Backside Processing Steps Elimination and Cost Reduction by Multi Beam Full Cut Laser Dicing

Rogier Evertsen, Rene Hendriks

Advanced Laser Separation International (ALSI) NV, Platinawerf 20G, 6641TL Beuningen, the Netherlands
Phone: +31-(0)246782888, E-mail address: rogier.evertsen@alsi-international.com

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Abstract

In this paper, we will show the laser dicing separation trends in industry after the general acceptance of laser full cut dicing of common RFIC compound semiconductor substrates. We recognize the analogue of the semiconductor markets which already apply full backside metal cutting processes. The specific advantages of the multiple beam (MB) laser cutting are pointed out, including the laser dicing strategies that can be used to obtain the desired result. In summary, its implementation shows cycle time reduction, cost reduction, and the elimination of backside processes.

INTRODUCTION

The laser full cut dicing of common RFIC compound semiconductor substrates such as GaAs is generally accepted and in production throughout the market [1]. For several years now, 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). The obvious advantages of using such a laser dicing process are evident. Laser dicing separation is a non-contact type of separation, with a stable process, e.g. not subject to wear like diamond tips and blades, the ability to cut through a variety of materials [2,3], and with a small cutting width. Traditionally, the laser dicing process to separate the wafer has always a tradeoff between quality and speed, independent of the technology. The multiple laser beam technology has clear advantages over traditional laser dicing processes and process strategies which enable also full metal backside separation.

LASER SEPARATION TECHNOLOGIES

Over recent years, several laser-dicing technologies have been developed each having their specific characteristics for a separation process. The main dicing technologies that have become most common in the semiconductor industry are ablation laser dicing and sub-surface dicing. As sub surface dicing has its limitation on minimum street width and in principle not able to cut through non-transparent materials such as metals, we will focus on ablation laser dicing.
In ablation laser dicing, the wafer material is removed by irradiation of laser pulses which locally generate a combination of melt and vapor. The vapor pressure drives the molten material out of the wafer generating an opening also referred to as kerf (see figure 1). This technology is predominantly used for dicing through the whole wafer substrate thickness, even backside metallization. Depending on the application (wafer material, thickness, throughput, and die size), the laser type is chosen. Main laser process parameters that determine the interaction of laser light with the wafer material are wavelength, pulse duration and power. The size of the Heat Affected Zone (HAZ), the thickness and appearance of the resolidified molten material ('recast') and the resolidified particles ('debris') all depend on these parameters.

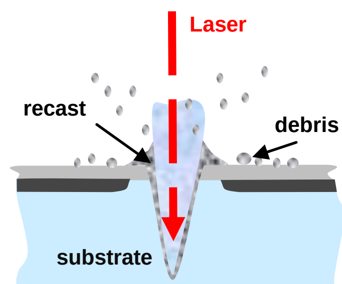

Figure 1, Principle of ablation laser dicing

MULTIPLE BEAM TECHNOLOGY

Nowadays, available industrial lasers can deliver high amounts of power. When such high powers would be exerted to a thin or brittle wafer substrate, the material is not only separated, but is also severely damaged. To obtain a good quality (no chipping or cracks) with a small or no HAZ, low laser power levels need to be applied. However, in that case, material removal rates and dicing speeds are low. The laser capability with respect to the available power is then far from utilized. To solve these issues, Philips and ALSI have developed a proprietary multiple laser beam technology. The basic concept is shown in figure 2. The main laser beam is split up into a plurality of laser beams, each having a low power level and therefore not compromising the quality, but as a group of beams keeping the material removal rate and thus the dicing speed high.

