EXCIMER LASER DEBONDER FOR 2.5D AND 3D INTEGRATION

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Published in the SUSS report V2 11/2014
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SUSS MicroTec has recently introduced an Excimer Laser based Debonding module (ELD300), which allows the stress free separation of a glass carrier wafer that was bonded to a device wafer by means of an adhesive layer in order to support the device wafer during thinning or backside processing steps. Temporary bonding of device wafers to a carrier is typically used for supporting the device wafer during various critical process steps such as thinning and backside processing in area of 3D integration, 2.5D interposers, MEMS or power devices. The laser debonder can be used as a stand-alone, semi-automated system or as an integrated process module in SUSS MicroTec’s XBC300 Gen2 platform. The debonding method used in the ELD300 system is based on a 308nm Excimer laser which is used to separate the glass carrier from the tape mounted, thinned device wafer. The ultraviolet (UV) light of the pulsed laser beam is absorbed in the adhesive or in an optional UV absorption layer within a few hundred nanometers. The absorbed laser energy breaks the chemical bonds in the adhesive or absorption layer without generating thermal stress on the thinned device wafer. After the actual laser debonding process the glass carrier wafer can easily be lifted off with close to zero mechanical lift-off force.

INTRODUCTION
In the last decades the semiconductor industry has witnessed two major developments: On the one hand the constant decrease of feature sizes, coinciding with Moore’s Law and leading to almost a doubling of integrated circuits per wafer every one to two years. On the other hand production processes are being transferred to increasingly larger wafers to save cost by being able to produce more dies per wafer. Additionally, in the last years a third market trend has emerged: Similar or different devices are placed next to each other on a carrier, a so-called interposer (2.5D technology) or stacked three-dimensionally (3D technology). The target is to create the shortest possible signal lines while at the same time increasing the number of input and output lines between the single devices in order to increase the signal bandwidth while reducing power consumption and heat dissipation. Instead of using classical wire bonding technologies this new technology uses photolithographic patterning of signal lines, through-silicon via (TSV) connections and contact pads with far smaller feature size in order to allow higher integration densities. High density through-silicon via fabrication typically requires the device wafers to be thinned to a final thickness in the range of 50–100μm.
In order to allow the processing of such thin wafers with commonly used production equipment the wafers are temporarily glued or bonded to another silicon or glass carrier wafer prior to thinning. After backgrinding and performing all necessary backside processes, the thinned device wafer is mounted on a dicing tape which is held in a metal or plastic frame. For further processing the temporarily fixed carrier needs to be removed (debonded) to allow the separation of the thinned device wafer into individual chips using a wafer saw. The debond process of the carrier from the device wafer can be effected mechanically or through a laser procedure. For the laser-based debonding process of wafers Excimer laser tools with a wavelength of 248nm or 308nm have been proved particularly successful. During the laser debonding process a laser beam is directed over the glass carrier to open the bond interface between the carrier and the adhesive material. The Excimer laser produces a very high energy density. Due to the short pulse length of only a few nanoseconds, hardly any thermal energy is distributed on the surface of or within the device wafer. In July 2014, the first semi-automatic laser debonding module was produced and qualified by SUSS MicroTec. Figure 1a shows a picture of this Excimer Laser Debonding (ELD300) module. The scan table with an on a tape frame mounted wafer is shown in Figure 1b during the Excimer laser debonding process. SUSS MicroTec has developed special chucks for tape frames for this module, guaranteeing that the bonded wafer pairs can be safely held during the laser debonding process even at high scanning speeds of the x-y table. After debonding with the Excimer laser, the glass carrier can easily be removed from the device wafer with a vacuum gripper. The thinned device wafer remains mounted on the dicing frame. Besides a stand-alone version, the Excimer Laser Debond module is also available as a process module for the XBC300 Gen2 platform, allowing a fully automated process with a throughput of 40 wafers/hour, including all, wafer and tape frame handling as well as carrier lift-off.

Figure 1 Excimer Laser Debonder ELD300: (a) Overall view of the process chamber; (b) inside view of the process chamber during laser debonding process of a wafer
OPTIMIZATION OF THE LASER ENERGY

For the Excimer laser debonding process of a specific temporary adhesive material two process parameters have to be optimized. The first parameter is the focus point of the Excimer laser. The Excimer laser offers sufficient depth of focus so that variations in adhesive or device wafer thickness typically do not require any readjustments. The second process parameter is the laser energy. The laser energy needs to be optimized for the specific absorption properties of the adhesive or UV absorption layer. Figure 4 shows the effect of single laser pulses with different energy levels in five different areas of a test wafer.

