Flexible LED Arrays made by all screen printing Process

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Introduction

Many flat panel display technologies were developed and commercialized since 1980s. Today, liquid crystal display panels (LCD) and plasma display panels (PDP) have the lion's share of the large size flat panel displays, but there may be some new contenders waiting in the wings. There is a demand to produce even thinner large panel displays, or even make them flexible. The organic EL display (OLED) is one of the new display technologies engineers developed. OELD is successful in reducing the thickness of the flat panel TV; however, OELD's manufacturing costs is much higher compared to LCDs or PDPs because of a long complicated photolithography process and expensive fluorescence materials required during production.

The solution is to use a screen-printing process that is capable to generate patterns with fewer steps compared photolithography and etching process. A series of advanced screen-printing process were developed to build functional circuit constructions for both active and passive components. In this study, the advanced screen-printing technology was applied to generate low electronic fluorescence patterns on flexible substrates to show the possibilities of low cost flexible displays.

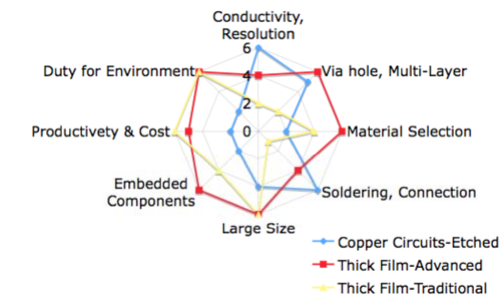

Fig. 1 Comparison of the circuit manufacturing processes

Advanced Screen-Printing Process

Previously, a screen-printing process was used for low resolution coating such as a solder mask for printed circuit boards; however, there have been many technical advances not only with resolutions, but also with material capabilities. Now, advanced screen-printing has been getting more values other than fine pattern generation. Fig. 1 shows the comparison between advanced screen-printing technologies and traditional screen-printing technologies and photolithography/etching technologies in the printed circuit manufacturing by a radar chart. Nowadays, the advanced screen-printing process can generate fine lines down to 10 microns with fine screen masks. Double layer and multi-layer constructions are available with low cost micro via holes. The new processes provide broader substrate choices for both of rigid and flexible circuits. The process does not need extra chemicals such as etching resist or striping chemicals, therefore the process does not produce large amounts of chemical waste. The process is very environmentally friendly, and eliminates the cost related to waste treatment. The material processing capabilities from advanced screen-printing technology is a major advantage compared to traditional photolithography and etching technologies. The process is able to manage not only passive materials including conductive and insulation materials, but also functional materials including photo-active materials and dielectric materials if they can be prepared as the condition of liquid or paste. As the results of the new capabilities, the advanced screen-printing technology is able to generate many kinds of electronic functions on rigid and flexible substrates including passive components and electronic fluorescence devices. The screen-printing process is much simpler compared to the photolithography/etching process, therefore the total manufacturing cost can be much smaller.

Basic Construction of the Flexible LED

Fig. 2 illustrates the basic idea for layer construction from the flexible EL sheet. All of the layers can be built by the screen-printing processes on the transparent ITO films. The first layer screen-printed is the fluorescence material with appropriated patterns; the second is the electron acceptance layer (actually insulation with high dielectric constant). It does not need patterning; plain screen-printing can be applied. The third layer is the electrode of the flexible EL. Electrically conductive silver paste can be used by screen-printing. The similar patterns as fluorescence layer with power lines are screen-printed, and finally, the top surface is covered with a insulation material to serve as the protection layer.

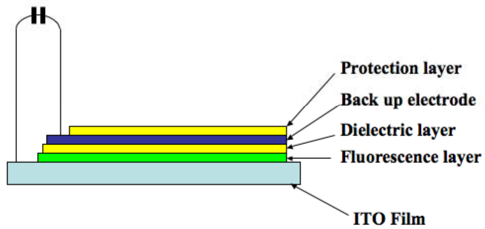

Fig. 2 Basic construction of the printed EL

Manufacturing Process

Several advanced screen-printing processes are employed to build EL devices on flexible substrates. Nowadays, screen-printing process is not the major technology for the pattern generation in printed circuit manufacturing because of lower resolution compared to the photolithography/etching process. However, the advanced screen-printing process developed recently has an equivalent pattern resolution with more advantages as shown in Fig. 1. The major advantage of the screen-printing process is that material formation and patterning can both be processed in two steps as shown in Fig. 3. It needs several steps by photolithography/etching process with additional processing materials such as photo resist and etching solution as shown in Fig. 4.

