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FABRICATION OF ELECTROPHORETIC DISPLAY PANEL USING PREPATTERNED BARRIER RIB

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Fabrication process of electrophoretic display panels was investigated by utilizing transparent soft mold press, which enables to guide uniform packing of charged TiO_2 particles and colored particles for color e-Paper display. For this process, transparent soft mold was prepared by reacting silicone solution (silicone prepolymer/curing agent = 10/1 wt./wt.) into the base mold. While pressed with the transparent soft mold under 1.5 ∼ 3.0 Kg_f/cm^2 of pressure at 60 ∼ 90°C, the photosensitive film was exposed to UV light at 365 nm in the range of 800 ∼ 2,000 mJ/cm^2. The transparent soft mold was demolded by rolling up to give electrophoretic display panels with precise geometry. The process of obtaining colored electrophoretic display was also discussed.

Keywords: electrophoretic display; patterned barrier rib; photoresist; transparent soft mold press

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INTRODUCTION

Electrophoretic display has recently stimulated tremendous interest due to potential commercialization in the field of information displays including e-books, e-newspapers, low-power portable display, wall-sized display, and rollable display, etc. Electrophoretic displays typically consist of micron-sized capsules filled with nano-sized charged TiO_2 particles, suspension fluid, charge control agents, and particle stabilizers. When exposed to an electric field, these charged particles move either up or down within the microcapsules, creating images such as text and pictures [1–3]. However, the process for microencapsulation of these charged particles has been one of intricate processes for the electrophoretic displays. Recently, SiPix Co. developed new microcup process for electrophoretic display panels to eliminate intricate encapsulation process [4,5]. The company also demonstrated mass production capability of electrophoretic display panels by roll-to-roll process.

In this paper, we present a new transparent soft mold press (TSMP) method to fabricate electophoretic display panels with prepatterned barrier ribs for the inclusion of charged particles.

EXPERIMENTAL

Materials

An epoxy derivative photoresist (SU-8, Microchem Co.) and a photosensitive glass (PEG-3, Hoya Co.) were respectively used to make the base mold for the transparent soft mold. The transparent soft mold was prepared with mixture of SH-9555 A and B (Dow Coring Co.) and by using mold release agent (Nabakem R-2, Nambang Chem. Co.). Photosensitive paste used for the fabrication of barrier ribs in electrophoretic display panel was formulated with photosensitive vehicle and small amount of inorganic powder.

Mold Fabrication

The fabrication of base molds was carried out by the photolithograpic processes using either photoresist (PR) solution or photosensitive glass. In using photoresist solution as shown in Figure 1 (a), a glass substrate was successively cleaned with acetone, ethanol, and distilled water for 3 min. three times. The SU-8 negative PR was dispensed onto the cleaned glass and then spin-coated. After leveling for 2 min, the coated glass was baked at 90°C for 10 min in a convection oven. The PR coated glass was exposed to UV light at 365 nm through photomask, followed by development of unexposed area to give a base mold. In the photosensitive glass method

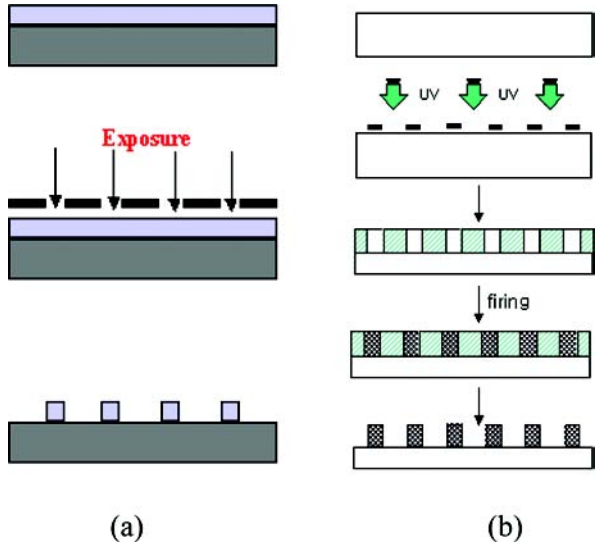

FIGURE 1 Fabrication scheme for base molds using (a) PR solution and (b) photoglass.

