Patterning Barrier Ribs of PDP by Transparent Soft Mold

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Abstract

A new PDP barrier rib formation technique was investigated utilizing transparent soft mold made of silicon resin. Transparent soft mold was fabricated by pouring a silicone resin into the base mold made with photosensitive glass. The photosensitive barrier rib paste was coated on the glass substrate and dried in a 90 ℃ convection oven for 20min. The transparent soft mold was pressed on top of the semi-dry barrier rib layer and then irradiated with a UV lamp to a total dose of 900~1000 mJ/㎠. The soft mold was then removed from the pressed barrier rib by winding up and fine pattern of barrier rib was obtained. The photosensitive barrier rib paste makes the demolding easy due to reduced interfacial forces and shrinking of paste materials.

1. Introduction

Barrier ribs in the color PDP are indispensable to maintain the discharge space between two glass faceplates as well as to prevent optical crosstalk in adjacent cells.[1)]

Several methods are available for the formation of barrier ribs for PDP including screen printing and sand blast method. Currently sand blast method is widely used, but it has problems such as partial deformations in barrier ribs, low usage of raw materials and mismatch with other PDP process due to handling fine powders.(Fig.1)

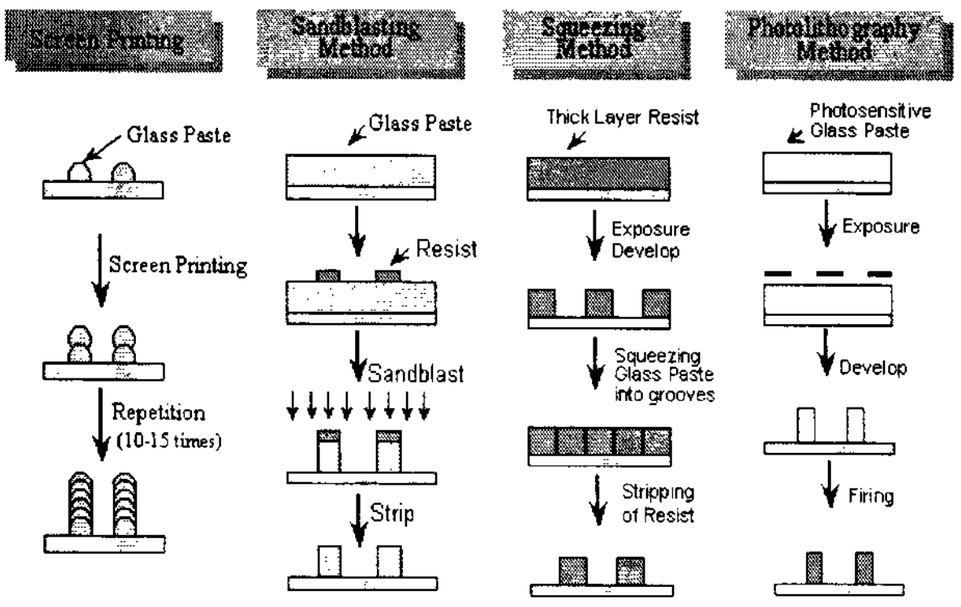

Fig 1. Various Barrier Rib Formation Process

As the size of PDP increase over 60 inches and high resolution (XGA grade) is needed, various methods are considered for application to the patterning of barrier ribs in manufacturing of PDP.

Recently, photolithography and LTCC-M(Low Temperature Ceramic Cofired on Metal) methods were also introduced. [2-5)] Simple press or LTCC-M methods are highly desirable for the formation of barrier ribs for PDP. However, those methods have difficulty in the demolding process.

In this work we investigated a new technique for the formation of barrier ribs utilizing photosensitive barrier rib paste and transparent soft mold. We first made a photosensitive barrier rib paste incorporating binder polymer, solvent, multifunctional monomers and photoinitiator with the barrier rib powders.

