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Advanced manufacturing technologies on color plasma displays

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ABSTRACT

The mass production of the color plasma display started from 1996. However, since the price of the panel is still expensive, PDPs are not in widespread use at home. It is necessary to develop the new and low-cost manufacturing technologies to reduce the price of the panel. This paper describes some of the features of new fabrication technologies of PDPs.

Keywords: PDP, fabrication, insulating film, rib, phosphor,

1. INTRODUCTION

Flat panel displays have always been essential to realizing wall-hanging TVs and space saving PCs, but for many years, severe size limitations seemed as though they would always keep the technology on the periphery and prevent it from becoming central to the AV and PC industries. By mass producing large plasma display panels, however, Fujitsu has opened up a new chapter in the history of this product. With the start of mass production of 42 inch PDPs in October 1996, at the same time as the announcement of the first commercial shipments to customers worldwide, PDPs are now well on their way to becoming the display of choice in large flat panels. Wall-hanging televisions have finally moved out of the realm of science fiction and into the reality and everyday life. This paper reports new fabrication technologies used in the formation of insulation film, barrier ribs, and phosphor layers.

2. STRUCTURE AND OPERATION PRINCIPLE OF AC-TYPE COLOR PDP

Figure 1 is a diagram showing the panel structure of a AC-type color PDP put into practical application. A plasma display consists of two parallel glass panels on which electrodes covered with a dielectric glass layer have been etched. The 0.1 mm wide gap between the two plates is then filled with a xenon/neon (XeNe) gas mixture. When voltage is applied between the electrodes, ionized gas collects at the surface layer according to the polarity. The collected charge is called the wall charge, and it produces an internal voltage difference (wall voltage). As a result of the surface discharge, ultraviolet ray radiation occurs. These ultraviolet rays activate phosphor dots, which then emit visible light. A color display is achieved by controlling the luminance from individual phosphors in the three prime colors. To maintain the discharge, the polarity of the external voltage is reversed. The applied voltage is lower than the initial voltage because the wall voltage remains inside the cells, so once discharging occurs, it continues unless it is stopped.

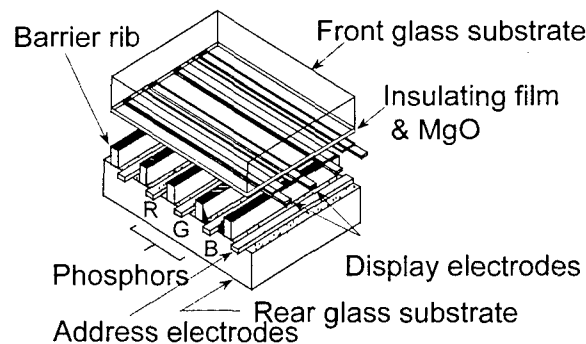


Fig.1 Structure of experimental panel

3. PDP FABRICATION PROCESS

PDP fabrication does not have an established process yet, so PDP fabrication processes differ depending on the panel makers. Figure 2 shows a typical fabrication process currently in operation. The front panel first goes through the patterning of transparent electrodes, followed by sputtering a film of chromium/copper/chromium (CrCuCr). The BUS electrodes (CrCuCr) are then patterned, a dielectric layer screen-printed and a final protective layer of Magnesium Oxide evaporated on. The back panel is processed a little differently: Address electrodes (CrCuCr) are first constructed, followed by printing of a dielectric layer and a rib pattern. The ribs are then sandblasted and a fluorescent layer is screen printed, with the sealant construction as the final step. The materials in PDP have several important characteristics. The materials have a low gas discharge rate and a tolerance against vacuum ultraviolet. They are also heatproof up to 350C. Therefore, a glass material with a low melting point is usually used as material for insulation film and ribs. The low-melting-point glass and phosphor in this PDP fabrication process are powder, which is most remarkable because the fabrication process can use such powder material to form precise cell structure.

