Closed-type Barrier Ribs of PDP via Micro-Molding Process

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Abstract
In this study, waffle type barrier ribs for counter electrode discharge cells were prepared via micro-molding process. The master mold was prepared by UV lithography and working mold was manufactured by replicating the master mold. The UV paste used in this study consisted of ceramic powders for the barrier ribs, binder, hardener, and dispersant was filled into cavities of a polymeric mold by action of capillary pressure developed between mold and paste. The results demonstrated a possibility of one-step process for the manufacturing of waffle type barrier ribs embedded with sustaining electrodes.

1. Introduction
In recent years, various manufacturing routes for the barrier ribs of plasma display panels (PDP) have been explored, which include printing, sand blasting, chemical etching, photosensitive paste, and rolling of green tape [1]. Among the routes, the sand blasting and chemical etching process are currently used by most of the PDP producing companies. There are, however, several shortcomings of the sand blasting process that include generation of toxic industrial waste, difficulty in formation of fine-dimension ribs, and non-uniform rib morphology.

In addition, the demands for high definition PDP TV are increasing in recent years with the competition with LCD TVs in the market. Increase in resolution of PDP, however, reduces volume of discharge cells, which eventually leads to decreased luminance and luminance efficacy of PDP. One of the efforts to attack this issue is to use counter electrode discharge cells. In these cells, sustaining and scan electrodes are embedded inside barrier ribs such that the discharge occurs between opposite barrier ribs. This arrangement of electrodes makes full use of discharge volumes inside the cells and therefore, the reduction in luminance and luminance efficacy with high resolution may be minimized. In addition, ITO sustaining and scan electrodes, dielectric layer, and MgO protective coating on front plate may not be required with this structure, making the panel much more economical compared with conventional co-planer electrode panel. Recently, Mori et. al. [2] developed a process for the counter electrode discharge cell using green sheets and reported luminance efficiency of 2.5 lm/watt. In their process, ceramic sheets were laminated to form the electrodes inside the barrier ribs. This process, however, consisted of many processing steps and various types of materials.

In this study, possibility of using a micro-molding process in manufacturing counter electrode discharge cells was explored. In this process, barrier ribs were formed by filling UV sensitive paste into cavities of micro mold. The sustaining counter electrodes can be formed by filling Ag paste into the trenches formed in the barrier ribs. This molding process is one-step process and has possibility of cutting processing costs dramatically.

2. Experimental

Figure 1 shows schematic illustrations of processing steps involved in the micro-molding process. Firstly, master molds were prepared using UV photolithography of SU-8 photoresist. Working molds were prepared by replicating the master mold. For the working mold, PDMS elastomer was used. The mold cavities were filled with UV sensitive paste containing ceramic powders of barrier ribs. The filling process was conducted by capillary pressure formed between mold and paste.

After the working mold cavities were filled with the paste, the paste was cured by UV irradiation and mold was removed from the sample. The sample was then heated to sintering temperature for densification of powders. The morphology of the barrier ribs were examined using SEM for distortion or cracking during sintering process.

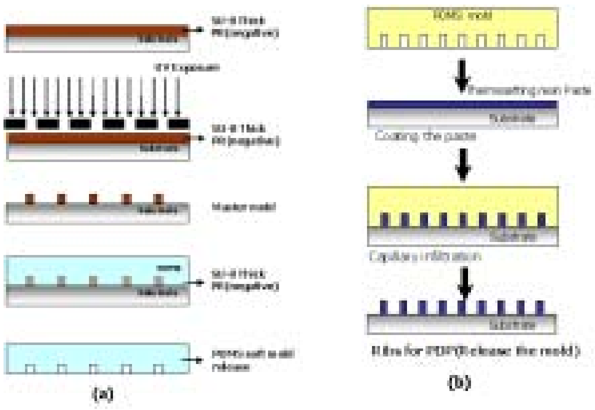


Fig. 1. Schematic illustrations of processing steps of micro-molding process.

3. Result and discussion

3.1. Preparation of master mold

For the counter electrode discharge cells, a new discharge cell was designed in this study such that the sustaining electrodes are embedded inside the barrier ribs. As schematically shown in Fig. 2, the electrodes were embedded to the top part of the barrier ribs. In order to manufacture such structure, master mold was prepared in two steps such that top part of the barrier ribs has trenches in which the sustaining electrodes can be formed.

