APPLICATION OF PHOTOSENSITIVE POLYIMIDE: MASK SAVING PROCESS FOR BUFFER COATING

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Issues in the LSI polyimide buffer coating process which uses photosensitive polyimide also as a mask of passivation film etching are reviewed. Change of lithography wave length from g-line to i-line causes the difficulty in the polyimide patterning. However, today's improved polymers, both ester type and ionic type, have enough ability to open 10 um windows. Dry etching condition must be adjusted to reduce the reaction products because this process cannot apply hard ashing. It is clarified that the adhesion to the molding resin after PCT is improved by F at the polyimide surface and is deteriorated by O2 plasma treatment. Fluorinated polyimide can keep good adhesion even after O2 plasma treatment.

1. Introduction

Polyimide buffer coating has become indispensable for today's LSIs to insure their reliability, because of the chip size getting larger, the package getting thinner and the package process getting complicated like LOC[1]. Up to now, polyimide film has been usually patterned separately from passivation film. In other word, this process needs two cycles of lithography step (Two Mask Process=TMP). Since fine patterns were not required for the polyimide opening in this process, non-photosensitive polyimides, which are less expensive than photosensitive has been widely used.

On the other hand, new approach of the process cost reduction by reducing process steps, using polyimide film also as a mask for passivation patterning (One Mask Process=OMP), is starting. Non-photosensitive polyimide can be also used for this process but there are limitations. For example, there are windows of redundancy fuse which are much smaller than the pad windows not only in memory devices but also in today's logic devices, and the size and pitch of pad windows are also becoming smaller. Therefore it is difficult for non-photosensitive
polyimide, which has poor patterning ability, to be applied to those devices and photosensitive polyimide became to have advantage in this process. Higher material cost of photosensitive polyimide can be ignored by the effects of process step reduction.

This paper reviews the issues in OMP with photosensitive polyimide from the view point of application engineering.

![Fig.1 Process flow](image-url)
2. Process Flow

Figure 1 shows the process flow of OMP with photosensitive polyimide compared with TMP with non-photosensitive polyimide. On the top metal layer, passivation film, which is generally SiN, SiON or SiN/PSG is deposited. In the case of TMP, the pad windows, and the fuse windows if needed, are patterned with photoresist mask and dry etching. After removing the photoresist, polyimide is coated and patterned with another photoresist and wet etching. The windows of polyimide can be larger than the passivation film windows because the passivation film is not etched any longer. In the case of OMP, photosensitive polyimide is coated on the passivation film, then exposed, developed and baked. Dry etching is applied to open the windows through the passivation film with the polyimide pattern as a mask. In both cases, post-treatment, light ashing and/or wet treatment is applied for cleaning and adhesion improvement. The thickness of polyimide is generally 5 to 20 μm depending on device and package.

As mentioned above, OMP remarkably reduces the process steps but following should be taken care of; 1. Polyimide patterning ability because the polyimide itself is used as a mask, 2. Dry etching condition and post-treatment because elimination of resist stripping step causes the difficulty in removing the etching reaction products, 3. Adhesion to the molding resin because it is affected by the dry etching condition and post treatment.

3. Polyimide Film Property

It is widely known that there are two types of polyimide, ionic type and ester type, and that the former has good film property but poor patterning ability while the latter shows contrary tendency[2]. Actually, ionic type shows better in some of the mechanical, physical and electrical properties. From our experience, however, those differences do not affect on any device reliability as far as they are used for the buffer coating.

4. Patterning Related Issues

The trend of lithography process causes difficulty in polyimide patterning. Today, i-line stepper is widely used and g-line stepper is disappearing. The transparency of light through
polyimide becomes lower with the wave length getting shorter as shown in Fig. 2. Those situations cause the shortness of the light strength for enough photo-crosslinking at the bottom of the polyimide, leading to pattern deformation or under cutting. To solve the issue, increase of the transparency and adjustment of the photosensitivity to i-line are applied to the latest polyimides. By those improvements, both types of polyimide can be patterned into 10um windows today, as shown in Figs.3 and 5.

![Fig.3 SEM photographs of ionic type photosensitive polyimides after developing. Window size:10um, coating thickness: 10um](image)

Although the best results in patterning are almost the same for both ionic and ester type, patterning properties are different. In the case of ionic type, the pattern size changes with developing time as shown in Fig.4, while ester type shows small changes. The cause of this phenomenon is the solution of exposed area during developing.

On the other hand, there is another issue in ester type. Opening failure can happen because of tailing as shown in Fig.5. This phenomenon is caused by the elution of the insufficient photo-crosslinked polymer from the sidewall, mainly because of inadequate focus setting in exposure.