3.1 Insulating film formation process

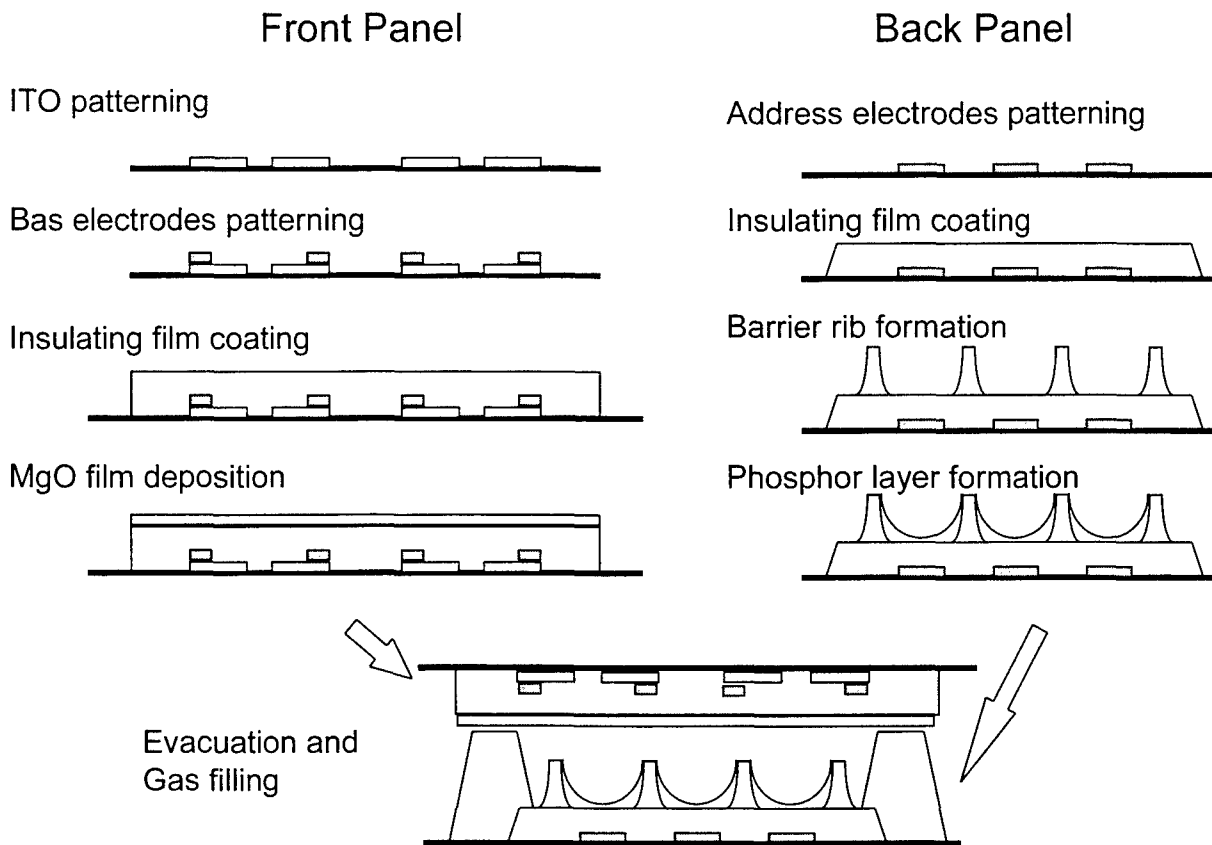


Figure 2. Panel fabrication process

The insulating film of front panels plays an important role in accumulating the wall charge and limiting the electrical discharge current. The inflator material of the PDP is low-melting-point glass with a softening point in a range from 450 °C to 580 °C. The thickness of the insulating film is about 30 μm. Since film thickness depends greatly on electrical discharge characteristics, high thickness uniformity without any defects is necessary. Good level of transparency is also necessary because the film is used in the a front panel, which must pass light from the phosphors. To obtain a good level of transparency, any bubbles in the film must be completely removed by high-temperature firing. However, to prevent a reaction between melting glass and electrode metal during the firing process, the material of the low-melting-point glass was

carefully selected. Screen-printing, slot die coating, roll coating, and sheet lamination are used for the coating of the insulation film.

Screen-printing method

Screen-printing is a method to coat the insulator with paste that comes from a squeegee through a screen mesh made of stainless-steel wires. The film thickness of the insulation layer can be controlled by selecting the mesh specifications (i.e., mesh wire diameter and pitch of meshes). The advantage of using this method is that shape and detailed patterns can be printed. However, immediately after printing, the film has mesh marks because of thickness variations. Since mesh marks cause irregularity in the display, sufficient smoothing is required. To obtain a smooth surface, a leveling time of ten minutes is required after printing.

Slot die coating method

Figure 4 is a schematic drawing of the slot coating method. Paste is dispensed on a glass substrate through a small gap in the feed head. The film thickness is adjusted by controlling the coating parameters, such as the moving velocity of the stage, slot gap of the die, and paste supply pressure. Basically, this method can coat only rectangular areas, whereas the screen-printing method can coat areas in a variety shapes.

