Optical and dielectric properties dependent on glass composition for photolithographic process of barrier ribs in PDP

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Abstract

Refractive index of glasses is important to develop a photosensitive paste for barrier ribs in PDP. We investigated the refractive index and dielectric constant of glasses by contents of silica in B_2O_3-Al_2O_3-SiO_2 glasses. It is confirmed that the refractive index of the glass system is changed by the composition of glasses

1. Introduction

Plasma display panel (PDP) has attracted much attention for a high definition display device because of its intrinsic characteristics such as a flat, thin, light and large area display compared to a cathode-ray tube (CRT) [1-3]. To actualize the high definition of PDP, one of the important factors is to achieve the accuracy of barrier ribs. The roles of barrier ribs in the PDP are to prevent the crosstalk of phosphors and to maintain the discharge space. The present PDP is required that barrier ribs can be provided with a pattern having a high aspect ratio up to 120~150 μm of height and 60~80 μm of width [2-3]. Therefore it is important that barrier rib is developed to have materials with a high aspect ratio. Each of the present companies has different methods that form barrier ribs in PDP. Recently, some methods such as sand blasting, acid etching and photolithography processes are used to form barrier ribs.

The photolithographic process as shown in Fig. 1 can be used to form patterns of barrier rib with high accuracy and a high aspect ratio [3]. Controlling the refractive index of photosensitive paste for the photolithographic process is one of the significant technologies. To form barrier-ribs with only one step process and highly accurate pattern, it is required to have a similar refractive index between glass frits and organic components. The refractive index of glass frit should be in the range of 1.5~1.65 because the refractive index of organic components is commonly in the range of 1.5~1.65 [2-3]. The reflection and the scattering during the exposure process can be reduced by controlling the refractive index of a paste.

The purpose of this study is to provide optimal refractive index of glasses for the photolithographic process and a basic result of optical properties in glasses. The glasses were prepared in the B_2O_3-Al_2O_3-SiO_2 glass system. We examined the refractive index of these glasses with different contents of SiO_2 as well as the electrical and other optical properties.

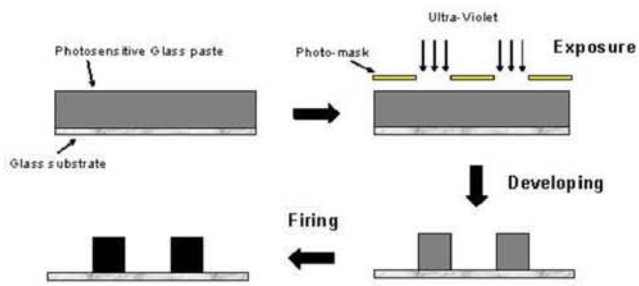

Fig. 1. Photolithographic process of barrier ribs in PDP

2. Experimental

The glasses were prepared by mixing high purity powder of B_2O_3, Al_2O_3, SiO_2, BaO, Li_2O, MgO, and CaO (Aldrich, USA). The compositions of the glasses were (50-x)B_2O_3-xSiO_2-23Al_2O_3-27(CaO-BaO-MgO-Li_2O), where x is 10, 15, 20 and 25 in wt%. The raw materials were melted in platinum crucibles at 1200℃. After 30-60 min in the electric furnace, the glass melts were quenched into a stainless roller to make glass cullet for frit and put into a graphite mould of a square and annealed for 1h for bulk. Predicted refractive index was calculated by the Appen's equation; $n = 1/100\sum n_i p_i$, where n_i and p_i is refraction factor and mole percentage of each component, respectively [4]. The refractive index was measured at wavelengths of

480 nm, 546 nm and 589 nm using a multi-wavelength Abbe refractometer (DR-M2, ATAGO). Using the UV-Visible spectrometer (UV-2450, Shimadazu, Japan), reflectance spectra was measured. Samples were tested for density using the Archimedes method. The dielectric constants of glasses were determined by LCR meter (4284A, Agilent, USA) at 1MHz

3. Results and discussion

Fig. 2 shows the predicted refractive index and the experimental refractive index at 480 nm, 546 nm and 589 nm with increasing the SiO_2/B_2O_3 ratio. Experimental refractive index is decreased by increasing the SiO_2/B_2O_3 ratio [5-6]. On the other hand, the theoretical values by the Appen equation are sharply changed when the SiO_2/B_2O_3 ratio is within 0.2~0.4 because of the refraction factor of B_2O_3. However, for photolithographic process of barrier ribs, the refractive index of all glasses was observed in the optimal range (1.5~1.65).

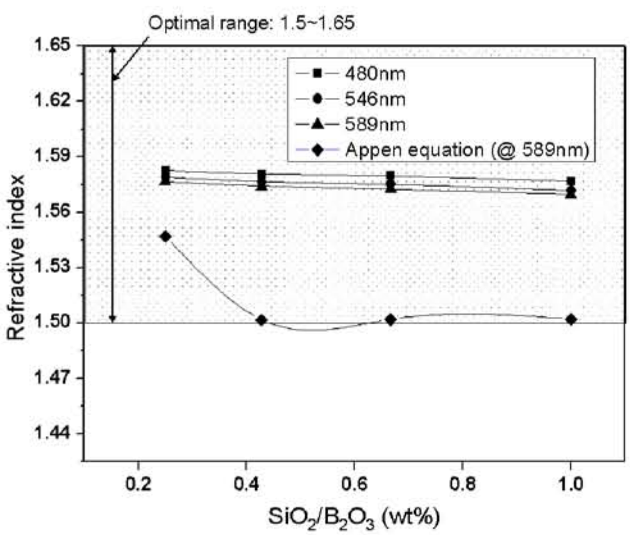

Fig. 2. Theoretical and experimental refractive index of glasses with increasing SiO_2/B_2O_3 ratio.

