WAFERS: EDGE GRINDING

Reducing Breakage of Thin Wafers to Zero: Wafer Edge Grinding with the Laser Microjet

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THE CHALLENGE BEHIND BACK GRINDING

The market for thin wafers is expanding. Thin wafers represent less than 5 percent of the total production of wafers today, but their share is expected to reach between 20 and 30 percent in the next couple of years. With shrinking thickness, however, new challenges appear; handling is one of the main concerns, because it is extremely difficult to handle silicon wafers thinner than 100 microns due to their high brittleness. Especially thin wafers requiring backside processing represent a real problem.

Thin silicon wafers are produced from thick wafers possessing round edges to protect them from chipping at the edge. After the last front-side process, thick wafers are mechanically ground to a thickness ranging from 200 microns down to 50 microns. This back-grinding process creates a sharp edge, or knife edge, that is more sensitive than the surface of the wafer; micro-cracks can appear all around the edge (see Figure 1). On the surface of the thin wafer, stress is efficiently released by methods such as chemical mechanical polishing (CMP), spin etching or dry polishing. But these processes are ineffective on the edge of the wafer: the micro-cracks remain. Propagation of these cracks happens frequently; the slightest mechanical solicitation can lead to wafer breakage.

At this phase of production, wafers are already very valuable since most of the process steps are complete, making it critical to eliminate the loss of wafers because of the propagation of micro-cracks from the knife-edge. The need for innovative technologies able to reduce damage generated by the thinning step is obvious. Today, no technology is able to grind or polish the sensitive edge of thin wafers. Consequently, the solution is to completely remove the problematic area. The requirements for this application, however, are very stringent: the process should apply no mechanical constraints on the wafer, nor generate new micro-cracks by either thermal or mechanical stress, while precisely following the wafer outline. Only one process is able to fulfil all these conditions: the water-jet guided laser, which can cut off the outer 0.5 to 2 mm of the wafer without any damage.

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THE WATER-JET GUIDED LASER: AN INNOVATIVE PROCESS

The water-jet guided laser (laser microjet) is a unique process based on the combination of a laser beam and a water jet. Focusing a laser through a pressurized water chamber couples it to the water jet exiting the nozzle. The low-pressure water jet then guides the laser beam by total internal reflection at the water/air interface, in a manner similar to conventional glass fibers (see Figure 2).

The water jet acts as a fluid optical wave-guide of variable length that remains stable while penetrating into the material, which means that the beam size impacting the material is always constant, resulting in an excellent kerf parallelism. By controlling the laser pulse parameters, this method can be applied for grooving with a well-defined depth.

A broad range of laser sources can be used. Nd:YAG lasers, either long-pulsed or Q-switched, are most often used. Frequency-doubled Nd:YAG lasers emitting green light, and even the ultraviolet light generated by frequency tripled Nd:YAG lasers, are all being guided to the work piece by the water jet. Indeed, the laser wavelength can be chosen freely as long as it fits the water transmission spectrum. The laser power can be applied either as continuous wave or as pulsed light. For many applications, pulsed laser power is preferred, because during the pause between the pulses the water jet will be able to efficiently cool the work piece in the laser-processed area, keeping heat-affected zones to a minimum.

In addition, there is no problem with surface contamination caused by small particle generation from the process. The removed material is instantly cooled by the water jet and will not attach to the work piece surface. Finally, the particles are washed off using a thin water film. Wafers remain clean and free of particles and micro-cracks.

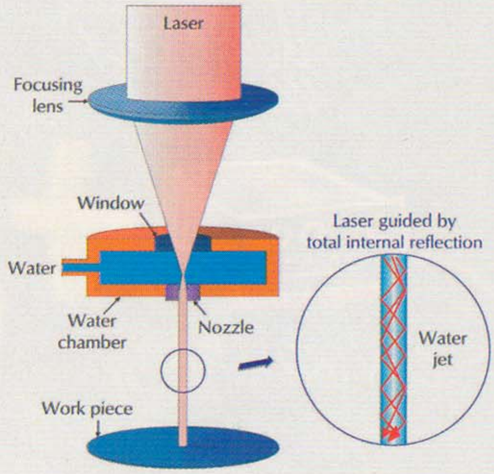
De-ionized water is used for the jet to make sure that the water does not contain anything that could either absorb or scatter the laser light. The nozzle is usually a diamond with a precision-drilled and polished circular hole for the water to exit through (aperture of diameter is 25 to 100 microns). As the jet itself is only hair-thin, the water consumption is surprisingly low, in the order of 1 liter per hour, although the jet speed is 200 m/s (at 300 bar water pressure). Directly underneath the nozzle, the water jet contracts to 83 percent of the opening diameter of the nozzle, which makes it an even thinner and more precise tool for cutting and drilling. At present, the minimum beam diameter that can be reached is 20 microns.

The laser microjet is used for dicing of thin wafers; to the specific problem of removing the micro-cracks in thin wafers, it offers a very efficient solution in edge-grinding, which can be performed either after or before back-grinding. This operation cannot be carried out by conventional laser cutting due to the significant thermal load generated by the process.

FIGURE 1

Back-grinding of thick wafers creates a "knife edge."

