

Drilling of Wafer Bump Stencils with Laser Microjet®: Up to 40'000 holes per hour. (M602)

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ABSTRACT

Solder mask stencils are metal or plastic perforated sheets used to apply solder paste to land locations where the paste will be re-flowed to attached electronic components. Wafer bump stencils are used for screen-printing solder paste or conductive adhesives onto wafers to form bumps used in Chip-on-Board connections. Stencils are made of stainless steel, Nickel or Polyimide (Kapton®). Since a large number of small apertures must be drilled in the thin metal or plastic sheet, precision, quality and speed are paramount.

The apertures can be produced by etching or standard laser cutting. The last has the advantage of high flexibility, speed, and is able to cut out very small apertures. However, the problem with classical laser cutting is cut quality. In fact, standard laser cutting needs a post-treatment to clean the stencil and remove burrs on its backside. Using a short pulse laser guided by a water jet, a burr-free, clean cut can be reached. In comparison with the conventional laser the difference is, at the very least, quite remarkable. Additionally, the water jet prevents thermal damage and oxidation. No post-treatment is therefore necessary.

1. INTRODUCTION

10 years ago, scientists at the Institute of Applied Optics of the Swiss Federal Institute of Technology of Lausanne in Switzerland succeeded, for the first time, in creating a laser guided in a stable water jet, called Laser-Microjet® by its inventors.

The principle difficulty of this idea [1] lies in the geometry of the water chamber in which the water jet and laser are coupled.

From laboratory experiments to the industrial machines working today around the world, the Laser-Microjet® (LMJ) went through several optimization cycles. However, the original idea remained unchanged, proving constantly its efficiency and offering new machining possibilities in large application fields, like cutting or drilling of wafer bump stencils.

This hybrid system allows to join the force of a powerful Nd:Yag laser and the delicateness of a low-pressure water jet.

LMJ is, in other words, particularly adapted for critical applications where the fragility of the material or its extreme hardness complicates its machining with other methods. The LMJ has its place in several industries including the automotive, medical device manufacturing, electronics, machine- tools, and solar energy industries.

In general, solder mask stencils are made of stainless steel, Nickel or Polyimide (Kapton®) perforated sheets used to apply solder paste to land locations where the paste will be re-flowed to attached electronic components or, in the case of wafer bump stencils, to form special solder bumps (figure 4). These bumps are used to create chip-on-board connections. Since a large number of small apertures must be drilled in the thin metal or plastic sheet, precision, quality and speed are paramount.

The employment of "wafer bumps" as chip interconnections provides several advantages over standard lead-frame packaging, in particular: More compact board designs are possible since the chip connectors are directly under the chip; due to the much shorter chip interconnections lower parasitic noise in the circuit is reduced.

2. LASER MICROJET® OPERATING PRINCIPLE

In order to couple the light into the water jet, the laser beam is focused into the nozzle of the water jet, whilst passing through a pressurized water chamber. With this unique laser cutting technique a free laminar water jet is used as an optical wave guide in order to guide a high power laser onto the sample [2]. The main advantages of this method compared to conventional laser cutting are:

- ▬ Parallel sidewalls (even in thick samples),
- ▬ Very low thermal load of the sample due to the cooling between the laser pulses exactly at the place where it was heated before,
- ▬ Efficient expulsion of the melt due to the high momentum of the water-jet.

The schematic of the used setup is shown in Figure 1.

The laser is coupled to a large core step-index fiber (200 microns core diameter) and then the fiber exit is imaged onto the nozzle entry with variable demagnification. Using a fiber between the laser and the basic machine is more practical for placing the laser and the machine in the lab, and the intensity profile of the laser on the nozzle entry is more flat-top like resulting in a longer nozzle lifetime than observed with a Gaussian beam profile. The used lasers are either flash lamp pumped pulsed YAG lasers with pulse durations of less than 120 ns, or multimode Q-switched lasers operating at 1064 nm, 532 nm, and 355 nm, with pulse durations of less than 1000ns. We use pure de-ionized and filtered water at 50 to 500 bars for the water jet. The nozzles are made out of sapphire or diamond in order to generate a long stable water-jet. The laser beam is focused through a quartz window into the nozzle, very much like with a usual fiber coupling and is thereafter reflected in the water-jet at the air-water interface due to the refractive index step (Figure 2).