Roll coating method

The roll coating method is widely used to coat such as photo resists. There are different kinds of roll coating methods, but the reverse roll coating method is described here because it can be applied to coat films in a wide range of thickness. Figure 5 is a schematic drawing of a roll coater. First, paste is applied onto two metal rolls (A roll and Comma roll), then paste on the A roll is transferred to a rubber roll (C roll). Paste on the C roll is transferred to a glass substrate. The advantage of this method is that the paste has a very wide range of the viscosity, enabling thick paste coating of ribs. Any swelling in the paste at the starting and terminating points of the coating area is controlled by changing the elevation of the C roll. The shape of the coating area is limited rectangles, similar to the slot coating method.

Sheet lamination method

Figure 6 is a schematic drawing of a sheet lamination method. The technology of the method is generally the same technology used for hybrid ICs. After removing the cover film, the sheet is laminated on the glass substrate between heated rolls, and the base film is removed. The sheet becomes an insulating film after firing. The advantage of this method is good thickness uniformity in the film and easy operation. However, film thickness cannot be adjusted during the process.

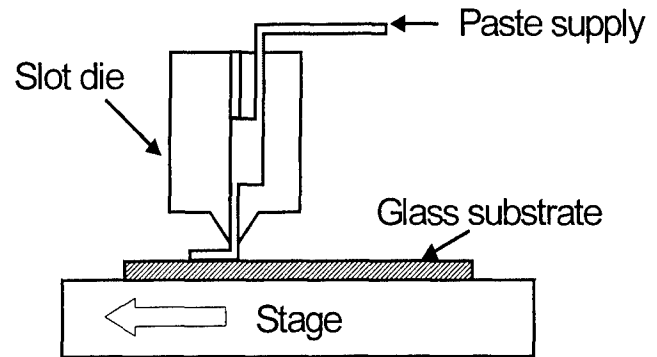


Figure 3. Slot Die Coating Method

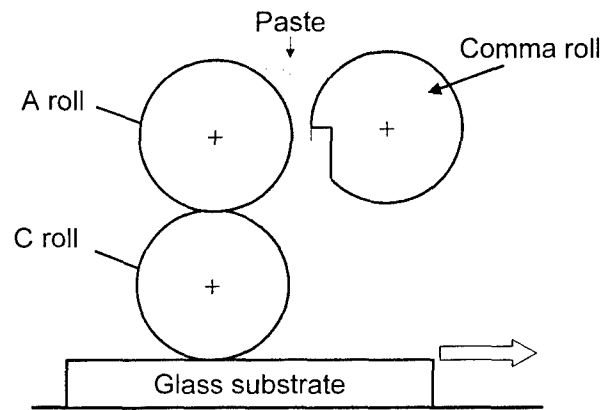


Figure 4. Roll Coating Method

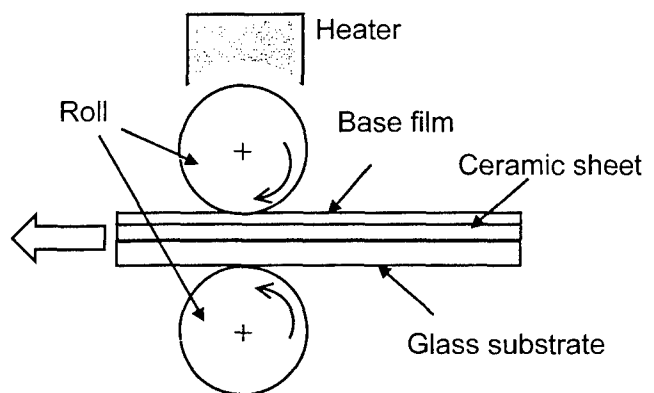


Figure 5. Sheet Lamination Method

3.2 Barrier rib formation process

Barrier ribs are formed on the back panel, and parallel ribs are usually used because they are easy to fabricate in AC-type PDPs. The ribs have a height of 140 μm , width of 70 μm , and pitch of 360 μm . The material in the ribs are frit glass containing ceramic filler. The fabrication method is a combination of different kinds of formation technologies. The following methods are proposed fabrication methods of barrier ribs.

- Screen-print method
- Sandblasting method
- Photo paste method
- Lift off method
- Mold method

Among these, Sandblasting, photo paste, lift off and mold methods are explained.

Sandblasting method

The sand blasting method has been the technology used for the mass production of large PDPs. Figure 6 shows a formation process using the sandblasting method. The sandblasting method is a newly developed process technology to fabricate barrier ribs, replacing the thick film printing method. First, rib material is coated all over a glass substrate by the paste coating method and then dried. Dry film is formed on the material to protect it during the sandblasting. Sand(powder) is sprayed on it by compressed air to cut the rib material except at areas where the dry film has formed. After that, the dry film is removed and the glass substrate is fired. Previously explained film coating methods (screen-printing, slot die coating, roll coating, and sheet lamination) can be used as the formation method of the rib material. Thickness uniformity and material homogeneity of coated thick film are important for ensuring a precise rib shape. In addition, since the sandblasting rate strongly depends on the amount of resin in the paste, drying conditions must be stabilized. Figure 7 are SEM photographs of ribs formed by the sandblasting method. The formation method using sandblasting with the photo exposure method provides sufficient accuracy for pattern formation. However, a lot of rib material is lost by this method during removal of paste by sandblasting.

