High Heat Resistant Peelable Temporary Bonding Film and New Debonding System with Xe Flash Light Irradiation

Yuta Akasu, Emi Miyazawa, Tetsuya Enomoto, Yasuyuki Oyama, Shogo Sobue, Ryoji Furutani,
Yuki Nakamura and Takashi Kawamori,
Showa Denko Materials Co., Ltd.
Address
48 Wadai, Tsukuba-shi, Ibaraki, 300-4247
Ph: +81-29-864-4000; Fax: +81-298-64-4008
Email: akasu.yuta.xidwk@showadenko.com

Downloaded from http://meridian.allenpress.com/ism/article-pdf/2020/1/000302/2708789/i2380-4505-2020-1-000302.pdf by guest on 06 December 2022

Abstract

We have developed a new temporary bonding film (TBF) and new debonding system with Xe flash light irradiation, named photonic release system, for advanced package assembly process. Since new TBF has a high Tg over 200 ºC after curing and shows good chemical resistance to developer, resist stripper, and plating chemicals, no delamination, voiding, and swelling were observed after thermal and chemical treatment in the bonded structure of wafer and glass carrier. In addition, by adopting a metal-sputtered glass carrier, wafer could be debonded by Xe flash light irradiation in less than 1 ms through the glass carrier with no damage. Residual TBF on the wafer surface could be peeled off smoothly at ambient temperature without residue on the wafer. In this research, we also demonstrated the good applicability of this temporary bonding film to the typical packaging process by using test vehicle including 12 inch mold wafer and the advantage of photonic release system.

Key words

Temporary bonding film, Photonic release system, Peelable, Heat resistance

I. Introduction

In the coming era of 5G tele-communication and IoT (Internet of Things), heterogeneous integration technology becomes more important for creating a high-speed wide-bandwidth data transmission system and multi-task operating system. Especially, advanced semiconductor packages utilizing 3D-stacking or embedded and fan-out wafer level packaging technologies are being widely used in order to achieve higher electrical performance in smaller and thinner form factor with lower energy consumption [1, 2].

In general, through the assembly process of advanced semiconductor packages such as curing of molding compound and dielectric material, sputtering, plating, solder reflow, etc., thinned wafer or dies are temporarily bonded on carriers with temporary bonding materials and the finished packages are debonded from carriers by laser irradiation or mechanical peeling [3-6]. Regarding temporary bonding materials, higher heat and chemical resistance are preferable in terms of applicability to wider process condition. In addition, debonding method with less stress and higher throughput is strongly required to ensure the better yield and productivity.

From these backgrounds, we have developed a new temporary bonding film (TBF) and debonding system with Xenon (Xe) flash light irradiation enabling good process applicability and productivity.

II. Concept

Fig. 1 shows a schematic image of debonding method using Xe flash light and laser. Xe flash light irradiation can cover larger area with single exposure in contrast to laser scanning. Moreover, the installation and maintenance cost of Xe flash lamp system is comparatively lower than laser system [7]. Thus, photonic release using Xe flash light is expected to have advantages in higher throughput and productivity.

Xe flash light irradiation is also well known to be applicable to curing of conductive paste [7-9], indicating that metal can convert effectively the light energy to heat energy. In order to apply this phenomenon to debonding, we set the suitable structure for photonic release as shown in Fig.2. Metal layer is located between glass carrier and TBF and so Xe light energy through glass carrier can generate heat energy selectively at metal layer, resulting in thermal stress mismatch between metal layer and TBF for initiating

delamination at the interface between metal layer and TBF. After debonding, residual TBF is peeled off from the package.