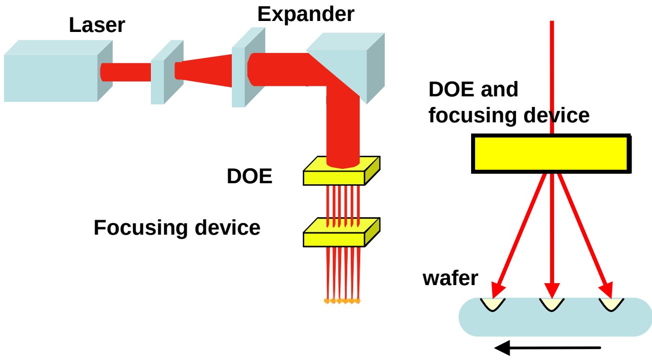

Figure 2, Concept of the multi beam laser dicing technology showing an overview (left) and shown in detail with substrate (right)

In this Figure, the beam splitting device consists of a diffractive optical element (DOE). This DOE splits the main laser beam up into a number of beams (in the situation illustrated in Figure 2 three beams) with a certain distance between them. Depending on the design of the DOE, a specific number of beams and distance between the beams is generated.

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 multi beam laser dicing process does not eliminate the HAZ, but minimizes the effect, allowing the use of the optimal power levels for each application. Visually, the slightly rougher but regular edges, compared to traditional techniques, have shown no reliability issues. Using the method, dicing kerfs can be reduced to below 20um in many cases, with no chipping on either front or backside. This allows the street size to be reduced, resulting in the opportunity to have more dies per wafer.

In addition, the MB concept gives the advantage of reducing the number of passes (‘traverses’), independent of the type of laser process, being it either an ablation process or a subsurface dicing process. In this way, a high throughput can be achieved. The applicability range of MB laser dicing goes from a range of thicknesses starting from 75um to 300um and beyond. It adds to single beam laser dicing the speed, flexibility and quality of the final cut by reducing the power density and minimizing the thermal load and at the same time achieve a high throughput.

The principle of the multiple beam process is shown in Figure 3. The figure shows an example of the distribution of three beams on a substrate during a pulse sequence of 8 shots. In this case, the traveled distance of the wafer between the pulses is exactly half of the spatial distance between the beams. Figure 4 shows a side-view of a MB laser diced sample after interrupting the first cutting pass and preparation of a cross-cut by breaking of the sample. The Figure clearly shows the efficient dicing process, which is a result from the use of a DOE and choice of an appropriate step based on the sample material.

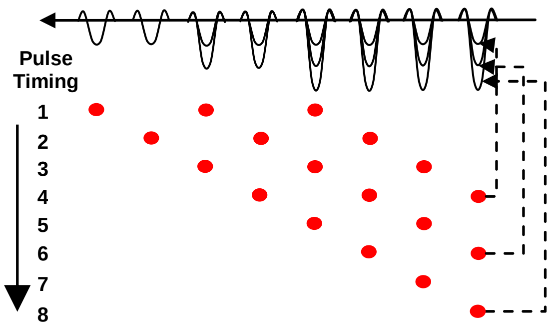

Figure 3, Schematic of the multiple beam process during one laser pass

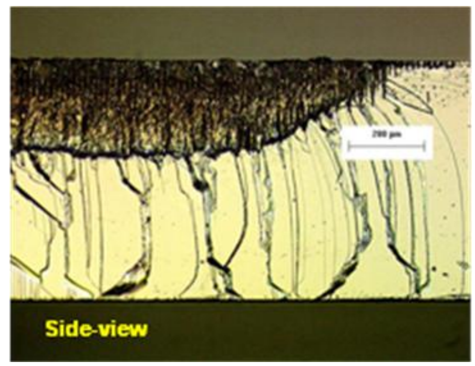

Figure 4, Side-view of a GaAs substrate with interrupted first laser dicing pass, made visible by breaking of the sample.

PROCESS SCHEME

The general process flow for multi beam laser dicing of semiconductor wafers either consists of a protect coating, MB laser dicing, and cleaning, or an additional post-processing step, depending on substrate thickness and final die dimensions. With the post-processing step, the die strength is fully recovered, and can even exceed the reference die strength of the traditional separation technologies.

