Laser slotting of silicon for inkjet printer heads

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ABSTRACT

Inside inkjet-printer heads, a silicon chip is used as a barrier between the orifice plate, which contains hundreds of nozzles, and the ink reservoir. The silicon chips used to create the barriers have to be drilled. The conventional manufacturing technique (sandblasting) does not anymore provide satisfactory results for the new generation of printers. The water-jet-guided laser, a hybrid technology which uses a water jet to guide a laser beam, has recently been adapted to this application, showing very promising results combining high processing speed and quality.

Keywords: inkjet printer heads, laser, water jet guided laser, silicon, slotting

1. INTRODUCTION

Inkjet printer heads represent one of the largest market shares of the total MEMS component market. There are two main inkjet technologies currently used by printer manufacturers:

1. *Thermal "Bubble" Jet Technology:* resistors create heat and vaporize ink to create a bubble. As the bubble expands, a very small quantity of the ink is pushed out of a nozzle onto the paper. When the bubble collapses, a vacuum is created, pulling more ink into the print head from the cartridge.

2. *Piezoelectric Jet Technology:* piezo crystals, located at the back of the ink reservoir of each nozzle, receive a tiny electric charge that causes it to vibrate. When the crystal vibrates inward, it forces a minute amount of ink out of the nozzle. When it vibrates out, it pulls some more ink into the reservoir to replace the dispersed ink.

A silicon chip is used as a barrier between the orifice plate, which contains hundreds of nozzles, and the ink reservoir (see Figure 1). To let the ink pass through, slots are created directly in the silicon wafer – prior to dicing. The wafer thickness usually varies between 600 and 700 microns. The size and the geometrical shape of the slots will vary depending on the technology used for the procedure (thermal or piezoelectric jet), as well as the size of the cartridge and the number of nozzles.

Until now, manufacturers of inkjet printer heads have focused on reducing fabrication costs while improving product performance. Different technologies may be used for slotting the silicon barriers.

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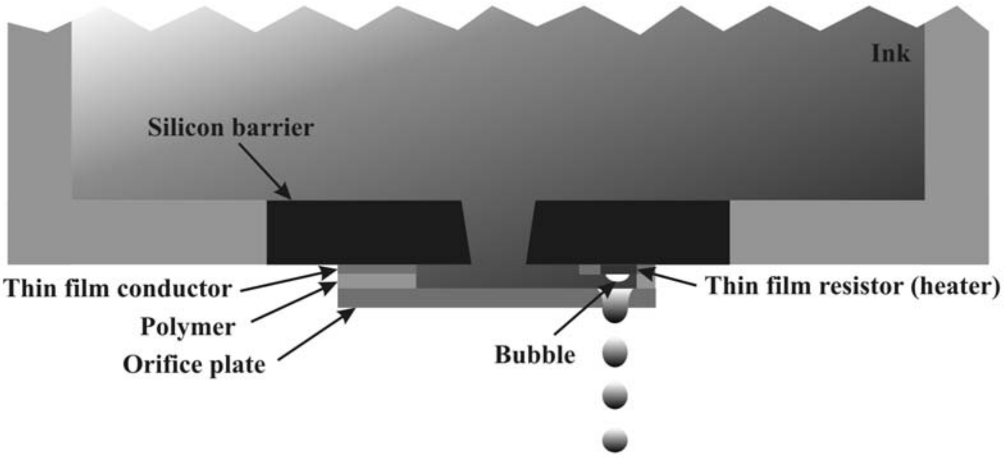

Figure 1: Basic principle of a inkjet-printer head

2. CONVENTIONAL MANUFACTURING PROCESSES

Silicon wafer slots larger than 150 microns can be created by mechanical methods – sandblasting. So far, these methods have not provided satisfactory results for narrow slots below 150 microns. Etching processes are slow, expensive and require masks. Sandblasting limits the diameter of holes and their density, as the edges tend to be conical. Additionally, this process is incompatible with cleanroom conditions. Dry laser slotting creates slag and micro cracks. Many drawbacks, additional processes and compromises have to be taken into account if conventional lasers are applied.

Another technology able to combine high quality and high speed is therefore needed for this particular application. The water-jet-guided laser technology has been recently applied to silicon slotting for inkjet-printer heads. Until now, the results are very convincing.

3. WATER-JET-GUIDED LASER

The water-jet-guided laser (also called Laser-Microjet) was developed in the nineties for medical applications and today is used for precision micro machining in a wide range of industrial fields, such as semiconductors and electronics. The basic principle of this technology is to use an ultra-thin, low-pressure water jet to guide a laser beam to the work piece. To achieve this, the laser beam is focused through a transparent window into a nozzle placed at the bottom of a water-filled chamber. The cylindrical water jet produced below the nozzle will guide the laser beam by means of total internal reflection at the water/air interface, similarly to conventional glass fibers (see Figure 2).