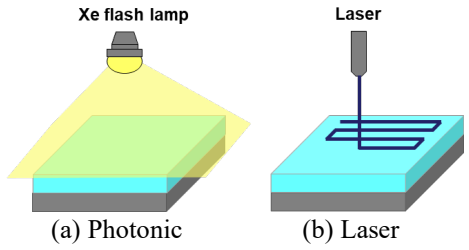

Fig.1 Schematic image of debonding method

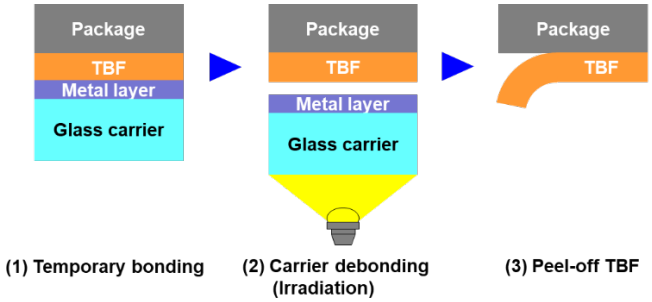

Fig. 2 Process flow of photonic release

Fig. 3 shows the material design concept of TBF. TBF contains elastomer and thermosetting resin. Elastomer plays an important role for achieving good lamination capability, bonding capability, and easy peel-off. Thermosetting resin enhances heat and chemical resistance by forming 3D crosslinking network after curing.

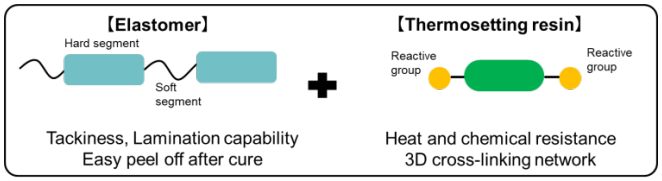

Fig. 3 Design concept of TBF

III. Experimental

III-I. TBF property measurement

Shear viscosity of the uncured TBF was measured by a rheometer ARES-G2 (TA instruments Corp.). Glass transition temperature (Tg) and elastic modulus of the cured TBF were measured by a dynamic mechanical analyzer RSA-G2 (TA instruments Corp.). 5% weight loss temperature (Td5) as an index of thermal stability was evaluated by a thermogravimetric analyzer TG/DTA6300 (Hitachi high-tech Corp.) in air or nitrogen atmosphere. 90º peel strength of TBF on several materials was tested by EZ-S (Shimadzu Corp.) at 50 mm/min. Evaluation of heat and chemical resistance were carried out using the test vehicle of glass and silicon chip bonded with TBF. Test vehicles after thermal treatment at 300 ºC for 1 h or dipping in various chemicals were checked visually if defects such as delamination, voiding, and swelling occurred or not. In addition, weight change after chemical treatment was also evaluated.

III-II. Demonstration 1 – 8 inch wafer thinning process

80 µm-thick TBF was laminated on metal-sputtered glass carrier at 100 ºC under vacuum. Subsequently, an 8 inch wafer and the TBF-laminated glass carrier were bonded using wafer bonder (LF12, SUSS MicroTec Corp.) under the condition of 3.5 kN for 2 min at 140 ºC. After bonding, the bonded sample was heated at 130 ºC for 30 min, followed by 200 ºC for 1 h in an oven. Wafer thinning was carried out using a wafer backgrinder (DAG810, DISCO Corp.). 400 µm-thick wafer was thinned down to 70 µm with a grinding wheel of 600 mesh, and finally finished at 50 µm thickness with a grinding wheel of 8000 mesh.

Photonic release was carried out using a Xe flash light system (PulseForge®1300, NovaCentrix Corp.) under the condition of pulse energy density of 8.0 J/cm^2 and pulse width of 1000 µs. After photonic release, TBF was peeled off from the thinned wafer by manual.

III-III. Demonstration 2 – Die first fan-out process

Chips with Cu pillar bumps (CC80, WALTZ Corp. 150 µm-thick) were bonded on the TBF-laminated glass carrier (10 cm x 10 cm) with 50 N loading for 10 s at 130 ºC using a flip-chip bonder (LFB-2301, Shinkawa Corp.). After curing TBF, bonded chips on TBF were molded with the granule type epoxy molding compound (Showa Denko Materials Corp.) using a compression molding machine (CPM1080, TOWA Corp.) and then curing of molding compound was carried out at 175 ºC for 3 h. Overall thickness of molding layer was 220 µm. Photonic release was conducted as the same procedure as described above.

III-IV. Demonstration 3 – 12 inch mold wafer debonding

TBF was laminated on 12 inch metal-sputtered glass carrier and molding layer was formed on TBF by compression molding method. Photonic release was conducted as the same procedure as described above.