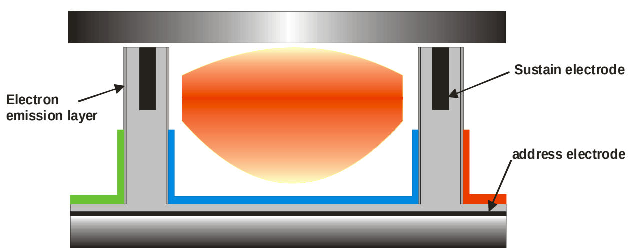
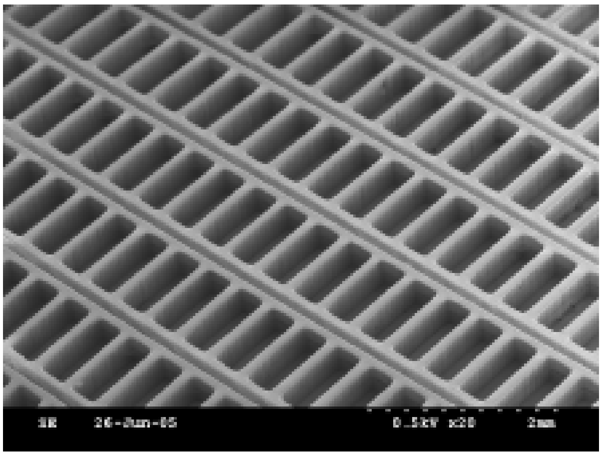


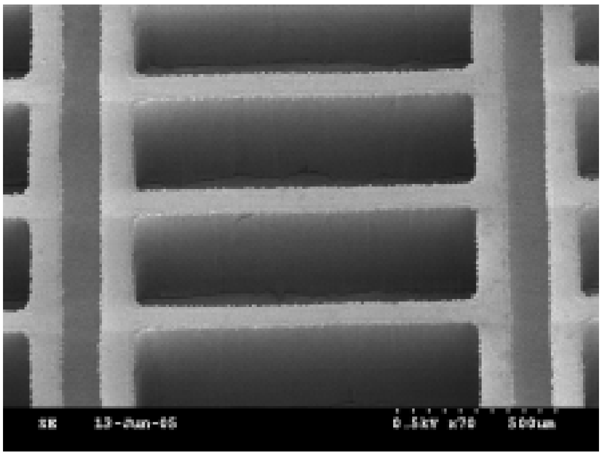
Fig. 2. Schematic illustration of counter electrode discharge cells designed for this study.

Firstly, the SU-8 photoresist was coated on the Si substrate and exposed to UV radiation to form waffle type barrier ribs. After the post-exposure baking of the first layer, photoresist layer was formed again on the exposed layer and the top layer was exposed again by UV photolithography. The doubly exposed sample was developed to remove unexposed volume. The height of the total layer was 200 μm and the thickness of barrier rib containing the electrode was 100μm and crossing rib without the electrode was 50μm.

Fig. 3 shows the SEM micrograph of master mold prepared by the UV lithography process. As shown in the figure, a mold for waffle type barrier ribs with trenches for sustaining electrodes was formed successfully. Since the process was two-step route, the delamination between the top and bottom layer, and swelling of crossing patterns during development occurred when processing conditions were not optimized.



(a)

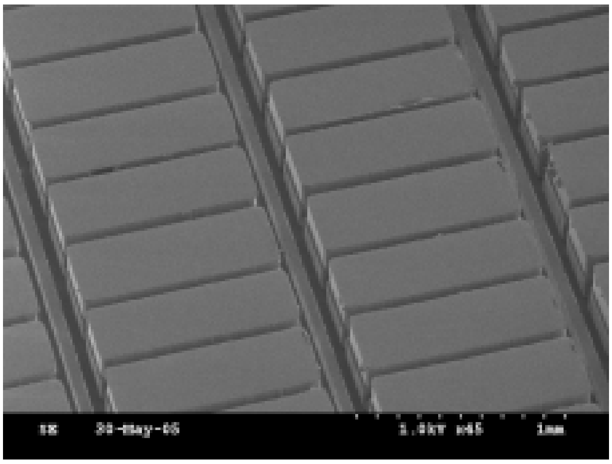


(b)

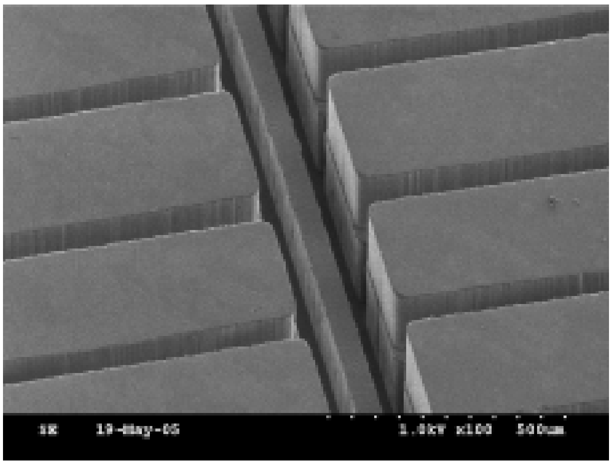
Fig. 3. SEM micrographs of SU-8 master mold prepared by photolithography process.

3.2. Working mold and barrier rib preparation

Figure 4 shows the SEM micrographs of working mold prepared by replication of the master mold. As noted from the figure, the master mold was precisely replicated by the PDMS elastomer. The trenches of the master mold that appear as lines in the working mold were difficult to replicate as its aspect ratio is larger than other structure. In order to increase the working mold releasing characteristics from the master mold, Si-based mold releasing agent was added to the PDMS working mold.



