

New process for screen cutting: water-jet guided laser

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ABSTRACT

Today's OLED manufacturers need high-precision, fast tools to cut the metal screens used to deposit the electroluminescent layers onto the substrate. Conventional methods – etching and dry laser cutting – are not satisfying regarding the demands of high-definition OLED displays. A new micro machining technology, the water jet guided laser – a hybrid of laser and water jet technologies that has been actively used in recent years in the electronic and semiconductor field – is now available to OLED manufacturers. This technology represents a significant improvement in screen, mask and stencil cutting, as it combines high precision and high speed. It is able to cut small apertures with totally clean edges (no dross or slag), as the water jet removes the particles and a thin water film is maintained on the material surface during the process. Because the water jet cools the material between the laser pulses, the cut material is free of any thermal stress. The water jet guided laser is also a very fast process: as an example, rectangular slots can be cut in 30 to 50 microns thick stainless steel or nickel at a rate between 25'000 and 30'000 holes per hour.

Keywords: Water-jet guided laser, screen manufacturing, laser cutting

1. INTRODUCTION

According to important market research institutes, the market of flat panel displays (FPD) is one of the fastest growing, with a projected annual growth rate exceeding 20% throughout the next few years. Indeed, FPD are today used in many electronic devices such as TV, computers, control panels, calculators, cellular phones and hand-held devices. Amongst the various existing flat display technologies, an interesting newcomer is organic LEDs (OLEDs) displays. Indeed, compared to the competitors, OLED displays offer advantages such as greater efficiency, easier production, enhanced physical flexibility and lower cost. It is foreseen that OLED technology, commercially available for only 5 years, will replace the present generation of liquid crystal displays (LCD) and plasma display panels (PDP). If the first targeted applications are small displays (cellular phones, digital camera, PDA), other applications should also benefit from this technology in a near future (computer and TV screens, flexible e-book).

Despite important improvements achieved in the laboratory, the milestone problem of this technology – sustainable serial production – has not yet been solved. Today's OLED producers are looking for new manufacturing techniques able to match the high requirements of this technology, while ensuring productivity. This is the case for the manufacturing of masks employed to deposit the electroluminescent material onto the substrate of the OLED display. Since etching and conventional laser are not technically satisfying regarding the demand in precision, quality and speed, alternative solutions are required. The water jet guided laser, a hybrid of laser and water jet technologies, is a significant improvement in mask cutting, as it combines high flexibility and speed at low costs.

2. OLED TECHNOLOGY

In an OLED cell, multiple organic layers forming a p-n junction are interposed between a metallic cathode and a transparent anode and placed on a transparent substrate. When the appropriate voltage – typically a few volts – is applied to the cell, the injected holes and electrons recombine in the thin emissive layer (usually constituted of polymers) to produce light – this is the phenomenon called electroluminescence (see Figure 1).

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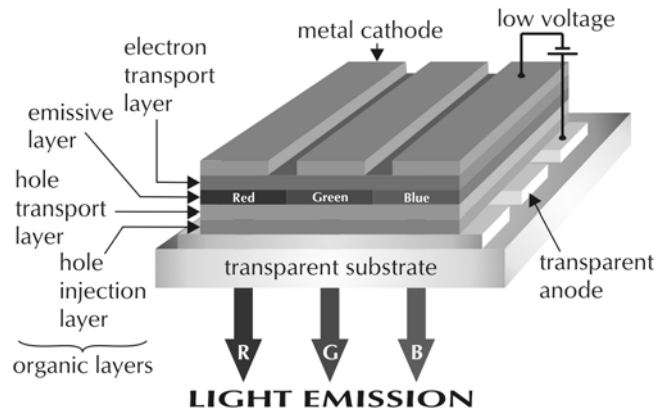


Figure 1. Basic structure of an OLED cell

Since OLED cells do not require backlighting, the resulting display is thinner than with other technologies. It is also brighter, even from a side-viewing angle, and faster. Another advantage of OLEDs is their low power consumption (20 to 30% lower than LCD's) providing maximum efficiency, thus minimizing heat and electrical interference in devices. They can also be produced on flexible substrates.

3. METAL SCREENS FOR EMITTIVE LAYER DEPOSITION

Metal screens are used during manufacturing of OLED displays to deposit the emitting layers onto the substrate of the panel. An OLED cell – corresponding to one pixel – contains all three colors (RGB). Therefore, the mask openings have to be rectangular, so at the end of the process a square containing the three colors is obtained. An example of mask configuration can be seen in Figure 2 (succession of 100 μm x 300 μm openings).

