A new technology for producing OLED masks

Water jet-guided laser cutting

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Flat Panel Displays (FPDs) are becoming an every day part of people's lives in today's modern information age. From your mobile phone, iPod or Blackberry to your High Definition Television Display (HDTV), they are omnipresent. There are different types of technologies employed in the manufacture of these devices. One of the most promising is the Organic Light-Emitting Diode display, or OLED for short, which are now entering into their 4th generation. They are energy efficient, easier and less costly to produce than other technologies and can even be manufactured using flexible substrates. How are they made?

Figure 1: Synova LSS1200 Laser Stencil System

OLED displays are based on the discovery that thin molecular films (polymers mainly) can emit light under certain conditions. 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. A voltage – typically a few volts – is applied to the cell to generate the recombination of injected holes and electrons in the emissive layer, producing light, a phenomena known as electroluminescence. The cell structure is depicted in figure 2. Due to the fact that OLED cells do not require backlighting, the resulting display is thinner than with other technologies. They are also brighter and have a wider viewing angle and can even be produced on flexible substrates. The power consumption is 20 to 30 % lower than LCD's, providing big improvements in efficiency, reducing heat dissipation and lowering electrical interference in devices.

OLED mask cutting process

Etching is currently the most widely used method for producing masks. It is, however, an expensive process and accuracy-related problems can arise as masks become larger. Lasers present several advantages compared to etching as they combine higher flexibility and relatively low running costs. However, dry laser cutting is limited due to the presence of heat-affected zones and thermal influences and as such, is unsuitable for the manufacture of fine-pitch structures, as these result in mask inaccuracies and warping. In addition, small particles and burrs remain after cutting, requiring additional post-processing steps to be applied.

For the manufacture of OLED displays, metal masks, typically made from stainless steel, nickel or invar are used for the deposition of emitting layers onto the substrate of the panel. Their thickness varies from 30 to 50 µm and their size tends to become larger due to current market trends especially in home television as well as due to higher production efficiency.

An OLED cell – corresponding to one pixel – contains all three colours (RGB). The mask openings are rectangular and at the end of the process a square containing the three colours is created. A simple example of a series of 100 µm x 300 µm opening masks is depicted in figure 4.

A new technology is now in use for the manufacture of these masks, which resolves the problems mentioned earlier with existing technologies. It is called the water jet-guided laser or Laser MicroJet, invented by the founder of the company Synova SA, based near Lausanne, Switzerland. The principle of the Laser MicroJet, is to focus the light beam from a high power pulsed laser into a hair thin low pressure water jet. From there, the beam is guided by the water jet by means of total internal reflection, due to the differences in air/water refractive index, to the work piece where

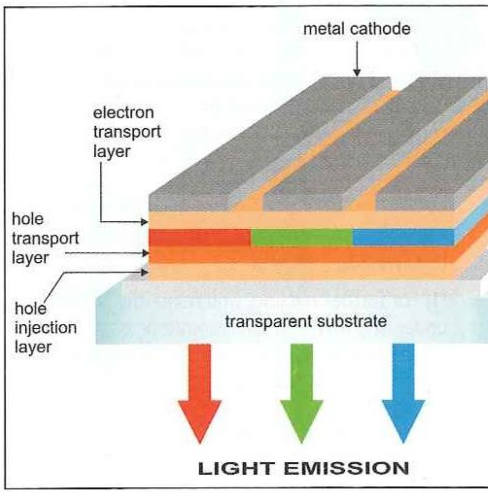

Figure 2: Basic structure of an OLED cell

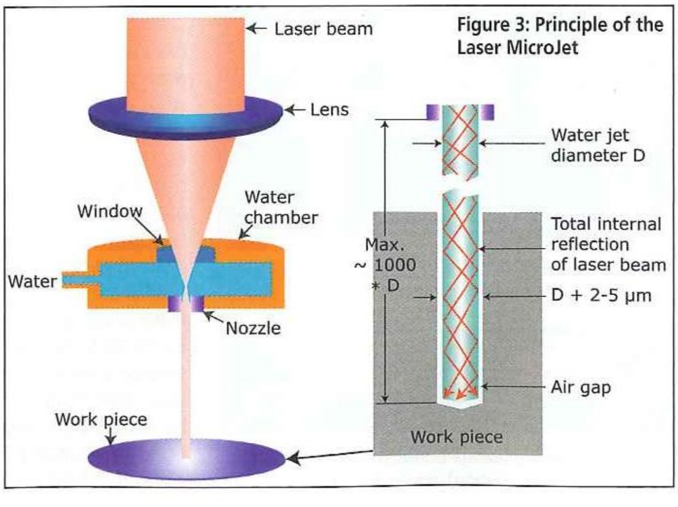

Figure 3: Principle of the Laser MicroJet

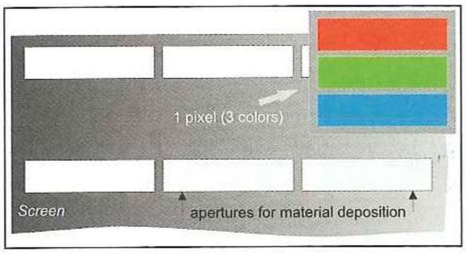

Figure 4: Example of mask design: A succession of rectangular openings results in a square pixel

ablation takes place, as shown in figure 3. As illustrated, the beam can reach deep into the material, leaving perfectly parallel kerf walls behind, something a conventional laser system can not do! The water has the added beneficial effects of providing a constant cooling to the target material between laser pulses as well as flushing ablated material away from the kerf and, since it forms a thin film on the surface, stops any deposition of material or contaminants.

