Closed-Cell Type Barrier Ribs using Molds Prepared by Inclined UV Lithography

Ki-In Kim and Yong-Seog Kim
Dept. of Materials Science and Engineering, Hongik University, Seoul 121-791, Korea
Phone : +82-2-322-0644 , E-mail : hernes@msn.com

Abstract

Symmetric closed-cell type barrier ribs of PDP were formed by capillary molding process using molds prepared by inclined UV lithography process. The effects of inclining angle of barrier ribs on the sintering shrinkage and luminance of panel were examined. The results indicate that the barrier ribs of inclined morphology affect the sintering shrinkage and luminance efficiency significantly.

1. Introduction

Recently, for the improvements in luminance efficiency, and resolution of PDP, closed-cell type barrier ribs such as SDR, DelTA, Waffle, and Hexa are being proposed [4].

Conventionally, such barrier ribs have been manufactured using the powder-blasting processes. This process is widely used for barrier ribs of stripe morphology, but manufacturing of the closed-cell type barrier ribs proved to be quite difficult, especially the ribs of fine dimensions. Authors have demonstrated that capillary molding process can be an alternative process for the closed-cell type barrier ribs of fine dimensions [1].

Most of the barrier ribs produced via the molding process has been of vertical morphology. The barrier ribs produced via the powder blasting process, on the other hand, forms a curvature at the root of barrier ribs. Therefore, there have been attempts to investigate the characteristics of vertical ribs produced by the molding process, which include mechanical properties, sintering stability, and its effect on luminance and its efficiency of the discharge cells.

In this study, therefore, an attempt was made to prepare barrier ribs with or without an inclined angle via the molding process. Using such barrier ribs, effect of the inclined angle on the sintering shrinkage of the barrier ribs produced by the molding process was examined. In addition, the effects on luminance and luminance efficiency of panel were measured.

2. Experimental

Master molds for the capillary molding process were prepared using a photoresist resin (SU-8, Micro-Chem, USA). A resin film of 200μm thick was formed on a silicon wafer by spin coating. The film was patterned for stripe, waffle, honeycomb and rectangular cells using Inclined UV lithography process. Inclined UV lithography process was conducted by inclining stage with respect to UV light as schematically shown in Fig. 1(a) [2,3].