Transparent soft mold made from silicone resin was used to press the photosensitive barrier rib paste and then UV was irradiated through the transparent soft mold. After UV curing the soft mold was delaminated by slow winding process. This process minimize the contact area between patterned barrier rib and mold enabling fine patterning of barrier ribs with high aspect ratio.

2. Experimental

2.1. Formulation of photosensitive barrier rib paste

Materials

Ethyl cellulose(Aldrich, viscosity:46cps at 5wt% solution in 80/20 Toluene/ethanol) was used as binder polymer for photosensitive barrier rib paste. Diethylene glycol mono-n-butyl ether(butyl carbitol, BC) and diethylene glycol mono-n-butyl ether acetate(butyl carbitol acetate, BCA) obtained from Tokyo Chemical Industry Co. were used as solvent(Tb=230℃) to dissolve EC binder polymer. UV curable monomers include dipentaerythritol-hydroxyl pentaacrylate (DPHPA) tested as pentafunctional monomer and pentaerythritol triacrylate (PETA), trimethylolpropane triacrylate

(TMPTA), trimethylolpropane ethoxytriacrylate (TMPEOTA) as trifunctional monomer and tripropylene glycol diacrylate (TPGDA), 1,6-hexanediol diacrylate(HDDA), ethylene gylcol dimethacrylate (EGDMA) as difunctional monomer and hydroxyethyl acrylate(HEA) as monofunctional monmer. Photoinitiators, such as Irgacure 184, Irgacure 651 and Darocure 1173 were obtained from Aldrich Chemical Co.. A mixture photoinitiator, HSP-188 was purchased from SK-UCB Co. and used as received. Barrier rib powder used in the paste has an approximate composition of PbO 60.0, SiO_2 10.7, Al_2O_3 29.0wt%, and trace (0.3wt%). Photosensitive glass(PEG-3) from Hoya Co. in Japan was used to make base mold. For easy demolding between base mold and soft mold, mold release agent was used, for example, Nabakem R-2, Nambang Chem. Co. Silicone materials such as dihydroxy polydimethylsilicone (PDMS) and Silastic E, room tempurature vulcanizing(RTV) type both from Dow Corning Corp. were used to make a transparent soft mold.

Formulation of photosensitive barrier rib paste.

The components of photosensitive barrier rib paste were mixed with the aid of mechanical stirrer and three roll mill(Exact Co., Germany) according to the process shown in Fig.2. First binder polymer(EC) was dissolved in a mixture solvent BC/BCA(30:70) with mechanical stirrer for 8-12hr to the extent which did not have any gels or coagulums. UV curable monomers and photoinitiator were added to this solution and the resulting mixture was stirred for 2hr.

