# High Precision Molding Process for Barrier Ribs of PDP by using a Soft Mold and a Green Sheet

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## Abstract

*In this paper, high precision molding process was developed using a soft mold to fabricate fine closed-types of the barrier ribs for PDP. A green sheet was employed to fabricate the barrier ribs in this process. The soft mold with good demolding characteristics was replicated from a master mold. An optimal forming load which would not fracture the soft mold was also determined. The barrier ribs of rectangular type with upper width of 30 ㎛ would be fabricated by this process.*

## 1. Introduction

The PDP (plasma display panel) market has grown substantially owing to the price reduction and improvement in its technologies. However, a number of issues still need to be solved to achieve "sustainable growth" of PDP in the market, especially its efficiency. There has been carried out researches about the low-cost manufacturing technology, realization of full HD (full high definition), and the generation of highly efficient plasma discharge for the sustainable growth of PDP. It is particularly important to make barrier ribs, which enable to dispense the phosphorus layer, provide the discharge space, and prevent cross-talk of discharge between neighboring cells in the PDP. Many manufacturing processes, such as screen printing, sandblasting [1], etching [2], photolithography [3], and molding process [4-7], have been developed to manufacture thin barrier ribs at low cost. Images of barrier ribs fabricated by sandblasting process are shown in the Fig. 1.

The molding process, which is classified as net shape manufacturing process, has merit of low cost because no mask is needed and it does not waste paste. This process is the simplest way to manufacture very thin barrier ribs at low cost if the mold would be used repetitively without damage and local defects on the large-area barrier pattern for PDP.

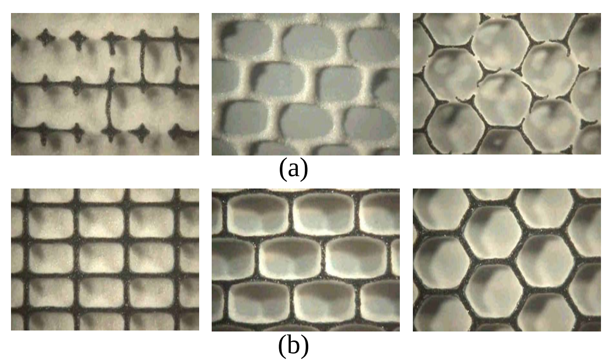

**Fig. 1. Barrier ribs fabricated by the sandblasting process, (a) collapsed, closed-type barrier ribs with 30 ㎛ in width and (b) good shape barrier ribs with 60 ㎛ in width**

Furthermore, the molding process utilizing a mold with cavity in the count shape of barrier ribs enables concurrent fabrication of a dielectric layer as well as barrier ribs. In addition, the molding process also made it possible to control the inclined geometry of barrier ribs, unlike other processes.

Various types of the raw materials such as a green sheet [4, 5], a thermally curable paste [6] and an UV curable paste [7] have been used in the molding process for fabrication of barrier ribs. A sheet of unfired ceramic, known as the green sheet, would be used without additional curing process.

In this paper, we developed a fabrication process to use the green sheet as a raw material for the barrier ribs. A soft mold is advantageous to transfer the barrier ribs to a substrate because its surface energy is lower than the metal mold. There is no energy input process such as UV light and temperature change to cure the raw material because the green sheets were used in this process. The green sheet also has merit of raw material which could not only reduce chemical reactions on the interface between a mold and a green sheet, but also improve demolding characteristics.

## 2. Experimental

### 2.1 Green sheets

Some mechanical properties of green sheet were obtained from the tensile tests of the ASTM D-882 for thin film sheet. The results of tensile tests for the green sheet properties at different temperature are shown in Fig. 2. The elastic modulus was 15 MPa at 2.5 mm/min stroke rate of UTM. As the temperature was increased from 20℃ to 60℃, the elongation was decreased from 500 % to 30% and the yield stress was decreased from 0.8 MPa to 0.15 MPa. Thus the filling process could be much more effective at higher temperature from the view point of forming process. The yield stresses versus temperatures data are shown in Table 1.

