot be intrude into the interface between two surfaces unless external force such as ultrasonic vibration. It can be estimated to be $14.7\text{mJ/m}^2$ as a required external energy of pattern peel. As mentioned previously, spreading coefficient S is defined thermodynamically for discuss the DI-water intrusion. When the intrusion occurs, DI-water continues invading in a two surface continuously. Therefore, it is thought that significant difference couldn’t be observed in size dependency of DFR pattern adhesion in DI-water.

4. Conclusion

We discussed the peeling property of the DFR pattern in air and DI-water under ultrasonic vibration. The DFR patterns can be

References