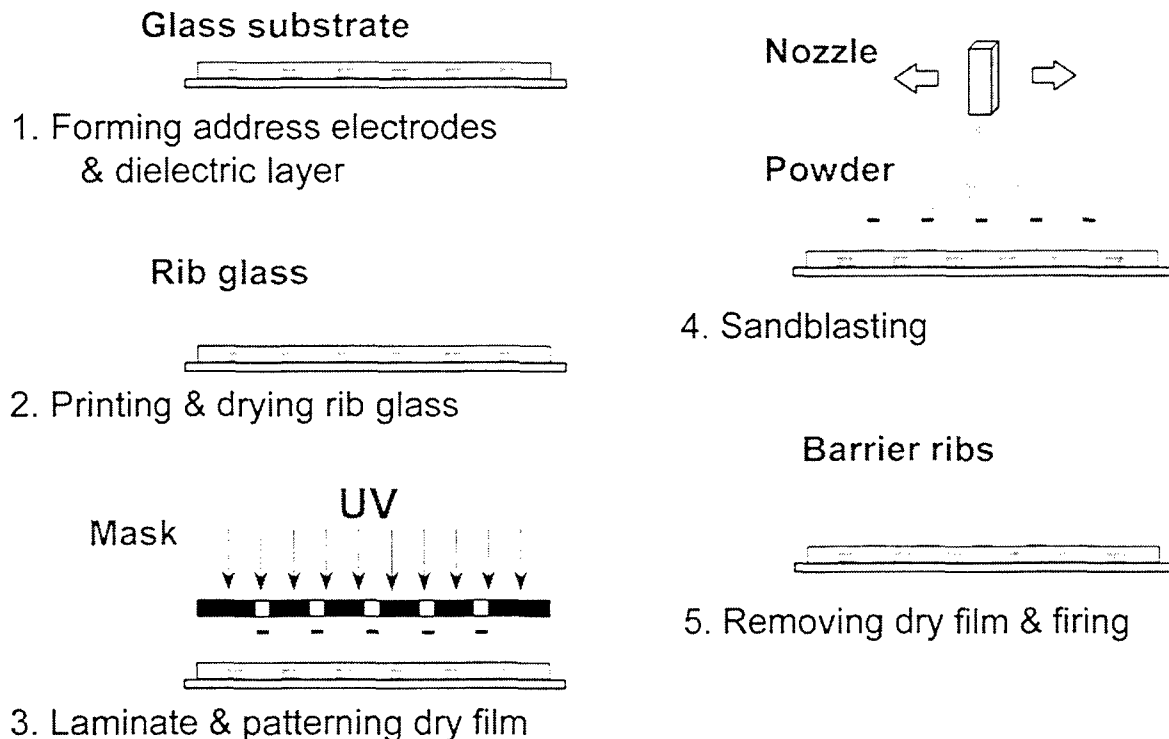
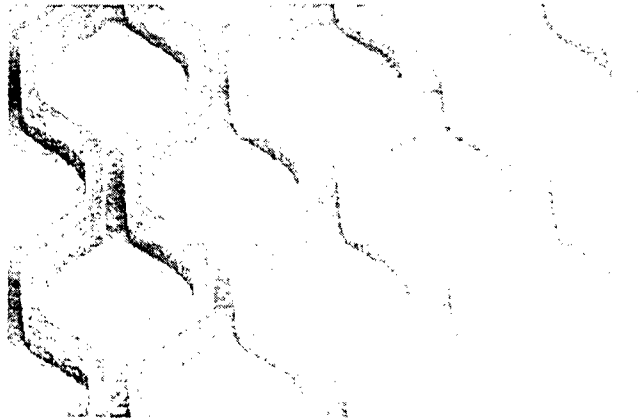
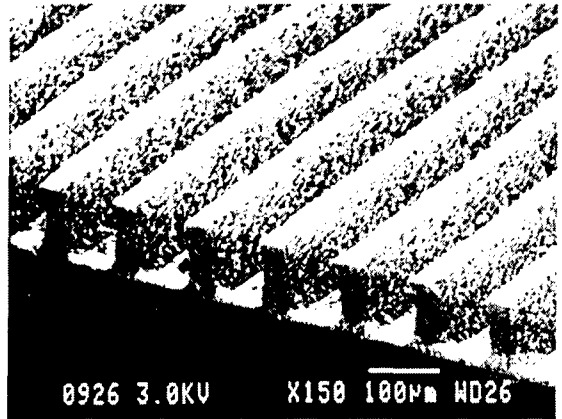


