

Saw + LMJ: A hybrid semiconductor dicing solution

Bernold Richerzhagen^{*a}, Martin Plankensteiner^c, Notker U. Kling^b, Keith Stay^a

^aSynova SA, Chemin de la Dent d'Oche, CH-1025 Ecublens, Switzerland

^bSynova USA Inc, 48521 Warm Springs Blvd., suite 314, Fremont, CA 94539, USA

^cDisco Hi-Tech Europe GmbH, Liebigstrasse 8, D-85551 Kirchheim, Germany,

ABSTRACT

The concept of combining the Laser MicroJet® (LMJ) water jet-guided laser with a standard industrial diamond blade saw was first proposed early in 2006. The idea has now been taken a step forward with a joint project between Synova SA and Disco Hi-Tech Europe GmbH. The hybrid machine being developed integrates an LMJ module in place of the second blade saw on a Disco dual-spindle machine. The resulting machine will be fully capable of sequencing the different processes to carry out dicing of complex and layered semiconductor wafer, in any possible combination. It will be possible to program both processes to run independently in parallel or allow sequential operation during the same cutting pass. This extraordinary flexibility, combined with the speed advantages, quality of material cutting and simplification in processing in a fully automatic mode for up to 300 mm wafers, all now available in a single machine, will greatly benefit the manufacturing community. This paper will provide some insight into the design and operation of the hybrid machine and some examples of the improvements gained from its use.

Keywords: Water jet-guided laser, wafer dicing, hybrid dicing, blade saw

1. INTRODUCTION

The original idea for developing a hybrid dicing and cutting solution for the semiconductor industry was first proposed several years ago internally in Synova. It was recognised at that time, that the advantages to be gained in blending the widely used diamond blade saw with the water jet-guided laser, also known as the Laser MicroJet® (LMJ), would provide an advanced next generation tool for the industry. The concept has now become reality following the agreement between Disco Hi-Tec Europe GmbH and Synova SA to jointly develop the machine and processes.

2. DESCRIPTION

The Hybrid Laser Saw (HLS) machine consists of a modified high performance Disco dual parallel spindle DFD6361 series saw, which can perform wafer loading, alignment, cutting, cleaning, drying and unloading fully automatically. The machines, which can accommodate wafers up to Ø 300 mm, are normally used for such dual-spindle applications as step cuts, bevel cuts, and dual cutting. In addition to silicon wafer dicing, they can handle ceramics, package singulation, and a wide variety of cutting and dicing tasks.

The modified version combining the two technologies, has one of the two saw blades removed and replaced by an LMJ optical head module, which is shown in the following Fig. 1.

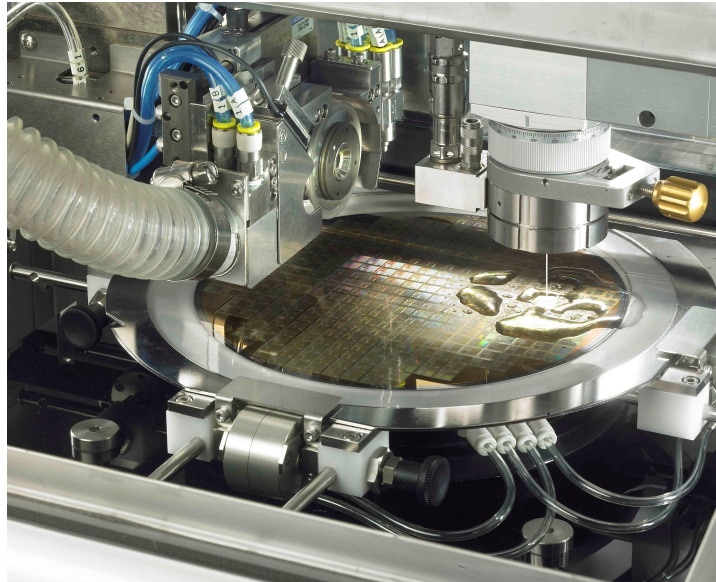


Fig. 1. View showing the Disco blade saw (left) and the Synova LMJ optical head integration (right).

The Hybrid Dicing™ process permits the best of both worlds for the cutting and dicing of both present day and future semiconductor products.

As a standard blade saw, the HLS can cut/dice wafer, providing the same quality, speed and dependable performance provided by all Disco machines.