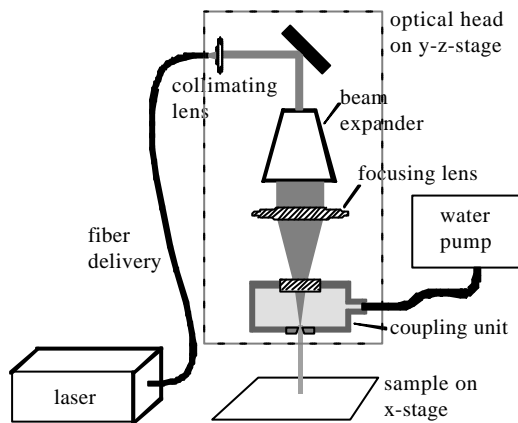


Figure 1: Schematic of the water jet-guided laser setup

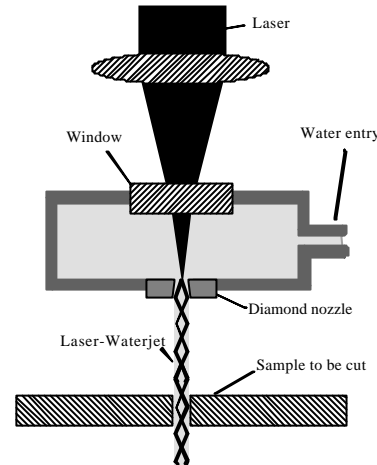


Figure 2: Detailed sketch of the coupling unit

The samples are clamped onto an x-stage, the optical setup is implemented in a “optics head” that is mounted on the y-stage. The z-variation of the stage is only necessary in order to adapt to the different working distances of different nozzle sizes (figure 3) and water pressures and is not used during the cutting process.

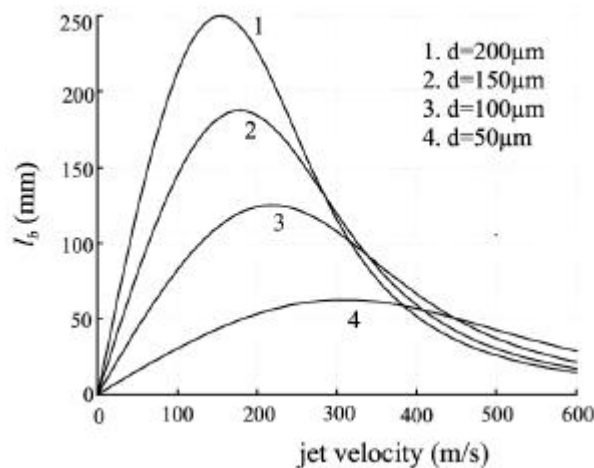


Figure 3: Stability curves for different nozzle diameters d ranging from 50 to 200 microns.

3. WAFER BUMP STENCIL DRILLING

For the fabrication of the stencils, a matrix of small apertures must be drilled in the metal or plastic sheet. Etching or standard laser cutting can achieve the apertures; they must be made a slight angle allowing the paste to be detached from the mask. The apertures can be rectangular or round. Precision, quality and speed are very important for this application. Typical stencil thickness' for wafer bump

applications range from 50 to 100 microns. For cutting thin metal foil, it is essential to reduce forces, and the heat affected zone (HAZ) on the sample.

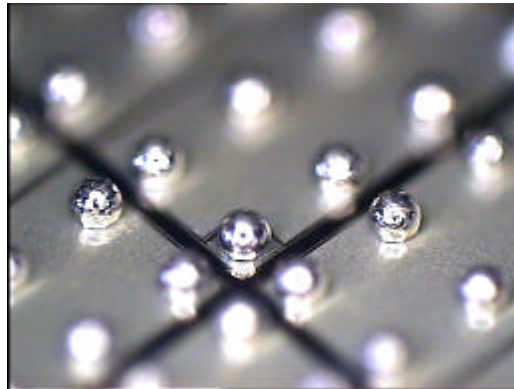


Figure 4 : Wafer bumps

Etching is the chemical method for drilling wafer bump stencil apertures. They are made in 2 steps. First the hole is perforated on one side, and then the other side is perforated. This procedure creates an internal bulge at the point of junction (figure 5), which is not optimum for the printing.



Figure 5: Schematic of etching (a) and Laser (b) cutting kerf section

Conventional laser and the LMJ can drill the holes in two ways: by trepanation drilling, in moving the axes in a circular motion; or by percussion drilling, without moving the axes (figure 6).



Figure 6: Schematic of trepanation drilling (a) and percussion drilling (b)

Laser cutting has the advantage of high flexibility, high speed, and is able to cut very small apertures. The problem with standard laser cutting is edge quality. In fact, laser cut stencils need a post-treatment to clean the stencil and remove burrs on the backside.

