Thin Wafer Laser Debonding – Fast and Without Fuss.

Temporary bonding of wafers to a glass carrier has emerged as a viable method for back thinning and subsequent backside processing. The processed thin wafers are finally debonded from their carriers prior to stacking. Excimer laser debonding enables the use of polyimide-based temporary adhesives that can withstand high temperatures up to 400°C.

Introduction

Thin wafers represent an important technological advance in achieving microelectronics devices with higher performance, efficiency as well functional density via

- reduced package thickness
- better heat dissipation
- increased TSV density

As a consequence, strong market growth is forecasted for thin wafer shipments (Fig.1)

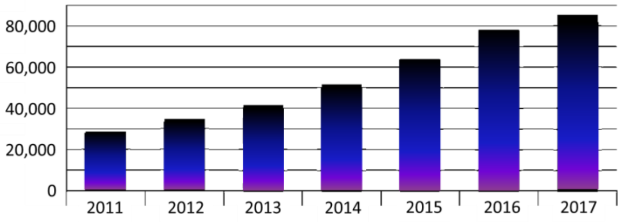
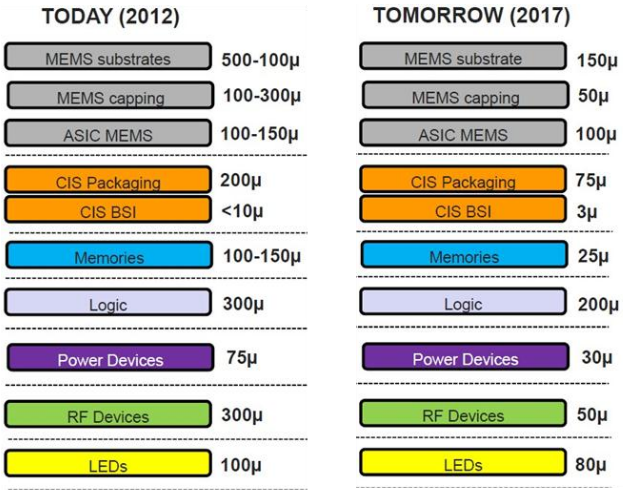


Figure 1: Thin wafer 2011-2017 shipment forecast in 300 mm equivalent (Source: Yole Forecast)

Following the overall trend to miniaturization of microelectronic devices, thin wafers constantly shrink in thickness. The main markets for thin semiconductor wafers together with the expected five year thickness figures are shown in Fig.2.



TODAY (2012)		TOMORROW (2017)	
MEMS substrates	500-100μ	MEMS substrate	150μ
MEMS capping	100-300μ	MEMS capping	50μ
ASIC MEMS	100-150μ	ASIC MEMS	100μ
CIS Packaging	200μ	CIS Packaging	75μ
CIS BSI	<10μ	CIS BSI	3μ
Memories	100-150μ	Memories	25μ
Logic	300μ	Logic	200μ
Power Devices	75μ	Power Devices	30μ
RF Devices	300μ	RF Devices	50μ
LEDs	100μ	LEDs	80μ

Figure 2: Thin wafer dimensions and markets (Source: Yole Forecast)

However, the delicate nature of thin wafers makes it impossible to handle them using existing process equipment and techniques. Temporary bonding of wafers to a glass carrier has emerged as a viable method for back thinning and subsequent backside processing of silicon wafers up to 300 mm diameter (Fig.3).

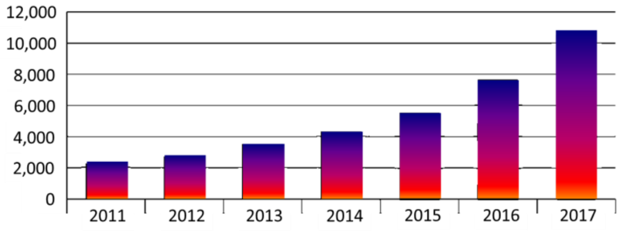


Figure 3: Number of debonded thin wafers (Source: Yole Forecast)

The processed thin wafers are then debonded from the glass carrier just prior to stacking. There are several techniques for performing thin wafer debonding, including mechanical, chemical, thermal, and laser-based debonding. This whitepaper looks at the basics of the laser debonding process, and some of the practical considerations related to its implementation.