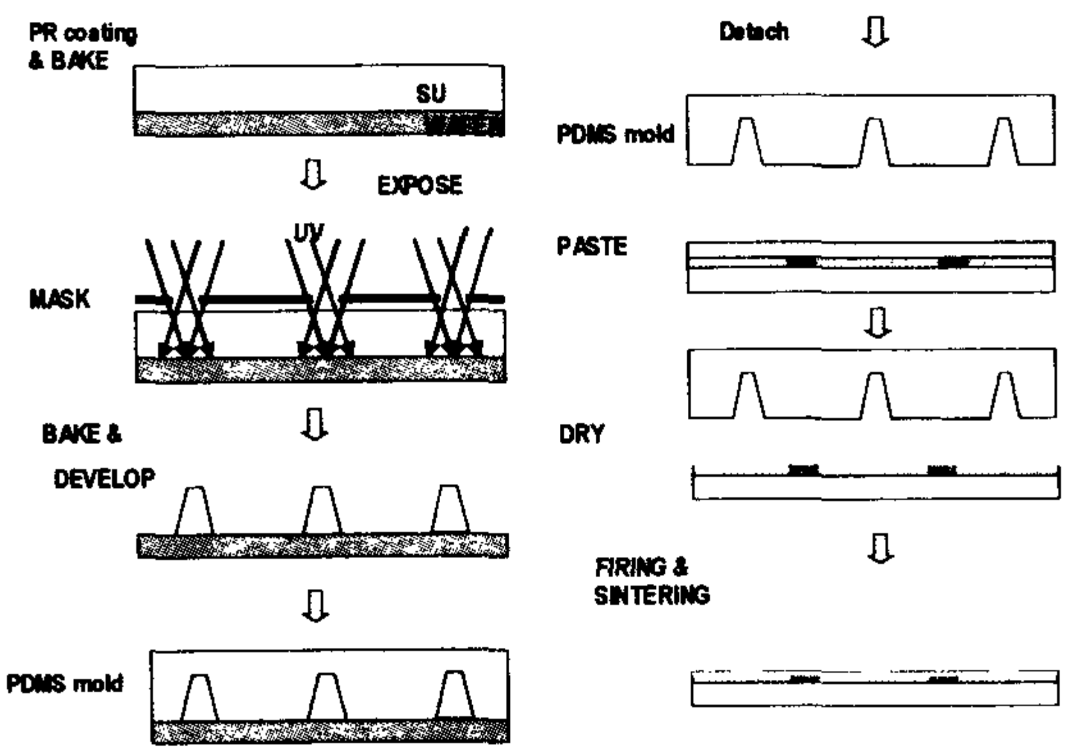


Fig. 1. Schematic illustration of (a) mold preparation and (b) capillary molding processes

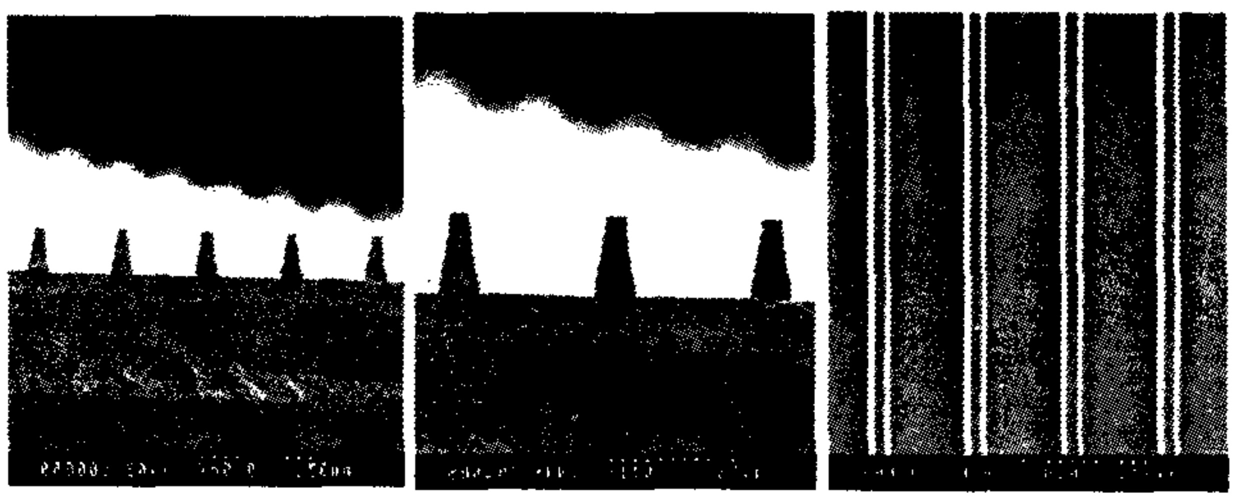
Subsequently, polydimethylsiloxane (PDMS) mixed with a curing agent, was cast on the top of the master mold and cured in a vacuum oven at 120°C for 30 minutes to replicate the master mold. The PDMS mold replicated was used as working mold for capillary molding process. The processing step of the mold preparation is schematically illustrated in Fig. 1(a).

Following the mold preparation, a thermally curable paste was printed on a glass plate (PD-200, Asahi Glass Co., Japan) and the thickness of the layer was ~40μm. The paste consisted of epoxy resin of biphenol A type, amine type hardener, dispersant, and ceramic powders (glass frit and alumina powders). Subsequently, the PDMS mold was placed on the top of the paste and kept in a drying oven at 120°C for 3 h for curing of the paste. After the curing, the PDMS mold was removed from the sample. A schematic illustration of the capillary molding process is shown in Fig. 1(b). After the molding process, the sample was heated at a rate of 5°C/min to prefiring temperatures (450°C) and kept for 1 h. The sample was then heated at the same rate to 570°C for sintering and held for 30 min at the temperature. The sintering was conducted in air atmosphere.