The integration of the Synova LMJ optical head provides additional high quality cutting capability to process wafer where a standard saw does not perform as well due to chipping, such as with thin wafer, low-k materials, Class III-V compound semiconductors, wafer with metal or oxide layers, etc.

The optical head assembly is the same part as is installed in standard dicing, cutting, edge grinding and stencil machines delivered by Synova. The head receives laser light from an external 1064 or 532 nm Diode-Pumped Solid-State (DPSS) laser, and focuses the beam into a hair thin jet of water, where it is guided by means of total internal reflection to the work piece, as shown in Fig. 2 [1, 2].

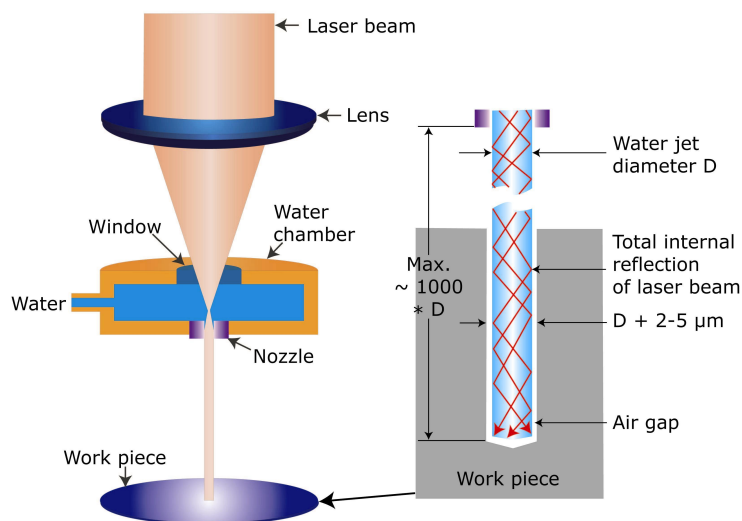


Fig. 2. The LMJ principle.

As can be seen from the image, the laser beam does not suffer from the most serious deficiency exhibited by standard dry lasers, as there is no divergence of the beam, which would otherwise result in limited depth of cut and non-parallel kerf walls. The nozzle sizes used can range from 30 to 120 μm depending on requirements. A small ablation plasma forming at the bottom of the jet generates an air gap between the water jet and the material walls, allowing high aspect ratios. Due to the vena contracta effect, the resulting jet is approximately 15 % smaller in diameter.

The water jet provides a continuous cooling medium to the cut edges during the lasers pulsed operation, resulting in no detectable thermal damage to the material. The low pressure water also expels ablated material from the kerf and prevents any contamination or re-deposition on the work piece surfaces, eliminating the requirement for surface protection measures. The LMJ also improves cutting quality, since it exerts only minimal mechanical forces ($<0.1\text{ N}$) on the work piece. This reduces possible material structural damage, which would otherwise result in micro-cracking and reduced fracture strength of the wafer.

3. APPLICATIONS AND SCENARIOS

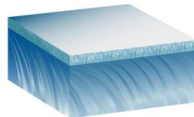
The HLS, due to its flexibility will provide for a several operational scenarios for the cutting and dicing of semiconductor materials, especially in the case of multi-layered, low-k or wafer with metallised layers. These materials will especially benefit from the machines ability to process a common work piece with both tools operating in parallel, but each one carrying out an independent procedure.

This two in one complete solution will greatly reduce overall wafer processing time, providing increased profitability for the user and an improved return on investment, requiring the purchase of only one instead of two or more tools to accomplish the same result.

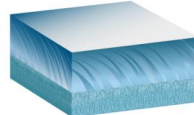
The HLS will be delivered as a turnkey package for integration into existing or new production facilities. The only consumable required, besides saw blades, is a common supply of filtered, deionised and degassed tap water.

Several different modes of cutting or dicing are foreseen, depending on the base material. These can be broken down as follows:

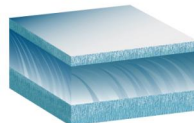
1) First LMJ then saw



2) First saw then LMJ



3) First LMJ then saw followed by LMJ



4) LMJ only

5) Saw only

The first case 1) is appropriate for wafer where the top surface consists of metal or oxide layers followed by bulk silicon. The LMJ will first cut an opening through the delicate top layers, which can then be followed by the saw, to finish the process.