As mentioned above, both types of photosensitive polyimide have patterning issues but they are controllable by process condition management. It is concluded that both type can be applied so far as those characteristics are comprehended.
Fig. 4 Pattern shape of ionic type polyimide vs. developing time

Dev. time = 15sec  35sec  55sec

Fig. 5 Tailing of ester type polyimide

Window size: 10um, coating thickness: 10um

Focus=+2.5um  Focus=0um  Focus=-2.5um
5. Etching and Post Treatment Issues

When the passivation film is etched with RIE, reaction products are deposited on the sidewall of opened windows as shown in Fig.6. In the case of TMP, these reaction products can be removed by O2 plasma ashing or resist stripping step. In the case of OMP, however, it is hard to remove them because polyimide film has to be remained and hard treatment which may remove or damage the polyimide cannot be applied. Then the RIE condition should be refined to reduce the deposition down to the amount which can be removed by light ashing (O2 plasma treatment) and/or light wet treatment.

6. Adhesion to Molding Resin

The adhesion between polyimide and molding resin plays a significant role in the reliability of LSI package. There are many reports on the relation between polyimide surface treatment and the adhesion to the materials on it[3-5]. Some of them reported that O2 plasma treatment improves the adhesion to the molding resin, that CF4+O2 gas plasma is effective for the adhesion to the another polyimide, that the higher surface wettability represents the higher adhesion, that the surface roughness is a factor of the adhesion or that surface chemical structure can explain the adhesion. The fact which has to be kept in mind here is that the polyimide surface in OMP is determined not only by the post-treatment but also by the RIE. To evaluate the effect of the combination of RIE and post-treatment, shear strength measurements were carried out. OMP processed polyimide samples were prepared. The RIE etcher was parallel plate type using CF4 gas. The tool for O2 plasma treatment was barrel type. Several chemicals for wet treatment were evaluated, but they are not mentioned here because no clear dependence was observed. Pillars of biphenyl type molding resin were formed on polyimide samples. They were pulled increasing the pulling strength and the strength when the pillar was pulled down was measured. The measurements were carried out before and after PCT which was done under the conditions of 128°C, 2.3 atoms and 48hours. The results are shown in Fig.7. Since no difference
was observed between two types of photosensitive polyimide, the result of only one type of polyimide are represented in the graph.

Photosensitive polyimide with only RIE (Sample A) or that with RIE and long O2 plasma treatment (Sample C) show higher adhesion than others before PCT. Interestingly, the sample with RIE and short O2 plasma treatment (Sample B) does not show high adhesion. Contrary to the results before PCT, the longer O2 plasma treatment causes the lower adhesion after PCT. Those results indicate that the effects of RIE and O2 plasma treatment come from different factor. To investigate the mechanism of the adhesion, contact angle measurement and surface analysis using ESCA are carried out and the results are summarized in Table 1. Contrary to the previous report, the lower contact angle represents the lower adhesion. It seems that concentration of F at the surface has strong relation to the adhesion degradation by PCT. To confirm this supposition, same tests were carried out using fluorinated polyimide. As shown in Fig.8, fluorinated polyimide shows

**Table 1** Atomic concentration and wettability of polyimide surface

<table>
<thead>
<tr>
<th>Sample</th>
<th>O(%)</th>
<th>F(%)</th>
<th>Si(%)</th>
<th>Contact Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>8.2</td>
<td>41.3</td>
<td>-</td>
<td>101</td>
</tr>
<tr>
<td>Sample B</td>
<td>20.9</td>
<td>4.1</td>
<td>0.7</td>
<td>60</td>
</tr>
<tr>
<td>Sample C</td>
<td>23.8</td>
<td>-</td>
<td>1.5</td>
<td>51</td>
</tr>
</tbody>
</table>
no deterioration of adhesion after PCT even when long O2 plasma treatment is applied.

There are some conflicts with the previous reports in our results. There may be some issues of congeniality to molding resins. Detail mechanism is still under study.

7. Summary
Photosensitive polyimide can reduce the process steps in the LSI buffer coating process. Latest polyimides, both ester type and ionic type, has patterning ability for the application. RIE condition and post-treatment which are related to the issues of reaction products and the molding resin adhesion are significant.

Acknowledgment
The authors are grateful to Michio Sakurai and Masashige Moritoki for their support of dry etching evaluation and SEM observation.

References
[2] Asano et al., "Photosensitive polyimides ; Fundamentals and applications"