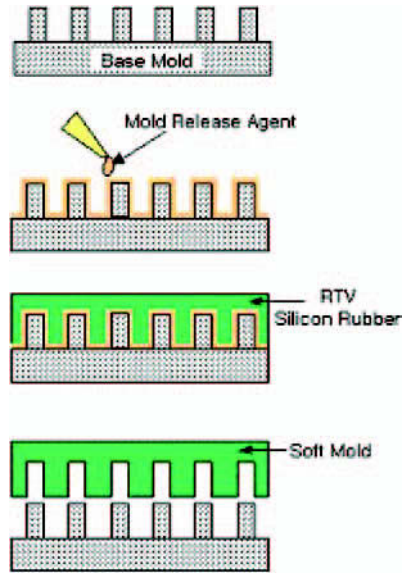

FIGURE 2 Fabrication scheme for a soft mold.

as shown in Figure 1 (b), the photosenstive glass was washed with isopropyl alchol and then distilled water. The cleaned glass was exposed to UV light at 365 nm through photomask and baked upto 600°C at 6°C/min of heating rate. Finally, the base mold was prepared by developing exposed area on the photosensitive glass with HF solution (10 wt.%).

The transparent soft mold was fabricated using base molds described above as shown in Figure 2. After spreading mold release agent on the base mold, silicone resin (silicone prepolymer/curing agent = 10/1 wt./wt.) was poured onto the base mold, followed by degassing. After curing it at 40°C for 3 hr, the transparent soft mold was taken off the base mold.

Transparent Soft Mold Press (TSMP)

Figure 3 illustrates the schematic process of TSMP. Photosensitive paste (200 ~ 300 μm of thickness) on a prepatterned ITO glass was coated using

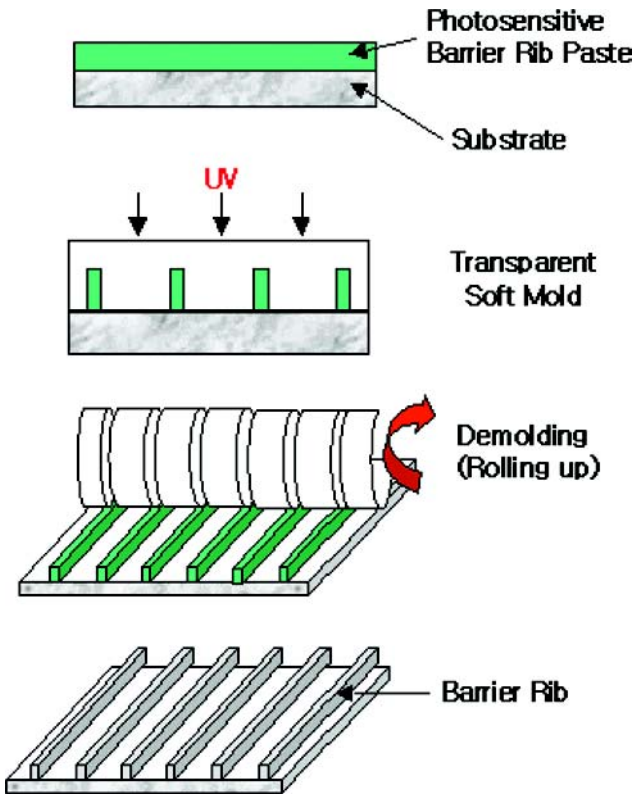

FIGURE 3 Scheme of transparent soft mold press (TSMP) process.

a bar-coater and then dried at 100°C in an oven until the content of residual solvent remains less than 10 wt.% in the photosensitive layer. While pressed with the transparent soft mold under $1.5 \sim 3.0\,Kg_f/cm^2$ of pressure at $60 \sim 90$°C, the photosensitive film was exposed to UV light at 365 nm in the range of $800 \sim 2{,}000\,mJ/cm^2$. The transparent soft mold was demolded by rolling up to give electrophoretic display panels with precise geometry.