The second case 2) is for wafer where a high quality back surface with no chipping is required.

The third case 3) is for when both the top and back surfaces are required to have the highest quality and be chip and burr free. However, such a cutting process cannot be achieved in a row, because the nozzle diameter of the LMJ needs to be

different when processed after vs. before the saw. To achieve optimum results, the width of the starting cutting process needs to be larger than the next one.

The fourth case 4) is when thin wafer is to be cut or diced, a process where the LMJ has proven its superior performance. As an example, it can cut 50 μm materials at speeds up to 300 mm/s providing very high quality results, which other technologies can not achieve.

Finally the fifth case 5) is for the simple cutting of bulk material, where production speed is the only governing factor.

Use of the LMJ in cases 1) and 2) for making the initial cuts through the top or back surface layers, will result in considerably reduced operating costs. Blade wear in cutting these layers would otherwise considerably reduce their useful lifetime, requiring more frequent blade replacement.

It should be noted, that all of the above processes are fully compatible with the use of suitable industry standard dicing tapes. There are no special tape requirements when using the LMJ.

4. RESULTS

Some initial results are presented in the following images, using 600 μm thick bulk silicon material. The cutting was performed using the Mode 2 operation, where the saw is used to perform the initial cut, followed by the LMJ making the final cut through the back surface. The blade used has a width of 55 μm , the LMJ nozzle a diameter of 40 μm . In this process, a first cut is made using the saw, the work piece is then positioned so that the LMJ can finalise the cutting using one or more passes. In the meantime the saw is making the second partial cut. This process is repeated until all cuts have been performed.

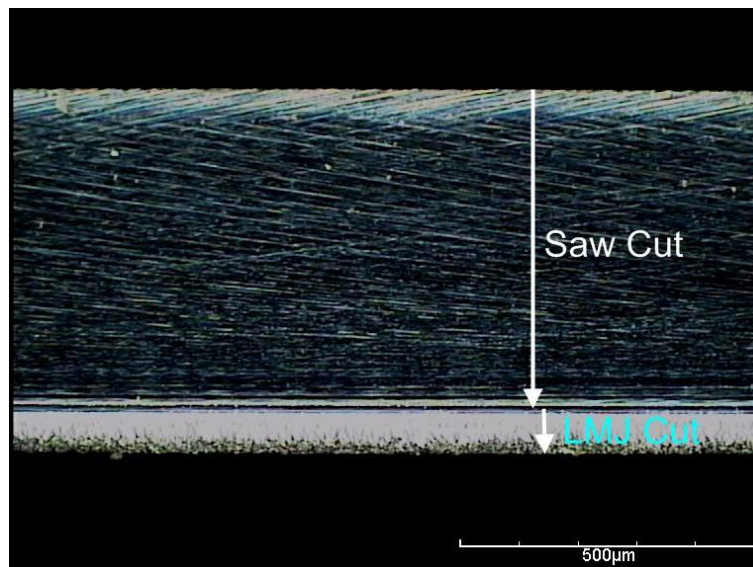


Fig. 3. View of the side wall of the material after cutting in Mode 2.

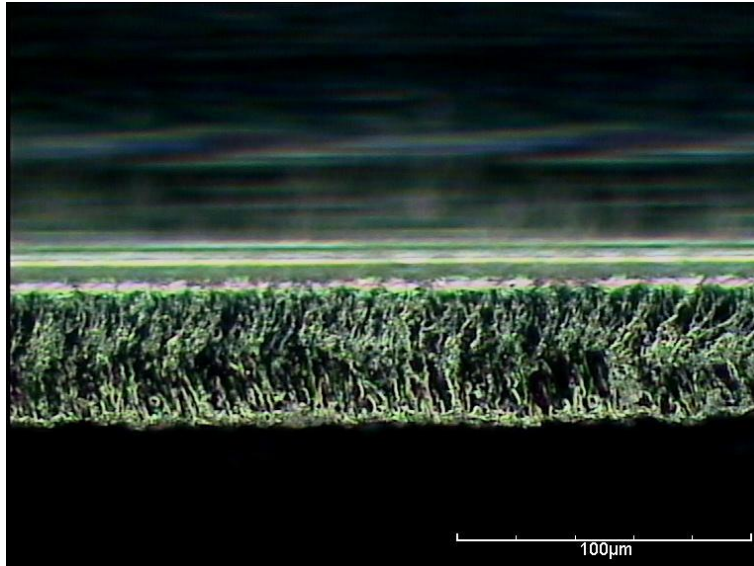


Fig. 4. Magnified view of the side wall of the material after cutting in Mode 2, showing the LMJ cut section.

