Paradigm Shift in Compound Semiconductor Production since the Introduction of Laser Dicing

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Keywords: Laser dicing, Multibeam, HAZ, Solar Cells, CSH

ABSTRACT

This paper will address the impact of multi beam laser dicing on the dicing process capability in the backend of the line, as well the advantages it brings for manufacturing optimization such as cycle time reduction, cost reduction, wafer and dicing yield improvement, and elimination of backside processes.

RETURN OF INVESTMENT

For several years now, technology leading compound semiconductor companies have introduced multiple beam laser dicing to replace conventional mechanical die separation technologies such as sawing and scribe & break (S&B). Upon installation of a multibeam laser dicing system, the obvious advantages of using such a laser dicing process become evident. The dicing kerf has been reduced to below 20um in many cases, with no chipping on either front or backside. As shown in figure 1 below, this increase in capability then allows the street size to be reduced down to 26um, allowing more die per wafer.

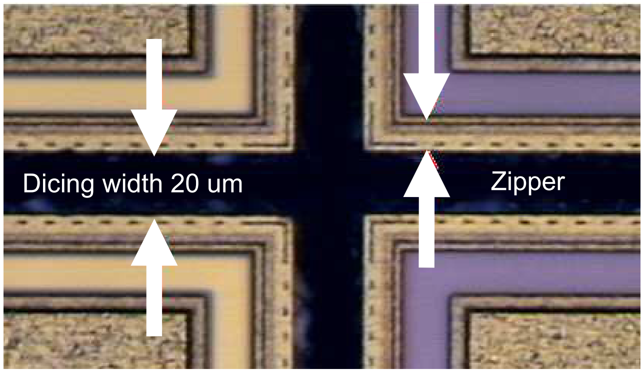


Figure 1, RFIC wafer laser diced and expanded on standard dicing tape with dicing streets of 26 micron wide. (Courtesy of TriQuint Semiconductor)

This is achieved by using a unique multiple beam technology, demonstrated in figure 2, which reduces the power density, minimizes the thermal load, and reduces the kerf width in the wafer.

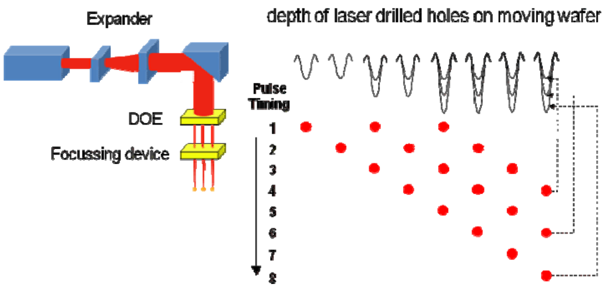


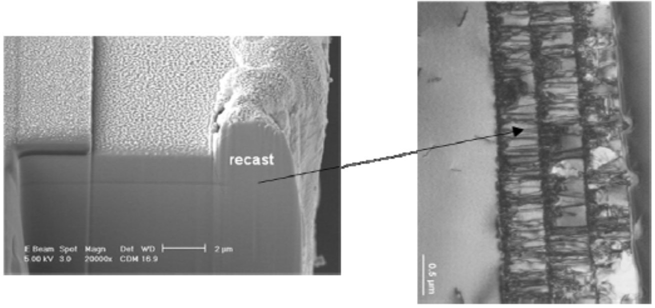
Figure 2, Principle of multiple beam technology.

The higher dicing speed of this process has led to a productivity increase of 5 to 8 times compared to any conventional separation system, and 3 to 5 times any other laser dicing concept. This increase in through-put is to a large extent achieved by the multiple beam technology which minimizes the number of traverses needed to dice through a wafer. This strong increase in through-put, together with street width reduction, no dicing yield loss, and high up time (>97%), allows a return of investment usually within 3 to 6 months.

MULTIPLE BEAM LASER PROCESS

When using any dicing process to separate the wafer it is always a tradeoff between quality and speed, independent of the technology. Currently available industrial lasers can deliver high amounts of power. However, when exerted at such high levels onto a thin wafer substrate, the material is not only separated, but may also be damaged severely. To get a good quality cut (no chipping or cracks) with a minimal heat affected zone, low laser power levels need to be used. Normally as a result, material removal rates and therefore dicing speed is lowered and the laser capability with respect to the available power is far from optimized. The multi beam does address these concerns.

The basic principle is to split the main laser beam up into a plurality of laser beams, each having a low power level and therefore not compromising the cut quality, and working concurrently as a group of beams, keeping both the material removal rate and the dicing speed high. Initially, semiconductor manufacturers had concerns over the visual appearance and the extent of the heat affected zone (HAZ) of the die after laser dicing. The advantage of a multibeam laser dicing process does not eliminate the HAZ, but clearly minimizes this effect. In addition, the recast generated by the first beam, which is of low power and intensity, thermally isolates the substrate for the subsequent following beams. See figure 3 below.



FIB of a laser diced GaAs wafer

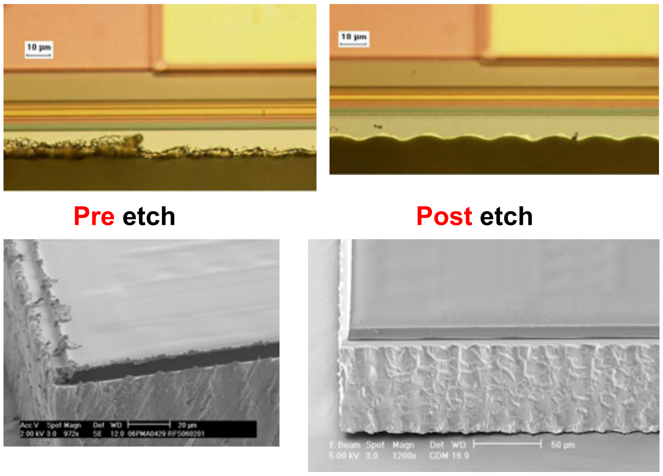
TEM of GaAs recast diced with 3 beams

Figure 3, FIB & TEM images of recast layer along the side wall of the die.