IV. Results and discussion

Table 1 summarizes typical TBF properties and Fig. 4 shows a thermogravimetric curve of cured TBF.

Viscosity of uncured TBF is lowered when heated at 100 ºC, indicating good adhesiveness and lamination capability at B-stage.

Cured TBF shows high Tg around 200 ºC and its Td5 is

Downloaded from http://meridian.allenpress.com/ism/article-pdf/2020/1/000302/2708789/i2380-4505-2020-1-000302.pdf by guest on 06 December 2022

over 300 ºC even in the air. As shown in Fig. 5, no voiding was observed after treatment at 300 ºC for 1 h. This means that cured TBF has good thermal stability.

Elastic modulus of cured TBF is less than 100 MPa and cured TBF is still soft after curing. Based on this feature, TBF is expected to work as a stress release layer to reduce the warpage of bonded structure.

Regarding peel test, bulk breakage doesn't occur during testing and cured TBF can be peeled off from Si, Cu, and molding compound easily.

Table 2 shows the results of chemical resistance test against various solvents, acids and bases utilized in packaging process. Consequently, no weight loss and no appearance change such as delamination and swelling were observed.

Table 1 Typical properties of TBF

Item			Unit	TBF
Before cure	Viscosity@100 ºC		Pa·s	1.0 x 10^5
After cure	Glass transition temp.		ºC	200
	5% weight loss temp.	In N_2	ºC	398
		In air		329
	Elastic modulus	25 ºC	MPa	82
		250 ºC		2.6
		270 ºC		1.8
	Peel strength	Cu	N/25 mm	8.3
		Si		14.8
		EMC		2.5

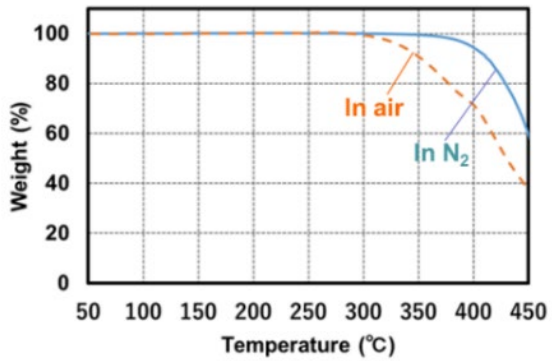

Fig. 4 Thermogravimetric curve of cured TBF

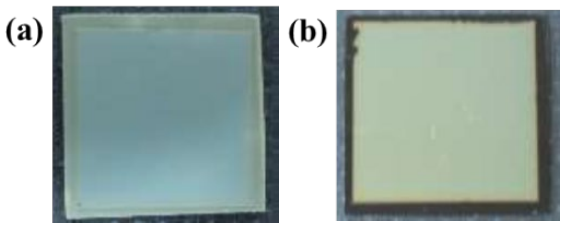

Fig. 5 Appearance of (a) before and (b) after heat resistant test

Table 2 Results of chemical resistance

Chemicals	Weight loss [wt%]	Appearance
PGMEA	0.0	No change
PGME	0.0	No change
IPA	0.0	No change
NMP	0.0	No change
DMSO	0.0	No change
2.38% TMAH	0.0	No change
3.7% H_3PO_4	0.0	No change
5% KOH	0.0	No change
30%NH_4OH	0.0	No change
30% H_2O_2	0.0	No change

The results of demonstration 1 are shown in Fig. 6. Bonding the 8 inch Si wafer could be performed without remarkable voids and Si wafer could be thinned down to 50 µm with no crack. Debonding the carrier was successful at the interface between metal layer and TBF by Xe flash light irradiation through the glass carrier. No carbonized layer on TBF surface was observed and we also confirmed almost no residue on the metal layer. Residual TBF on the Si wafer could be peeled off smoothly at ambient temperature. After peeling off, there was no particle residue on the wafer surface. It should be noted that glass carrier after debonding was reusable several times without cleaning although it was needed to adjust the irradiation condition accordingly.