Figure 2 Principle of the laser debonding process

Figure 3 Energy distribution and beam profile of an 308nm Excimer laser

Figure 4 Optimization of the laser energy density

PRINCIPLE OF EXCIMER LASER DEBONDING

The debonding method used in the ELD300 module based on a 308nm Excimer laser to separate the glass carrier from a tape mounted thinned device wafer. The UV light of the pulsed laser beam is absorbed in the adhesive or in an optional UV absorption layer within a few hundred nanometers. The absorbed energy breaks the chemical bonds in the adhesive or absorption layer without generating thermal stress on the thin device wafer so that the glass carrier wafer can easily be lifted off after the debonding process. For this procedure a laser beam is directed over the glass carrier to remove the bond interface between the carrier wafer and the adhesive material. Figure 2 shows the principle of the laser debonding process.

The Excimer laser works with an extremely high energy density in pulse operation mode. One pulse period lasts only a few nanoseconds, producing hardly any thermal energy to distribute on the surface of or within the device carrying wafer. Additionally, the Excimer laser offers a very homogeneous energy distribution leading to a low penetration of UV radiation in the absorbing material (Figure 3).
EXCIMER LASER DEBONDING PROCESS

For the ELD300 module the maximum available laser energy density that can be applied is 400 mJ/cm². The pulse frequency is programmable up to 50 Hz. During the debonding process the laser is directed over the glass carrier to open the bond interface between the carrier wafer and the adhesive material. In collaboration with material makers like Brewer Science, a large number of new materials were qualified to prove the reliability of the Excimer laser debonding procedure. Using Brewer Science’s new materials in combination with the ELD300 System, the laser debonding process of a 200 mm wafer takes less than 30 seconds on average. For a 300 mm wafer the Excimer laser-based debonding process takes less than 60 seconds. Figure 5 shows a device wafer before (Figure 5a) and after (Figure 5b) the Excimer laser release and glass carrier lift-off process.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Laser energy density [mJ/cm²]</th>
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<tbody>
<tr>
<td>1</td>
<td>270</td>
</tr>
<tr>
<td>2</td>
<td>230</td>
</tr>
<tr>
<td>3</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>140</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
</tr>
</tbody>
</table>

*Table 1 Investigation of the optimal laser energy density for the debonding process*

A summary of the different laser energy levels is shown in Table 1. The laser energy was decreased from 270 mJ/cm² (area 1) to 90 mJ/cm² (area 5). The higher the laser energy the larger the delaminated area. By reducing the laser energy density to 90 mJ/cm² the delaminated area is decreasing considerably. On the other hand, higher fluence may result in a stronger degradation of the UV absorbing material or more ablation residues. Cleaning or recycling of the glass carrier wafer will be more difficult with a larger amount of residues present. For the material example shown in this experiment the optimum laser energy was found to be 140 mJ/cm² (zone 4). That energy level did produce sufficient delamination while the residue level on the glass carrier was very low.
Dr. Tim Griesbach studied Mechanical Engineering specializing in Micromechatronics and Bio-Medicine Technology at the Leibniz University Hannover, Germany. After his studies he was working as a research assistant at the Institute of Microproduction Technology and earned a PhD degree from the Leibniz University Hannover for his research work on the development of a new manufacturing technology for the fabrication of micro sensors on flexible substrate materials. Dr. Tim Griesbach joined SUSS MicroTec as Application Scientist for permanent and temporary wafer-to-wafer bonding processes in September 2012.

The corresponding glass carrier wafer is shown in Figure 6. Residues of the UV release layer can be observed on the surface of the debonded glass carrier wafer (Figure 6a). These residues can be easily removed by an oxygen plasma cleaning process, which offers the possibility of the reuse of this wafer for new temporary bonding applications. The glass carrier wafer is shown in Figure 6b after an oxygen plasma cleaning step.

**SUMMARY**

For the stress free debonding of 200mm and 300mm wafers SUSS MicroTec is offering an Excimer Laser Debonding module ELD300, which can be used as a stand-alone, semi-automated system or as an integrated process module in SUSS MicroTec’s XBC300 Gen2 platform. For the debonding process a 308nm Excimer laser is used to separate the glass carrier from a tape mounted thin device wafer. The absorbed energy breaks the chemical bonds in the adhesive or absorption layer without generating thermal stress on the thinned device wafer. At the end of the laser debonding process the glass carrier wafer can easily be lifted off. In collaboration with material makers like Brewer Science, a number of new materials were qualified to demonstrate the reliability of the Excimer Laser Deboning procedure. Using Brewer Science’s new materials in combination with the ELD300 system, the laser debonding process of a 200mm wafer takes less than 30 seconds on average. For a 300mm wafer the Excimer laser-based debonding process takes less than 60 seconds.