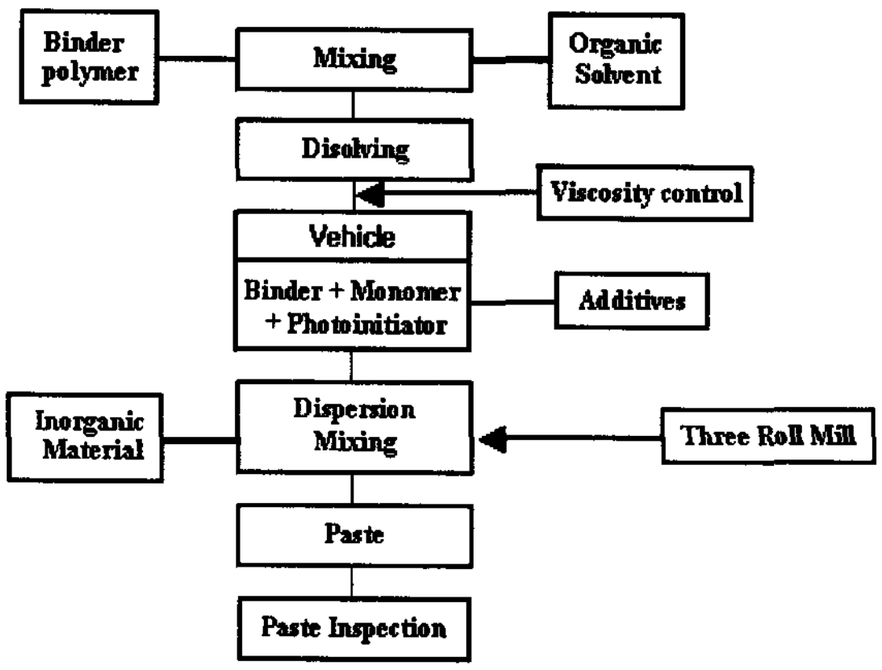

Fig 2. Formulation Process of Photosensitive barrier rib Paste

To this mixture was added barrier rib powder and the slurry was mixed with mechanical stirrer for 10~30min. The mixture slurry was then placed on the three roll mill and ground for 2-3 hr until a homogeneous paste with desired rheological property was obtained.

2.2 Patterning of Barrier Ribs PDP by Transparent Soft Press

We studied a new technique of barrier rib formation to obtain barrier ribs with high aspect ratios and to reduce the manufacturing cost of PDP. We also have examined this new transparent soft molding (TSM) process so that we can solve demolding problem which the current simple press method and LTCC-M method have had. We developed a photosensitive barrier rib paste which helps the demolding process after UV irradiation due to change in the interfacial area. The photosensitive barrier rib paste was prepared by incorporating binder polymer, solvent, functional monomers, photoinitiator and barrier rib powder.

Fabrication of transparent soft mold using photosensitive glass

Transparent soft mold was fabricated by pouring a silicone resin into the base mold made with photosensitive glass. Fig.3 shows the fabrication of the base mold and transparent soft mold using photosensitive glass and silicon resin.

