Technology

VPA series, Temporary Adhesive for Fan-Out Package

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Abstract

Temporary adhesives for the laser lift-off process are beginning to be used in the large sized Fan-Out Package. This adhesive requires laser lift-off properties, positional accuracy when bonding the chip, and adhesion strength that can withstand the heat and pressure applied during the subsequent molding process. We produced the VPA series corresponding to these requirements.

1. Introduction

In recent years, electronic equipment, including smartphones and wearable devices, have become thinner and lighter and at the same time there are increasing needs for higher performance, such as higher data throughput, higher processing speed, and higher graphics performance. Fan-out packaging is a semiconductor packaging technology where wires are directly connected to chips; it enables downsizing and greater packaging density and it can suppress the manufacturing cost while enhancing the performance. Accordingly, fan-out packaging is widely adopted in the packaging of mobile devices and high-density ICs.[1)]

To manufacture fan-out packages, epoxy mold layers and redistribution layers (RDLs) are formed on support substrates via temporary adhesive layers, then the support substrates are ablated, and individual packages are obtained by division.

Although the wafer size of fan-out wafer level packages (FOWLPs) manufactured around 2008 was eight inches, the current mainstream wafer size is 12 inches for the purpose of reducing the cost. In addition, to further reduce the cost in line with large area batch molding, various companies are developing panel level packages (PLPs) involving large substrates.[2)]

Temporary adhesive sheets are mainly used to form films on support substrates. However, as areas increase, it is becoming difficult to form films of temporary adhesive sheets evenly on support substrates and there is a high risk of breakage due to stress during mechanical ablation (mechanical method). Thus, it is difficult to apply temporary adhesive sheets to large-sized packages. Under such circumstances, varnish types of temporary adhesives suitable for laser lift-off are under consideration; such adhesives can be evenly applied using coaters and can be ablated at low stress.

The fan-out package manufacturing methods are broadly divided into two types as shown in **Fig. 1**: Chip-1st where chips are placed on a temporary adhesive as the first step and then molding and RDL formation are performed; and RDL-1st where an RDL is formed directly on a temporary adhesive and then chips are connected. For example, temporary adhesives to be used in ablation methods for the Chip-1st need to have laser lift-off properties, positional accuracy when chips are bonded, and adhesion strength that can withstand heat and pressure to be applied in the subsequent molding process. In addition, on the ablated panel substrates, there is residue of the temporary adhesive for which the quality was changed through laser irradiation. Accordingly, the method to remove such residue needs to be optimized as well.

Nippon Steel Chemical & Material Co., Ltd. has put the temporary adhesive VPA series that satisfy such needs on the market and it offers the products for applications for fan-out packages. The characteristics of the VPA series are described below.

2. Basic Performance of the Varnish Photosensitivity Adhesion (VPA)

The Varnish Photosensitivity Adhesion (VPA) has adopted our proprietary developed aromatic polymers having very high UV ab-

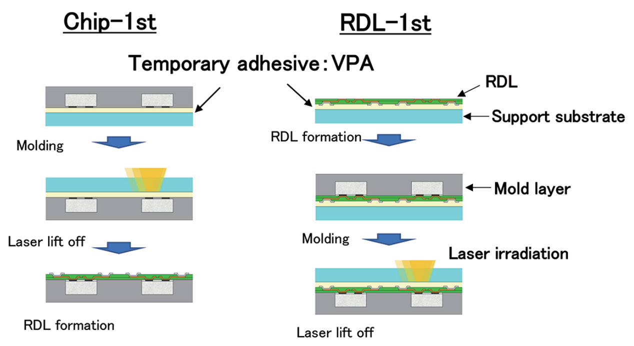

Fig. 1 Fan-Out Package process

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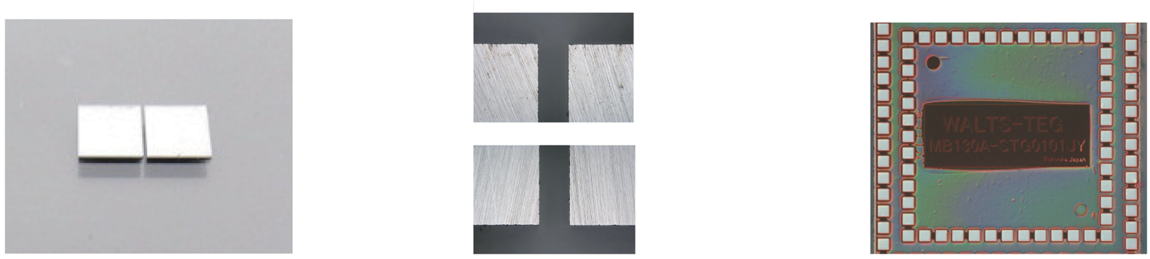
Table 1 Process wavelength type and designation of VPA series