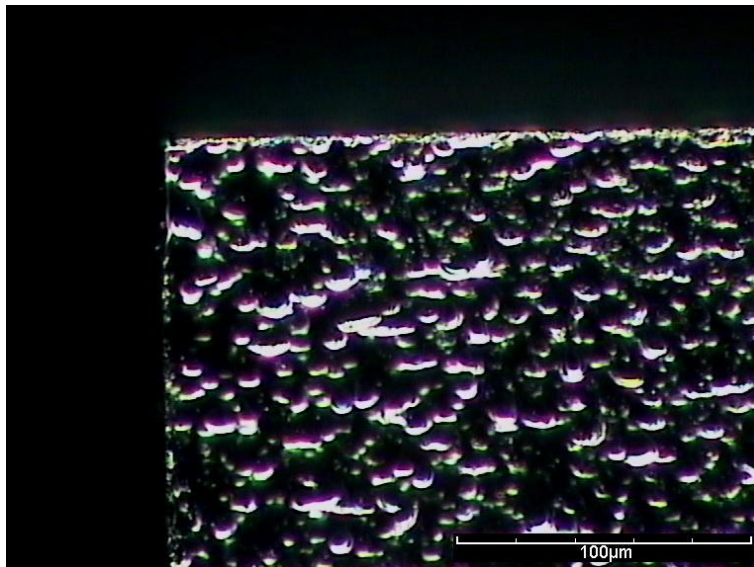


Fig. 5. Magnified view of the top corner surface.

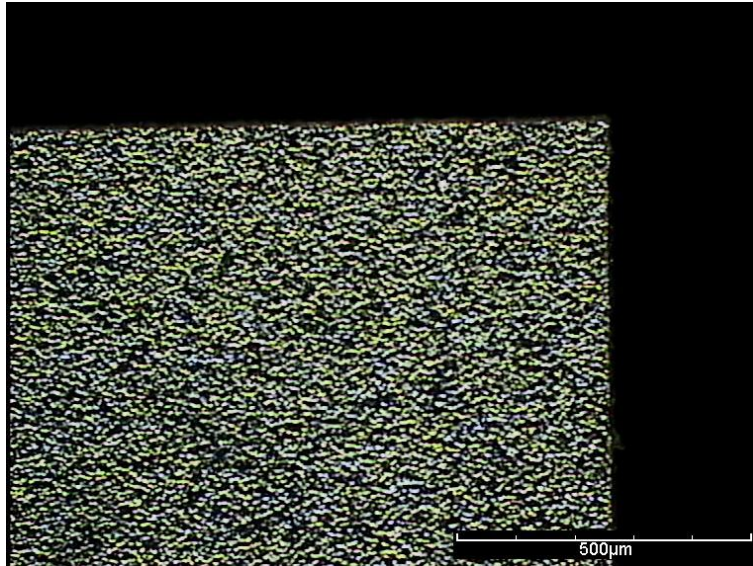


Fig. 6. Magnified view of the back surface corner.

The above images (Fig. 3 to Fig. 6) illustrate the high cutting quality results obtained from the initial tests. The top and especially the back surface edges exhibit no signs of chipping or burrs.

5. CONCLUSIONS

The HLS dual tool provides the user with the best of both worlds, performing both conventional sawing and LMJ cutting, permitting high processing speeds and top quality at the same time. The blade-saw is unbeatable in speed for cutting through bulk silicon; the LMJ technology is unrivalled when processing delicate materials and layers, with negligible material damage (insignificant heat affected zone (HAZ), and no burrs, contamination, chipping, etc.

The combined strengths of these two existing technologies / processes available now in one machine makes the HLS an even lower cost per unit manufacturing tool. The greatly reduced mechanical stress and damage experienced by the material, results in a significantly better chip yield, whilst the reduced usage of the diamond saw blade reduces machine-running costs, generating significant savings. And lastly, shortening the processing chain by at least one machine platform due to the combined tool, increases return on investment and reduces the cost of ownership.

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