

Novel Temporary Bonding Film Adapted to Xenon Flash Lamp De-bonding System for FOWLP Application

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Abstract

Temporary bonding film (TBF) is one of the key materials for assembly process of fan out wafer level package (FOWLP). In this paper, we have proposed a novel TBF and xenon flash lamp de-bonding system. The TBF was mainly composed of cross-linkable and low-polarity polymers to meet the various requirement for not only easy peeling-off after assembly but also stability against thermal and chemical environment exposed in FOWLP process. In order to evaluate applicability of the developed material, die-first/face up test wafer was assembled. As a result, it was found that the TBF has high stability and can be de-bonded by xenon light irradiation. In addition, the die shift through assembly process was within the estimated range. These results offer that the developed TBF is practically applicable for FOWLP assembly process.

Key words

Temporary bonding film, Xenon flash lamp de-bonding system, Fan out wafer level package

I. Introduction

IC packages are required to be smaller and more functional with the increasing performance demand of the electronic devices. Fan out wafer level package (FOWLP) is a key technology that realizes advanced packages and has been applied to various electronic devices such as smartphones and PCs lately. A temporary bonding is one of the most important processes in the FOWLP assembly and required to be low stress during de-bonding as well as easily removed without residue. Moreover, the material applied to this process must have thermal and chemical stability. [1-3].

As the conventional de-bonding methods, the following systems are proposed: heat de-bonding, mechanical de-bonding and laser de-bonding. However, in general, the heat de-bonding systems are only available under de-bonding temperature, the mechanical de-bonding systems force a great deal of stress on FOWLP during de-bonding, and the issue of the laser de-bonding systems is a lot of residue after laser irradiation that is difficult to be cleaned completely. Therefore, we have newly developed a novel temporary bonding film (TBF) that can be adapted to the de-bonding system with a xenon flash lamp [4]. Xenon flash lamps generate extremely high-intensity light pulses in a short time, and are widely used for various industrial applications. In addition, xenon light is expected as an effectual light source

due to its higher throughput than the traditional laser de-bonding systems because it allows large area irradiation at once. Furthermore, the xenon de-bonding system can be applied to even the wafers with large warpage because the xenon flash lamps have a larger focal depth than the laser light sources. The detail of the mechanism and effectiveness of the xenon flash lamp de-bonding system have been reported in the previous paper [4].

In this paper, we report the concept of newly developed TBF material and experimental results including chemical resistance, test wafer assembly and die shift measurement.

II. Material concept of TBF

Fig. 1 shows a new polymer system for the TBF adapted to the xenon flash lamp de-bonding method. Two approaches were introduced in this system to achieve the thermal and chemical stability as well as easy peeling-off after FOWLP assembly. The first was 3D-polymer network system formed by thermal curing between reactive groups, which enables firm cross-linking to increase thermal and chemical stability of the TBF. The second was to use low-polarity polymer to achieve easy peeling-off without residue even after reflow treatment, because it can reduce electrostatic interaction between the TBF and epoxy molding compounds (EMC) or that of TBF and silicon die. The schematic mechanism is

shown in Fig. 2.

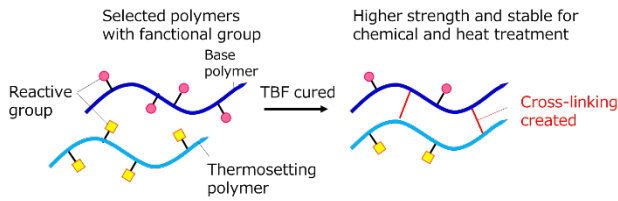


Fig. 1. New polymer system used for the developed TBF.

TBF consisted of high polarity polymers



TBF consisted of low polarity polymers

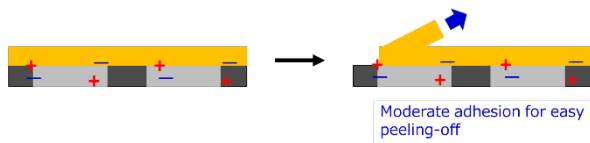


Fig. 2. Approach to realize moderate adhesion for easy peeling-off.

III. Experimental method

A. Chemical resistance test

Chemical resistance test was carried out using the test coupons composed of glass and silicon substrate bonded with the TBF. The test coupons were immersed into several organic solvents or acid and alkaline aqueous solutions supposed to be used for the RDL formation. After that, the measurement of weight change and appearance inspection were performed to examine whether the defects such as swelling, dissolving and delamination occurred or not.

B. Die-first/face up test wafer assembly

Test wafer assembly was conducted as shown in Fig. 3. A 12-inch glass carrier (700 μm -thick) with metal layers was prepared, and the TBF was laminated on it. Next, 240 pieces of dummy silicon dies (12 mm x 12 mm in size, 200 μm -thick) were temporary bonded on the TBF using a flip chip bonder. Then an EMC was applied using a wafer compression molding equipment with the thickness of 300 μm to encapsulate the silicon dies. After that, the grinding process was carried out to decrease the thickness of the EMC from 300 μm to 230 μm . Next, the heating treatment was performed that assumed the RDL formation and surface mounting assembly, i.e. the test wafer was heated at 230 $^{\circ}\text{C}$ for 2 h by two times and then put into reflow furnace at 260 $^{\circ}\text{C}$. Then, xenon flash light was irradiated to the test wafer from the bottom side of the glass carrier, and the glass

carrier with the metal layers was removed from the test wafer. Finally, a support tape was laminated onto the TBF in order to facilitate peeling-off process, and the TBF was removed with the support tape from the test wafer.