Coat ⇨ Dice ⇨ Clean

FULL METAL DICING

In the T&D, LED and VCSEL market areas, the laser separation of devices with full metal backsides is a common production process. In this area, the backside metals consist of a variety of materials, including Au, AuGe, Ni, Al, Ag, eutectics, and more recently, also Cu and CuW. Figure 5 shows an example of a LED based on a CuW substrate with full Au metal backside.

Technological and economical requirements have accelerated the application of Cu because of its excellent electrical and thermal properties and cost compared to other metal alternatives. Process investigation to the laser separation of Cu and mixtures containing copper such as CuW have shown it has distinctive properties and behavior under laser dicing. The challenges lie exactly in the mechanical and thermal properties. Depending on the production process, Cu wafers may show warping and upon heating a preferred direction for elongation or shrink.

Figure 6 shows the result of a laser diced 100um copper film. The process optimization included the choice of the DOE, including number of spots and spot distance for minimum TPT, the dicing strategy: mirror strategies minimize the thermal impact and elongation or shrink and pulse duration. Laser wavelength was found to be of minor importance. Therefore, the standard, robust, low cost, 1064nm IR system was applied.

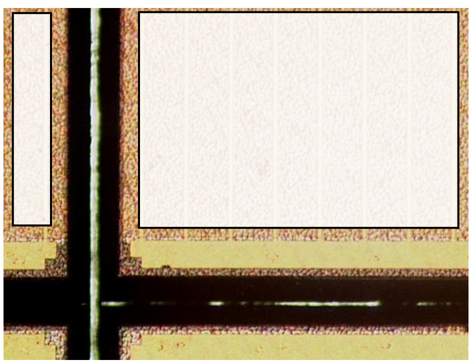

Figure 5, Example of a laser diced CuW LED wafer of 215um thickness with Au back metal

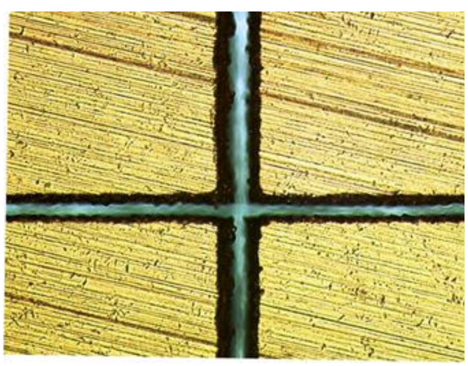

Figure 6, Example of a laser diced 100um full Cu wafer with a dicing width <24um and effective dicing speed>60mm/s

RFIC PRODUCTION AND PROCESS STRATEGIES

Usually, after the multiple beam laser dicing technology has been integrated into full production, additional capabilities of the dicing technology are explored. These secondary advantages may have an even larger contribution to reduce costs and improve yield. These include elimination of the expensive and time consuming backstreet etching. As shown in the previous section, the MB laser dicing of products with full backside metals is common in many different semiconductor market segments, such as T&D, high brightness LED and bonded wafer applications. This is opposed to the traditional blade dicing technology, which undergoes clogging and increased wear of its blades when cutting metals and metal stacks. The MB full cut laser dicing can cut through metals and metal stacks easily, as shown in the memory and processor segments with test elements and low-k materials in the saw street [4].

The no-metal backside products or back-etched street products, in which the metal in the streets at the backside of the product wafer has been removed by subsequent process steps are currently in high volume production. Back-etching of the backside metals involve lithography, wet etching and cleaning steps. As can be expected, the elimination of these back-end processes will lead to a process reduction and hence a cost reduction.

Normally, there is a trade-off between the throughput time, quality and the material stack. One would expect that GaAs substrates with full metal backside are more challenging to dice and will result in a higher TPT. Luckily, whereas the first assumption is correct, low TPT's can be maintained. This can be achieved by a careful consideration of the process parameters, including the choice for the DOE. Table I shows some of the general trends.