	VPA	
	308 nm Type	355 nm Type
Tensile strength	77 MPa	46 MPa
Elastic modulus	2.9 GPa	3.3 GPa
Elongation	4%	2%
Thermal decomposition temperature (5% weight loss under N2)	>340°C	>340°C
Glass transition temperature	200°C	120°C
CTE (TMA)	75 ppm/°C	85 ppm/°C



(a) Chip mounting image
Mounted in parallel at 100um intervals

(b) Chip top and bottom spacing image
Enlarged view

(c) Image of VPA and chip backside installation
Enlarged view from the glass side

Fig. 2 2 mm square chip mounted on support glass with VPA

sorbency and it tends to ablate by absorbing laser light (**Table 1**). Because the VPA also has reactive groups and forms cross-links through a heat curing reaction, the VPA shows high adhesiveness with support and panel substrates. Therefore, compared with the double-layer type for which the UV absorption function is separated from the bonding function, which is the mainstream for the varnish type, the VPA demonstrates excellent handling performance. As another characteristic, the use of a special chemical solution after laser lift-off makes it easier to dissolve and remove heat-hardened films from panel substrates although heat-hardened films do not dissolve much by general solvents, such as propylene glycol monomethyl ether acetate (PGMEA) and acetone.

3. Mountability

In the Chip-1st process, it needs to mount chips on support glass at high speed and high accuracy to respond to upsizing of panels and mixed mounting of different types of devices.

Figure 2 shows the positional accuracy of chips mounted on support glass with the VPA. A flip chip bonder was used to mount 2-mm-square chips in parallel at intervals of 100 μm (Fig. 2(a)).

All chips could be mounted at intervals of 100 μm as targeted (Fig. 2(b)). In addition, observing the back side of the chips from the support substrate side confirmed that the whole surfaces had been bonded without improper adhesion (e.g., voids) in the pad section (Fig. 2(c)).

Substrates with mounted chips are molded using sealing resin. In this manufacturing process, they are molded at high temperatures and high pressure to enhance the liquidity of the sealing resin.[3)] When multiple chips are highly densely mounted in a mixed way, in particular, it is necessary to fill very narrow sections between the chips with sealing resin and thereby the molding conditions become more severe. Therefore, temporary adhesives need to have high adhesion strength such that no problems (e.g., ablation and deviation) will occur at higher temperatures and higher pressure.

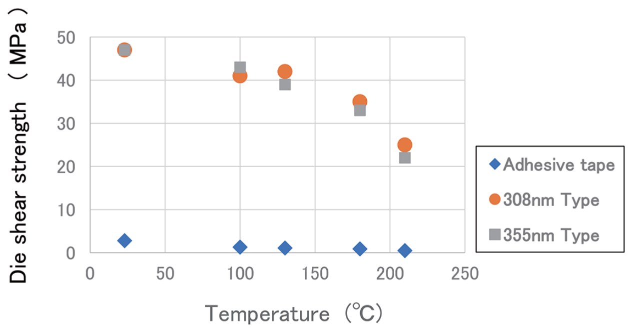


Fig. 3 Shear strength of 2 mm square chip mounted on support glass with VPA

The relationship between temperature and adhesion strength was evaluated using a die shear tester. The VPA and 2-mm-square chips were bonded to fabricate test pieces and they were heated at 23°C to 210°C. **Figure 3** shows the adhesion strength. The heating temperature of the substrates was determined assuming the temperature during molding (210°C). The results show that even at 210°C, the VPA retains an adhesion strength of 20 MPa or higher and thereby it has sufficient durability for the molding process at high temperatures and high pressure.

4. Laser Lift-off Properties

As described above, the VPA has high adhesiveness with chips and at the same time stable laser lift-off performance.

A VPA film was formed on glass with a diameter of 5 inches and the glass was bonded with a silicon wafer having the same area so as to fabricate a test piece consisting of three layers. Then the laser was irradiated from the support substrate side to evaluate the laser lift-off properties (**Fig. 4**). We provide materials for laser wavelengths of 308 and 355 nm. For 308 nm, the laser was irradicated at an energy density of 200 mJ/cm^2 and for 355 nm, at an energy density of 320 mJ/cm^2. For both types, the glass substrates could be smoothly ablated without applying heat and force (**Table 2**). The results show that ablation at high throughput is possible thanks to the highly sensitive lift-off properties of the VPA.