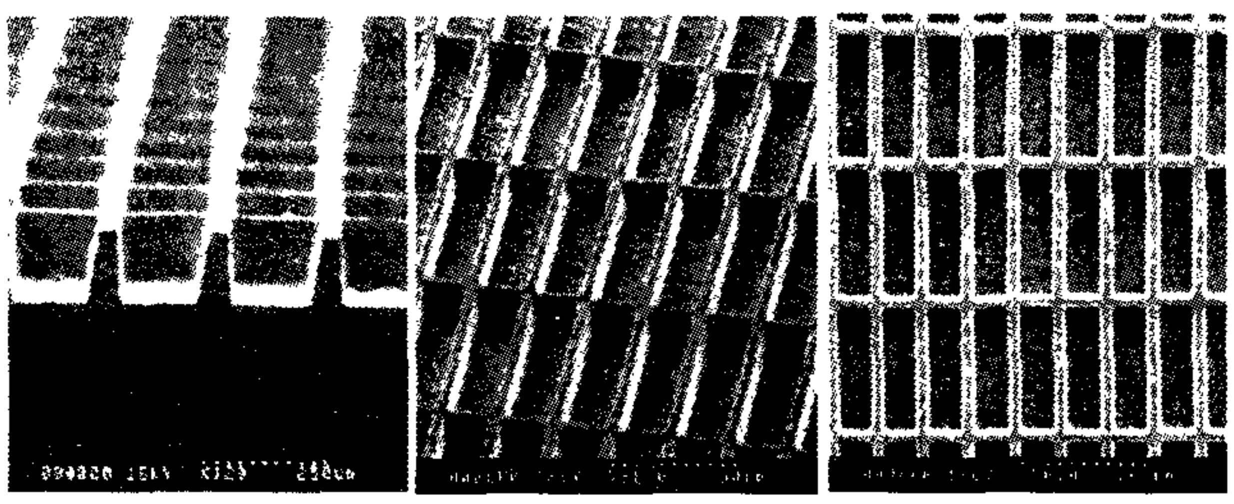
3. Results and discussion

3.1. Sintering behavior of inclined barrier ribs

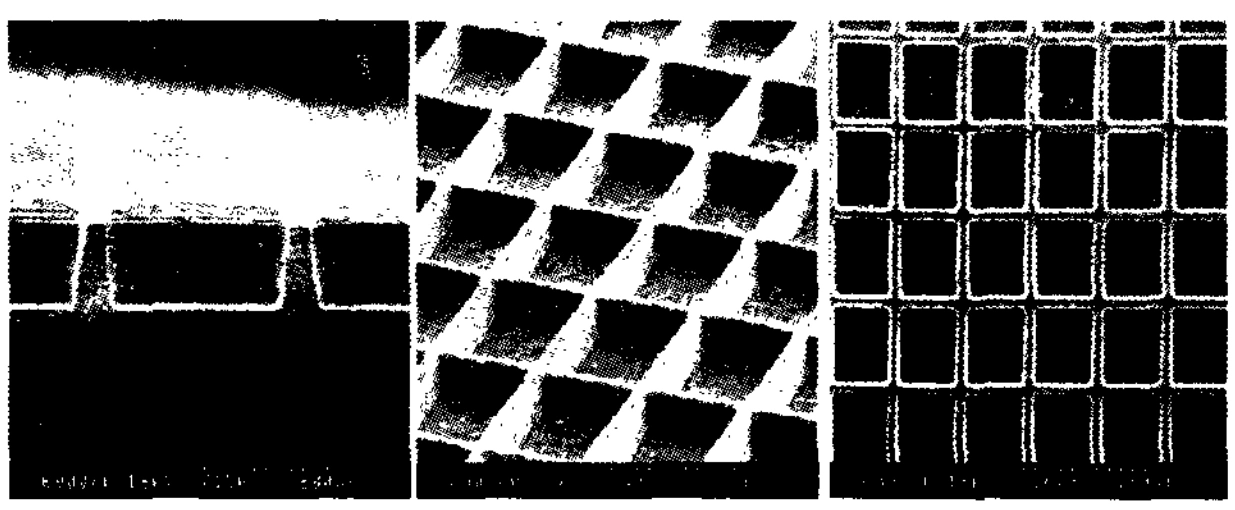
Fig. 2 shows the strip, rectangular, waffle and hexa type master molds prepared by inclined UV lithography process. The inclined angle was 10° for each type of barrier ribs. As noted from Fig. 2(a), a stripe type master mold with draft angle was formed with well-defined morphology. The draft angle of the sample was 10°. The rectangular, waffle, honeycomb type master molds with the same draft angle was prepared using the same procedure. As noted in Fig. 2(b), 2(c), 2(d), the draft angle was also formed with the mold.