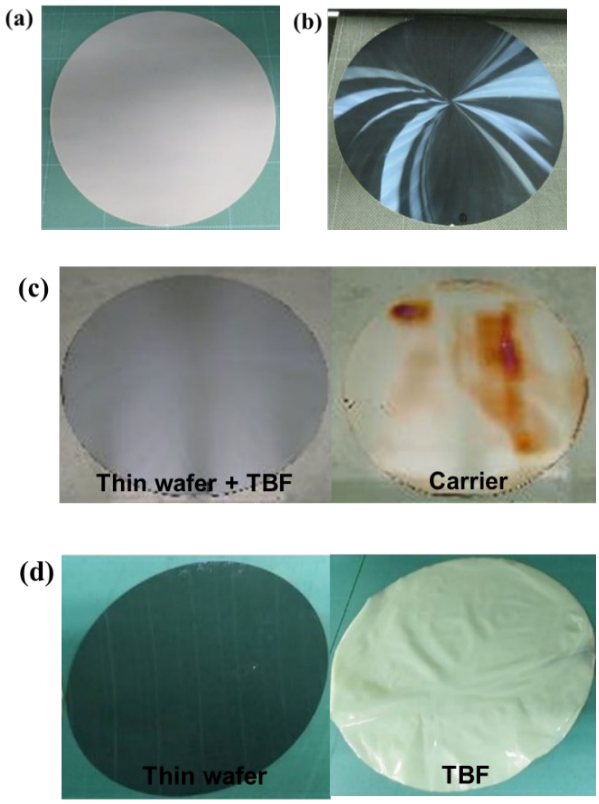

Fig.6 Results of demonstration 1 ((a) after bonding, (b) after grinding, (c) after photonic release (d) after peeling off)

Downloaded from http://meridian.allenpress.com/ism/article-pdf/2020/1/000302/2708789/i2380-4505-2020-1-000302.pdf by guest on 06 December 2022

Fig.7 shows the thermal simulation result right after Xe flash light irradiation. As we expected, selective heat generation at metal layer happened and a big difference in temperature between metal layer and TBF may induce the thermal stress mismatch at the interface, resulting in initiating the delamination at the interface. However, temperature at package region is still kept at ambient temperature and there seems to be no concern for thermal damage of package in photonic release process.

In our further study on the various metal layer, metal with higher coefficient of thermal expansion tended to be easier to debond (smaller light energy). This result indicates that debonding mechanism of photonic release is not ablating the TBF but thermal stress mismatch. In addition, we haven't observed carbonized layer on TBF surface after debonding and so this phenomenon also supports this debonding mechanism.

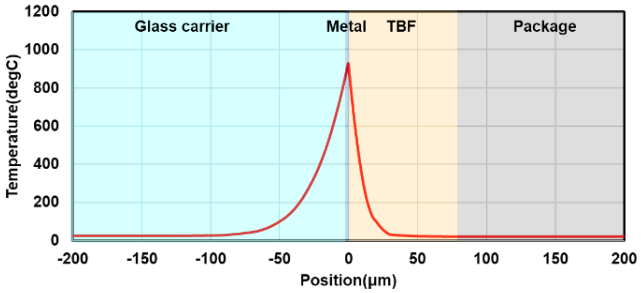

Fig. 7 Thermal simulation result of temperature distribution at 1000 μs irradiation

The results of demonstration 2 are shown in Fig.8. Cu pillar bumps were embedded in TBF layer, whereas surface of TBF layer was almost flat and there was no fillet on the side wall of chip. In addition, no penetration of molding compound into the interface between chip and TBF layer was observed. Die shift after TBF curing and molding were less than 10 μm and maximum warpage was ca. 200 μm after molding. Debonding by photonic release was also successful and TBF could be peeled off from the molded sample. There was no residue with a particle size of micrometer-order in the region of Cu pillar bumps on the molded sample, as shown in Fig.8 (e).

We also demonstrated photonic release in 12 inch wafer scale as shown in Fig. 9. In this demonstration, irradiation was performed stepwise across the entire 12 inch carrier because irradiation area was smaller than 12 inch carrier in test tool. Nevertheless, processing time was less than 30 s per wafer and no damage and no crack were observed after debonding.