Using a short pulse laser (0.5 μ s pulse length) guided in a water jet, a burr-free, clean cut can be reached. The water jet reduces any thermal damage and oxidation, to an undetectable level. The backside is completely burr free, without any post-treatment. Table 1 summarizes some of the advantages and disadvantages of the different fabrication methods for wafer bump stencil apertures.

Table 1: short summary of wafer bump stencils method

	Etched	Laser	LMJ
Shape of the cutting edge	-	+	+
Burrs	++	-	++
HAZ	++	-	+
Force free	++	+	++
Flexible production	-	++	++

Environmental concerns	-	+	++
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4. THE LMJ VERSUS CONVENTIONAL LASER

The LMJ should not be confounded with the conventional laser method. The LMJ has indeed indisputable advantages over this older technology. The main advantages for stencil drilling lie in more efficient melt expulsion and the cooling effect of the water jet.

The flowing water of the jet also enables continuous cooling of the workpiece - the LMJ is sometimes referred to as “cold laser cutting” - which ensures the absence of burrs, efficient melt expulsion, and the absence of deposition of slag. The water jet cooling of the thin metal foil strongly reduces material changes due to heating, that are inherent with the conventional laser. Finally, the edges obtained with this new laser process are almost perfect, making any further edge treatment unnecessary.



Figure 7: Possibilities of cutting kerf section with the LMJ

Contrary to the water jet, the gas jet, which is coaxial to the conventional laser, has not enough momentum for correct melt expulsion. The water jet prevents thermal damage, also visible by the absence of oxidation. With the LMJ, there is no contamination by re-deposition of slag (byproducts of ablation), in comparison with the conventional laser the difference is at the very least, quite remarkable.

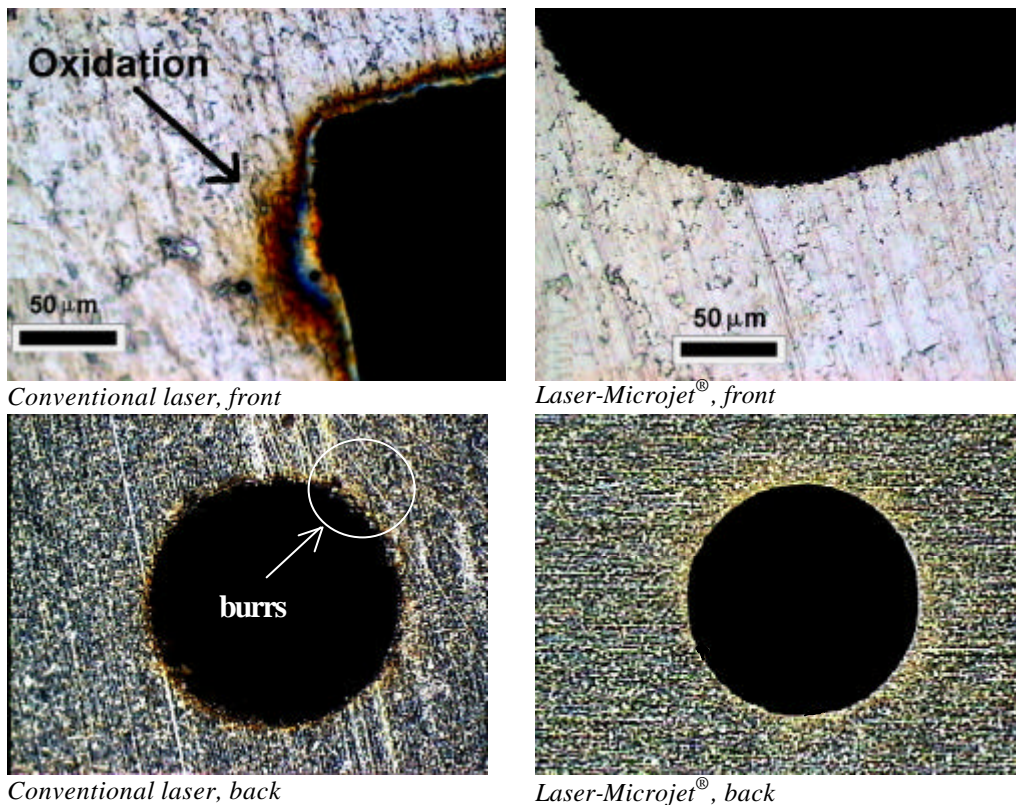


Figure 8: Optical microscope images of stencil apertures in 100 μm thick stainless steel

3. STENCIL DRILLING PERFORMANCE

For the trepanation mode (moving axes), the smallest hole diameter reached is the laser beam diameter + 1 micron, however for the percussion mode (without moving the axes), the hole diameter is same as the laser beam diameter. Very precise holes are possible to reach with the Laser Microjet[®] in both cases.