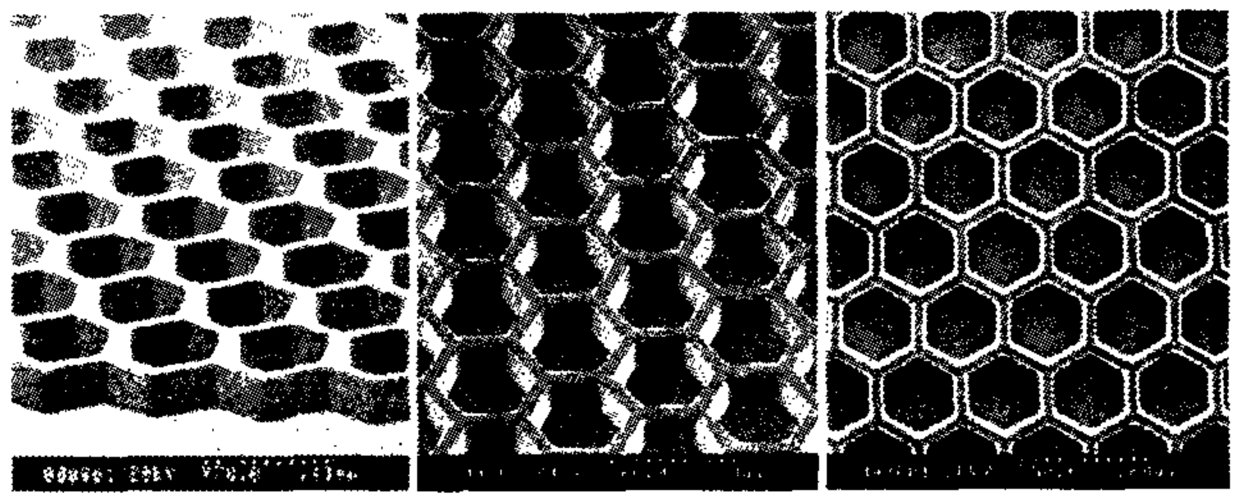
(a)



(b)



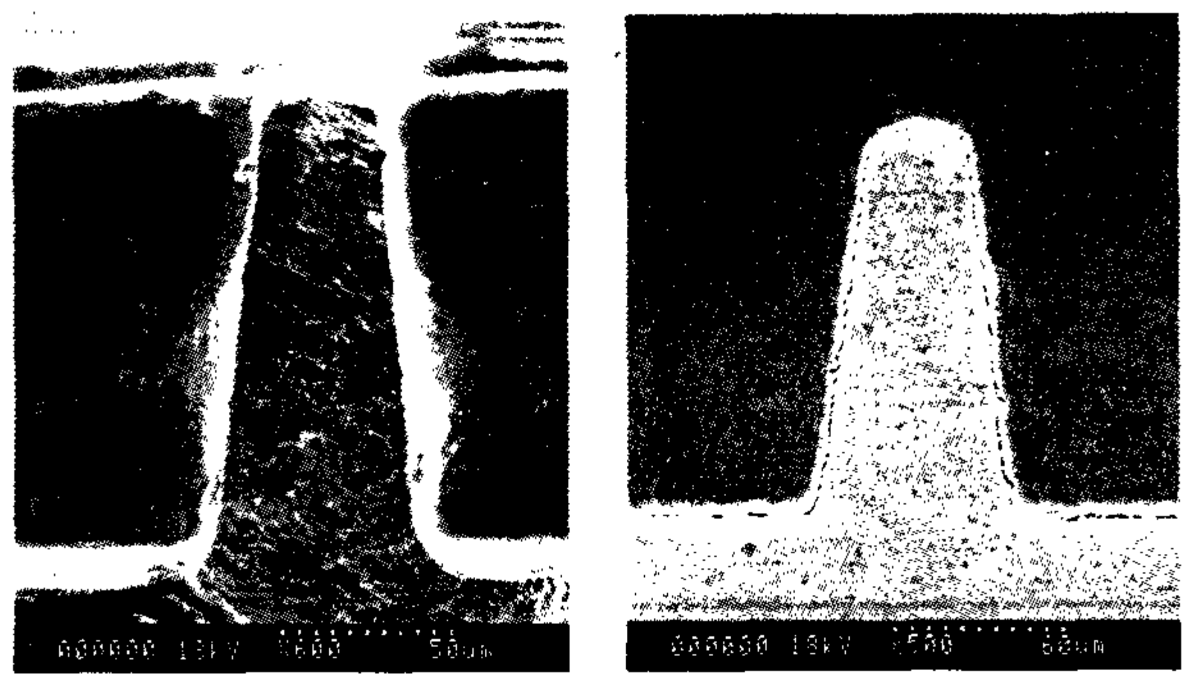
(c)