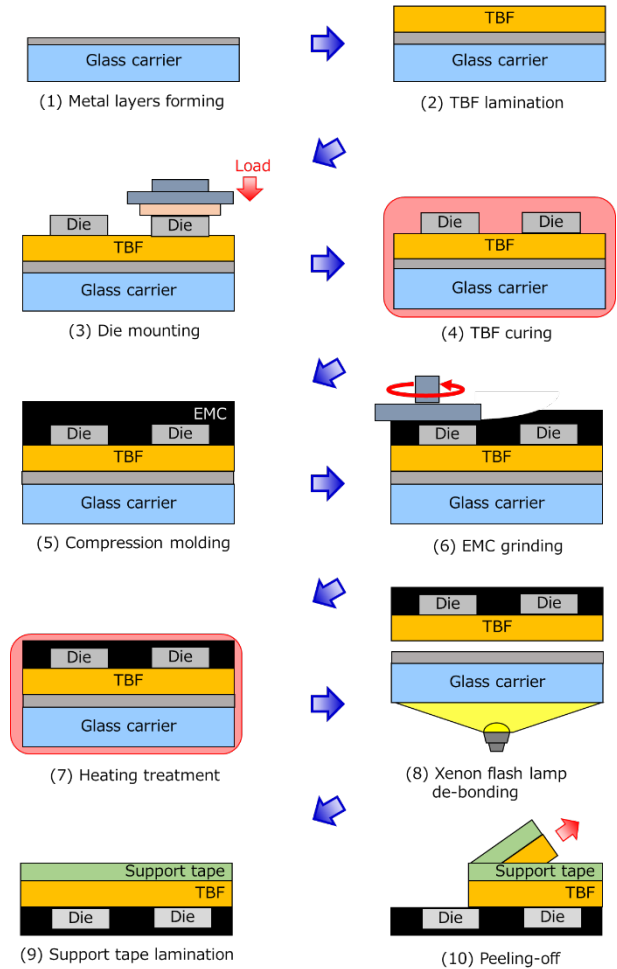


Fig. 3. Assembly steps of die-first/face up test wafer.

C. Die shift measurement

Die shift through the fabrication process was evaluated by a 3D topology optical measuring system. X and Y coordinates of dies were measured (A) after die mounting (Fig. 3 (3)), and (B) after peeling-off (Fig. 3 (10)). Each measurement was performed at 25 $^{\circ}\text{C}$. Then the die shift value was calculated from the difference between (A) and (B).

D. Calculation of estimated die shift value

Estimated die shift value (ΔD_E) between after die mounting and xenon flash lamp de-bonding was calculated with the following equations (1)-(3) [5].

$$\Delta D_E = \Delta L_h - \Delta l_c \quad (1)$$

$$\Delta L_h = \frac{S_{die}E_{die}\alpha_{die} + S_{EMC}E_{EMC}\alpha_{EMC}}{S_{die}E_{die} + S_{EMC}E_{EMC}} \Delta T L \quad (2)$$

$$\Delta l_c = \Delta T' \alpha_{die} L_{die} + \Delta T' \alpha_{EMC} L_{EMC} - CS \cdot L_{EMC} \quad (3)$$

ΔL_h is the die shift that occurs by raising the temperature just before the molding process. S , E and α are the elastic modulus, thickness, and CTE of the die or EMC, respectively. ΔT is the degree of the temperature change. L is the sample length. Δl_c is the die shift that occurs by cooling immediately after the molding process. $\Delta T'$ is the degree of the temperature change and CS is a rate of EMC shrinkage.

IV. Results and Discussion

Table 1 shows the results of chemical resistance test. From the results that there were no weight decrease less than 1% and no issue in the appearance, the developed TBF showed high stability against the chemicals supposed to be used in FOWLP assembly process.

The result of the die-first/face up test wafer assembly is shown in Fig. 4. No air void and delamination was observed after TBF curing, and the compression molding and EMC grinding could be performed without issues such as chip drift and delamination. Next, the total of three heating treatments assuming RDL formation did not affect serious damage such as delamination. After that, carrier de-bonding was successfully carried out by xenon flash light irradiation through the glass carrier. The glass carrier could be removed at the interface between TBF and metal layer without PKG damage and residue. Finally, TBF was easily peeled off from PKG by using support tape. The above results showed that the newly developed TBF has the great potential to be applied to the FOWLP assembly process. In addition, as shown in Fig. 5, no obvious TBF residue existed on the die surface after peeling-off.