CHIP SIDE HEALING (CSH)

Having a slightly rougher but more regular dicing edge compared to S&B or sawing, questions arose if the die strength and package reliability of laser diced die had changed. In fact, the die strength is fully recovered, and even exceeds the reference die strength of current separation technologies after laser dicing, in combination with a post process step. See figure 4 below.

Currently, several billons of laser diced RFIC dies have been packaged and no failures relating to laser dicing have been reported. The primary targets for which laser dicing technology has been introduced at these technologically leading companies, has been met and exceeded.



Pre etch

Post etch

Figure 4, Optical and SEM images of laser diced and subsequently etched dies (courtesy of Skyworks Inc.)

Usually after the multiple beam laser dicing technology has been integrated into full production, additional capabilities of this unique dicing technology have been explored. Apart from the primary advantages, the secondary advantages may have an even larger contribution to the efforts of companies to reduce costs and improve yield.

The secondary advantages can include a significant reduction of labor costs, as no post visual inspection is needed as in traditional dicing processes. This allows significantly less operator intervention, thus allowing one operator to manage an increased number of machines.

Additionally, expensive and time consuming backstreet etching can be eliminated by using the full potential of the multiple laser beam technology. Whereas for most dicing technologies the thick backside metal needs etching, the multibeam laser dicing cuts Au or Cu back metals of 5-10 um.

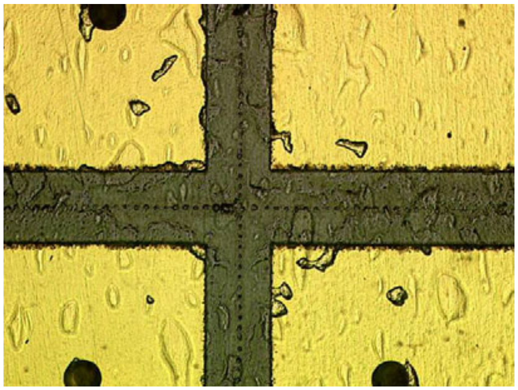


Figure 5, Example of a laser diced GaAs wafer with 8 um back metal, after stretching

LASER DICING OPTIONS

Along with the melt ejection, laser dicing technologies, sub-surface laser dicing technologies have been introduced. The sub surface technology focuses laser pulses inside the wafer substrate, modifying the crystalline structure, weakening and creating stress without material removal. Afterwards the wafer can be separated by expansion or with aid of a breaking device. Several advantages over mechanical scribe and break can also be achieved utilizing this technology but do not offer the major advantages that multi-beam ablation offer. The performance comparison of the traditional Scribe & Break, laser sub surface and the multiple beam ablation are illustrated below in figure 6.

A multiple beam, sub surface laser dicing technology is currently being developed, which will improve the productivity of such a process significantly.

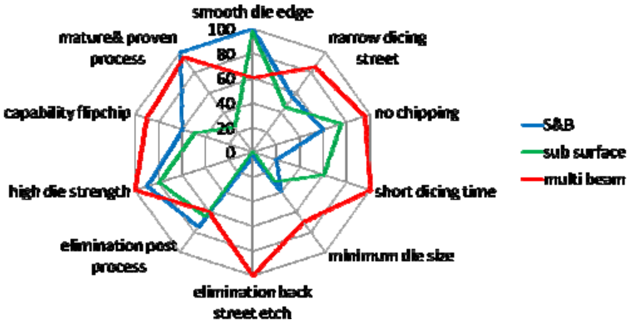


Figure 6, Comparison of parameters of interest with respect to dicing technologies

In addition, the versatility of the (ablative) melt ejection, multiple beam laser dicing technology to dice various types of substrates, a range of substrate thicknesses, and various wafer surface passivations, all on the same machine platform, has become a welcome enhancement of manufacturing capabilities. Next to these advantages, this technology also enables several roadmap requirements such as die shrinkage, flip chip wafer technology, and the trend towards thinner wafers (down to 30-50 um). With the list of applications still growing, multiple beam laser dicing is currently able to offer a solution for dicing different types of substrates and materials used in semiconductor manufacturing and solar cells, including GaAs, CuW, GaP, Ge, InP, $LiTaO_3$, Si, and SiC, with various front and backside passivations and or metallizations.

SUMMARY

In summary, a multiple beam laser dicing system is not just a different dicing solution; it is a paradigm shift in dicing technology, that enables compound semiconductor manufacturers to increase and broaden their capability and capacity in both front- and backend, increase dicing yield, and reduce the overall cost and cycle time, while addressing challenges in their product roadmaps.

ACKNOWLEDGEMENTS

The authors would like to thank all of the users for the valuable inputs and willingness to share the information.

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ACRONYMS

HAZ: Heat Affected Zone
TEM: Transmission Electron Microscopy
FIB : Focused Ion Beam
RFIC: Radio Frequency integrated circuit
S&B: diamond Scribe and Break
Au: Gold
Cu: Copper
Si: Silicon
SiC: Silicon Carbide
GaAs: Galium Arsenide
GaP: Galium Posphide
Ge: Germanium
InP: Indium Phosphide
$LiTaO_3$:Lithium Tantalate