Figure 6. Sand Blasting Method



DelTA Cell



25" SXGA Cell

Figure 7. SEM Images of Barrier Ribs made by sandblast^{1,2}

Lift off method

Figure 8 shows the formation process of ribs by the lift off method. First, in a lamination step, dry film is applied on the substrate where address electrodes are formed. Rib paste is then coated on the dry film, and channels in the dry film are filled with paste. After that, the dry film is removed. Finally, the rib material is fired. To obtain the desired section shape, exposure and development conditions are optimized. The optimization of the rib paste and dry film material is necessary to prevent the solvent from attacking the dry film in the coating process. The advantages of the lift off method is a low loss of rib material and a smooth surface on the side wall.

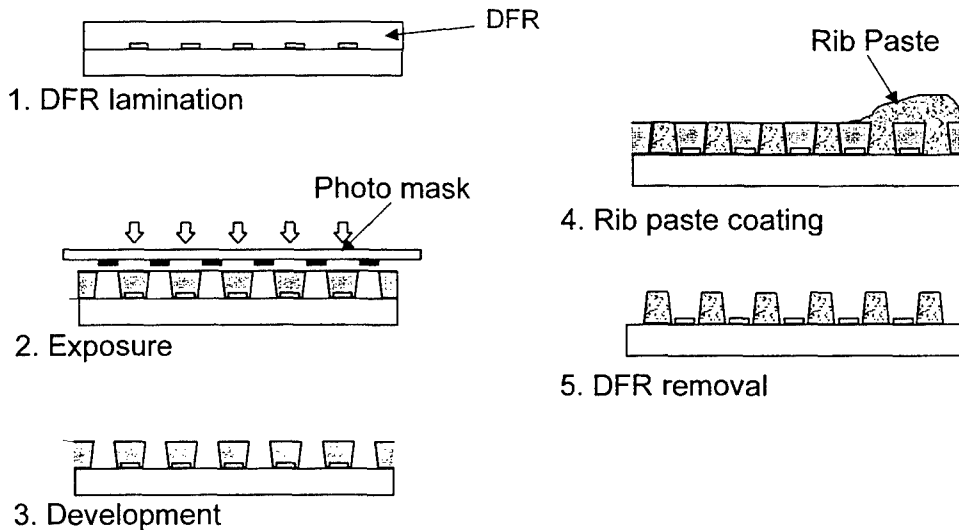


Figure 8. Lift Off Method

Photo paste method

Figure 9 shows the fabrication process of ribs by the photo paste method. Photo sensitive rib paste film is coated on the substrate where address electrodes are formed. After the paste is exposed, it is developed and rib paste in unexposed areas is removed. The advantage of photo paste method is that it is very simple since only exposure and development are done. However, because UV light is scattered by glass powder, exposing all of the film at one time is difficult.

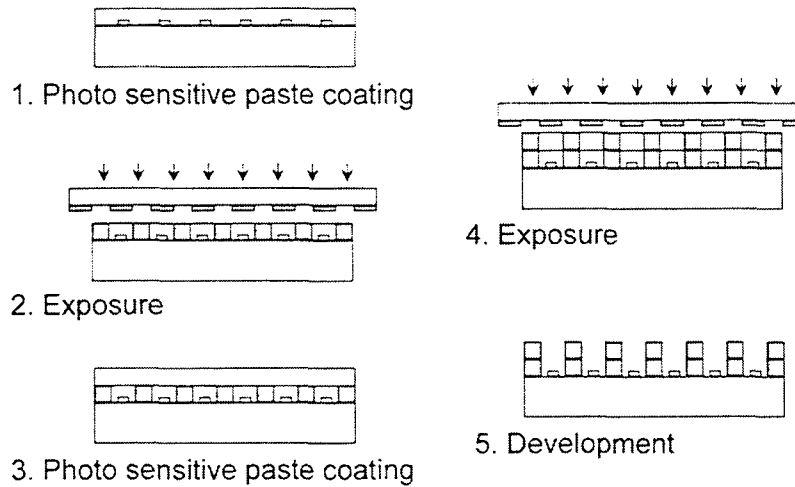


Figure 9. Photo Paste Method

Mold method

There are different mold methods and an example of one of them is shown in Figure 10. Rib paste is coated on a glass substrate. A mold is pressed on the paste film to modify the shape of the paste. The advantage of the mold method is a low fabrication cost due to its simple process.