Thin Wafer Process

A schematic of the key process steps for thin wafer processing using a temporary glass carrier wafer is shown below (Fig.4). Specifically, a wafer is front side patterned, and then bonded to a carrier substrate. The wafer is then back thinned, and back side processing is performed. Finally, 308 nm excimer laser light is introduced from the carrier side (which is transparent at the laser wavelength), causing gentle debonding of the wafer from its glass carrier.

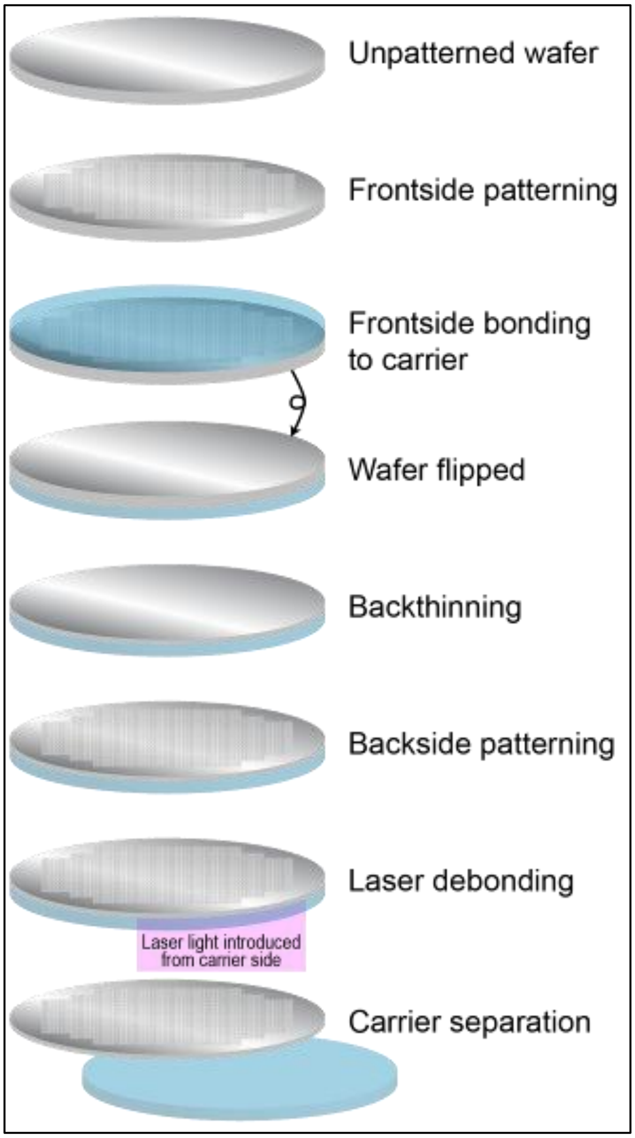


Figure 4: Illustration of elementary thin wafer process steps

In practice, the temporary adhesive for laser debonding is most commonly spin coated onto the wafer, which is then mated with the carrier. Bonding then occurs under pressure and elevated temperature. After thinning and backside processing, the laser initiated detachment occurs at the glass/adhesive interface. After laser debonding, the glass substrate is lifted off the thinned wafer, leaving some residual adhesive which is then removed using solvents.

The Excimer Laser Advantage

The most important advantage of 308 nm excimer laser debonding over other techniques is that it enables utilization of polyimide based temporary adhesives which can withstand exposure to temperatures as high as 400°C.

This enables the bonded assembly to successfully survive the temperature cycling experienced in steps such as dopant activation after ion implantation. In contrast, most thermally or chemically activated temporary adhesives have difficulties tolerating temperatures above 200°C.

Unlike thermal or chemical debonding, which utilize silicon carriers, laser induced debonding requires the use of glass carriers. In CMOS fabs, where ionic species are particularly undesirable, glass carriers are problematic to implement. So, laser debonding is likely to coexist along with other methods, with each having its own market niche.

