

A Technological Leap In Stencil Cutting

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In combination with water jet guided technology, laser performance takes a leap forward: high flexibility, high speed and the ability to cut small apertures with clean edges while avoiding dross and slag. Moreover, worked items are free of mechanical stress induced by inadequate fixation and workpiece vibrations and material no longer suffers heat damage. This new laser technology is a cool, clean and cost efficient way to cut stencils.

Stencils are used as masks when applying solder paste in multiple bumps on printed circuit boards or, as in the case of flip-chip technology, directly onto the active surface of the chip. Stencils are most commonly made out of sheets of stainless steel, but sheets of Nickel, brass and polyimide are used as well. The following discussion will focus on stainless steel stencils, as seen in Figure 1.

A stencil contains a large number of small apertures; typically between 1,000-5,000 with wafer bump stencils (used in flip-chip technology) often reaching 10,000

apertures and in some cases even 100,000 apertures. Consequently, a high cutting speed is required. High quality and robustness are also prerequisites of the stencil manufacturing process. The tapered angle of the apertures must be controlled in order to ensure the solder detaches easily from the stencil. To ensure high soldering quality, the volume of solder paste in each bump has to be very precise and consistent. In other words, a burr-free stencil with precisely cut apertures is paramount.

Stencil manufacturing technologies

A wide range of different technologies is used in stencil manufacturing, namely, chemical etching, conventional laser cutting, Nickel electroforming as well as mechanical methods, primarily punching and milling. Within this array of tools, the laser offers a very attractive alternative combining good quality, flexibility in forming aperture shapes, and a relatively low cost compared to the other employed methods. When the number of apertures is extremely high, parallel methods such as

etching and electroforming are more productive, however, quality is compromised in the case of etching, whereas costs rise in the case of electroforming.

When quality demands are high, the laser is the most cost efficient technique. Electroforming offers the highest precision when working with small dimensions, but it is also considerably more expensive than the laser. The limitation of the laser is found mainly in the quality of the backside, the side from which the solder paste is added and from where the blade wipes over the stencil to determine the exact volume of each bump. The laser cut quality is good, although not perfect. Typically in the case of small apertures, small particles and burrs remain after cutting. If these defects are not removed, they will lessen the efficiency of the wiping step, consequently causing a variation in dispensed volumes.

Drawbacks of conventional laser cutting

Due to the large assist gas nozzle employed in conventional laser cutting, typically 0.5-1.0mm in di-

Figure 1 - A 210x300mm stencil mounted on a frame (left) and a close-up showing round apertures with 300µm diameter (right)

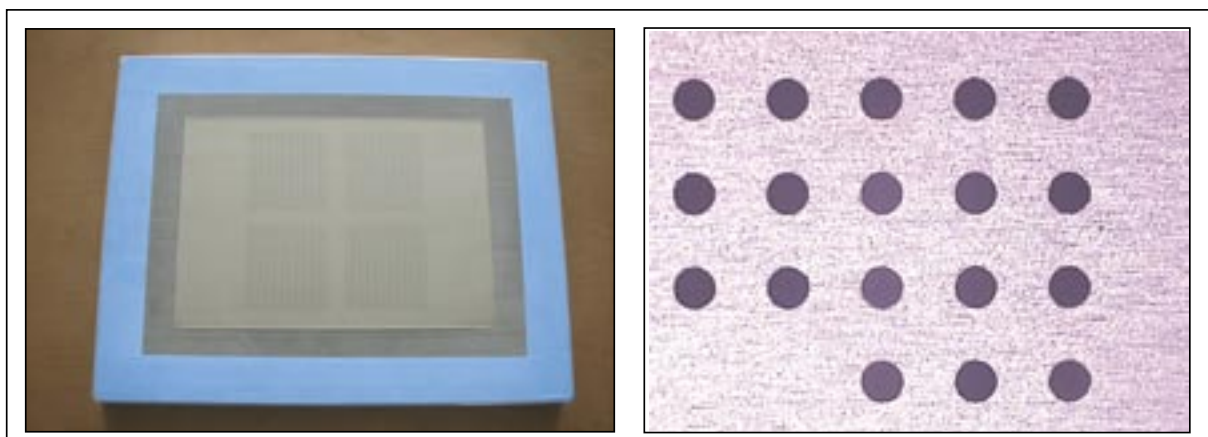




Figure 2 - The Laser Stencil System LSS 800

ameter, a considerable mechanical force is exerted on the work piece. This is usually in the range of 1-5N, despite the fact that the pressure of the assist gas for melt removal is merely 6-15 bars. When the pressure applied to the molten material is insufficient, there is a high risk of leaving multiple apertures partially or totally filled with slag and dross formations. Additional steps, such as cleaning and repair cutting take time and should be avoided.

