Paper Display Module Having Backside Electrode

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Abstract

This paper presents a paper display module, which is fabricated on a flexible paper substrate by using a printing method. Due to the price competitiveness superior to the existing semi-conducting processes, the printing technology has begun to get into the spotlight as a manufacturing tool in many industrial fields, including printed electronics, flexible displays, PCB circuits, RFID-tag, and so on. The paper display module has 75 segments. The size of each segment is 5.78mm × 4.60mm and the thickness is around 220μm, including paper thickness, 100μm. The substrate is 130gsm paper which is generally applicable to a color laser printer. The printed paper display is more flexible than the radius of curvature, 5mm. For increasing the effective display area ratio, the address and common electrodes are located in the backside of the paper. Thus, the ratio is around 82 %. The fabricating process consists of 6 steps: Via-hole laser drilling; Backside electrode printing; Bottom electrode printing; Dielectric printing; Phosphor printing; Transparent electrode printing. As the electrodes, silver ink was used. The via-holes are automatically filled when the backside electrode and bottom electrode are printed in turn.

Introduction

Electro Luminescence Devices (ELDs), which produce visible light by a substance exposed to an electric field, have been particularly useful in applications where ruggedness, speed, brightness, high contrast, and a wide angle of vision are required. Electroluminescence was first observed and fabricated from silicon carbide (SiC) by Henry Joseph Round in 1907 [1]. Georges Destriau, the first discoverer of the powder ACEL, published a report on the emission of light from zinc sulfide (ZnS) powders [2]. The first thin-film EL structures were fabricated in the late 1950s by Vlasenko and Popkov [3]. The ELDs have been revitalized in 1980s and have advanced in recent years, especially for back light unit of the liquid crystal display (LCD), lighting device, and advertising board. It is due to the success of the commercialization, including the manufacturing methods as well as the development of materials. This paper presents a paper display module[21], which is fabricated on a flexible paper substrate by using a printing method.

Recently, in spite of worse resolution and limited application areas, various micro-printing technologies have begun to hit the spotlight, due to its fast manufacturing time, mass production ability, and low cost competitiveness of these technologies as compared to existing lithographic processes for manufacturing some parts used in the manufacture of display units, electronic papers, RF-ID information devices, and so on [4]. The photolithography and electro plating methods require acid washes, a substantially larger amount of material, and a long manufacturing time. The word, 'PEMS' stands for "Printed Electro- Mechanical System" which is fabricated by means of various printing technologies. Passive and active components in 2D or 3D such as conducting lines, resistors, capacitors, inductors and TFT [5], which are printed with functional materials, can be classified in this category.

The printing methods for PEMS devices, which have an advantage of one-step direct patterning, .include the inkjet, gravure, screen, flexo, offset, and pad printing,

Even though the inkjet is regarded as one of the most powerful processes for a noncontact direct patterning, it still has many problems. An inkjet-printed pattern is obtained from complex relationships between several components; the inkjet head, inkjet system, ink, pattern geometry, substrate, environment, and so on. Each of the components also has a lot of parameters and a lot of issues. For example, parameters of the inkjet head include nozzle geometry and its tolerance, piezo material geometry and its tolerance, piezo material property, assembling tolerance, hydraulic cross talk, structural cross talk, electrical cross talk, driving waveform, driving frequency, satellite, nozzle cleaning, inkjet head pressure and so on[13].

Conventional inkjet print heads for industrial applications such as conducting electrode use low-viscous (10 cP) functional ink under a room-temperature environment. The pattern printed by inkjet systems requires post-processes including drying, curing, and sintering. The volume and final pattern shape are drastically changed after post-processing [14]. The ink drying condition should be controlled subtly for obtaining a flat surface geometry. Therefore, the fabrication of display parts via an inkjet system is not that easy and cheap. The cost of the equipment is still expensive [13].

The screen printing method is one of the most reliable and easily accessible direct patterning methods for PEMS devices. By using silver particle paste and lead-free solder paste, electrode printing and packaging processes have been widely used. It has a great advantage in the area of cost and productivity. Screen printing equipment is less expensive than the inkjet system and it is simpler than the inkjet process, which has thousands of inkjet nozzles, and the gravure offset process, which has the second ink transferring process. However, the screen printing method is not so satisfactory for applying to the display and semiconductor industry in view point of precision. In order to print patterns precisely in a whole area through the screen printing method, one of the most critical things is to maintain the same printing condition over the entire area, including off-contact speed, mesh tension, shear rate of pasted, which is almost impossible. These printing conditions depend on the precisely grinded squeegee, adequate ink formulation, printing process technology, screens of fine mesh, and precise screen printers [15-17]. The screen printing method cannot make patterning on a curved surface, since it uses the screen mesh and flat squeegee.