The Laser-Microjet[®] can cut up to 20 000 round apertures per hour in nickel stencil thick between 20 and 80 microns, applying the trepanation method.

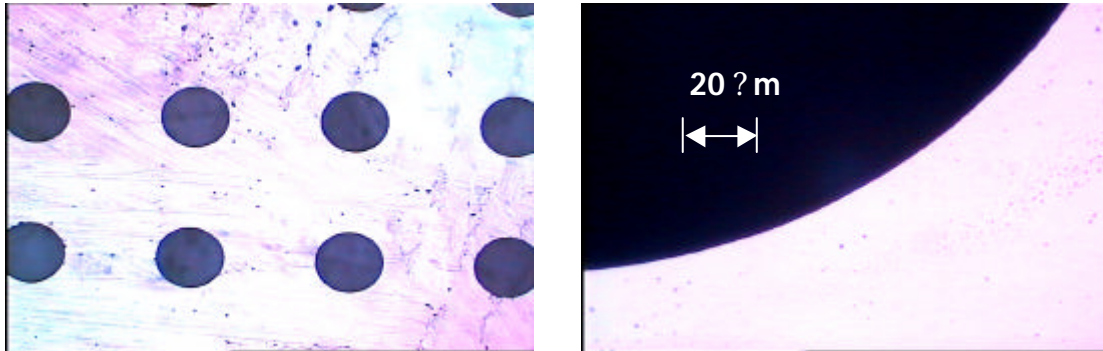


Fig. 9: Results of trepanation drilling: *Matrix of 10x10 holes in a 50 microns Ni foil*

When applying the percussion drilling method, the Laser-Microjet[®] can drill up to 40 000 round apertures per hour in a less 100 microns thick nickel stencil. Percussion drilling allows very small holes and high speed but the roundness is less precise.

With the LMJ, it is possible to obtain more than 10 000 holes/ cm² (matrix 100X100) in a 50 microns thick foil in 900 seconds.

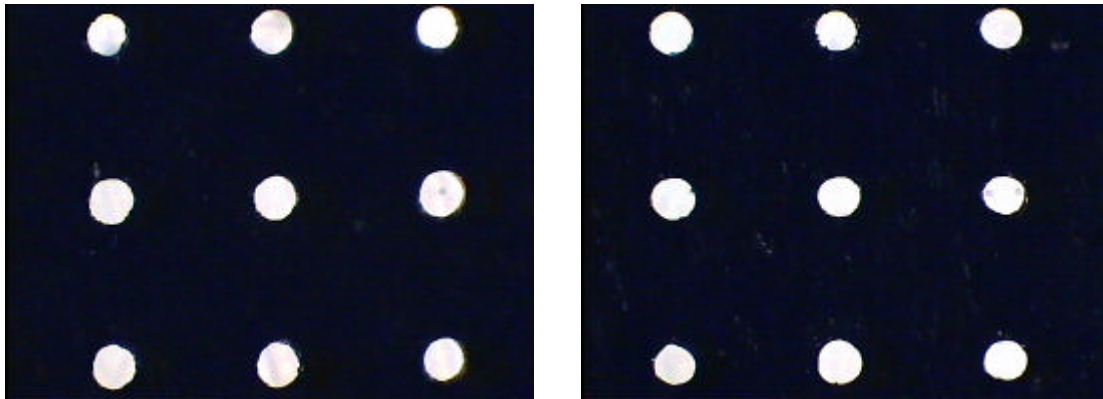


Fig. 10: Results of percussion drilling: *60 μm diameter hole, front 50 μm diameter hole, back*

4. SUMMARY AND CONCLUSION

The water jet guided laser has impressive capabilities compared to other standard methods. High cutting speed, excellent cut quality, burr-free, no post treatment necessary, very low tolerances, efficiency melt expulsion, no warping and thermal deformation, no mechanical damages, no scratching, no needs for cutting gas and especially the ability of the system to re-cool the sheet and its inherently high flexibility.

In summary, because of the important improvements in quality compared to conventional laser stencil drilling, the Laser-Microjet[®] process will be the best choice for wafer bump stencil cutting in the future. Synova SA offers a state-of-the-art machine, especially adapted for cutting of Wafer Bump Stencils.

5. REFERENCES:

1. Hecht, J. (1999). City of Light. New York, Oxford University Press.
2. Richerzhagen, B. (1993). Entwicklung und Konstruktion eines Systems zur Übertragung von Laserenergie für die Laserzahnbehandlung. Micro-Engineering Department. Lausanne, EPFL: 105.

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