Measurements

Rheological properties of the photosensitive paste was measured with universal dynamic spectroscopy (Physica, UDS 200) while viscosity of photosensitive vehicle was measured with Brookfield viscometer (DV II+) using RV spindle 07 at 24°C. Transmittance of the soft mold was measured with UV-Vis spectroscopy (UV-2100, Shimadzu Co.). Pattern geometry of base mold, transparent soft mold and barrier ribs in electrophoretic display

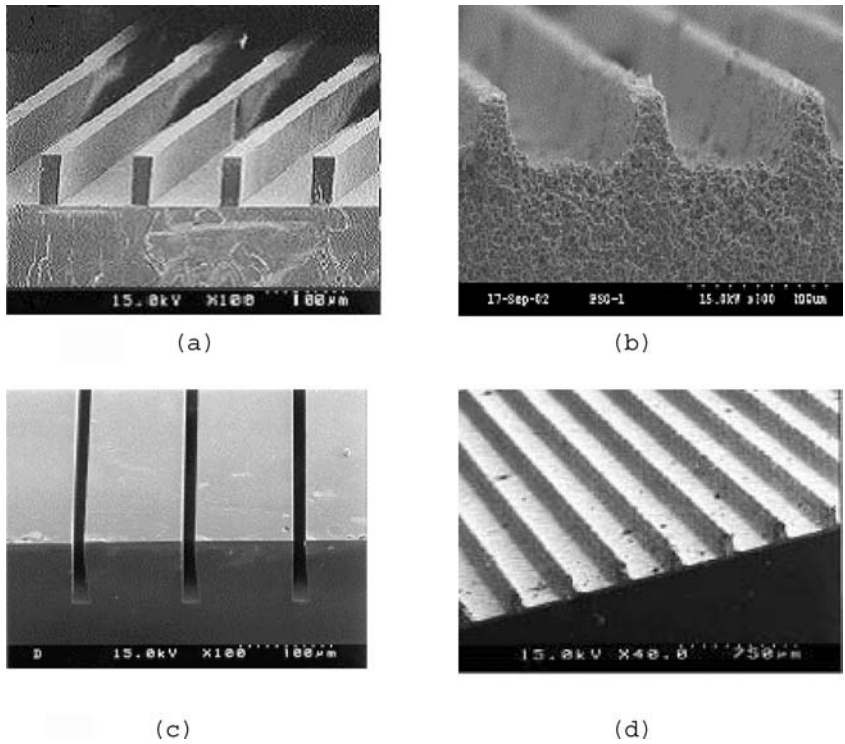

FIGURE 4 SEM images of base molds prepared with (a) SU-8 PR and (b) a photosensitive glass; (c) SEM image of the soft mold fabricated using the base mold, (d) SEM image of the electrophoretic display panel prepared using TSMP process.

panel was observed with field emission scanning electron microscope (Hitachi S-4200) and polarized microscope (Axiolab-pol, Zeiss Co.) equipped with a monitor and camera (MC 80 DX).

RESULTS AND DISCUSSION

In the photolithographic process of making base mold, a negative photoresist (SU-8) was used because this type of photoresist was especially useful for obtaining high aspect ratio of barrier ribs in the base mold. The photolithographic condition was optimized through the experiments on the spin coating, UV exposure, and developing steps. SEM image of base mold obtained with SU-8 is presented in Figure 4 (a), showing the barrier ribs with well-defined geometry (height $50 \sim 80\,\mu m$, width of barrier $20 \sim 50\,\mu m$, gap between ribs $100 \sim 150\,\mu m$).