(d)

Fig. 2. SEM micrographs of SU-8 master molds: (a) stripe type, (b) rectangular type, (c) waffle type and (d) honeycomb type.

Figure 3 shows morphology of waffle type and stripe type barrier ribs after sintering. The inclined barrier ribs of fully dense microstructure were formed by the molding process. The pitches of waffle type barrier ribs either of vertical morphology or of inclined morphology were measured and the sintering shrinkage was estimated (Table 1). The sintering shrinkage of vertical ribs was measured to be almost twice that of inclined ribs. The larger area at the bottom of the barrier ribs must have reduced the sintering shrinkage.



(a) (b)

Fig. 3. Sintered barrier ribs of inclined angle: (a) waffle type and (b) stripe type

Table 1. Sintering shrinkage of waffle type barrier ribs.

	Shrinkage (%)
Vertical ribs	1.88
Inclined ribs	1.14

3.2.Effect of morphology of closed-cell type barrier ribs on luminance and its efficiency of PDP

Using the rear plate with barrier ribs of various types, panels were prepared by vacuum sealing process. Prior to actual measurement of luminance of the panels, rectangular type and stripe type panels were evacuated and purged with Ne-4%Xe discharge gas for number of times and their luminance were measured (Fig. 4). As noted from the figure, the luminance increased with the number of evacuation and purging in both type of barrier ribs. With the stripe type ribs, maximum luminance was obtained when the number is 4. With the rectangular type ribs, however, the maximum was achieved only when the number reaches 10, indicating that the closed-cell type barrier ribs needs extensive evacuation to remove residual gases inside the discharge cells. In this study, such evacuation conditions were adopted for closed-cell type barrier ribs.