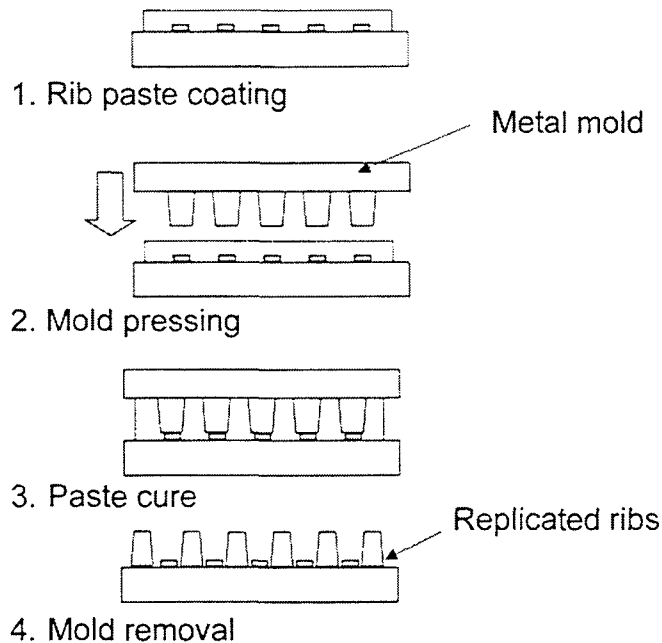
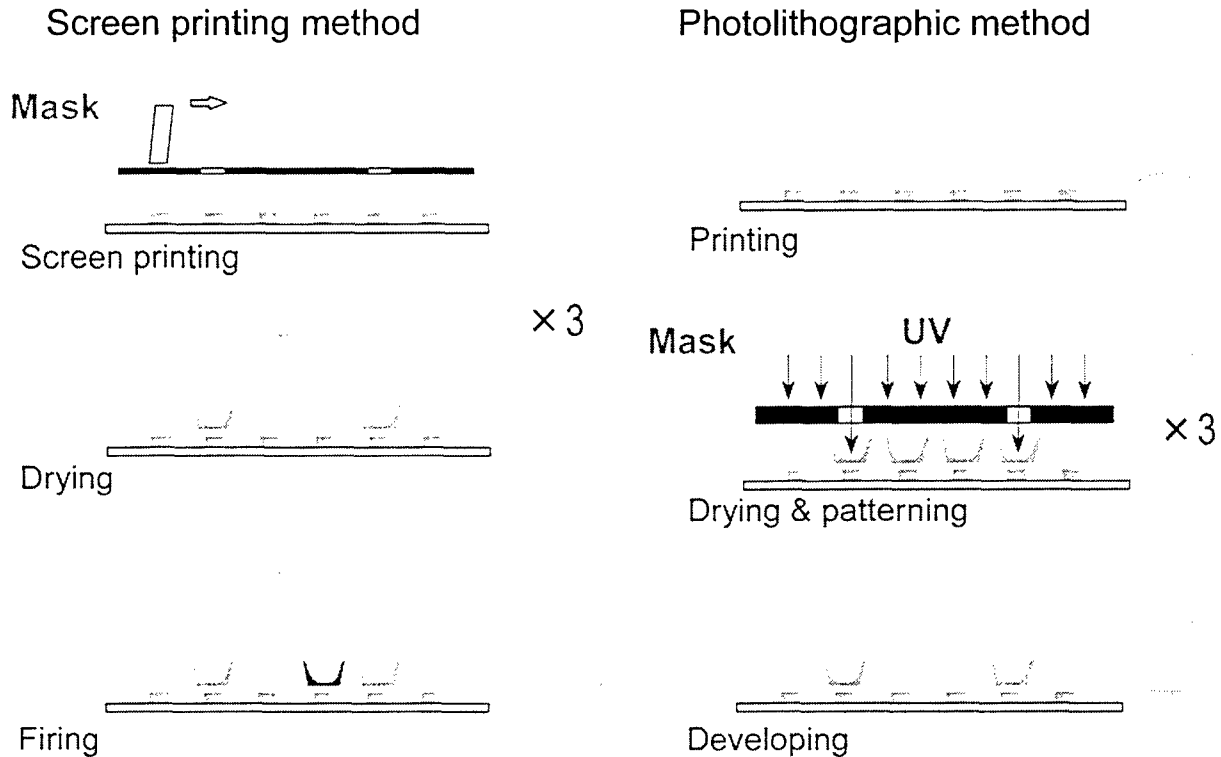


Figure 10. Mold Method

3.3 Phosphor formation process

The phosphor formation process of PDPs is explained in this section. To cover the surface of ribs on the back panel, phosphors of AC-type PDP are formed. The following methods are currently being developed as phosphor formation processes of PDPs.



