Improvement of the BCB Adhesion on Cr/Au Metal Layer for RF Packaging Module

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2. Sample Preparation

The needs for the better radio frequency (RF) front-end module make the RF packaging issues more important. Benzocyclobutene (BCB) is a well-known material as an RF packaging dielectric due to its low relative dielectric constant (2.65) and low tangent loss (0.002 at 10GHz) [1]. However, organic materials, like BCB and Polyimide, have very poor interfacial fracture resistance (adhesion) to metals [2]. There have been many researches to overcome this issue, like plasma treatment, coating of adhesion promoter (AP3000) with BCB, partial cure of BCB before metallization, and annealing [3]-[5]. However, these attempts were concentrated on the adhesion of metal on BCB, not adhesion of BCB on metal. There are rare studies on the adhesion of BCB on metal, thus research is needed in this area. For example, in the case of thin-film microstrip (TFMS) line, which is popular transmission line in the RF packaging module, thick BCB layer (~30 μm) is located on the large area of ground metal.

In this study, we tried to improve the adhesion of the BCB on chrome (Cr)/gold (Au) metal layer by insertion of the inorganic materials, like silicon nitride (SiNx) and silicon oxide (SiO2). The diesaw test, adhesive tape test, 85 °C/85 % RH (relative humidity) reliability test and shear test were executed to examine the adhesion strength.

2. Sample Preparation

Figure 1 shows the whole structures of the samples used in the experiment. Sample 1 (Fig. 1(a)) has a same structure of the conventional TFMS line without signal line. The substrates used in this study were 4-inch silicon wafer, deposited with low pressure chemical vapor deposition (LPCVD) SiNx for the DC blocking. The 20 nm thick Cr adhesion layer and 300 nm thick Au layer were deposited by e-gun evaporator. The adhesion promoter, AP3000 and 20 μm thick BCB 3022-63 were spin-coated on Au and fully cured at 250 °C for 1 hour in an N2 environment. Additional plasma enhanced chemical vapor deposition (PECVD) SiN and SiO2 layer thickness of 50 nm were inserted between the Au and BCB in sample 2, 3 (Fig. 1(b), (c)) before BCB coating to enhance the adhesion of BCB on Au, respectively. It is worth comparing the sample 2 and 3, because SiNx and SiO2 have a different chemical structure and both are widely used in semiconductor process. To deposit the low stress SiNx (or SiO2), mixture of low frequency (187 kHz) and high frequency (13.56 MHz) power was used [6]. Oxygen plasma was treated on every interface before the thin-film deposition, because of the cleaning of contaminants and the activating of surface. Removal of gold oxide by annealing was followed by the PECVD SiN (or SiO2) deposition [7]. We also checked the stresses of the all thin-films used in the experiment because large residual stress can cause the delamination of the thin-films. Thin-films were deposited after measuring the initial Si wafer deflection. The measurements were taken using a Tencor FLX-2320 stress measurement system. The processing conditions and stresses of the thin-films are listed in table 1. These stresses were measured at room temperature. Measured stresses of the thin-films were relatively low enough to prevent the adhesion failure.

Table. 1. Process conditions and stress of the thin-films used in the experiment

<table>
<thead>
<tr>
<th>Layer</th>
<th>Process conditions</th>
<th>Stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCB 3022-63</td>
<td>Cured @ 250 °C, 300 mTorr (N2 environment) for 1 hour</td>
<td>27</td>
</tr>
<tr>
<td>PECVD SiO2</td>
<td>Deposited @ 300 °C</td>
<td>-432</td>
</tr>
<tr>
<td>PECVD SiNx</td>
<td>Deposited @ 300 °C</td>
<td>-210</td>
</tr>
<tr>
<td>Cr/Au</td>
<td>Evaporated @ 3×10⁻⁶ Torr</td>
<td>14</td>
</tr>
<tr>
<td>LPCVD SiO2</td>
<td>Deposited @ 800 °C</td>
<td>8</td>
</tr>
</tbody>
</table>

3. Adhesion Test : Qualitative

There are many methods to evaluate the adhesion between the thin-films such as adhesive tape test, peel off test, scratch test, indentation test, shear test, modified-Edge Liftoff Test and diesaw test [8]-[12]. Among them, we adopted the adhesive tape test, diesaw test and shear test to evaluate the adhesion strength because of its simple procedure.

Samples were coated with AZ1512 photoresist before the diesaw test for avoiding the unwanted external influences. For the diesaw test, prepared samples were cut into 2 × 2 cm square dies at a speed of 10 mm/s by a...
DAD-3350 dicing saw. In the sample 1, most of the BCB was delaminated from the Au after diesaw test. The reason for this result is adhesion strength between the Au and BCB was weak to withstand the external force during sawing. Moreover, remained BCB on the Au was peeled off by adhesive tape test. Microscope image of the sample 1 after diesaw test is shown in Fig. 2.

In the sample 2, which is PECVD SiNₓ was inserted, most of the BCB was not delaminated from the Au after diesaw test. Moreover, the BCB on Au was not peeled off by adhesive tape test. In the sample 3, the result of the adhesion test was same as sample 2. 2 × 2 cm square dies of sample 2 and 3 were carried into the 85 °C/85 % RH reliability tester to check the adhesion strength at more harsh conditions. After every week, samples were cut into 5 × 5 mm square dies. Even samples were in the high temperature / high humidity conditions during 1000 hours, BCB on Au was not delaminated and pass the adhesive tape test. Pictures and microscope images of the sample 3 is shown in Fig. 3. There were no noticeable changes after diesaw test and adhesive tape test. This is because insertion layers of PECVD SiNₓ (or SiO₂) have high bonding strength to both the Au and the BCB. Additional experiments were done with sputtered Cr/Au with same thickness. However, it was enough to ignore the influence of the deposition method of the metal.

4. Adhesion Test : Quantitative

Shear test was executed to evaluate the quantitative value of adhesion strength of BCB on Cr/Au. The measurements were taken using a Dage-4000 bond tester. BCB bumps of cylindrical shape and 5.2 μm height were fabricated using dry-etch BCB. The applied loading rate was 10 μm/s with a shear height of 0.2 μm. The results of the shear test are shown in Fig. 4. Sample 2 and 3 shows much higher shear strength than sample 1. It is noticeable that shear strength is not constant as the BCB bump diameter changes. Concentration of stresses in the interface near the shear tool might cause this phenomenon [13].

5. Conclusion

The methods to dramatically improve the adhesion of the BCB on metal were investigated. The reason of this improvement is the insertion layer of SiNₓ (or SiO₂). Each layer of the structure showed the relatively low stress. The diesaw test, adhesive tape test, 85 °C/85 % RH reliability test and shear test were executed to evaluate the adhesion strength. The adhesion strength of the proposed structure was strong enough to endure the high temperature / high humidity conditions over 1000 hours. RF packaging modules increase the demand on BCB, and adhesion issue is important. Proposed structures can be applicable to the reliable RF packaging module.

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References