The capabilities and performances of this process are different from those of conventional dry lasers [1]. First, because the water jet is cylindrical and the laser beam parallel, kerf walls are parallel. The working distance – corresponding to the stable length of the jet – can be several centimeters long, depending on the jet diameter. Therefore, there is no need of focus control.

Second, heat damage is nonexistent, since the water jet cools the edges between the laser pulses. The temperature of the cut edge rapidly decreases to the water temperature and heat generated by the laser is not conducted further into the material. The negative effects of heating, such as micro cracks, oxidation, structural changes or low fracture strength, do not appear.

Contamination is greatly reduced, as the water jet, whose pressure ranges from 50 to 500 bars, develops a high kinetic energy fully dedicated to the removal of the molten material. Additionally, a thin water film is generated on the wafer surface during the process, preventing particle deposition. Since the water jet is very thin (diameter ranging from 20 to 100 microns), the mechanical force applied on the wafer is negligible (less than 0.1 N). As a result, the process does not generate chipping or micro-cracks.

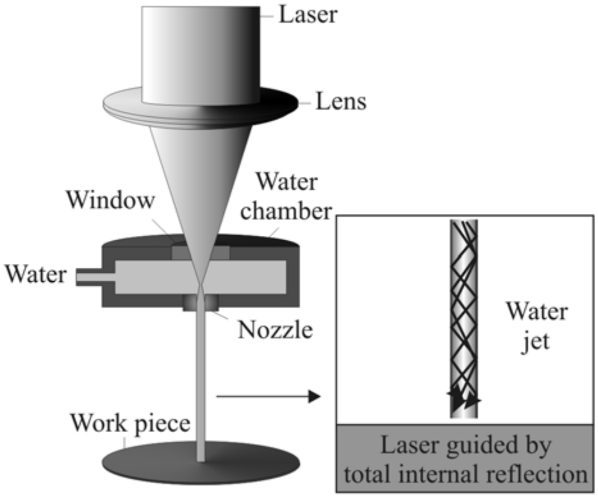

Figure 2: Basic principle of the water-jet-guided laser technology

For several years, the water-jet-guided laser technology has been successfully used for semiconductor micro machining (dicing and grooving). The process is especially efficient on thin wafers and on brittle materials (such as GaAs) since it is a damage-free tool [2]: high process rates are reached, virtually no chipping on the wafer front and back side can be observed, heat damage to the material is negligible and surface contamination is low. The technology has therefore an important potential for silicon slotting for inkjet-printer heads. For this specific application, additional advantages include straight slot walls, no transition region (vertical slot ends) and the possibility to program the slot width – as it does not depend on the nozzle diameter.

4. DAMAGE-FREE LASER SLOTTING

The first tests of the water-jet-guided laser for silicon-barrier slotting in 2005 gave very promising results. Slots in 675-µm thick patterned silicon wafers were achieved in 10 seconds per slot (overall cutting speed: 1.2 mm/s). To protect the fragile structure on the wafer front side, the slotting has been executed from the backside and the process that was applied for the slotting ensures that the slot ends are always very steep (see Figure 3). For this sample, a green Nd:YAG laser (wavelength 532 nm) has been coupled with a 100-µm nozzle.

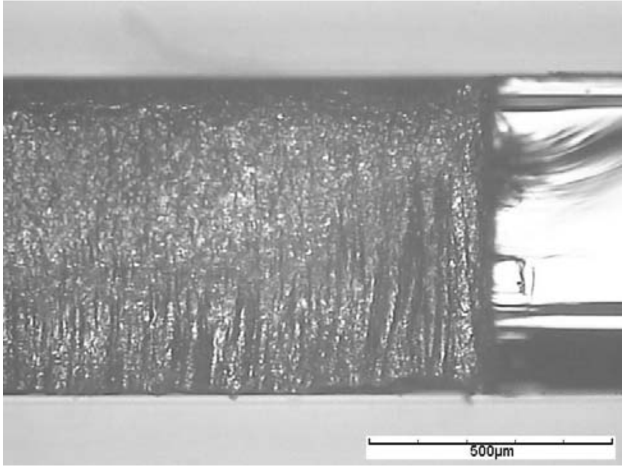

Figure 3: Slot end (broken after cutting)

Some issues remained after these preliminary tests. First, the exit edge was a bit chipped. Second, the speed needed to be improved.