IGBTs and Si based Power Devices

Because of this, excimer laser debonding is most useful for IGBT and silicon based power devices (MOSFETs, etc), because these often require ion implantation and activation to create back side drain contacts [1]. However, for CMOS device wafers, active elements are typically all on the front side, and are thus completed before bonding to the carrier wafer. Furthermore, the eutectic bumps used on CMOS wafers will reflow when exposed to high temperatures, so exposure to high temperatures is avoided anyway.

Layer Selective Debonding with Excimer Lasers

The laser debonding process is conducted with a 308 nm excimer laser. UV lasers work via a cold process very much different from infrared lasers.

IR lasers penetrate far into the adhesive layer and easily cause debonding through a thermal mechanism (e.g. heating). Oxide layers are put into the assembly to absorb this infrared light, but if these are imperfect and the laser light penetrates through, it can damage wafer structures. After infrared laser debonding, residual adhesive must be physically peeled off.

In contrast, the 308 nm ultraviolet light emitted by excimer lasers is absorbed very near the glass/adhesive interface, penetrating only just a few hundred nanometers. Thus, it leaves the thin wafer entirely unaffected. Furthermore, the ultraviolet light from the excimer laser debonds through a primarily photochemical means, by directly breaking chemical bonds in the adhesive polymer.

This non-thermal process breaks down the temporary adhesive at the glass/adhesive interface. Depending upon the polymeric backbone of the temporary adhesive, the precise debonding mechanism may vary. Modern laser debondable adhesives are designed in such way to have an easy and reliable debond, where the carrier wafer can be just lifted of the thinned device wafer.

There are two basic approaches for implementing excimer laser based debonding, namely, line scanning and step-and-repeat.

In line scanning, the naturally rectangular output distribution of the excimer laser is reshaped into a thin line, which is focused on to the carrier/adhesive interface. The length of this laser line is slightly greater than the wafer diameter, and the width is typically around 200 µm, depending on the laser output power. This line is then scanned over the surface of the wafer a single time in order to produce debonding.

In step-and-repeat, a homogeneous laser square or rectangular field (typically about 5 mm on each side) is projected at the carrier/adhesive interface, and an exposure is made which is sufficient to cause debonding. Then, the wafer is indexed a distance corresponding to the spot height, and the process is repeated until the entire wafer surface is covered.

The mechanical simplicity of the line scan approach more readily lends it to higher throughput. But, it also typically requires a higher power laser because the light is spread over a larger area, thus lowering the energy density. Also, away from the wafer center, much of the laser energy is wasted (since the line goes off the edge of the wafer when the line is anywhere except the very center of the wafer).

Conversely, the step-and-repeat method requires less laser power, yet is still capable of reaching up to 40 wafers/hour throughput even at low laser pulse frequency of 20 Hz.

The necessary laser power for step-and-repeat also depends upon the number of laser shots utilized in each exposure. However, it is quite possible to achieve debonding with a single laser shot with a relatively modest power laser.