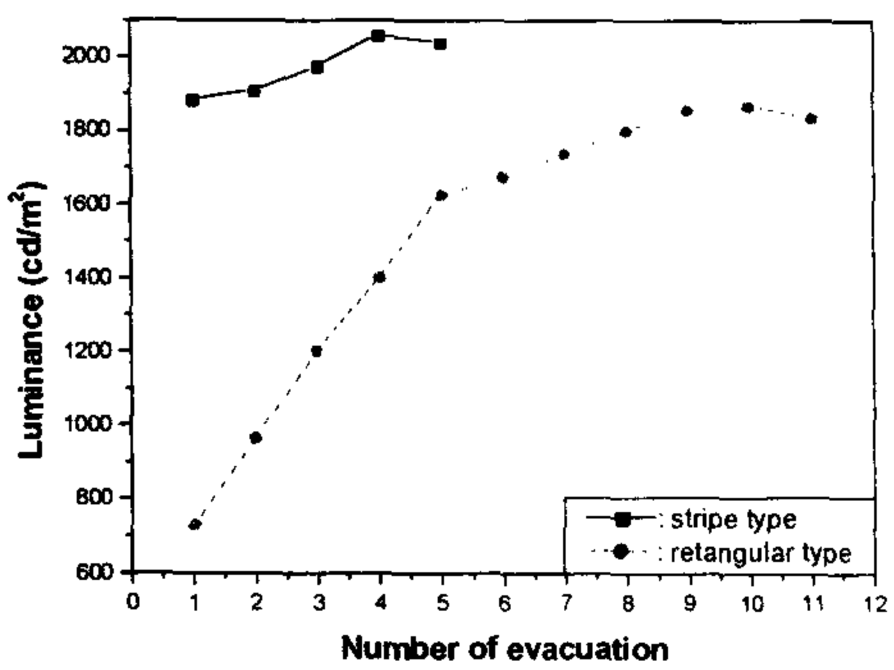
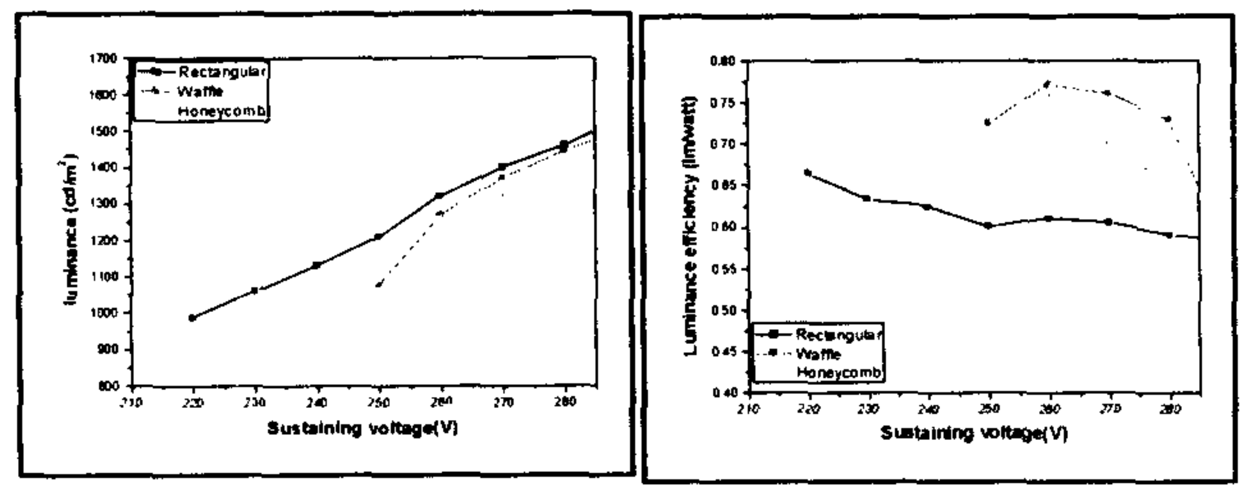


Figure 4. Effect of number of evacuation on the luminance of panel with closed-cell type barrier ribs.

Figure 5 shows the effect of barrier ribs types on the luminance and luminance efficiency of the panels. The luminance of such panels was similar to each other. The luminance efficiency was highest with waffle type barrier ribs, followed by honeycomb and rectangular type cells (Fig. 5(b). The area of phosphor layer coating with rectangular type cell was the largest, followed by waffle and honeycomb structure (Table 2), indicating the efficiency is not determined by the area of phosphor layer coating in the discharge cells. Rather, the efficiency seems to be affected by discharge characteristics inside the cells.



(a) (b)