The gravure offset printing method has been adapted by PDP electrode and PDP EMI mesh filter manufacturer like Samsung and LG. The gravure offset printing method is based on contact ink transferring between the two plates[18-20]. Gravure offset printing transfers ink from plate cylinder to blanket cylinder and then to a substrate like a glass, paper, and flexible film. Since this printing process uses relatively high viscous ink, the volume and final pattern shape are not much changed after post-processing. If the gravure offset printing unit is combined with a roll to roll web providing system, it is very cost-effective for the mass production of the flexible electronic devices like RFID tags, E-paper displays, solar-cell devices.

In this paper, we present several kinds of printing process for PEMS device and a paper display module with backside electrodes, which is wholly-printed on a flexible paper substrate. For increasing the effective display area ratio, the address and common electrodes are patterned on the backside of the paper.

Paper Shrinkage Test

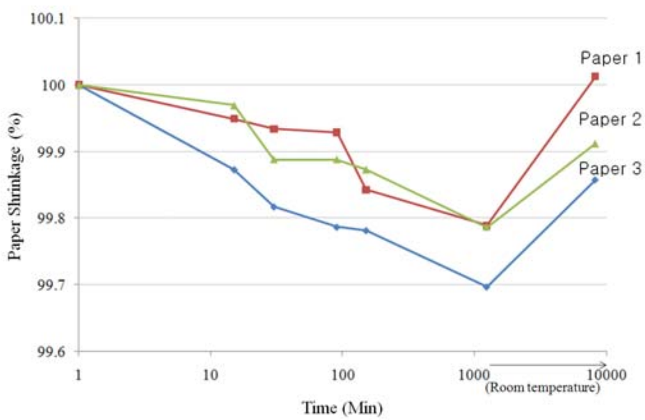

***Figure 1** Contraction of paper according to the curing time.*

For fabricating an electronic device on a paper by printing technique, the phenomenon of paper shrinkage should be fully understood, because several kinds of electrical ink are printed, dried, and cured repeatedly at different temperature.

Paper made by Advance Paper Co., Ltd was experimented for paper shrinkage test. It is double-side printable general paper for laser jet, ink jet, and copy machine. On the paper, 2 dots were marked at approximately 200 mm interval. The temperature of oven was 120°C. Figure 1 shows the paper shrinkage according to the curing time. The distance between the dots was measured three times by micro calipers and was averaged. As the time in the oven increases, the paper shrinkage makes steady progress. This experiment was continued till 1200 minutes. After 1200minutes, the paper was carried out of the furnace and was left at room temperature. We measured that the distance of the dots after 8200 minutes and the shrinkage of the paper is recovered. The meaning of this figure 8 is that the 200mm paper may experience the shrinkage of several hundreds of micron even during 15minutes in the 120°C furnace. Therefore the less time in the oven, the better and the finer resolution can be obtained.

Paper Display Module

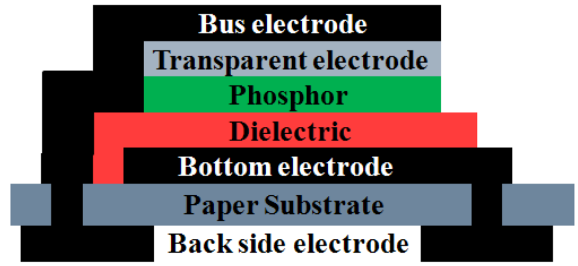

***Figure 2** Structure of paper display module.*

The paper display module consists of 6 layers. The paper substrate is a general paper which is introduced in the previous chapter. First, via holes are bored by laser, which left the less paper bur around the holes than drilling. The back side electrodes, which include common and bus electrode, are printed on the back side. The bottom electrode is printed on the front side. At this time, bottom electrode and back side electrode are connected each other. Then, the dielectric, phorsphor, transparent and bus electrode are printed step by step.

***Figure 3** Paper display module: (a) Front side. (b) Back side.*

The paper display module has 75 segments. The size of each segment is 5.78mm × 4.60mm and the thickness is around 220um, including paper thickness, 100um. The substrate is 130gsm paper which is generally applicable to a color laser printer. The printed paper display is more flexible than the radius of curvature, 5mm.

For increasing the effective display area ratio, the address and common electrodes are located in the backside of the paper. Thus, the ratio is around 82 %.

Conclusion

In this paper, we present the design and fabrication of the printed EL segment display, which is wholly-printed on a flexible paper substrate. The screen printing process and gravure printing process for obtaining fine line printing pattern in large area substrate are described. Phenomenon of paper shrinkage is also examined according to the time in the furnace.

The fabricating process consists of 6 steps: Via-hole laser drilling; Backside electrode printing; Bottom electrode printing; Dielectric printing; Phosphor printing; Transparent electrode printing. As the electrodes, silver ink was used. The via-holes are automatically filled when the backside electrode and bottom electrode are printed in turn. The paper display module has 75 segments. The size of each segment is 5.78mm × 4.60mm and the thickness is around 220um, including paper thickness, 100um. The effective display area ratio is around 82 %.

As a result, we expect that the printed paper display module can be a powerful alternative for general advertisement which is printed only with media ink. The suggested display module on a flexible paper substrate can also be applied to disposable paper-display.

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