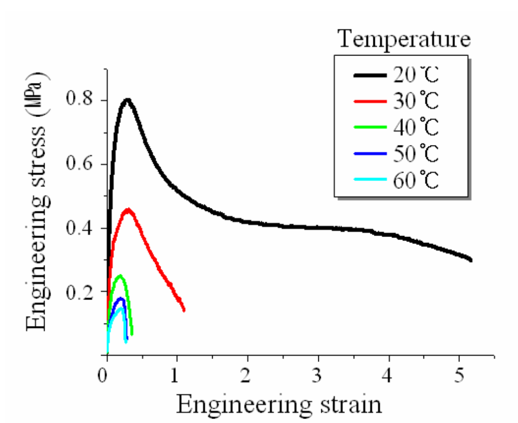


**Fig. 2. Strain-stress curve of the green sheet at different temperatures**

**TABLE 1. Changes of yield stresses according to temperatures**

| Temp. | 20℃ | 30℃ | 40℃ | 50℃ | 60℃ |
|---|---|---|---|---|---|
| Y.S (MPa) | 0.8 | 0.45 | 0.25 | 0.18 | 0.15 |

### 2.2 Fabrication of mold

A metallic master mold for a working mold was fabricated by a series of photolithographic process, replica process of PDMS, and electroforming process using SU-8 photoresist, PDMS and Ni as shown in the Fig. 3. A negative type SU-8 photoresist was used to make the barrier ribs 3-D pattern on a Si wafer. SU-8 was coated on the Si wafer to have 200 ㎛ in height by a spincoater. After soft baking of SU-8 layer, a doubly inclined exposure technique was used to create an inclined barrier rib wall profile in the 3–D PR base mold. The inclined UV exposure angle of 4 ° with the intensity of 20 $mJ\ /\ cm^2 \cdot \sec$ was employed to give 30 ㎛ of upper and 60 ㎛ of lower width in the barrier rib.

The base mold made of SU-8 photoresist could be used to make directly a working mold by replication process but the master mold made of the SU-8 photoresist pattern can not be used repeatedly because SU-8 pattern was not durable enough compared with the metallic master mold. Thus Ni mold was replicated by the electroforming process from polydimethylsiloxane (PDMS) which was obtained from the SU-8 PR base mold. In order to get Ni metallic mold from PDMS soft mold two seed layers (Cr and Au) were deposited by an E-beam evaporator to give required electric conductivity in the electroforming process.

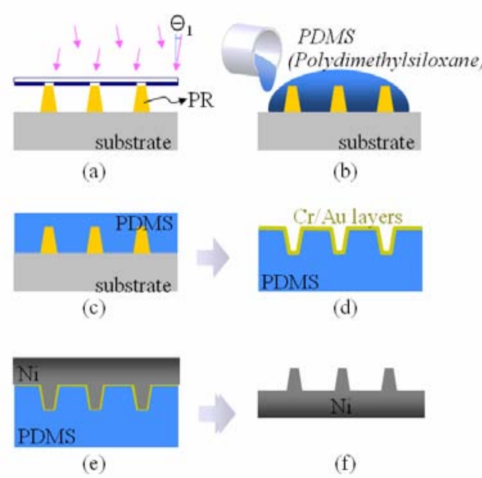


**Fig. 3. Fabrication process of a metallic master mold; (a) photolithography, (b) pouring PDMS, (c) curing PDMS, (d) depositing seed layers, (e) Ni electroforming and (d) Ni master mold**

Then the working mold is replicated from the Ni master mold using UV curable resin which was supported on the PET film of 200 ㎛ in thickness. The UV curable resin was obtained from SK-Cytec company. The SEM images of base mold with SU-8 pattern and the PET based working mold are shown in

Fig. 4.