ZUSAMMENFASSUNG

Eine neue Feinst-Zerspanungs-Technologie - der Wasserstrahlgeführte Laser oder Laser MicroJet - wurde für das Schneiden von OLED Masken entwickelt. Indem ein haarfeiner Niederdruck-Wasserstrahl und ein leistungsstarker kurz gepulster Ytterbium-Faser-Laser kombiniert wurden, konnte das Problem von Hitzeschäden vollständig gelöst werden. Diese Technologie ist in der Lage, zierliche Öffnungen mit absolut sauberen Kanten (ohne Krätze, Schlacke oder Absonderungen) zu schaffen, wobei die geschnittenen Öffnungen frei von Verunreinigungen und thermischer Beanspruchung sind.

RÉSUMÉ

Une nouvelle technologie d'usinage d'extrême précision a été mise au point pour la découpe des masques OLED : le laser guidé par jet d'eau ou le laser MicroJet. L'association d'un minuscule jet d'eau à basse pression et d'un laser fibre ytterbium performant à courtes pulsations a permis de résoudre entièrement le problème lié aux dégâts causés par la chaleur. Cette technologie est capable de créer des ouvertures fines aux bords parfaitement nets (sans fissures, débris ou re-déposition), qui ne sont pas affectées thermiquement et ne présentent aucune contamination.

SOMMARIO

Una nuova tecnologia di microlavorazione – laser guidato da getto d'acqua o Laser MicroJet – è stata sviluppata per il taglio di maschere OLED. La combinazione di un getto d'acqua finissimo a bassa pressione e un potente laser in fibra di Ytterbium ha consentito di risolvere completamente il problema dei danni provocati dal calore. La tecnologia è in grado di generare piccole aperture con bordi perfettamente puliti (provi di graffi, scorie o segregazioni), con tagli privi di contaminazioni e senza sollecitazione termica.

Alternative solutions

With all of these advantages, the Laser MicroJet is well suited to the OLED mask cutting process. The actual cutting width is determined by the diameter of the nozzle used, which can vary from 30 to 120 µm. The cutting speed in turn depends on the thickness and composition of the mask material, the thinner the piece, the higher the speed. As an example, rectangular 100 x 300 µm openings in 50 µm stainless steel can be cut at a rate of 20,000 openings per hour with an IR fibre laser and 40 µm nozzle. The openings resulting from this cutting are shown in the microscopic image (figure 5), and are constant and cleanly cut, with no signs of heat damage, burrs or deposition.

Within the fast-growing market for flat panel displays, OLED technology offers many advantages. Today's producers are looking for new manufacturing techniques becoming available, to match the exacting requirements of this technology in terms of quality and productivity. This is especially the case for cutting masks used to deposit

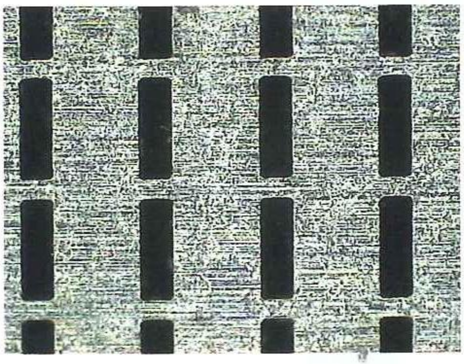

Figure 5: Image of openings 100 x 300 µm in 50 µm stainless steel

the emitting material onto the substrates.

Since etching and conventional lasers are not entirely satisfactory, alternative solutions are needed. The water jet-guided laser allows a significant improvement in mask cutting, as it combines high flexibility and high speed with low manufacturing costs. It is able to cut small openings with clean edges, avoids the problems of dross and slag and the mask is free of mechanical and thermal stress, as well as heat damage.

Using equipment such as the Laser Stencil System LSS1200 (figure 1) from Synova, the cutting of OLED masks, becomes an economical, repeatable and reliable process and is readily adaptable to many kinds of similar cutting processes. The machine, which will handle material up to 1200 mm in width, also exists in two smaller models for 800 and 1000 mm widths. The company provides turnkey, fully automated laser cutting systems to their core markets, the semiconductor, electronics (that is, flat-panel displays and MEMS), photovoltaic, tooling, medical and automotive industries, as well as to peripheral markets, including the watch and micro-mechanics industries. In addition, it offers Laser MicroJet modules for end-user integration, and has recently made its core Laser MicroJet technology available to select equipment manufacturers through licensing partnerships.

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