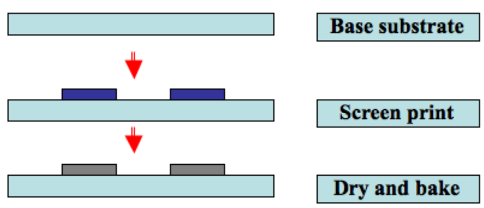

Fig. 3 Basic patterning process of the thick film circuits

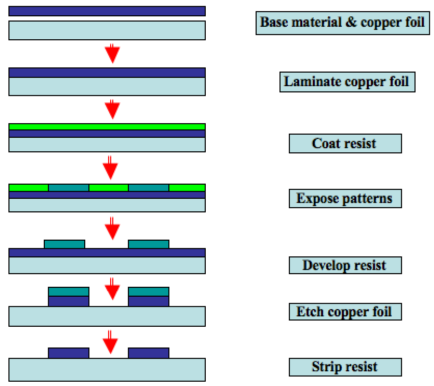

Fig. 4 Basic patterning process of the copper foil circuits

Fig. 5 shows the basic manufacturing process of the flexible EL sheet with the advanced screen-printing process. The total process is much simpler compared to the standard LCD manufacturing process or new OLED manufacturing process. The process needs only screen-printers and baking ovens. The standard equipment for the solder mask process for the typical multi-layer printed circuit boards is available. Since process does not need any processing materials such as photo resist or strong chemicals, it does not produce chemical waste, nor will it require extra facilities for waste treatments.

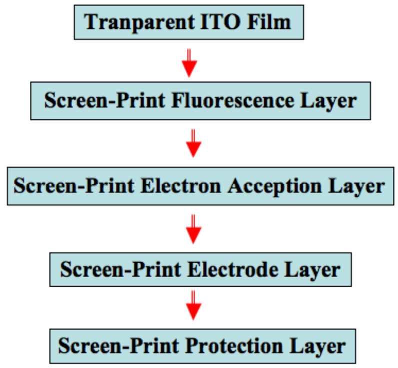

Fig. 5 Basic process of the printed EL

Trials and results

The trial was conducted on the PET based ITO films because the transparency of the substrate layers are required. PET based ITO films were supplied by Oike Sangyo, Sheldahl and Technimet as the base substrate materials for the construction. All of them have surface resistance lower than 500 ohms per square centimeters and light transmittances higher than 90%. The thicknesses of the base films are all 50 microns.

One of the ink materials from the FEL-190 series produced by Fujikura Kasei was used as the fluorescence layer. The ink's fluorescence component is inorganic; therefore, the layer can be relatively thick. One of the FEL-615 series produced by Fujikura Kasei was used as the electron accepter layer. The dielectric constant of the material is higher than 50. A traditional silver conductive paste was used for the electrode layer. A standard solder mask material of the flexible circuits was used as the protection layer.

Fig. 6 shows the example of the flexible EL sheets. The total thickness of the sheets is less than 100 microns, making the sheets are very flexible. Four 1.5 volts batteries activated the EL components and generated blue lights from the flexible sheet.

Fig. 6 Example of the flexible EL maid by all screen-printing process

Fig. 7 Cross section photo of the printed flexible EL

Fig. 7 shows the cross section photo of the EL components built on the flexible substrate. The fluorescence layer is not very uniform because of the relatively large particle sizes of the inorganic fluorescence materials. But the advanced screen-printing process could keep secure insulation between the electrodes.

Discussion

The trials show evidence that the advanced screen-printing process can produce flexible EL devices with required pattering using simple procedures and equipment. All of process can be applied to RTR (Roll to Roll) system without a big investment. The total manufacturing cost could be remarkably lower compared to the photolithography process for volume productions.
The particle size distribution from the current inorganic fluorescence materials is broad and is not capable to generate fine resolutions, but the flexible EL panel could be capable for large sign board applications.

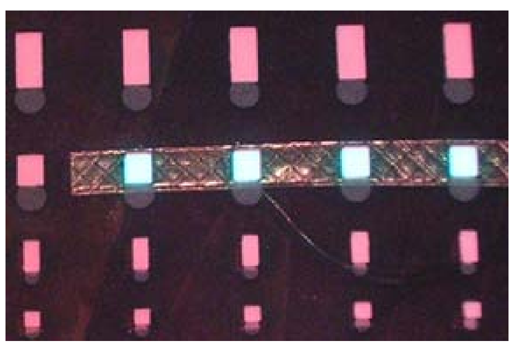

Fig. 8 Flexible EL dot array made by screen-printing process

Fig. 8 shows another trial of dot matrix with the flexible EL. The smallest dot sizes are around 0.5 mm. It can be the passive matrix type flexible display with suitable signal and power lines made by another advanced screen-printing process with a high-conductivity silver paste. Red color and green color is available by changing fluorescence material, therefore full color displays could be very possible with low cost manufacturing.

Reference

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2. "Introduction of Printable Electronics", Dominique Numakura, Nikkan Kogyo Shinbun, January 2009