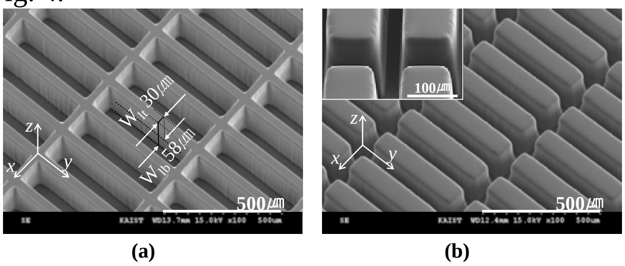


**Fig. 4. SEM images of (a) the base mold and (b) the replicated working mold**

### 2.3 Fabrication process of barrier ribs

The roll-pressing process to fabricate the barrier ribs of PDP using the PET based soft mold is illustrated in Fig. 5. The green sheet which is laminated on the soft mold as a material for the barrier ribs is stuffed into cavity of the soft mold by a filling roller. Then the green sheet filled into cavity is transferred onto the substrate. After that the soft mold is peeled off from the barrier ribs. Finally, the barrier ribs formed on the substrate are sintered.

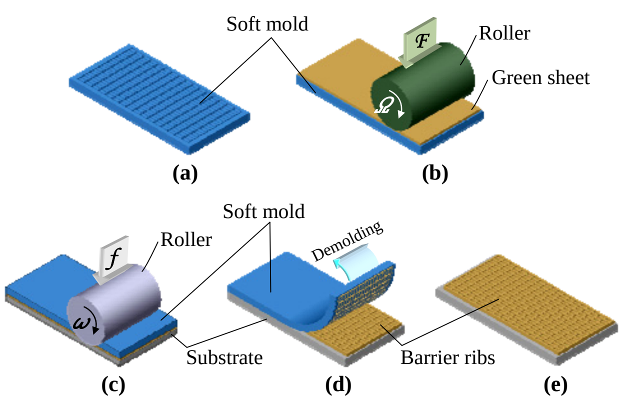


**Fig. 5. Roll-Pressing Process to fabricate barrier ribs using the soft mold, (a) fabrication of the soft mold, (b) lamination of the green sheet on the soft mold, (c) roll forming of the green sheet, (d) transferring the formed green sheet to the substrate and demolding of the soft mold, and (e) barrier ribs on the substrate**

## 3. Results and discussion

### 3.1. Comparison of metallic and soft mold

The Ni metal mold as a hard mold and PET film based soft mold were used in the roll pressing process. The Ni metal mold had better mechanical properties than the PET based soft mold in the elastic modulus and yield strength. But the Ni metal mold had a bad demolding property since the Ni metal surface had a high surface energy and low flexibility compared to the polymer soft mold. Many methods such as SAM treatment and DLC coating were used to reduce the adhesion between the hard mold and the transferred materials, i.e. barrier ribs. In this process spraying of release agent FLEX-A obtained from nambang-CNA company was tried onto the metal mold to reduce the adhesive. The thickness of release agent could be uniformly controlled on the Ni mold surface because the green sheet material was incrementally filled into the cavity of the Ni mold by a roller in the roll-pressing process. However, demolding process still exhibited problems due to large surface area and stiff metal mold. On the other hand soft mold was found to give acceptable barrier rib patterns in the roll-pressing process due to low surface energy and flexible mold property. Some characteristics of roll-pressing process using the two types of mold are shown in Fig. 6. The Ni mold sprayed with the release agent would not transfer the barrier ribs to the glass substrate after the green sheet was pressed by the roller with a forming load of 1 kN. The barrier rib pattern was successfully transferred onto the glass substrate in the case of soft mold. When the forming load of the roller was 3 kN, the cavity patterns of soft mold was fractured on the PET based film.