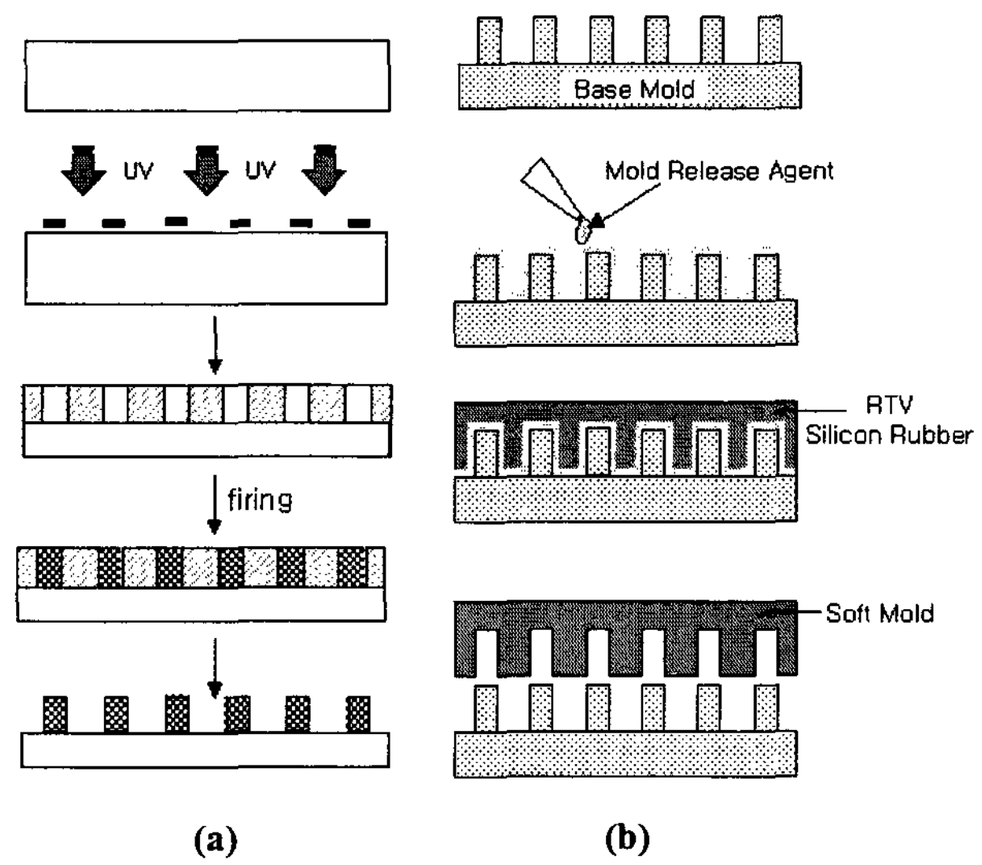

Fig 3. Fabrication of the base mold and transparent soft mold using photosensitive glass and silicon resin

RTV type silicone resin was poured on the base mold made of photosensitive glass. It was subjected to vacuum for 30 min to remove air bubbles. It was then cured at room temperature for about 12 hrs. The soft mold formed was released from the base mold by slow winding process.

Barrier rib patterning by TSM process

The formation of barrier rib by a new transparent soft molding(TSM) process using photosensitive barrier rib paste is shown in Fig. 4. The photosensitive barrier rib paste was coated by bar coater on the rear glass panel of PDP and dried in a 90℃ convection oven for 20min. The transparent soft mold was placed on top of the semi-dry barrier rib layer and then irradiated with a UV lamp to a total dose of 500~600 mJ/㎠. The soft mold was then released from the pressed barrier rib layer by slow winding process. The transparent soft mold was rinsed in ethanol, and washed thoroughly using an ultrasonic apparatus for reuse. After demolding, the patterned barrier rib was fired in a high temperature oven, which was heated up to 550℃ for 30min. A fine pattern of barrier ribs without any binder polymer or other organic components was obtained through this firing process.