(a)



(b)

Fig. 4. Working mold prepared by replicating SU-8 master mold.

Fig. 5 shows the barrier ribs formed by filling UV sensitive barrier rib paste into the cavities of working mold via action of capillary pressure developed between working mold and the paste. After the filling process, the paste was cured by UV irradiation and the working mold was removed from the sample. The working mold releasing characteristics were affected mainly by the type of organic components used in the paste and doses of UV irradiation. Thus, in this study, the organic components were selected to maximize the mold releasing characteristics.

After the mold release, the sample was then heated to sintering temperature to remove organic additives in the paste and densify the ceramic powders. As noted from the micrograph, dense waffle type barrier ribs were formed by the process. The ribs, however, were distorted slightly at the junctions of crossing ribs and longitudinal ribs. As demonstrated in our previous works, the distortion is due to unbalanced sintering stress at the junction [3].

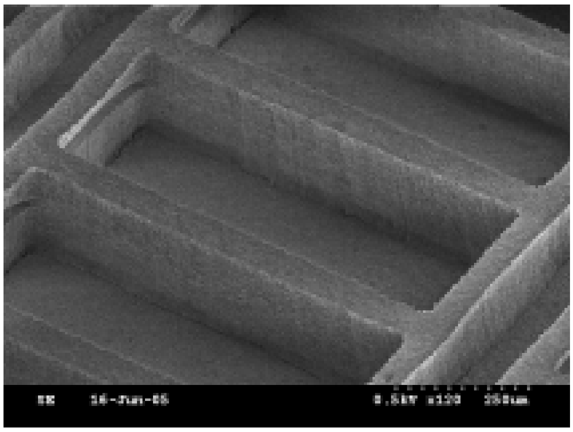
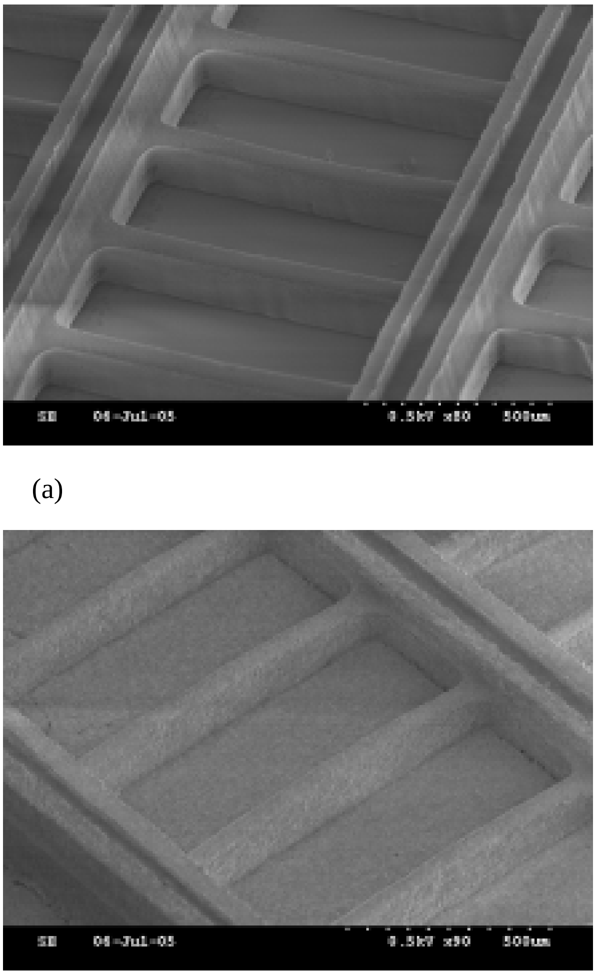


Fig. 5. Waffle type barrier ribs with sustaining electrode trenches prepared by micro-molding process.

In order to reduce the sintering distortion at the junction, semi-closed discharge cells were designed. The cell was designed to have only half the length of the original height. In this way, the sintering stress at the junction of crossing ribs can be canceled each other. Fig. 6 shows SEM micrographs of the semi-closed discharge cells prior to and after sintering at 570^{o}C for 30 minutes. As noted from the micrograph, the distortion at the junction is negligible, suggesting a possibility of manufacturing the discharge cells.

The discharge characteristics of such counter-electrode discharge cells are under investigation and will be reported subsequently.



(a)

(b)

Fig. 6. SEM micrographs of semi-closed cells: (a) prior to sintering and (b) after sintering at 570^{o}C for 30 minutes.

4 Conclusion

A processing route to manufacture discharge cells with counter sustaining electrodes embedded inside barrier ribs was developed via micro-molding process. Master mold was prepared by two-step UV-lithography and working mold was manufactured by replicating the master mold. The UV paste developed was filled into the cavities of the working mold by action of capillary pressure to form the barrier ribs.

5. Acknowledgments

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6. References

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