Laser Dicing of Silicon and Composite Semiconductor Materials

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ABSTRACT

Dicing of semiconductor wafers is an example of an application requiring a processing quality superior to what can be achieved using classical laser techniques. For this reason, sawing the wafers with a diamond-edged blade has been developed into a high-tech process, that guarantees good and reliable cuts for Silicon wafers of more than 300 microns thickness. Today, wafer thickness is getting thinner; down to 50 microns and also more brittle III-V compound semiconductors are used more frequently. On these thin wafers; the laser begins again to compete with the diamond saw, because of laser cutting-quality and cutting-speed, are increasing with decreasing wafer thickness. Conventional laser cutting however has the disadvantages of debris deposition on the wafer surface, weak chip fracture strength because of heat induced micro cracks. An elegant way to overcome these problems is to opt for the water-jet guided laser technology. In this technique the laser is conducted to the work piece by total internal reflection in a 'hair-thin' stable water-jet, comparable to an optical fiber. The water jet guided laser technique was developed originally in order to reduce the heat affected zone near the cut, but in fact the absence of beam divergence and the efficient melt expulsion are also important advantages. In this presentation we will give an overview on today's state of the art in dicing thin wafers, especially compound semiconductor wafers, using the water-jet guided laser technology.

Keywords: Laser cutting, water-jet, Silicon, GaAs, compound semiconductors.

1. INTRODUCTION

The dicing of Silicon wafers is an indispensable process in the manufacture of integrated circuits. Dicing is one of the last operations in the transformation of Silicon wafers into chips. The wafer's value is highest at the time of dicing, necessitating fast and sure operation. Considering that the electronics market becomes always more demanding in terms of clock frequency and miniaturization, wafers get thinner and thinner. Composite materials, at the same time very brittle and expensive, have indisputable advantages over silicon-based materials, such as higher frequency operation, better signal processing in congested frequency bands, and greater power efficiency. An average annual growth rate of 22% of the compound semiconductor IC market is forecasted for the 2002-2007 period. The expectation for the total IC market is only 10% for the same duration (source: IC Insights). Today, if the most important application remains the wireless communication industry, GaAs is revealing its potential in opto-electronics for applications in the military, the medical and especially the LED-lighting domains. The water jet guided laser, called "Laser-Microjet®" or "LMJ", developed by Synova, Switzerland, has become increasingly popular in the semiconductor industry over the past years.

2. CUTTING WITH LASER AND WATER

The laser beam is focused in a nozzle while passing through a pressurized water chamber (see Fig. 1). The water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water-air interface, in a manner similar to conventional glass fibers. The water jet can thus be referred to as a fluid optical wave-guide of variable length.

The water jet is essentially transparent for the laser beam. However, if the laser beam encounters a body, which absorbs it, the surface of the material is heated to such an extent that plasma is created. The plasma separates the water jet and the material from one another and it efficiently couples the energy to the work piece.

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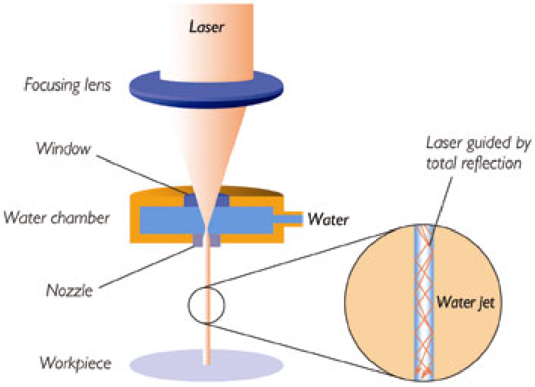

Fig. 1: Microjet® principle.

The plasma only remains as long as the laser beam is activated. Because a pulsed laser is used, the continuous water jet is able to immediately re-cool the cutting kerf, resulting in a strongly reduced thermal load of the work piece.

The liquid used is de-ionized, de-gassed filtered water.	
Water pressure	20-500 bars
Water jet speed	up to 300 m/s (at 500 bars)
Water jet diameter	30, 40, 50, 60, 75 or 100 microns
Water flow rate	5-100 ml/min

Table 1: Characteristics of the water jet.

The main advantage of the system is its excellent cutting quality obtained because of:

- the absence of thermal stress and contamination due to constant cooling and rinsing by the water jet.;
- the absence of mechanical constraints on the parts to be cut, the water jet pressure being kept low (50 to 500 bars with a jet diameter varying from 30 to 100 microns).

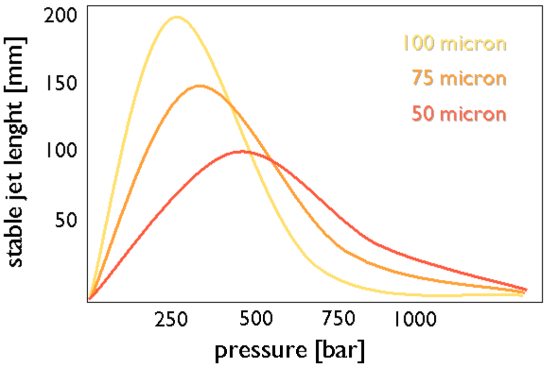

Fig. 2: The stable jet length is measured from the nozzle inlet until the position where the first drop is formed. The maximum working distance of water jet guided laser cutting is closely correlated to this value and varies analogously concerning nozzle diameter and pressure.

3. LMJ COMPARED TO SAW

In recent years, the established method of separating the Silicon chip by sawing it with a diamond-edged blade has been perfected into a high-tech process by the ever-growing demand of the semiconductor industry for faster cutting speeds, greater accuracy, smaller kerf widths and enhanced cutting quality. Nevertheless, the possibilities of abrasive cutting would seem to have reached their limit as far as the above-mentioned criteria are concerned.

