Damage Free Dicing Method for MEMS Devices

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This paper presents a dicing method for MEMS devices without damages during the dicing process. The method is based on bonding and detachment of a glass cap plate by using thermoplastic adhesive. Sand blast technique was used for the fabrication of glass cap plate which has concavities in the depth of 100µm. The thermoplastic adhesive was screen printed on the glass plate. The plate was thermocompression-bonded to silicon wafer at 210°C and diced to individual chips without damages from water or dicing dusts. The chip was mounted in the package while the glass cap was removed at 330°C.

Keywords: dicing, damage free, MEMS, thermocompression-bonding, thermoplastic adhesive

1. Introduction
In recent years, many MEMS devices have been developed in many fields such as sensor, Optical MEMS, RF-MEMS, etc. Release process is a key process for the fabrication of micro mechanical structures(1). The release process is performed in wafer process because of mass productivity and reducibility, then the wafer is diced to individual chips. However, conventional dicing machine uses water to cool rotating blade during the dicing process. The water or dicing dusts damage the micro structures and contaminate the MEMS devices.

Covering the silicon wafer with UV-tape during the dicing process can protect the surface of MEMS devices. The tape’s adhesive strength can be reduced with UV light after dicing, but weak adhesive force is remained on the tape. The weak force is enough to break the micro mechanical structures such as accelerometer and optical mirror, etc. Some workers use shallow slits formed by half dicing technique or deep R.I.E. method. The MEMS devices is split to individual chips along the slits after release process. However, split impulse sometimes damages the micro mechanical structure, and slight particles lose the performance and the reliability of MEMS devices.

In order to solve the problem, we proposed the damage free dicing method using a detachable glass cap plate with concavities to protect MEMS devices from the dicing damages. Because the method is used in backend-process, the view of cost-effective and easy adaptation to product facility is important. The fabrication of glass plate and coating of thermoplastic adhesive are performed by inexpensive materials and process.

2. Concept
The concept of the damage free dicing method is shown in Fig.1. Micro mechanical structures are fabricated and released on a silicon wafer. A glass cap plate with concavities is aligned and bonded to the silicon wafer. The glass plate protects the micro mechanical structures from the water or dicing dusts during the dicing process. Then, the glass cap is removed when the silicon chip is mounted in a package. The glass cap fabrication, bonding and detachment are performed as follows.

3. Fabrication of Glass Cap Plate
Some of MEMS devices such as micro scanner have the height of a few hundreds micron, so that deep etching technique is necessary for the fabrication of concavities. A polished Pyrex glass and sand blast technique were used for making concavities. Dry film was adhered on 0.5mm thick glass plate and patterned 1mm square as a mask for the sand blast process. The sand of #220 SiC and the pressure of 0.35MPa were used because large sand and high pressure are recommended to make high aspect shape. As a result, trial concavities in the depth of 0.1mm were formed on 4inch glass wafer. The depth up to 2mm can be formed by sand blast technique(2).

4. Bonding and detachment
Thermoplastic adhesives of STAYSTIK series(Techno alpha Co., Ltd.) were selected because the adhesives do not produce out-gas during bonding process(3). A thermocompressor

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(TMV1-200A, Tsukuba Mechanics Co., Ltd.) and 4cm² glass plate were used for the pre-experiment of bonding. An insulating type STAYSTIK 373 was screen printed on the glass plate. The plate was prebaked at 170°C to evaporate flammable solvent in thermoplastic adhesive. The gel condition of adhesive changed to solidified condition. The thickness of adhesive layer was 14 micrometer. The glass plate and silicon plate were bonded by changing the temperature and pressure. As the result, over 90% area was bonded around 200°C by the pressure of over 0.4MPa. The pressure corresponds to 1.25kN for 4cm² area because the air cylinder’s diameter of TMV1-200A is 63mm. So, the force of 24.5kN is necessary for 4inch wafer by the calculation. Though special ordered EVG520 thermocompression bonding system (EVG Japan KK) can produce the force of 40kN, a standard EVG520 system (the force up to 3.5kN) was used in this experiment as the pre-bonding use.

STAYSTIK373 was coated on 4inch glass cap wafer with screen printing method. After coating and prebaking, the glass wafer was aligned to the silicon wafer by holding small gap with EV620 alignment system (EVG Japan KK). The glass wafer was placed on silicon wafer and mechanically clamped, then both wafers were pre-bonded by EVG520 at 210°C by the force of 2kN in a vacume chamber of 4.5×10⁻⁶Torr. About 20% to 40% area of 4inch wafer was bonded at the condition. Then, the partial area of the wafer was bonded by TMV1-200A at 210°C by pressure of 0.5MPa as shown in Fig.2.

After bonding, the glass-silicon wafer was diced with a conventional dicing saw. Water immersion was not observed inside area covered with glass cap because the thermoplastic adhesive showed enough strength for the dicing process. Then, the diced chip was heated around 300°C about 10 seconds, the adhesive was thermally decomposed, so that the glass cap was removed by weak force. Figure 3 shows the photograph after detachment. Some adhesive was remained on the silicon area bonded with glass cap, but the electrical short-circuit was not occurred because of insulating property of adhesive.

5. Combination with chip mounting process
The property of the adhesives are summarized in the table 1. The bonding temperature of STAYSTIK 101 or 301 is over 300°C. So, STAYSTIK 101 or 301 was coated on the bottom side of silicon chip. The bonded chip was lifted by vacuum and bonded on other plate at 330°C. The glass cap was removed at the same time as shown in Fig.4. Therefore, the glass cap detachment is possible in chip mounting process using a conventional die-bonder.

6. Conclusion
We proposed a new method to dice MEMS devices, and demonstrated by glass cap plate and thermoplastic adhesives. After bonding the glass cap plate and silicon wafer, it was diced with conventional dicing saw. After dicing, the glass cap was removed from silicon chip at 330°C combined with chip mounting process. The method can be adopted in the present mass-productive facility, because the method is accomplished with inexpensive materials and well-established equipments. The method is adoptable for large (4 or 6inch) wafer, therefore it will be effective method to dice and mount the MEMS devices for final packaging.

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References
(3) Data sheet of STAYSTIK, Techno alpha Co., Ltd

<table>
<thead>
<tr>
<th>Name of adhesive</th>
<th>Character</th>
<th>Bonding Temp.(°C)</th>
<th>Detaching Temp.(°C)</th>
<th>Die-shear strength kg/cm²</th>
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<tbody>
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