FIGURE 2

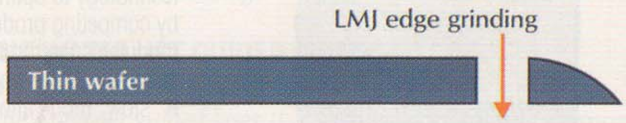


Principle of the coupling unit: the water jet guides the laser beam.

EDGE-GRINDING AFTER BACK-GRINDING

The first method developed with the laser microjet to remove the regions with micro-cracks around the wafer edge acts directly on the thin wafer after back-grinding. It reduces wafer breakage during the final steps (especially handling) to almost zero, removing the knife-edge generated by back-grinding all around the wafer (see Figure 3).

FIGURE 3



Edge-grinding after back-grinding eliminates the "knife edge."

The result is a very clean edge, as can be seen on the microscope images (Figure 4) which show the edge of a 100-micron thick silicon wafer before and after laser microjet edge grinding. For this application, a Nd:YAG fiber laser has been used (wavelength: 1064 nm, pulse repetition rate: 50 kHz, average power: 55 W). The water pressure was 400 bars and the nozzle diameter was 50 microns. With these parameters, the laser microjet reaches a cutting speed of 40 mm/second.

As the demand for thin wafers is increasing, there is the need for new technologies able to reduce wafer breakage during handling in the last production steps.

EDGE-GRINDING BEFORE BACK-GRINDING

There is a second way to remove the brittle edge of thin wafers with the laser microjet. The idea here is to stop the micro-cracks before back-grinding. The laser microjet is used to groove the thick wafer near its edge, with a grooving depth at least equal to the thin wafer thickness (see Figure 5). After back-grinding, the wafer will be free of micro-cracks because the knife edge is already separated from the wafer.

Figure 6 shows a 725 micron-thick silicon wafer grooved in a way so that the damaged edge will be removed during the back-grinding step. For this application, the diode-pumped Nd:YAG fiber laser has been used (wavelength: 1064 nm, pulse repetition rate: 50 kHz, average power: 80 W). The water pressure was 320 bars and the nozzle diameter was 75 microns. The wafer has been grooved at a distance of 1 mm of the edge and the grooving depth was 80 microns. The resulting process speed was 50 mm/second.

It should be noted that the wafer is exceptionally clean and free of particles; no heat-affected zone is visible. The micro-cracks that will be formed during back-grinding and starting at the knife edge cannot propagate to the rest of the wafer.

CONCLUSIONS

As the demand for thin wafers is increasing, there is the need for new technologies able to reduce wafer breakage during handling in the last production steps. Two efficient solutions are now available to cut off the brittle knife edge of thin wafers: edge-grinding before and after back-grinding using the laser microjet. The choice between these two possibilities depends on the application and on the existing production line, as they both reduce wafer breakage to almost zero. It is proven that microjet-processed thin wafers have much higher fracture strength during all final steps, especially during handling.

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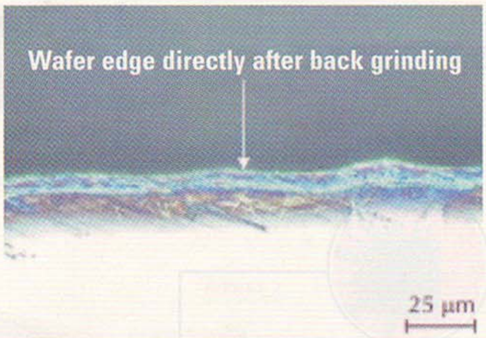
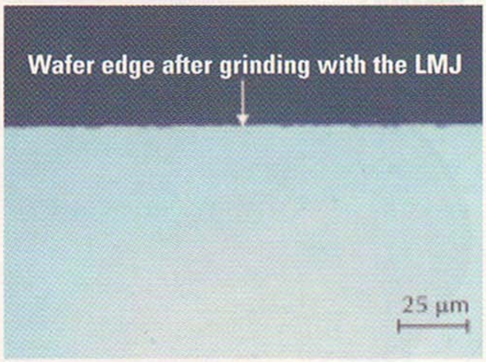
FIGURE 4



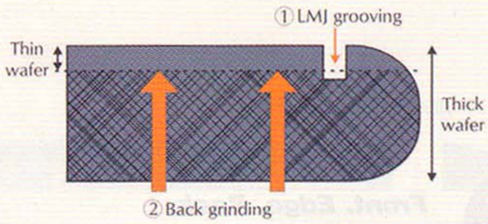
(a)



(b)

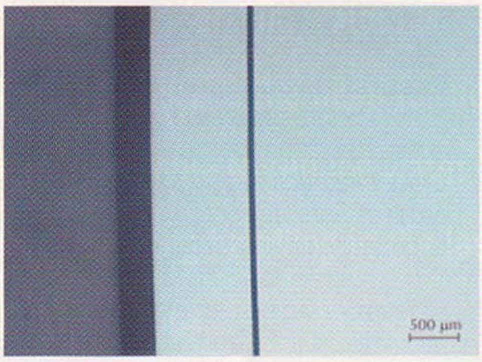
Difference in quality before edge-grinding (a) and after (b).

FIGURE 5



Edge-grinding before back-grinding also eliminates the "knife edge."

FIGURE 6



Microscope image of the grooving in a thick silicon wafer, before back-grinding.