High-Precision Screen Cutting with the Water-Jet Guided Laser

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Abstract

Compared to LCD and plasma-display technologies, OLEDs offer indisputable advantages such as greater efficiency, easier production, more physical flexibility and lower cost. Today's electronic consumable producers are looking for new manufacturing techniques able to match the high requirements of this technology. One example is manufacturing of metal screens used to deposit the electroluminescent layer onto the substrate. Since etching and conventional laser cutting are not satisfying regarding the future demand of high-definition flat displays, new solutions are required. The water jet guided laser, a hybrid of laser and water jet technologies, allows a significant improvement in screen, mask and stencil cutting, combining high precision and high speed at low production costs.

The combination of laser beam and water jet is achieved by focusing a laser beam through a pressurized water chamber into a nozzle. The water jet emitted from the nozzle guides the laser beam by means of total internal reflection at the water/air interface, in a manner similar to conventional glass fibers. This original technology is able to cut small openings with clean edges, avoiding dross and slag; the cut material is free of mechanical and thermal stress. For 50-micron thick stainless steel, it is possible to drill square openings at a rate of 30'000 openings per hour and more.

Introduction

Flat panel displays (FPD) are used in many electronic devices such as TV, computers, control panels, calculators, cellular phones and hand-held devices. According to the main market research institutes, the FPD-market is one of the fastest growing markets, with a projected annual growth rate exceeding 20% throughout the next few years.

Compared to existing flat displays, the organic LED (OLED) technology offers important 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 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 FPD 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 Laser Microjet, 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.

OLED Displays

OLED displays are based on the discovery that thin molecular films (polymers mainly) emit light. 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 emissive layer to produce light – this is the phenomenon called electroluminescence (see Figure 1).

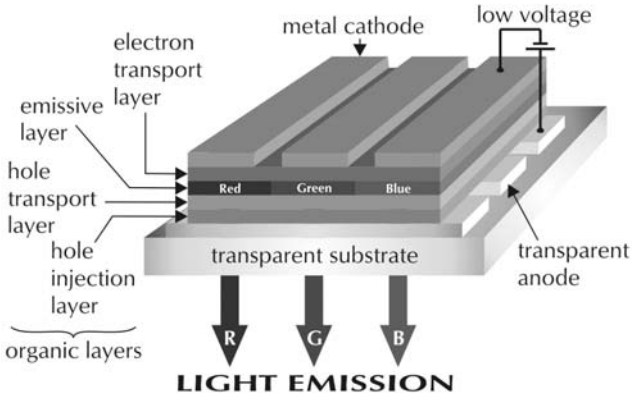

Figure 1.Basic OLED cell structure

Since OLEDs 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.

Metal Screens

Metal screens are used during manufacturing of OLED displays to deposit the emitting layers onto the substrate of the panel. These masks are usually made in thin sheets of stainless steel or nickel/steel alloys (thickness between 30 and 50 µm).

An OLED cell (corresponding to one pixel) contains all three colors (RGB). The shape of the mask openings is thus 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).

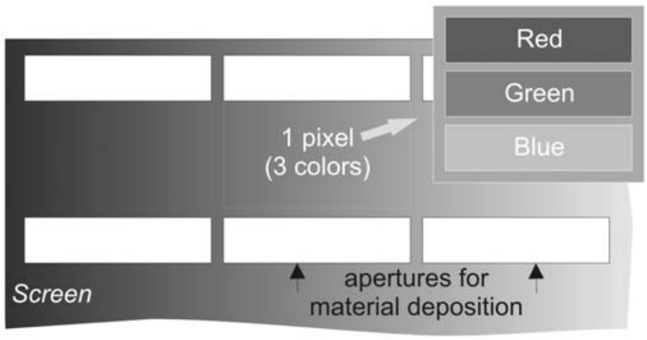

Figure 2. Example of mask design: the rectangular openings are separated to obtain square pixels

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 common method for producing these screens. It is however an expensive method and accuracy-related problems can arise as panels 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 hybrid method combining a laser beam with a low-pressure water jet 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.

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).