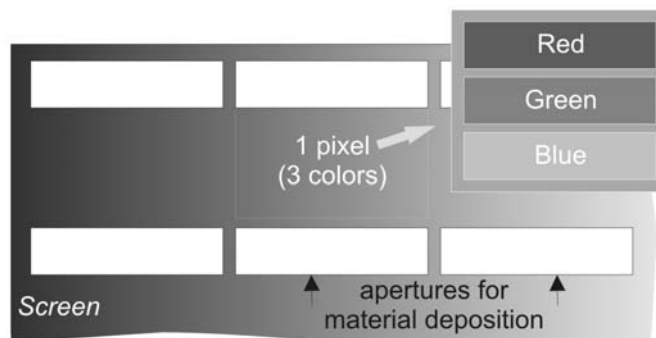


Figure 2. Example of mask design: a succession of rectangular openings results in square pixels

The usual materials for these masks are stainless steel and nickel/steel alloys, and the thickness of the sheets typically ranges from 30 to 50 μm. A single mask can be used for parallel fabrication of several small screens. For example, as one cell-phone screen has more than 30'000 pixels, the total number of openings in the mask can reach 3 millions. The cut quality is paramount – very precise and constant shapes are required. In addition, due to the production requirements, screens must be manufactured at high speed.

Etching is currently the most widely used method for producing these screens. It is however an expensive process and accuracy-related problems can arise as screens become larger. Lasers present several advantages compared to etching as they combine high flexibility and relatively low running costs. Dry laser cutting is however limited due to the presence of heat-affected zones, making its use for fine-pitch structures unsuitable, as heating generates inaccuracies and bending. In addition, small particles and burrs remain, imposing post-processing steps. The water jet guided laser is a new cutting technology that provides excellent quality in a single step process, permitting lower costs when compared to the other

available processes for higher production rates. It has been recently adapted to screen cutting and already achieves very promising results.

4. WATER JET GUIDED LASER

The concept of the water jet guided laser (also called Laser-Microjet) is to guide a laser beam into a water jet. This is achieved by focusing a laser beam into a nozzle while passing through a pressurized water chamber. The water jet emitted from the nozzle guides the laser beam by means of total internal reflection that takes place 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 (see Figure 3).

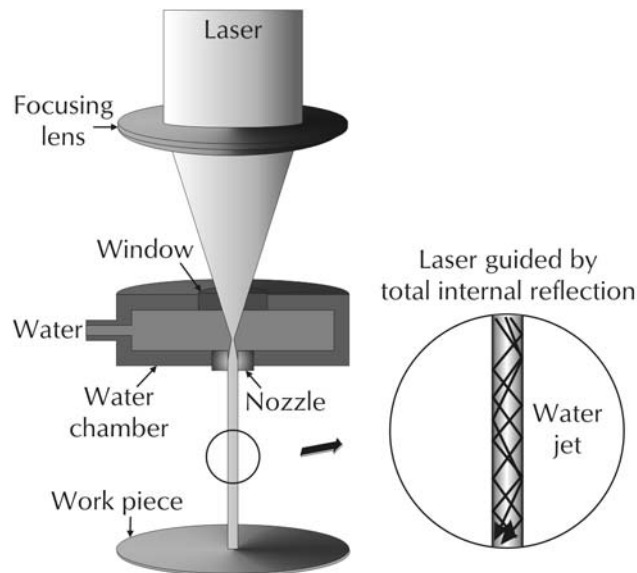


Figure 3. Laser-Microjet principle: the laser beam is guided by total internal reflection at the water / air interface

The primary function of the water jet is to guide the laser beam onto the work piece where the ablation takes place. Nevertheless, the water jet has two other major effects proving to be very important for precision cutting. First, the water jet prevents heat damage within the material by cooling the cut edges between the laser pulses. The heat-affected zone, as a result, is negligible. The second important, ancillary effect of the water jet is to expel the molten material from the cut. Because of its high momentum, the water jet is much more efficient than any assist gas. It also avoids surface contamination that may be caused by laser ablation; the water jet instantly cools all removed material, and remaining particles are maintained in suspension in a thin water film covering the screen during cutting. This system prevents particles to reattach to the screen surface. Additionally, the mechanical force applied by the water jet to the screen is negligible (less than 0.1 N).