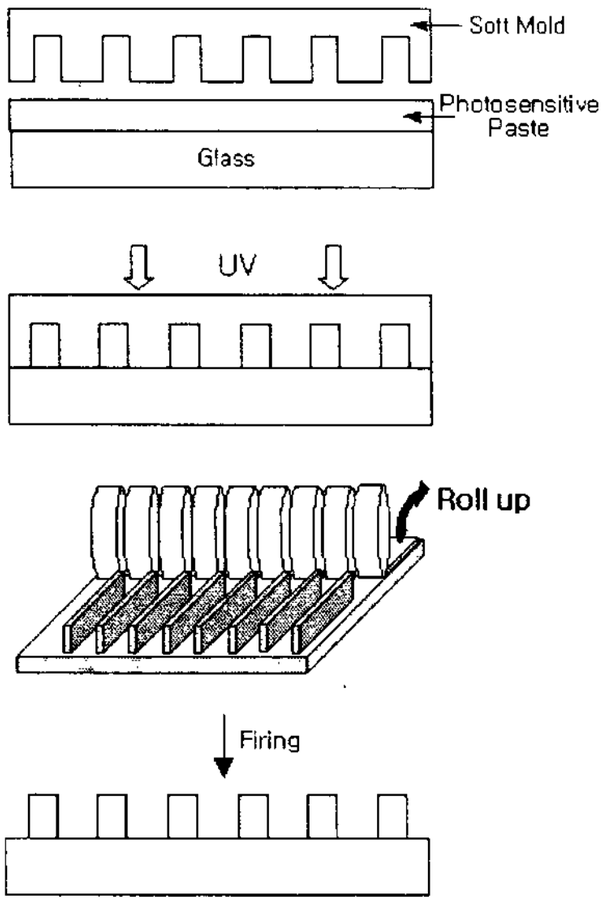

Fig 4. Formation of PDP barrier rib by TSM process

3. Results and discussion

3.1 Photosensitive barrier rib paste formulation

The effect of component and concentration of photosensitive barrier rib paste was examined to optimize the paste formulation and photolithographic process. EC is soluble in organic solvents such as α-terpineol, texanol, 3-methoxy-3-methyl butanol, BCA, and BC. Fig. 5 shows the rheological property of binder polymer (EC) solution. When the content of the solvent is low, the viscosity of the binder polymer solution is excessively high, causing air bubble problems in the barrier-forming paste, which results in poor printing property and smoothness of the coating surface. On the other hand, a high content of solvent poses problems of settling of dispersed particles, thus making it is difficult to stabilize the composition of barrier-forming material. In addition, long time is required for drying. Therefore the content of the mixture solvent BC/BCA(30:70) was set is at 85 % by weight. We also found that the mixture photo-initiator(HSP188) gave optimum photosensitivity in the UV exposure stage due to high sensitivity at 365㎚ UV light source used in this experiment. As for photoreactive monomers, trifuntional TMPEOTA monomer was found to have higher photosensitivity than other monomers. The optimum formulation of photosensitive barrier rib paste was found to be 0.4g EC, 2.0g BC/BCA(30:70), 1.0g PETA, and 0.2g HSP-188 in the vehicle. The percent ratio of vehicle to barrier rib powder was about 40:60 by weight. [6-7)]

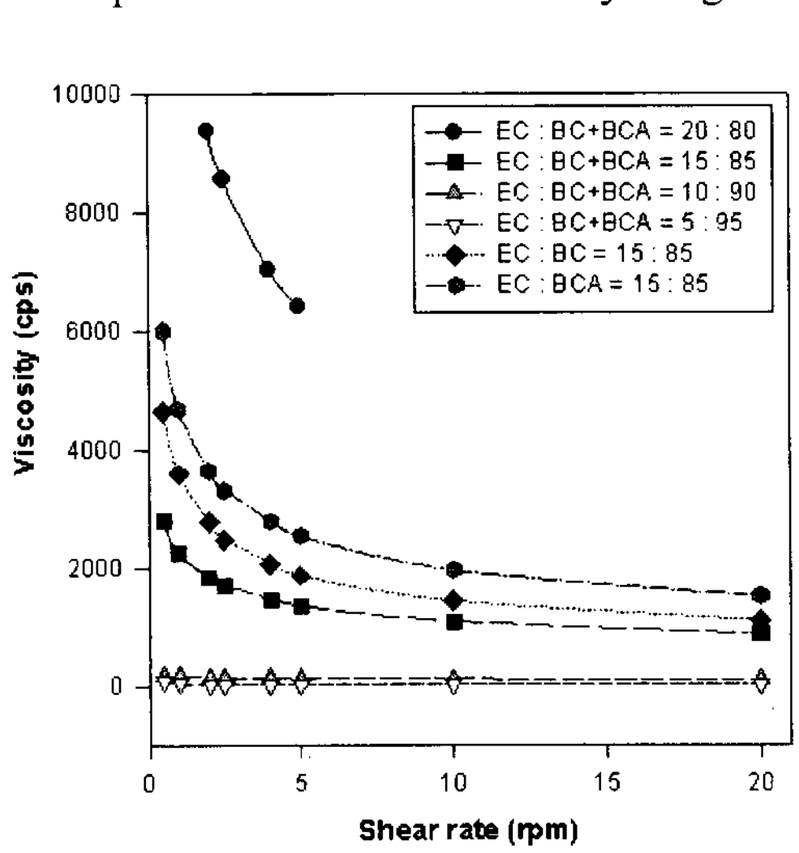

Fig 5. Effect of solvent mixture and concentration of ethyl cellulose on the rheological properties

3.2 Barrier Rib Formation by Transparent Soft Molding (TSM) Method

Transparent soft mold was fabricated by pouring a silicone resin into the base mold made with photosensitive glass.

Table 1 shows the fabrication condition of the base mold using photosensitive glass. The dimension of base mold measured with SEM is shown in Table 2.