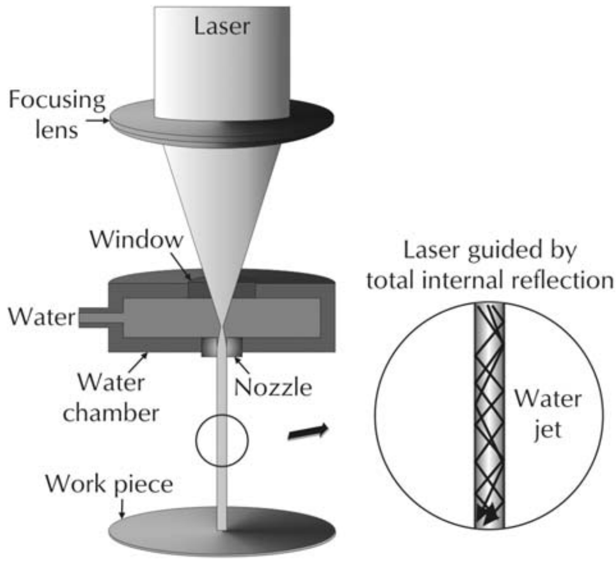

Figure 3. Laser-Microjet principle: the laser beam is guided by total internal reflection at the water / air interface

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 expels the molten material from the cut, because of its high momentum, more efficiently than any gas expulsion. It also avoids surface contamination that may be caused by laser ablation (like small particles and drops of molten material); 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.

The second important, ancillary effect of the water jet is to prevent heat damage within the material by cooling the cut edges between the laser pulses. The heat-affected zone, as a result, is negligible. Hence the water jet guided laser can be called a "cold laser".

An important point is that the mechanical force applied by the water jet to the screen is negligible (less than 0.1 N). As a comparison, the gas jet usually accompanying conventional laser cutting creates a mechanical force typically in the range of 1 to 5 N.

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.

Table 1. Cutting rates of the Laser Microjet

	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

Water Jet Guided Laser and Screen cutting

Because quality and speed are determining factors, 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).

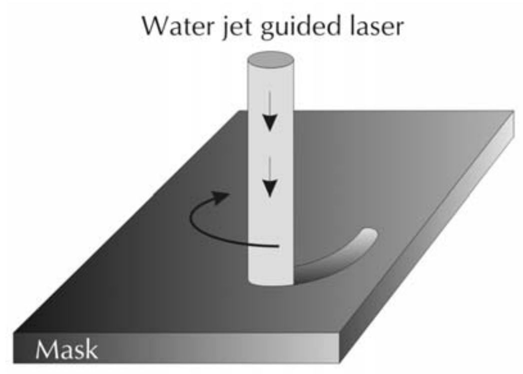

Figure 4. Trepanation drilling

The water jet guided laser process is not only very precise, but also very fast (three to five times faster than conventional laser cutting in same conditions), and less expensive than etching. In the case presented before (see Figure 2) where rectangular openings need to be drilled (dimensions: 100 µm x 300 µm) in 50-µm stainless steel, the Laser-Microjet 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.

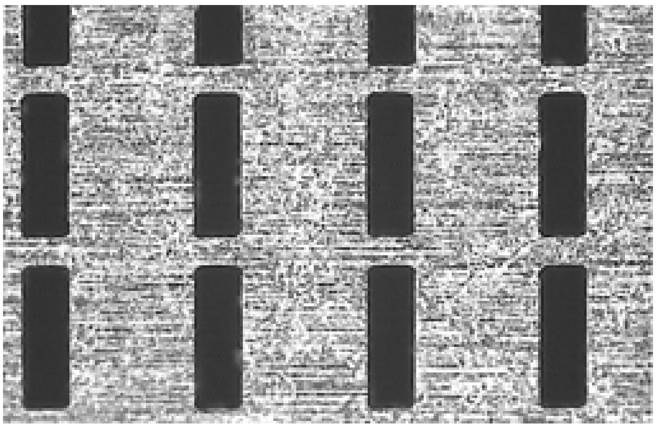

Figure 5. Rectangular openings, 100 x 300 µm wide, in 50-µm stainless steel, rate: 20,000/hour

With the water jet guided laser, 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 ultra sonic cleaning process. The material has no visible heat affection.

Conclusions

Within the fast-growing market of flat panel displays, the OLED technology offers many advantages. 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 Laser-Microjet, 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.