The indisputable problems of the saw today are as follows:

- Chipping (front and back side)
- High consumption of saw-blades leading to high consumption costs
- Mechanical stress and the formation of cracks
- A lack of constant cutting quality due to wear of the saw-blade
- No reliable forecast of the service life of a saw-blade
- Less suitable for very thin wafers
- Only straight contours can be cut

Speed and cutting quality have attained their limits. In the case of thin wafers, the mechanical damages caused by the saw are so important that changes in the process flow are necessary in order to use the saw (dicing before grinding). Multi-project wafers have different chip sizes; the saw would have to stop at a certain position in order to avoid cutting through a die. To avoid this, the street geometry is limited and some dies have to be first picked up before other dies can be cut. This makes the whole singulation process very complicated. Using the water jet guided laser, dicing of silicon wafer becomes faster, more accurate, and open new possibilities in wafer and chip design.

Si Wafer thickness	Cutting speed (no limit
50 µm	200 mm/sec
100 µm	75 mm/sec
200 µm	40 mm/sec
300 µm	20 mm/sec

Table 2: Cutting speed

4. LMJ VERSUS CONVENTIONAL LASER OR ABRASIVE WATER JET

Although conventional laser cutting is able to compete with the diamond-edged saw-blade in terms of speed and width of cut, it lags far behind when it comes to quality. The laser's intense thermal effect on the Silicon, in particular, gives rise to cracks, structural changes, burrs and deposits on the wafer surface. A high-precision tool in all other respects, and certainly one that has increasingly replaced conventional cutting processes, the laser has been unable to establish itself in the field of semiconductor technology, with the exception of a few applications. The laser is familiar in the field of Silicon processing for marking wafers or cutting round components, such as high-voltage thyristors and diodes. Yet a host of compromises have to be accepted even in these applications. Two such compromises are the need to apply a special protective coating, which has to be removed after the laser processing stage with solvent, and the time-consuming necessity of reprocessing the cut edges.

Another cutting process that may be used for free shape cutting tasks is abrasive water jet cutting. The abrasive water jet is able to ablate material by means of its kinetic energy alone. In this context, water is forced through a nozzle at high pressure (3000 bar) and subsequently mixed with abrasives to create a water-particle mixture.

Both cutting processes, classical laser cutting and abrasive water jet, have established themselves as reliable cutting tools, particularly in the metalworking industries. However, because both processes have their limits, caused by "hot" cutting on the one hand (laser) and high kinetic forces on the other (abrasive water jet). Thought has been given for some time now as to whether both processes could be combined, with the advantages of each individual process being retained: the „cold“ cutting of the water jet and the „low-force” cutting of the laser. Finally this combination was realized by the inventors of the water jet guided laser, using a non-abrasive low-pressure water jet in which a pulsed laser beam is guided.

5. CUTTING OF COMPOUND SEMICONDUCTORS

Compared to common Si wafers, chip singulation of GaAs wafers is a real challenge. This is mainly due to the material's mechanical and chemical properties. Furthermore, pure compound GaAs contains 51.8 %wt arsenic, and is therefore considered as a hazardous material. It is described as toxic by inhalation and a possible human carcinogen. These facts raise a lot of concerns from an environmental, health and safety standpoint. Security in general is not the only characteristic that renders GaAs wafers difficult to dice. GaAs is also far more brittle and fragile than Silicon. Besides the low cut quality, cutting GaAs with traditional laser is very dangerous because of the arsine gas emissions. With the water jet-guided laser all the arsine is constraint into the water that can be treated with usual filters. It is also important to consider that although GaAs's price is not as high as it used to be, it is still a costly material.

Regarding safety issues, several tests have been performed with the LMJ and have shown that no arsine gas is detected in the air while cutting GaAs wafers[1]. This is not surprising since the laser beam is coupled in a water jet and laser pulses are very short (around 450 ns). The time for interaction of the laser light with the material is therefore very short and immediately followed by the cooling effect of the water. Though, the concentration of Arsenic in the wastewater is high. Therefore, the wastewater should to be appropriately filtered or recycled.

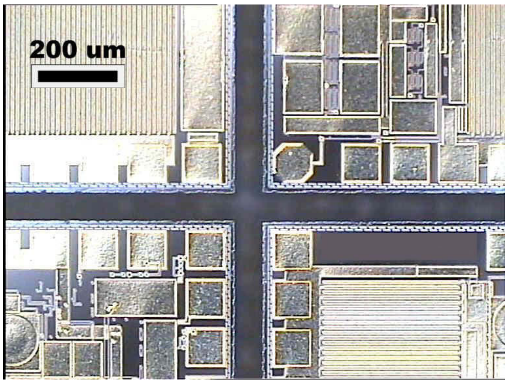

Fig. 3: Chipping free dicing in GaAs (wafer thickness: 75 um; diameter: 60 um; cutting speed: 80mm/s)

6. CONLUSION

The water jet guided laser shows indisputable advantages over the more traditional abrasive saw and conventional laser technologies for the dicing of GaAs wafers. Even although improvements have been done to these methods over the years, they will soon be replaced as wafers become thinner and employ more costly and critical materials. The Laser-Microjet® is a recent technology that is constantly revealing its great potential, and GaAs is not the only material on which the LMJ has already shown industry-leading results.
To conclude, almost no material is too brittle, too sensitive for the Laser-Microjet®

REFERENCES

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