5. WATER JET GUIDED LASER AND SCREEN CUTTING

Because of its original features, the water jet guided laser is well suited for screen cutting. It is three to five times faster than conventional laser in same conditions, and less expensive than etching. For an optimal quality-to-speed ratio, the Laser-Microjet is used in trepanation-drilling mode: the axes are moved on a controlled path (circle, rectangle, and so on) to produce precise openings (see Figure 4).

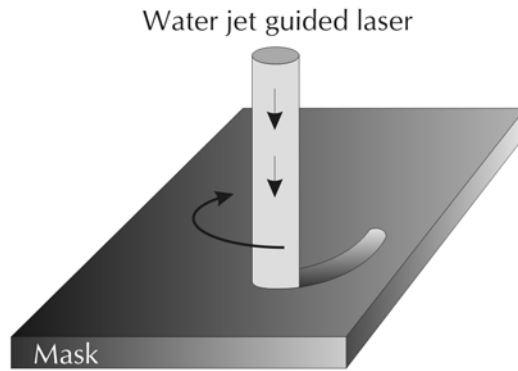


Figure 4. Trepanation drilling

The cutting width depends on the nozzle diameter, ranging from 25 to 75 μm . Very small openings are therefore possible, the minimum tool radius currently being 12 μm . The cutting speed depends on the thickness and the material of the screen; the thinner the pieces, the higher the speed. Table 1 shows some drilling rates in stainless-steel sheets, in function of the thickness, for two common shapes of openings: rounds and squares.

Mask thickness: 100 μm		
Type of opening	Opening size	Number of openings per hour (rate)
Round	ϕ 150 μm	8,000 / hour
Square	150 μm x 150 μm	6,000 / hour

Mask thickness: 50 μm		
Type of opening	Opening size	Number of openings per hour (rate)
Round	ϕ 80 μm	30,000 / hour
Square	90 μm x 90 μm	25,000 / hour

Table 1. Cutting rates of the water jet guided laser

In the case presented before (Figure 2), where rectangular openings need to be drilled (dimensions: 100 μm x 300 μm) in 50- μm stainless steel, the water jet guided laser achieves a drilling rate of 20'000 openings per hour. In these dimensions, a 40- μm nozzle is usually used. An infrared fiber laser has been selected for this application. Openings are very constant and clean; processed screens show no burrs and very few non-adhering particles, which are easy to remove with a standard ultrasonic cleaning process. The material has no visible heat affection (see Figure 5).

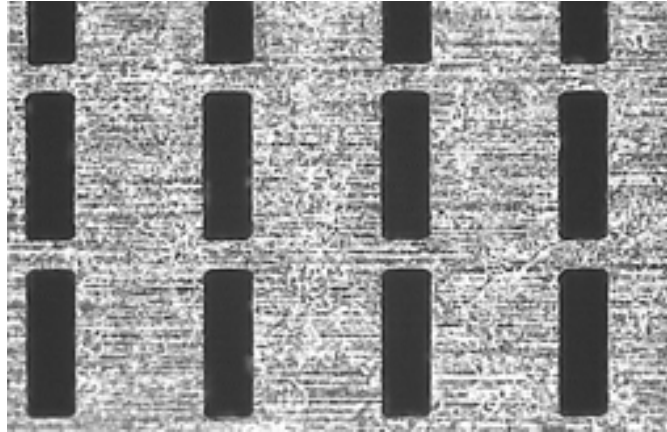


Figure 5. Rectangular openings, 100 x 300 μm wide, in 50- μm stainless steel; rate: 20'000/hour

CONCLUSIONS

Within the fast-growing market of flat panel displays, the OLED technology has several assets. Today's producers are looking for new manufacturing techniques available to match the high requirements of this technology in terms of quality and productivity. This is the case for cutting of screens used to deposit the emitting material onto substrates. Since etching and conventional laser are not entirely satisfying, according to the requirements imposed by the future demand of high-quality flat displays, alternative solutions are needed. The water jet guided laser, a hybrid of laser and water jet technologies, allows a significant improvement in screen cutting, as it combines high flexibility and high speed at low manufacturing costs. It is able to cut small openings with clean edges, avoiding dross and slag; the screen is free of mechanical and thermal stress, as well as of heat damage.