In another method of making base mold a photosensitive glass was used for the formation of barrier ribs, however, the surface roughness of this base mold, as seen in Figure 4 (b), was not smooth enough to be employed for fabricating the transparent soft mold. The surface roughness of the base

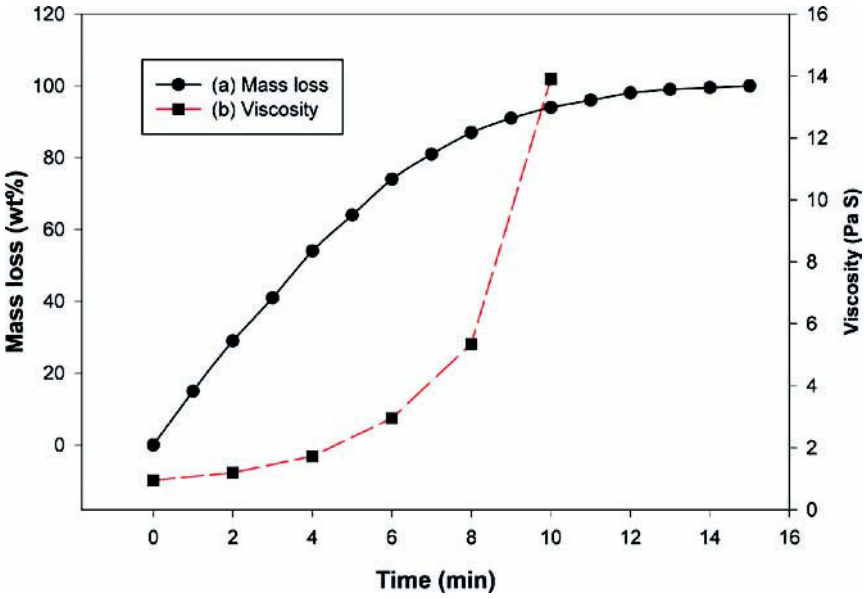

FIGURE 5 (a) Variation of the content of residual solvent in the film dried at 90°C in IR oven and (b) corresponding viscosity changes of the photosensitive paste both as a function of time.

mold was greatly improved by sputtering with Ar gas, but these results were not included in this work. The transparent soft mold exhibited around 80% of transmittance at 365 nm from UV-Vis spectroscopy, which was required for the next TSMP step.

Viscosity of the photosensitive paste, molding temperature, pressure, and the intensity of radiation will play a decisive role during TSMP process of fabricating electrophoretic display panels. A thorough control over these

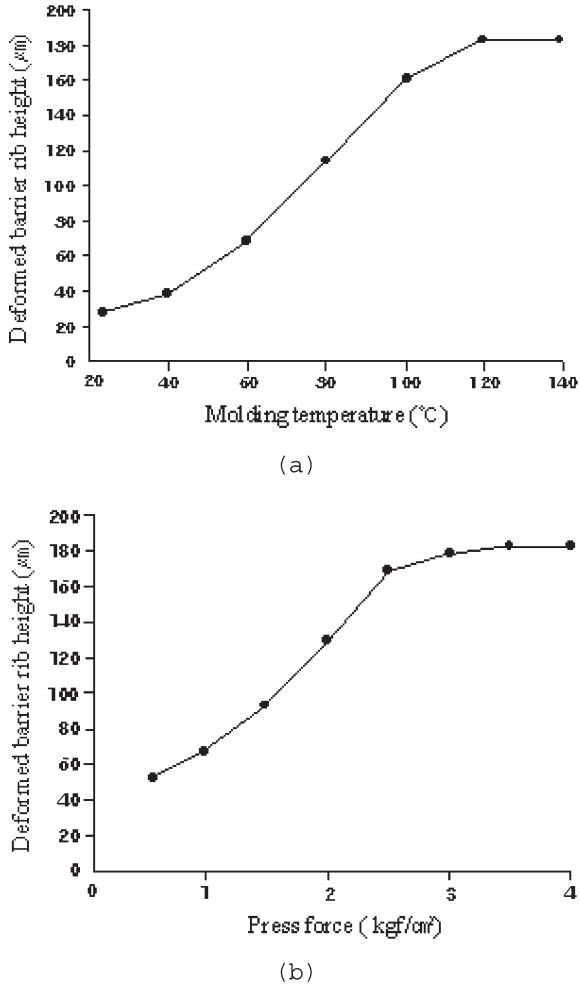

FIGURE 6 Barrier rib height of semi-dried film (a) with increasing molding temperature at 1.5 Kg_f/cm^2 of applied pressure and (b) with increasing applied pressure at 110°C.