As an additional consequence, insufficient melt removal will facilitate residual heat transfer from slag to the work piece. Heat load generates heat-affected zones, oxide layers on the walls, soot on the stencil, as well as greater positioning errors. Stainless steel expands by 16-18 μ m per meter per degree Celsius. Consequentially stencils measuring 500x500mm need to be cut with an average temperature as stable as $\pm 0.6^{\circ}\text{C}$ to achieve a $\pm 5\mu$ m tolerance. In conclusion, it is vital to minimise the heat propagation in the work piece.

A new laser cutting method

A new laser hybrid stencil forming technique has been developed, the water jet guided laser (Laser-

Microjet), which combines a laser beam with a cooling water jet and provides very high quality in a single step process. The solution is offered by Synova, Switzerland.

The stainless steel stencil is, in terms of cost efficiency with high quality cutting, best cut with the new water jet guided, long pulsed, near-infrared laser. This type of laser is available with nozzle diameters ranging from 28 to 150 μ m. In comparison, a human hair has a diameter of 40-100 μ m. There are currently two machine types available from Synova for stencil cutting with the Laser-Microjet

technique:

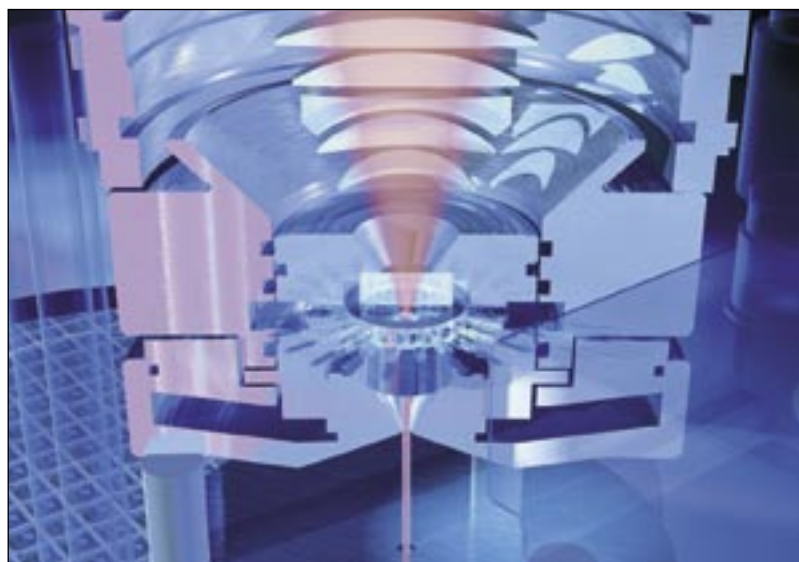
- The LCS300 is a 300x300mm working area XYZ-machine with linear motors for fastest acceleration and 3 μ m precision.
- The LSS800 is a 700x900mm working area XY-machine with integrated stencil software including a quality control routine to verify all apertures in the design. It handles stencils on frames using a very convenient fixture system. Linear motors enable 5 μ m positioning precision.

The water jet guided laser offers a high production rate, depending on the thickness, from approximately one rectangular hole per second measuring 1x1mm, or up to 20 percussion drilled 50 μ m holes per second. The perfect edge quality (as cut) is illustrated in Figure 5, and the stencil is ready for use directly after having been cleaned for a minute in an ultrasound bath with pure water.

The laser stencil system

The LSS 800 (Figure 2) produces stencils with a tolerance as low as 5 μ m over a 700 x 900mm cutting area. The fixture system handles stencils on frames in an accurate, easy-to-load manner without inducing stress in the material, which is vital in order to obtain the

Figure 3 - The principle of the water jet guided laser



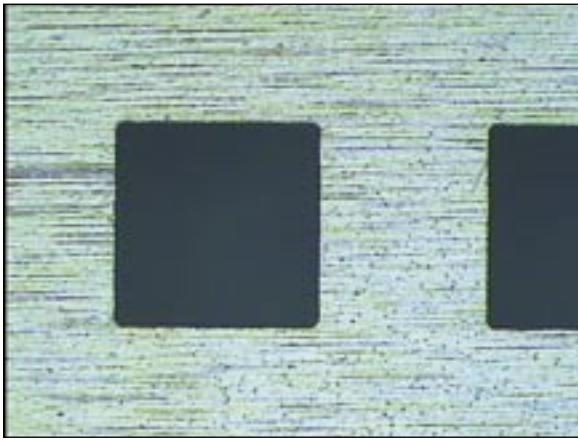


Figure 4 - Square apertures 475 μ m wide in 200 μ m stainless steel (rate: 4000/hour)

best final result. Being a precision driven application, it must always initiate with a good fixation. An integrated stencil software package ensures perfect quality. In case of any uncompleted apertures on the stencil, an automatic correction function repairs the stencil. Equipped with a machine base in granite, linear motors and modern electronic positioning feedback systems, it is relatively easy today to build an accurate machine that offers precise tool positioning. The process itself is now the determining factor in order to provide higher precision and quality.