5. Ease of Residue Removal

Because laser irradiation areas are uneven, the energy density at the periphery is lower. Accordingly, to completely ablate the substrates from the glass after molding, the edges of the irradiation areas on the major axis side are overlapped and the edges of the irradiation areas on the minor axis side are overlapped (Fig. 4). Consequently, the laser is repeatedly irradiated to the overlapping sections and removal of residue at these sections tends to be difficult due to the heat from the laser irradiation. However, in the residue removal process, to suppress damage to the mold layer, the residue needs to be uniformly removed at both the overlapped and non-overlapped sections.

As methods to remove the residue, wet etching using chemical solutions and dry etching involving plasma treatment are used. As chemical solutions to be used in wet etching, there are various types; A solution that dissolves the residue itself and another solution that permeates into the residue and swells to ablate it. An appropriate type is used according to the properties of the residue. On the other hand, the gas types, mixing ratio, and density need to be optimized so as to remove the residue of temporary adhesives most effectively for dry etching.

To remove VPA residue, the back side of a panel substrate after laser lift-off was protected with masking tape and then it was immersed into a special chemical solution for eight minutes. This succeeded in removing the residue including at the overlapped sections (**Fig. 5**). In addition, without masking tape, a panel substrate was subject to vacuum plasma treatment for five minutes and then immersed into a chemical solution for one minute. This method could remove only VPA residue without damaging the mold resin layer.

6. Conclusion

The VPA shows high adhesiveness with support substrates and chips as a temporary adhesive for fan-out packaging and has sufficient durability at high temperatures and high pressure in the molding process. With regard to the mountability on chips, high accuracy and high density mounting is possible. We provide VPA products that can be ablated by laser lift-off in the wavelength ranges of 308 and 355 nm at high throughput. Residue after laser lift-off can be removed using a special chemical solution.

It is expected there will be increasing demand for higher productivity and lower cost through large area batch molding in fan-out package manufacturing processes. We will continue development and improvement in the future as well so as to satisfy customer needs.

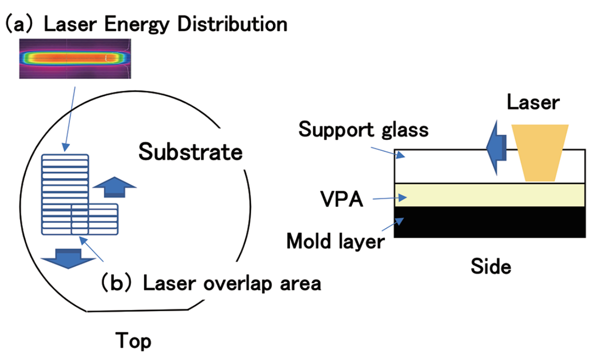
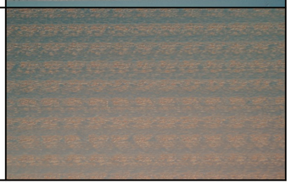
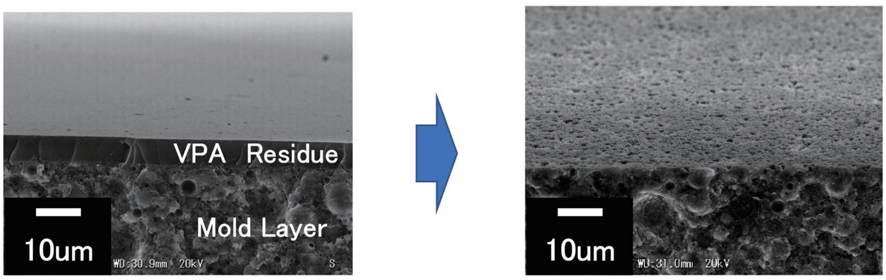


Fig. 4 Laser beam irradiation diagram

Table 2 Laser lift-off results

Laser wavelength	Irradiation energy	Laser release	Optical micrograph VPA residue on Si wafer
308nm	220mJ/cm^2	OK	
355nm	320mJ/cm^2	OK	



(a) Before removing residue (b) After removing residue

Fig. 5 Cross section of panel substrate after laser lift-off process

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