Table 1. Results of chemical resistance

Chemicals	Treatment condition	Results*	Test coupon after the test
PGMEA	25 °C, 15 min	Passed	
DMSO	60 °C, 15 min	Passed	
IPA	25 °C, 60 min	Passed	
30% H ₂ O ₂	25 °C, 60 min	Passed	
2.38% TMAH aq	25 °C, 15 min	Passed	

*Pass: TBF weight change is less than 1% and no appearance change

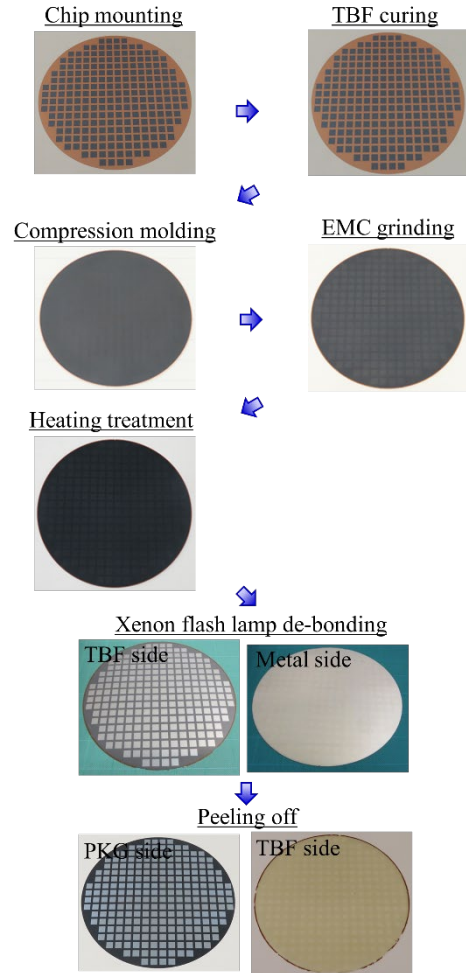


Fig. 4. Photographs of the test wafer after each assembly process.

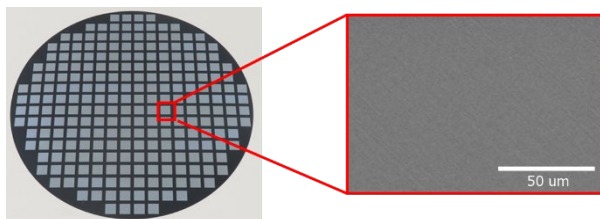


Fig. 5. SEM image of the die surface after peeling-off.

The values of the die shift measured along the X and Y-direction were plotted and shown in Fig. 6. The slope of the fitted straight lines for both X and Y-direction were negative, and this indicated that the shrinking die shift occurred. In addition, the result showed that there was no significant difference in the die shift between the X and Y-direction.

Table 2 shows the comparison of the die shift between estimated and measured results. The measured die shift was approximately 5 μm , and this value agreed well with calculated result. This means that there is a great prospect to reduce the die shift close to zero by adjusting the die position at temporary bonding.

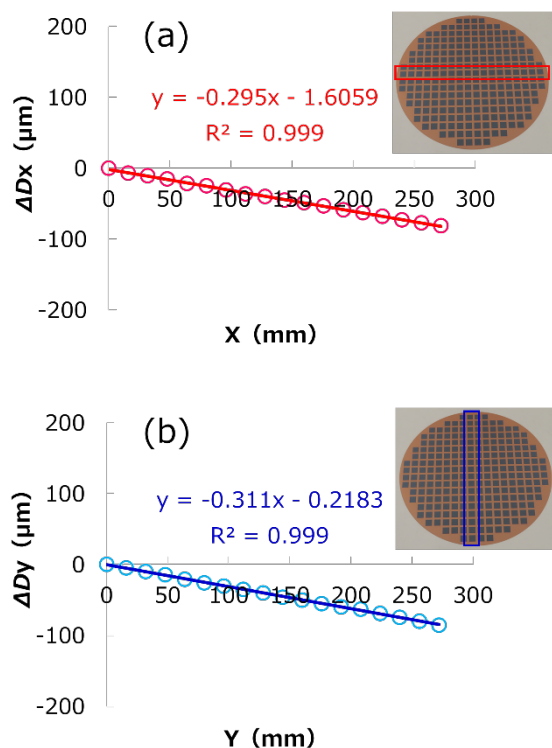


Fig. 6. The values of the die shift measured along (a) X-direction and (b) Y-direction.

Table 2. Estimated and measured die shift (ΔD) values per die pitch (n=18).

Item	ΔD
Estimated value	-5.7 $\mu\text{m/pitch}$
Measured value	-4.9 $\mu\text{m/pitch}$

V. Conclusion

In this work, we have proposed the novel TBF and xenon flash lamp de-bonding system and demonstrated the applicability to FOWLP assembly. The results showed that the developed TBF would be durable against thermal and chemical environment supposed to be exposed in FOWLP assembly process, and was able to be de-bonded by xenon light irradiation without residue. Furthermore, the measured die shift was around 5 μm , which is close to estimated value and will be improved by reflecting the obtained results.

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