parameters was essential to construct electrophoretic display panels with well-defined geometry. Therefore these process parameters were optimized by the systematic experiments. Figure 5 (a) shows the variation of the content of residual solvent in the film dried at 90°C in IR oven, and Figure 5 (b) represents the corresponding viscosity changes of the photosensitive paste both as a function of time. It revealed that optimum viscosity for TSMP processing was measured to be in the range of $5 \sim 10\,\text{Pa}\cdot\text{s}$, corresponding to around $10 \sim 15\,\text{wt}\%$ of residual solvent content.

Effect of either increasing temperature at fixed applied pressure or increasing applied pressure at constant temperature is shown in Figure 6 (a) and (b) on changes in height of barrier ribs. These results show that increasing either temperature or applied pressure on TSMP process results in decreased viscosity of semi-dried photosensitive film, and therefore optimum condition was set at 120°C and $3.0\,\text{kg}_\text{f}/\text{cm}^2$ for the reproducible patterning of barrier ribs.

It was shown in Figure 4(d) that barrier ribs for electrophoretic display panel was obtained by UV exposure while pressing the transparent soft mold, followed by demold process of rolling up the soft mold at a slow rate. It was also observed that the photopolymerization of the paste smoothly

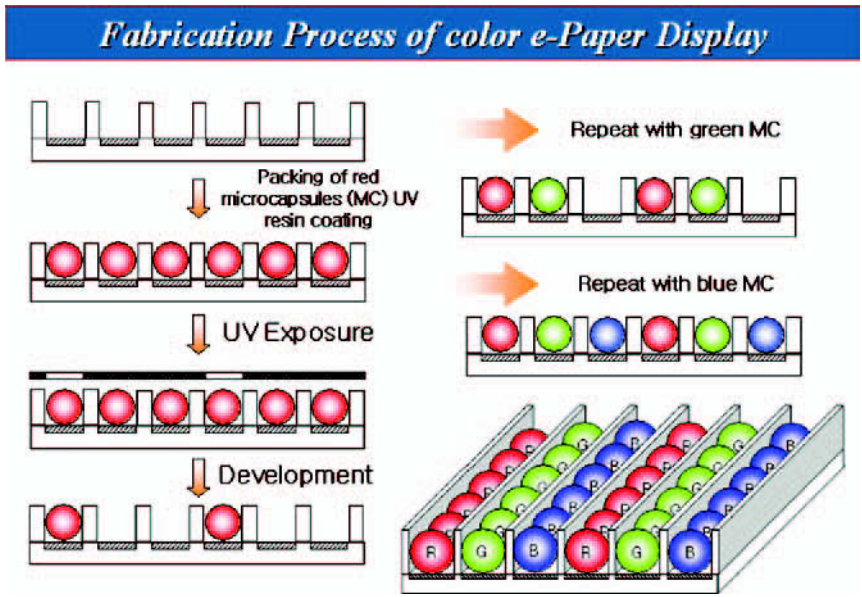

FIGURE 7 Process of making color e-Paper panel using prepatterned barrier rib substrate.

proceeded under $900 \sim 1{,}000\,\mathrm{mJ/cm^2}$ of the intensity of UV radiation, resulting in the fabrication of barrier ribs without any structural deformation after demolding process. Fabrication of panel with prepatterned barrier ribs made it possible to obtain color e-Paper display panel as shown in Figure 7 by successive photolithographic process with microcapsules containing red, green, and blue colored particles with charge.

CONCLUSIONS

It was found that viscosity of the photosensitive paste, temperature, pressure, the intensity of radiation will play a decisive role during TSMP processing in the fabrication of electrophoretic display panels. By controlling these parameter through TSMP process, electrophoretic display panel was successfully fabricated without any structural deformation. It was noted that substrate with prepatterned barrier ribs make it possible to obtain a color e-Paper display panel.

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