The LSS 800 has a Gerber interface based on CAM 350 and is fully CAD compatible. The system is compatible with stencils in stainless steel, Nickel and black polyimide, without the need to switch laser sources and can handle a varying range of thicknesses from 10-200 μ m. With the front door of the machine closed, there is no laser radiation emitted outside of the machine. The LSS 800 is qualified as laser-class-1, thus no safety goggles are required for operation. The precision fixture handles frames with thicknesses of 10-40mm.

The water jet guided laser

Laser-Microjet is a hybrid method which utilises a laser beam for cutting and a water jet for guiding the laser power directly onto and thru the work piece. The water jet applies a high, localised pressure on the work piece exactly on

the cut interface, achieving perfect material removal. Within the water jet, the laser beam is conducted by total internal reflection at the water-air interface. It can be thought of as a cooling liquid and as an optical fibre which directly contacts

the work piece, resulting in the delivery of consistent laser power with a constant spot size. This is possible due to the wave guiding function of the water jet, creating a focal depth of several centimetres.

Figure 3 shows a cross-section of the opto-mechanical element in which the laser beam is coupled into the water jet. The pulsed infra-red laser beam is focused into the nozzle orifice with an aperture diameter of 30-150 μ m. Between the nozzle and an optically transparent window (white), water is supplied under pressure (blue arrows). The exit of the coupling unit is a nozzle aperture, where a water jet containing and guiding the laser beam is formed.

The flow rate is kept low due to the hair-thin water jet diameter. For example, when using a water jet measuring 50 μ m in diameter and

250 bar water pressure, the flow rate is only 1.5 litres per hour, even lower for thinner jets. The thinnest jet currently available is 28 μ m in diameter. When used at a typical water pressure of 400 bars, only 0.5 litre of DI water is consumed per hour.

High pressure – low force

The water jet works with pressures normally ranging from 200-400 bar, thus high enough to quickly remove all molten material, keeping the cut clean, while being low enough to leave the material unscathed when exposed to the bare jet. Only the laser beam is employed to cut the material.

Due to its very small diameter, as thin as 28 μ m, the microjet exerts an external mechanical force on the work piece less than 0.2-0.01 N. In comparison, the force of 1-5 N applied by the conventional gas assisted laser cutting process is at least 5 times greater. The gravitational force of a standard office paper sheet in A4 size is 0.05 N, the same magnitude of the microjet. We can conclude that the force from the microjet is truly negligible. Nevertheless, this water pressure is successful in efficiently removing all molten material, because it is strongly localised to the cutting area and the molten material front.

Figure 5 - A corner of an aperture at higher magnification. The jet diameter was 40 μ m as indicated by the scale-bar



Efficient cooling

The water jet guided laser benefits from very efficient cooling of the kerf between the laser pulses thanks to the constant cooling action of the water jet. The water expels the molten material, removing any dross, extracting heat-load, and prevents heat propagation outside the immediate cutting area. In conventional laser cutting, gas pressure, frequently compressed Nitrogen or air, is applied to remove metal melted by the laser beam. This method cools much less efficiently than the water jet. When using Nitrogen or air, traces of heat can be seen with the naked eye in forms of brown or coloured oxides on the stencil. Heating of the work piece increases the tolerance determined by the positioning accuracy, resulting in a less precise cutting process.

Between 5,000 and 20,000 high quality, round apertures with di-

ameters between 350-600 μ m are cut within an hour by applying a trepanning method. As for squares of the same size, the rate is 2,500-4,000 apertures per hour. Figures 4 and 5 show square apertures, each cut with the Laser-Microjet in less than a second. The edge is very clean and the material has no visible heat effects.

Wafer bump stencils

Round apertures with diameters of 30-60 μ m can be percussion drilled at rates of up to 20 holes per second or 72,000 holes per hour. Such small apertures are needed in very high numbers with highly accurate positioning in wafer bump stencils for flip-chip technology. Particularly thin wafer bump stencils are an example of a most delicate and demanding application whereby the heat input must be kept as low as possible. Equally important, the aperture and its backside require

the highest level of cleanliness.

Cutting features with Laser Microjet

Synova is currently offering Laser Microjet in diameters as thin as 28 μ m and is conducting lab tests with laser guiding water jets as thin as 17 μ m. In this case, rectangular apertures can now be cut with corner radii as sharp as 14 μ m, and the high pressure applied by the water jet ensures optimal material removal in the corners of the cut. The cutting speed is limited by the pulse repetition rate of the laser to ensure the best overlap between pulses. The very low contact force helps to maintain excellent work piece stability during the critical moment in which the aperture is pierced through. The high-speed water jet efficiently and instantly removes any residual heat-load in the work piece between laser pulses.

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