Screen-printing method

Figure 11 shows the phosphor formation process by the screen printing method. The screen printing method is commonly used for forming phosphor layers. However, printing phosphors evenly between the fine-pitched ribs (130 μm pitch) requires high-quality technology and high-precision screen masking.

Photolithographic method

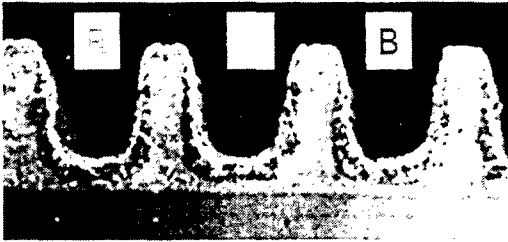
Figure 11 also shows the phosphor formation process by photolithographic method. Photosensitive phosphor paste is made of photo resists in which phosphor particle of specified colors are evenly dispersed. The prepared paste is coated to the entire surface of a rear substrate with barrier ribs. This substrate is then dried to evaporate the solvents in the paste at 100-120 $^{\circ}\text{C}$. Any remaining paste on top of the barrier ribs does not cause any problems. Next, the dried film is exposed by UV light through a photo mask. The exposure and development of this paste produces a phosphor paste layers for the three primary colors. Finally, the substrate is fired to burn out all organic ingredients remaining in the phosphor paste layers and ensure that the phosphor layers consist of only phosphor particles. The primary issue of using this method this method is on the recycling of removed phosphor material. Figure 12 shows SEM images of phosphor layers made using screen printing method and photolithographic method.

Screen printing method



- Simple and established process
- High precision screen mask
- Short life time of screen mask

Photolithographic method



- Higher patterning accuracy
- Available for any shape
- More process steps

Figure 12. SEM Images of Phosphors

Dusting method

Figure 13 shows the phosphor formation method by the dusting method. Photo tacky material is coated on the rib surface. After UV light exposure, the part exposed UV light has tacky adhesion. Under such a condition, when the phosphor powder is sprinkled, the phosphor remains only in a cohesive part.

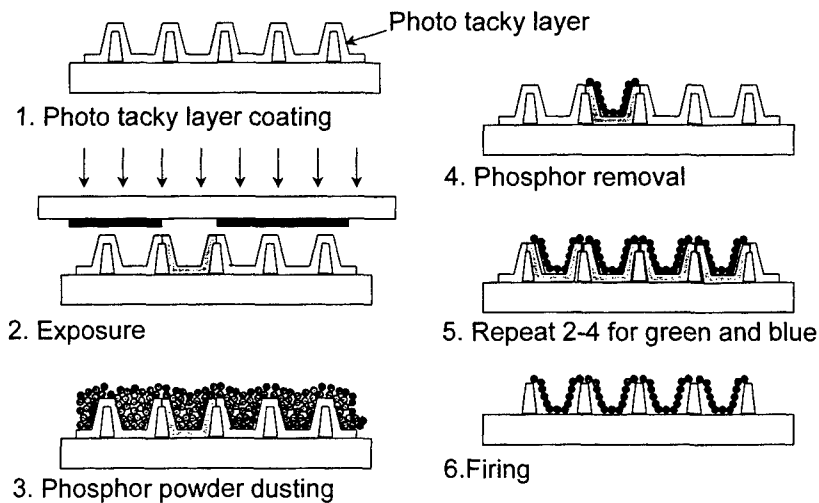
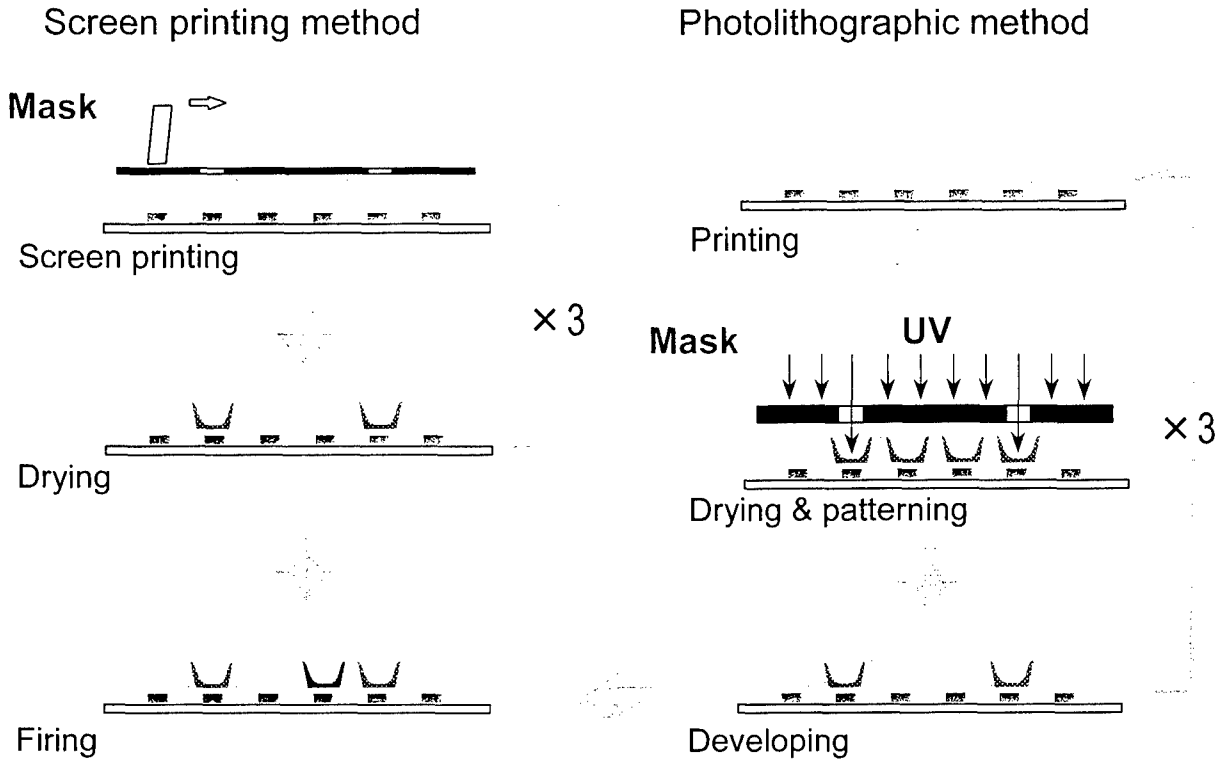