TABLE I

PROCESS PARAMETERS

Parameter	Production aspect
No. of spots - higher	More efficient process Same or better TPT, lower HAZ
Distance between spots - lower	More efficient metal separation

Attention points during the full backside metal process development are device reliability and quality, and packaging and handling issues. During ablation cutting, evaporated and molten material is ejected from the dicing kerf. The main part of this debris is removed by the exhaust. The remainder of this debris will be deposited on the wafer surface. The wafer surface can be protected by a temporary water soluble coating to protect the active area against the thermal impact and to enable easy removal afterwards. However, this debris should not contain too much metal. Because the metals have a high thermal capacity, the debris tends to penetrate the soft coating and physically bond to the wafer surface. It has been found that the metal containing debris is hardly removed after post-processing and/or cleaning. Secondly, metals mixed with the recast layer on the side of the die may influence the electrical characteristics. Obviously, this is not allowed. A handling issue may be the particles from the sidewall. After dicing and post-processing, any remaining metals or metal flakes, such as Au, which have not been removed from the sidewall,

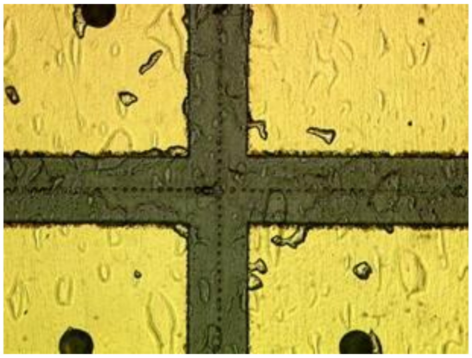

Figure 7, Example of a laser diced 100um full Au wafer with a dicing width <17um and effective dicing speed>75mm/s

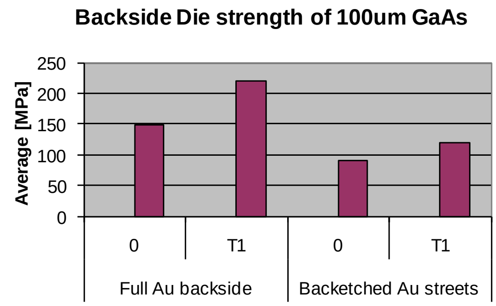

Figure 8, 4-point Die strength comparison of GaAs substrates with full Au metal backside and with back-etched streets

may cause particles and pollution during the subsequent steps such as pick-and-place.

These attention points can all be addressed and overcome by the optimization of the process parameters, including DOE. Figure 7 shows an example of the backside of a 100 µm thick GaAs RFIC wafer (after stretching) with full Au on the backside, with a total dicing width ≤ 17 µm and a TPT which is similar to the back-etched street product.

Apart from the cost reduction, there are strong indications that the reliability in relation to the die strength will improve. Figure 8 shows a comparison of the backside die strength of GaAs substrates with full Au backside and with a back-etched street. The Figure shows both a higher initial die strength after MB laser separation and a higher value after the post-processing.

CONCLUSIONS

In summary, this paper describes the full cut dicing of RFIC GaAs products with full metal backside. As already shown in other markets, the MB full cut laser dicing enables full cut metal separation up to 250 um. However, no matter what laser dicing solution is chosen, it will always be a trade off between quality and speed. The multiple beam technology from ALSI provides a solution to go around this impasse and maintain both high quality and speed. MB full cut laser dicing also applies to GaAs-based technologies, separating the dies by cutting through both the substrate and the backside metal layer, up to thicknesses of 7 and beyond. The development of such a production process includes tuning of the MB full cut laser dicing process parameters such as step, power and DOE. It has been shown that this offers cost reduction, without the loss of throughput time or without loss of process efficiency. In addition, there is a strong indication supported by data that the final product chip strength will show better values as opposed to products without metal backside or products with back-etched streets. This also shows that for future substrate developments with metal backside such as CuW, Si, and SiC this may be applicable as well.

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ACRONYMS

ALSI: Advanced Laser Separation International
HAZ: Heat Affected Zone
MB: Multiple Beam
DOE: Diffractive Optical Element
S&B: Scribe and Break