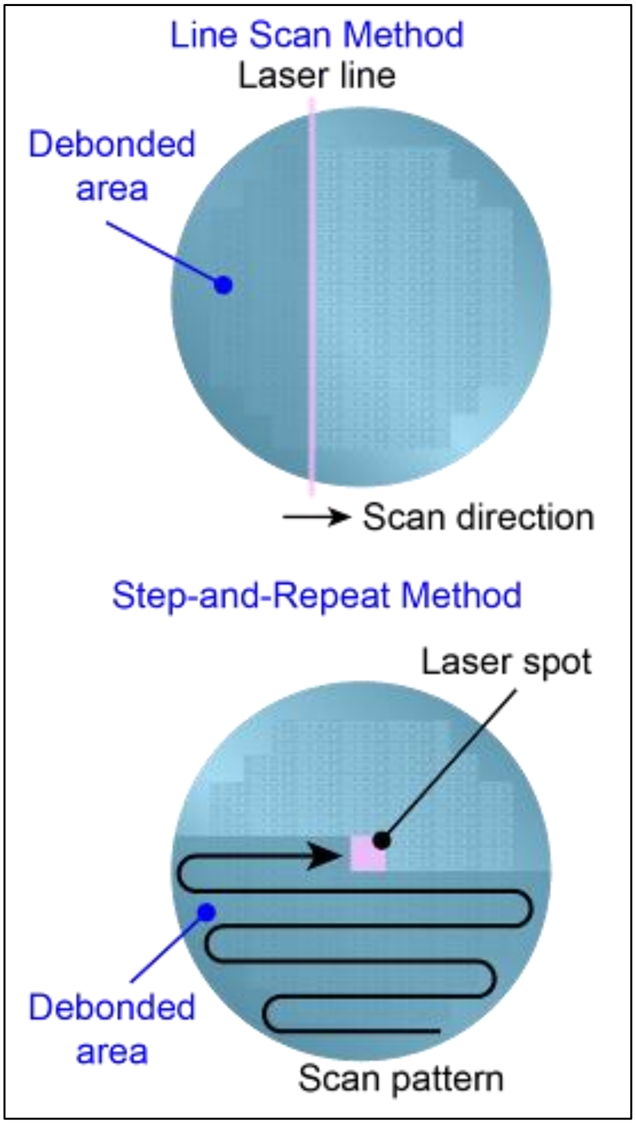


Figure 5: Excimer laser thin wafer debonding approaches

The minimum required laser power for debonding is also dependent upon wavelength because of absorption in the glass carrier. Specifically, a typical glass carrier might absorb about 5% of the incident laser light at 308 nm, while the absorption at 248 nm could be 95%. Thus, nearly 20 times more laser power would be required at 248 nm to achieve the same energy density at the glass/adhesive interface as with 308 nm. There are also subtle differences in the specifics of the light/adhesive interaction between the two wavelengths. However, in general both wavelengths can be successfully employed.

COMPexPro thin wafer debonding

Excimer lasers such as the COMPexPro (Fig.6) deliver a high energy pulse that is naturally rectangular in shape with uniform intensity distribution. This beam can readily be manipulated with beam shaping optics to match the necessary processing area on the work piece, and to have a homogeneous intensity distribution of ~1%, rms over its area.

Figure 6: COMPexPro excimer laser series

These requirements would be much more difficult to achieve with other UV laser technologies, such as the diode-pumped solid-state laser. They typically deliver much lower pulse energies and have a Gaussian beam profile that is harder to transform into a uniform and rectangular flat-top profile.

Example calculations carried out for 200 mm and 300 mm diameter thin wafer excimer laser debonding indicate a reasonable throughput of at least 60 wafers per hour already for modest excimer laser operation at 20 Hz repetition rate.

Excimer Laser Parameters and Wafer Throughput

Wafer Size	**200mm**	**300mm**
Wavelength	308 nm	308 nm
Fluence	250 mJ/cm^2	250 mJ/cm^2
Field Size	50mm x 2mm	50mm x 2mm
Pulses/Wafer	400 pulses	900 pulses
Pulse Rate	10Hz	20Hz
Throughput	>60 wafers/hr	>60 wafers/hr

Table 1: Excimer laser parameters and throughput

Such requirements can be fulfilled with compact and affordable low power excimer lasers. The Coherent COMPexPro excimer laser family is an ideal source for thin wafer laser debonding. It provides up to 20W of output at 308 nm at a maximum pulse energy of 500 mJ and a maximum repetition rate of 50 Hz. All combined in a 1682 x 375 x 793 mm one-box design housing. The COMPexPro operates from either 110V or 220V standard, single phase power.

Conclusion and Outlook

In conclusion, excimer laser debonding represents an economically viable method that can deliver the throughput required for fab process equipment. The characteristics of the polymeric adhesives it employs make it particularly advantageous over other debonding techniques in the manufacture of power devices, or any other components that require exposure to high temperature during manufacture.

References

[1] T. Uhrmann, R. Delmdahl: Laser debonding enables advanced thin wafer processing; Solid State Techn. 56, 18–20 (2013).