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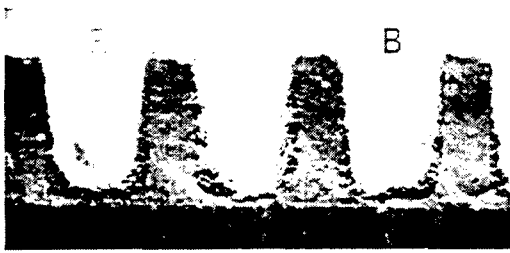
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Photolithographic method

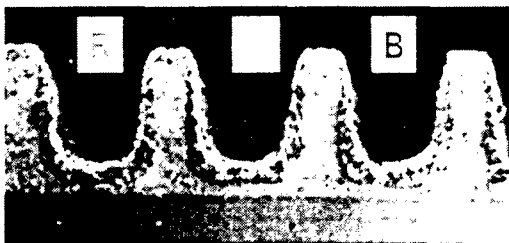
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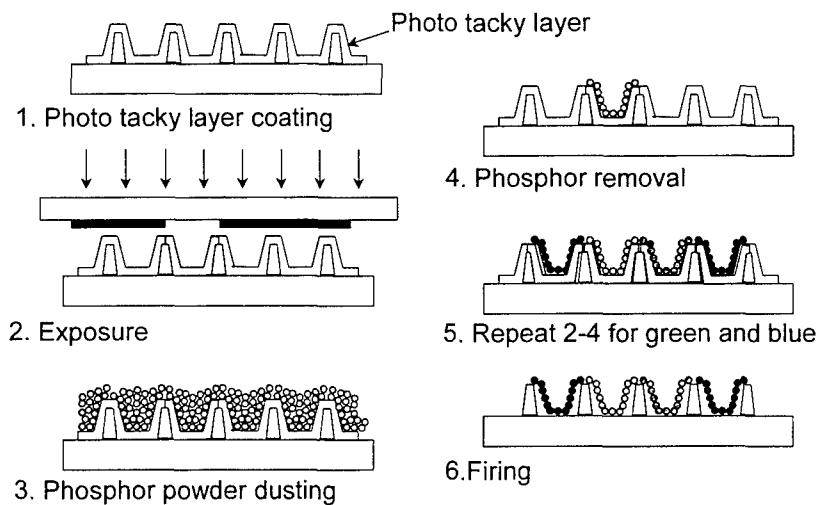


Figure 13. Dusting Method

4. SUMMARY

Advanced Color PDP manufacturing technologies has are reported. PDPs have been shown, step by step, to have qualities the make them the expected favorites for use in large screen displays. However, because, the mass production of PDPs started relatively recently, the mass production technology currently in operation still has many problems. Moreover the manufacturing process must be developed to lower costs even further.

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