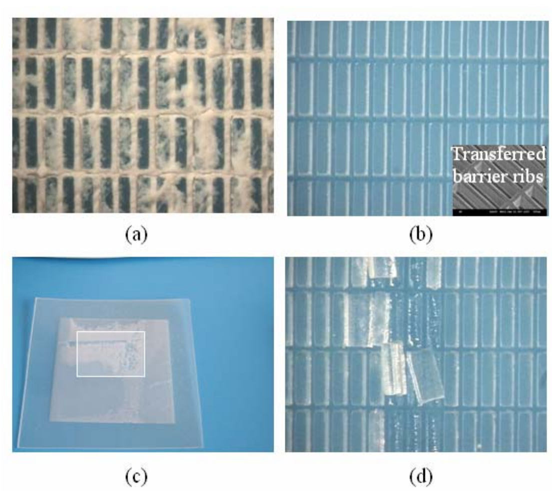


**Fig. 6. The characteristics of the molds used in the roll-pressing process; (a) the green sheet was not transferred to the glass substrate in case of Ni metal mold ; the forming load=1kN, (b) the green sheet was successfully transferred to the substrate in case of soft mold based on PET film ; the forming load=1kN, (c) the fractured soft mold ; the forming load=3kN and (d) the image of the**

**fractured the soft mold pattern**

### 3.2. Fabrication of barrier ribs

The barrier ribs were fabricated by the roll-pressing procedure using the 4-inch PET film based soft mold. SEM images of the barrier ribs transferred to the substrate according to a forming load of the roller were shown in the Fig. 7. The green sheet material was filled into the soft mold along the long side of the rectangular type pattern to reduce the flow resistance. Fig. 7 shown that the optimal forming load for one path in the roll-pressing process is about 0.5 kN when the diagonal size of the soft mold was 4 inches. Images of barrier ribs so formed on the substrate after sintering are shown in Fig. 8.

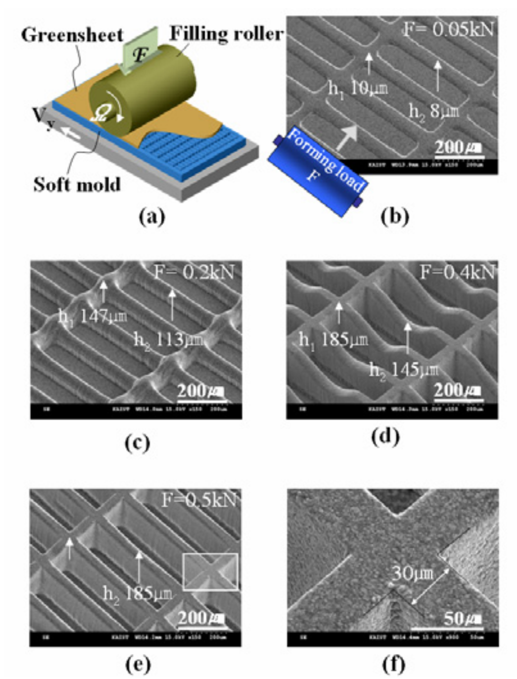


**Fig. 7 Green sheet patterns by the roll-pressing process, (a) a schematic of filling the cavity of soft mold with the green sheet, (b) F= 0.05kN, (d) F=0.2kN, (d) F=0.4kN, (e) F=0.5kN, (f) an enlarged photo of Fig. 5 (e)**

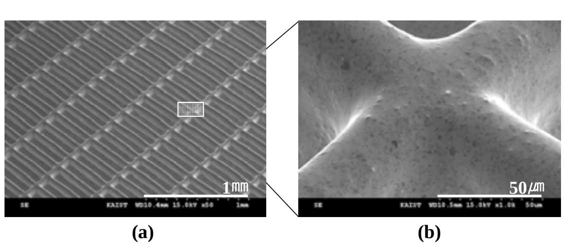


**Fig. 8 Barrier ribs after the sintering process**

## 4. Summary

In this study, the barrier ribs were fabricated by the roll-pressing process using the soft mold method. The green sheet material was filled into the cavity of soft mold by a filling roller in the roll-pressing process. This method was found to be effective in filling the green sheet into the cavity of the soft mold. This new method of molding process enabled the fabrication of barrier ribs without incurring the problems that could occur in a molding technology using UV curable or thermally curable barrier rib pastes because less physicochemical reactions between the mold and the green sheet could occur. The PDP barrier ribs with 30 μm upper width and 200 μm height could be fabricated by this new direct molding process.

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