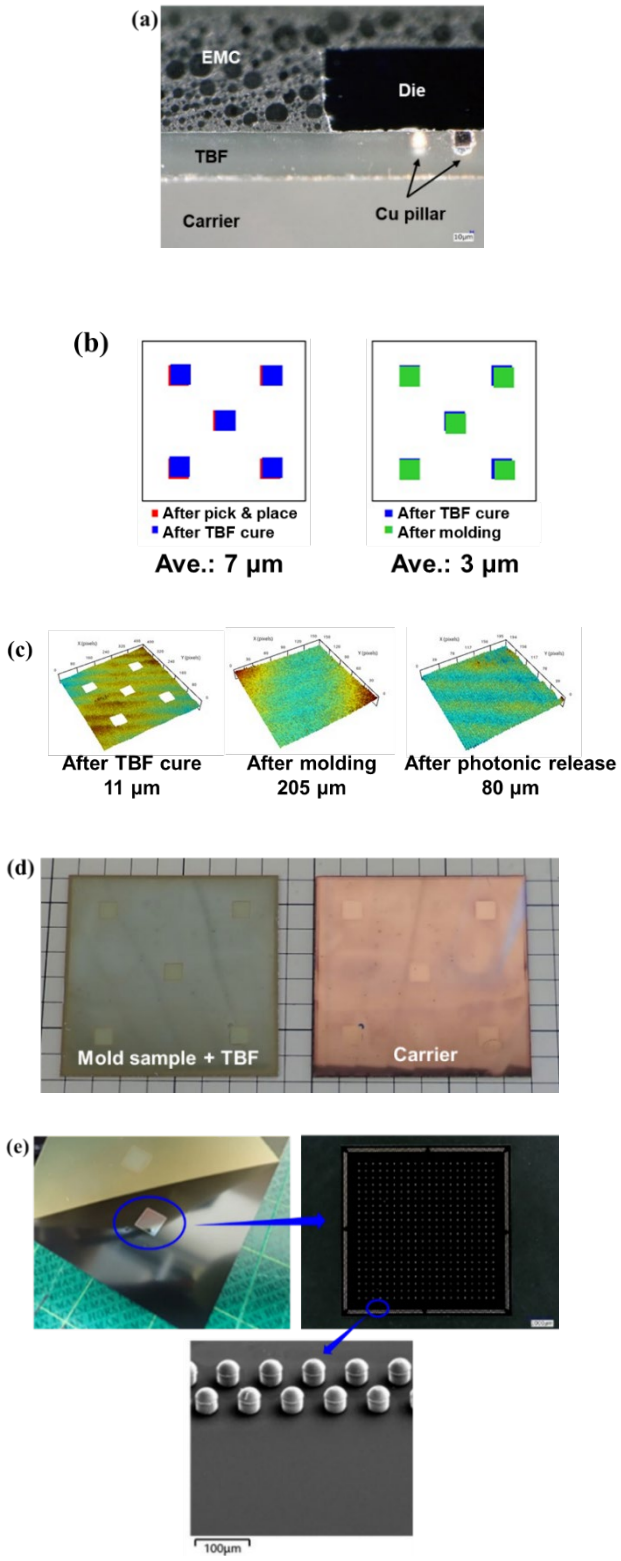

Fig.8 Results of demonstration 2 ((a) test vehicles from a cross section (b) die shift , (c) warpage, (d) after photonic release (e) after peeling off)

Downloaded from http://meridian.allenpress.com/ism/article-pdf/2020/1/000302/2708789/i2380-4505-2020-1-000302.pdf by guest on 06 December 2022

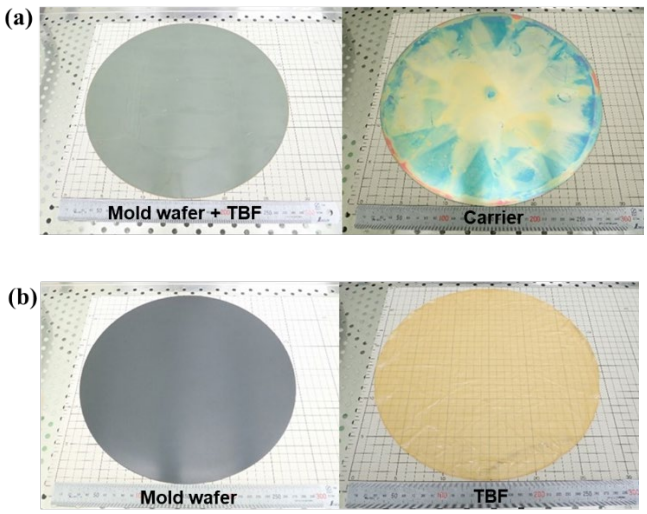

Fig.9 Results of demonstration 3 ((a) after photonic release (b) after peeling off)