To reduce irregularity, a smaller nozzle (30 µm) has been used to execute a “race-track” contour with removal of the inner part (see Figure 4). The same laser (green) has been used.

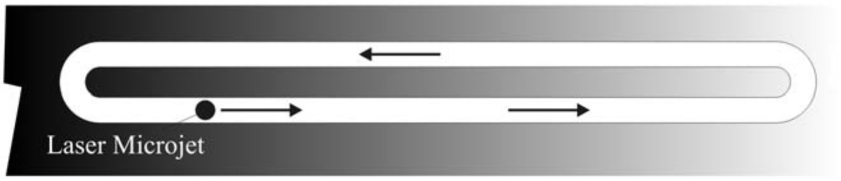

Figure 4: Race track

With these settings, the chipping on the laser exit side (the wafer front side) could be reduced to zero and the straightness of the slots could be improved further. The water jet has removed the remaining inner part automatically in all cases and no parts remained within the slot. Taking into account that no protection coating has been used, the cleanliness is outstanding (see Figure 5).

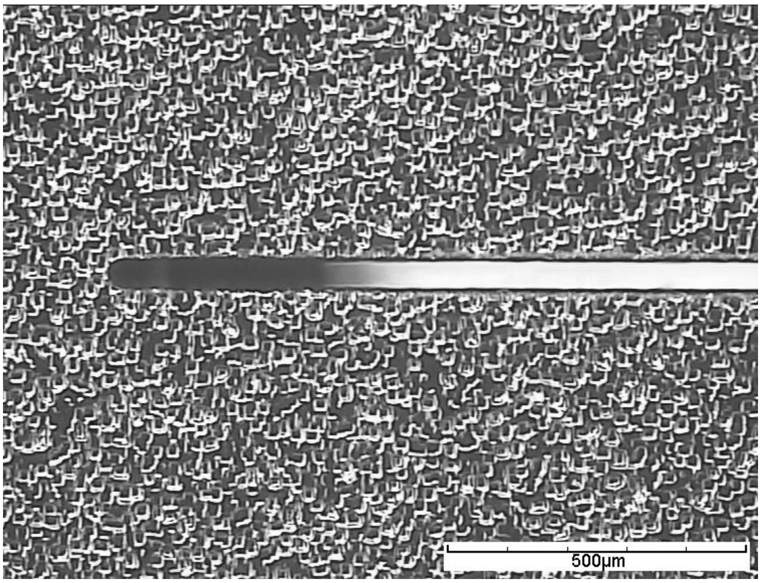

Figure 5: Chip backside, free of chipping

Further steps aimed at improving speed by modifying the axis setting (acceleration). With the same laser and nozzle, an overall speed of 5 mm/s has been achieved in 22 passes, reducing the cutting time by a factor of 2: only 5 seconds per slot. Even at this speed, the cut quality is maintained (see Figure 6).

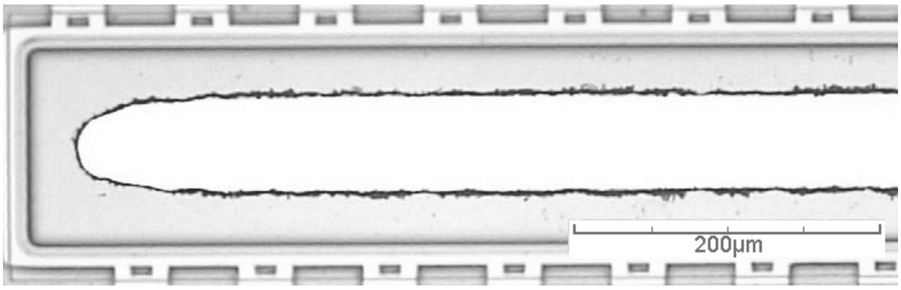

Figure 6: Slot exit side

Using a 35-µm nozzle, speed could be even more increased: 9 mm/s in 9 passes, again reducing the cutting time by a factor of 2 – only 2.6 seconds per slots. For these last tests, the edge is insignificantly rougher.

5. CONCLUSION

The water-jet-guided laser technology has proved its capabilities of matching the requirements of silicon slotting for inkjet-printer heads. After a short phase of parameter optimization, the required quality and speed were not only reached but also surpassed. Additionally to producing through-slots, the process can also be used to create blind slots with very accurate control of the depth – variations at the bottom of the slots are kept to a minimum. The produced slots are free of any length or depth limitations and the quality remains constant over time. The processing speed is high due to a very efficient material removal and high laser power of up to 100 Watts.

REFERENCES

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