Table 1. Fabrication condition of base mold using photosensitive glass

Step	Condition
UV Exposure	Expose Dose : 1000~2200 mJ/㎠
Firing	1 step : 6℃/min to 500℃ 2step : keeping at 500℃ for 1hr 3step : 6℃/min to 600℃ 4step : keeping at 600℃ for 1hr
Etching	10wt% HF Aq. soln.
Drying	100℃/10min

Table 2. Dimension of base mold

Dimension	height	width	pitch
Design	220 ㎛	80 ㎛	400 ㎛
Photosensitive glass base mold	211.6± 0.5	79.5 ± 0.5	399.0 ± 0.5

Silicone resin (SH-9555) was poured on the base mold made of photosensitive glass. It was subjected to vacuum for 30 min to remove air bubbles. It was then cured at room temperature for about 12 hrs. The soft mold formed was released from the base mold by slow winding process.

The photosensitive barrier rib paste was coated on the glass substrate and dried in a 90℃ convection oven for 20min. The rheological property of photosensitive barrier rib paste which exhibits reduction in viscosity as the shear rate is increased is desirable. This thixotropic characteristics of barrier rib paste promote fast leveling of paste and provide a smooth surface, with uniform thickness, and no pinholes. Photosensitive barrier rib paste should have a viscosity between 32,000 and 42,000 cps when barrier rib powder is well dispersed. When this paste was screen printed onto a glass substrate, it gave a coating 300 ㎛ with ease, which is then ready for the press and exposure steps. The transparent soft mold was pressed on top of the semi-dry barrier rib layer and then irradiated with a UV lamp to a total dose of 500~600 mJ/㎠. The soft mold was then removed from the pressed barrier rib by winding up and a fine pattern of barrier rib was obtained. Exposure to ultraviolet ray under the pressed state helps reduces the interfacial adhesive force between the soft mold and the photopolymerized barrier rib. After demolding, the barrier rib was fired in electric furnace, which was heated up to 550℃ for 30min. After the firing barrier ribs having high aspect ratio as shown in Fig. 6 were obtained.

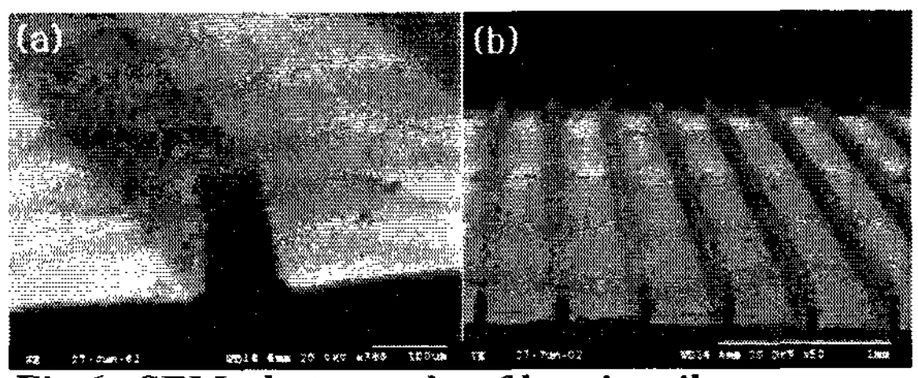

Fig 6. SEM photographs of barrier ribs

4. Conclusion

The effect of photosensitive barrier rib formulation and transparent soft molding process on the patterning of barrier rib for PDPs was studied. Some important results from the study include. (1) Barrier ribs with high aspect ratio could be obtained by the new transparent soft molding(TSM) process. (2) The photosensitive barrier rib paste makes the demolding easy due to reduced interfacial forces and shrinking of paste materials. (3) For the successful TSM process of forming barrier ribs the base mold is important and photosensitive glass was suitable for the fabrication of mechanically stable base mold. We solved the major problems facing the conventional press method of fabricating PDP barrier ribs by using both soft mold and photosensitive paste. We hope that this technique will contribute to achieving barrier rib with various structures and high aspect ratios as well as reducing the cost of manufacturing PDPs.

5. References

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