V. Conclusion

We have developed a new TBF with high heat and chemical resistance. It also shows good bonding property and can be easily peeled off without residues. In addition, we have demonstrated a novel debonding system of photonic release. This system can offer high throughput and less damage debonding. Combination of new TBF with photonic release will be the promising countermeasure for enhancing processability and productivity in advanced packaging technology.

Acknowledgment

We would like to acknowledge the collaboration with Hitachi High-Tech Corporation and NovaCentrix for Xe flash lamp system.

References

[1] D. Zhang, J.JQ. Lu, "3D Integration Technologies: An Overview," in *Materials for Advanced Packaging*, 2nd ed., D.Lu, C. Wong, Ed. Cham, Switzerland: Springer, 2017, pp. 1-26.

[2] M. Töpper, A. Ostmann, T. Braun, K.D. Lang, "History of Embedded and Fan‐Out Packaging Technology," in *Advances in Embedded and Fan-Out Wafer Level Packaging Technologies*, B. Keser, S. Kröhnert, Ed. Hoboken, NJ, USA: Wiley, 2019, pp. 15‐64

[3] R. Puligadda, "Temporary Bonding for Enabling Three‐Dimensional Integration and Packaging," in *Handbook of Wafer Bonding*, P. Ramm, J. J. Lu, M. M. V. Taklo, Ed. Weinheim, Germany, Wiley-VCH Verlag GmbH & Co. KGaA, 2012, 329‐345.

[4] Y. S. Yang, K. S. Hwang, R. Gorrell, "Laser Releasable Temporary Bonding Film with High Thermal Stability," in *2019 IEEE 69th Electronic Components and Technology Conference (ECTC)*, Las Vegas, 2019, pp. 330–333.

[5] K. Kennes, A. Phommahaxay, A. Guerrero, O. Bauder, S. Suhard, P. Bex, S. Iacovo, X. Liu, T. Schmidt, G. Beyer, E. Beyne, "Introduction of a New Carrier System for Collective Die-to-Wafer Hybrid Bonding and Laser-Assisted Die Transfer," in *2020 IEEE 70th Electronic Components and Technology Conference (ECTC)*, 2020, pp. 296–302.

[6] H. G. Lee, D. S. Kim, J. H. Cho, J. H. Lee, J. Y. Park, M. H. Kim, J. W. Lee, "A Study on the Mechanical Debonding Process of Temporary Carriers for 3-D TSV Wafer Level Packages (WLPs)," in *2020 IEEE 70th Electronic Components and Technology Conference (ECTC)*, 2020, pp. 303–308.

[7] K. A. Schroder, S. C. McCool, W. R. Furlan, "Broadcast Photonic Curing of Metallic Nanoparticle Films," in *Technical Proceedings of the 2006 NSTI Nanotechnology Conference and Trade Show*, Vol. 3, Boston, 2006, pp. 198-201.

[8] M. Carter, J. Sears, "Photonic Curing for Sintering of Nano-Particulate Material," in *Advances in Powder Metallurgy & Particulate Materials – 2007: Proceedings of the 2007 International Conference on Powder Metallurgy & Particulate Materials*, Denver, 2007, pp. 9/68–9/75.

[9] H. S. Kim, S. R. Dhage, , D. E. Shim, H. T. Hahn, "Intense pulse light sintering of copper nanoink for printed electronics," *Applied Physics A*, Vol. 97, 2009, pp. 791-798.

Downloaded from http://meridian.allenpress.com/ism/article-pdf/2020/1/000302/2708789/i2380-4505-2020-1-000302.pdf by guest on 06 December 2022