INDUSTRY INSIGHT

Screens in Flat Display Manufacturing

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The market of flat panel displays (FDP) is fast growing – FPDs are used in many electronic devices such as TV, computers, control panels, as well as for smaller displays such as those used in calculators and cellular phones. In fact, according to the main research institutes, it is one of the fastest growing markets, with a projected annual growth rate exceeding 20% throughout the next few years.

Compared to commercial flat displays, the organic LED (OLED) technology offers indisputable 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). The first targeted applications are smaller displays (cellular phones, digital camera, PDA). However, in a near future, other applications will benefit from this technology (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 searching 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 future demand of high-definition flat displays, alternative solutions are required.

The Laser Microjet, a hybrid of laser and water jet technologies, allows a significant improvement in mask cutting, combining high flexibility and high speed at low costs.

OLED Technology

The most promising flat display is OLED (Organic Light Emitting Diodes) display, a technology presenting many advantages upon traditional liquid-crystal displays (LCDs). Its origin is based on the discovery that thin molecular films (polymers mainly) emit light. More precisely, multiple organic layers (usually a hole-injection layer, a hole-transport layer, an emissive layer, and an electron-transport layer), forming a p-n junction and interposed between a metallic cathode and a transparent electrode, are placed on a transparent substrate. When the appropriate voltage, typically a few volts, is applied to the cell in forward direction, the injected holes and electrons recombine in the emissive layer to produce light – this is the phenomenon called electroluminescence.

Since OLEDs do not require backlighting, the resulting display is thinner when compared to any other technology. They are 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. Furthermore, they can also be produced on flexible substrates.

Evaporation Masks

Manufacturing of flat displays using OLEDs requires metal screens to deposit the emitting layers onto the substrate of the panel. These masks are mainly comprised of thin sheets of stainless steel or nickel/steel alloys (thickness between 30 and 50 microns), containing a large number of apertures (from 100, 000 to several million). For this application, the cut quality is paramount: very precise, constant shapes are required. In addition, due to the production exigencies, they have to be manufactured at high speed.

An OLED cell (corresponding to one pixel) contains all three colors (RGB). The shape of the apertures is rectangular, so at the end of the process a square containing the three colors is obtained. A typical mask configuration is a succession of 200 microns x 66 microns aperture.

A large amount of these apertures must be drilled in masks for OLED displays. A single mask can be used for parallel fabrication of cellular phone screens, each requiring more than 30,000 apertures, which makes in total more than 3 millions apertures in the mask.

Currently, the most common method for producing these screens is etching. It is an expensive method, presenting accuracy problems, as panels become larger. Lasers present several advantages compared to etching as they combine high flexibility and relatively low running costs. Laser-based cutting is however limited at present due to the creation of heat-affected zones, making its use for fine-pitch structures unsuitable.

Heating generates inaccuracy in dimensions, which is from a precision point of view, unacceptable. 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. The Laser Microjet possesses all the advantages of laser processing without its well-known drawbacks.

Laser Microjet

The combination of laser beam and water jet is achieved by focusing a laser beam through a pressurized water chamber into a water jet 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 fibres. The water jet can thus be referred to as a fluid optical wave-guide of variable length.

Only the laser is used for ablation; the primary function of the water jet is to guide the laser beam onto the work piece, nevertheless, the water jet has two other major effects proving to be very important for precision cutting.

Firstly, the water jet expels the molten material from the cut. This is due to the pressure of the water jet (ranging from 100 to 500 bar) which is much more efficient than any gas expulsion. It also avoids surface contamination that may be caused by small particle generation from the process; the water jet instantly cools all removed material, thus preventing that the particles reattach to the work piece surface. In addition, the particles are washed off using a thin water film. Work pieces remain clean and free of particles.

It is important to note that the mechanical force applied by the water jet to the work piece is negligible (less than 0.1 N). As a comparison, note that the gas jet usually accompanying conventional laser cutting creates a mechanical force typically in the range of 1 to 5 N, at least ten times higher than in the case of the water jet.

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 extremely thin. Hence the water jet guided laser can be called a “cold laser”.

The cutting width depends on the nozzle diameter, ranging from 25 to 75 microns. Very small apertures are therefore possible, the minimum tool radius currently being 12 microns.

The cutting speed depends on the thickness and the material of the work piece; the thinner the pieces, the higher the speed.

Mask Cutting

For the particular application of flat display manufacturing where quality is an important factor, the Laser Microjet produces masks using trepanation drilling: the axes are moved on a controlled path, allowing the making of precise apertures.

The process is not only very precise, but also very fast (three to five times higher speed than conventional laser cutting in same conditions), and less expensive than etching. In the typical case presented before where many rectangular apertures need to be drilled (dimensions: 200 microns x 66 microns) in 50-microns stainless steel, the Laser Microjet achieves a drilling rate between 15,000 and 20,000 apertures per hour. In these dimensions, a 40-microns nozzle is used, which corresponds to a cutting radius of 18 microns.

Applying this technology, the apertures are very constant, the edges of the cuts clean, showing no burrs, having very few particles, easy to remove with a standard ultra sonic cleaning process, and the material has no visible heat affection.

Summary

As the flat display market is fast growing, the OLED technology offers indisputable 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 the manufacturing of screens used to deposit the emitting material onto the substrate of the flat panel. Since etching and conventional laser are not fulfilling these requirements, imposed by the future demand of high-quality flat displays, alternative solutions are sought.

The Laser Microjet, a hybrid of laser and water jet technologies, allows an important improvement in screen cutting, combining high flexibility and high speed at low costs. It is able to cut small apertures with clean edges, avoiding dross and slag; the screen is free of mechanical and thermal stress, as well as of heat damage. A future target is to decrease the diameter of the water jet.

Editor’s Note: Synova S.A. was founded in 1996 and is located in Lausanne, Switzerland. The company manufactures cutting edge laser systems for the semiconductor, electronic, automotive, energy and medical industries based on the water jet guided laser, a new laser technique which was invented by the founders in the early nineties at the Federal Institute of Technology in Lausanne, and then patented by the company’s owners. For more information, visit www.synova.ch.