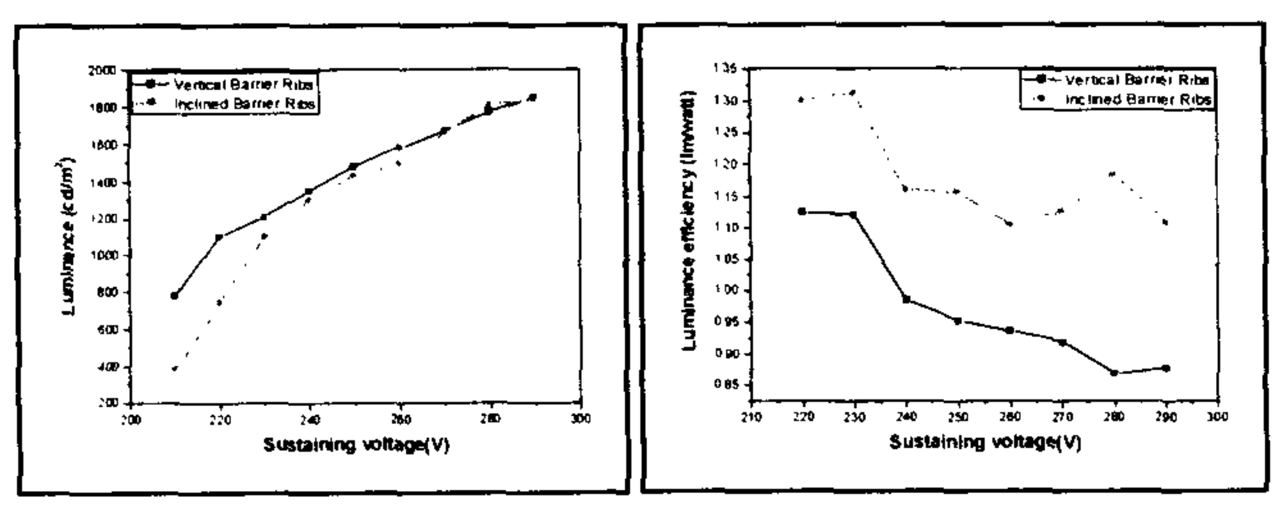
Fig. 5. Effect of barrier rib types on luminance (a) and luminance efficiency (b) of panels.

Table 2. Area of phosphor layer coating area calculated.

	longitudinal (μm)	Lateral (μm)	Rib thickness (μm)	Height (μm)	Area (μm²)
rectangular	649	216.3	16.6	140	359278.28
Waffle	433.3	324.5	19.05	140	328048.66
Honeycomb	220.67		20.66	140	311873.06

3.3. Luminance of stripe type cells with or without inclined angle

Stripe type barrier ribs with or without the inclined angle were prepared and the effects of inclined angle on the luminance and its efficiency were examined. In the case, the average width of the vertical ribs at top was 34.6 μm and that of inclined ribs 46.8 μm. As shown in Fig. 6(a), the luminance of the panels was similar to each other. The inclined angle did not affect the luminance significantly. The luminance efficiency of panel with inclined ribs was slightly higher than that of vertical barrier ribs. Although the thickness of barrier rib was thicker than that of vertical ribs by 12 μm, the luminance efficiency was improved by almost 20%. This indicates that the angle of the barrier ribs does affect the luminance efficiency.



(a) (b)

Fig. 6. Luminance (a) and luminance efficiency (b) of PDP panel with barrier ribs of inclined angle or of vertical ribs.

4. Conclusion

Inclined closed-cell type barrier ribs were prepared using inclined UV lithography process. The sintering and luminance of the panel with inclined barrier ribs were compared with that of the panel with vertical ribs. The sintering shrinkage of the inclined barrier ribs were smaller compared with vertical ribs. The inclination of the ribs also improved the luminance efficiency of the panel.

5. Acknowledgements

This work has been supported by 21th century frontier R&D program of ministry of science and technology of Korea. Authors would like to appreciate the financial support of the program.

6. References

[1] Y. H. Kim, Y. S. Kim, 2002 IMID Digest, pp 1088-1091(2002).

[2] H. Sato, T. Kakinuma, Jeung-Sang Go, S. Shoji. MEMS Japan 2003IEEE, pp 223-226(2003)

[3] M.-H Han, W.-S Lee, S,-K Lee,S,-S Lee, MEMS Japan 2003IEEE, pp 554-557(2003)

[4] H. Uchiike, T. Hirakawa 2002 SID Digest 25.1 , pp 844-847(2002)

[5] T. J. Chang, Y. S. Kim, 2003 IMID Digest 21.2, pp 362-364(2003)

[6] K. I. Kim, Y.S. Kim, 2003 IMID Digest P3.22, pp 788-790(2003)