The reflectance of the glasses in the B_2O_3-SiO_2-Al_2O_3 glass system with increasing the SiO_2/B_2O_3 ratio was observed at the range from 3.2 to 5.2 in the range from 400 to 700nm for the wavelength. However, the coefficient of reflection (reflectance) depends upon the refractive index. The relationship between the reflectance and the refractive index was given by the following equation;

$$R = (n-1/n+1)^2 \quad (1)$$

where R is reflectance, n is refractive index [4,7]. In Fig. 3, the refractive index of glasses with increasing the SiO_2/B_2O_3 ratio was calculated by the equation (1) with the reflectance of the glasses.

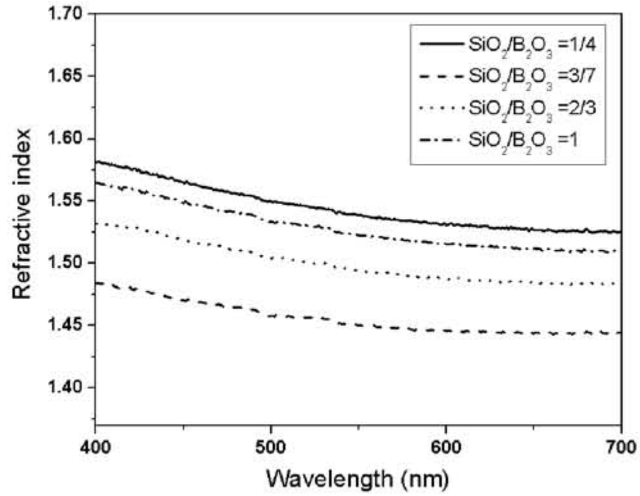

Fig. 3. Refractive index calculated by the reflectance of the glasses with increasing the SiO_2/B_2O_3 ratio.

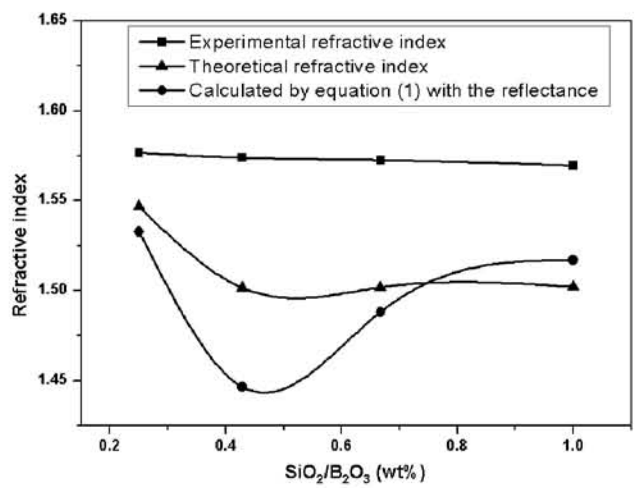

Fig. 4. Refractive index of glasses with increasing the SiO_2/B_2O_3 ratio at 589nm of the wavelength.

Comparing to various refractive indices of glasses, which were experimental, theoretical and calculated by equation (1) with the reflectance in Fig. 3. The glasses with increasing the SiO_2/B_2O_3 ratio should have low refractive index. However, the refractive index of the glass consisted of the ratio of SiO_2/B_2O_3: 3/7 was lowest in the all glasses. It should be related to the glass composition of the B_2O_3.

Moreover, the refractive index of the glasses calculated by equation (1) with their reflectance should be more similar to the theoretical refractive index than the refractive index, which was directly measured as shown in Fig. 4. The refractive index calculated by the reflectance was determined with the range of 1.47~1.53 at the wavelength of 589nm. Comparing to the experimental refractive index, the difference of the refractive index should be contributed to the experimental errors such as the thickness of sample and surface roughness.

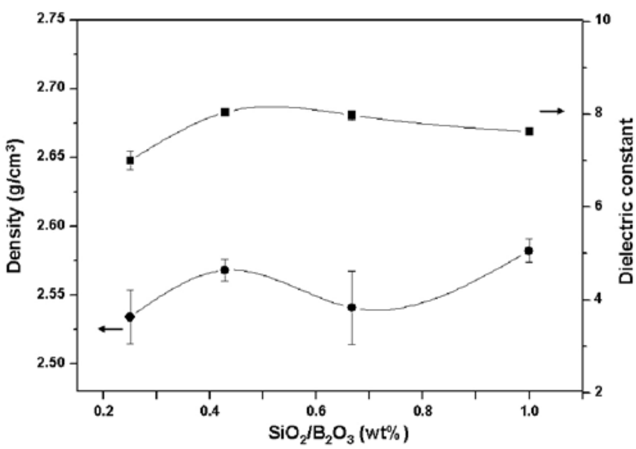

Fig. 5. Dielectric constant and density of glasses with SiO_2/B_2O_3 ratio.

As shown in Fig. 5, the dielectric constant and the density of glasses have about 7.66 and 2.56g/cm^3, respectively. However, the dielectric constant of glasses is related to their density and refractive index. With pervious results of the relationship between the dielectric constant and density, dielectric constant and refractive index [8], we plotted the relationship of density, refractive index and dielectric constant based on the search a database of Interglad 6.0 in Fig. 6.

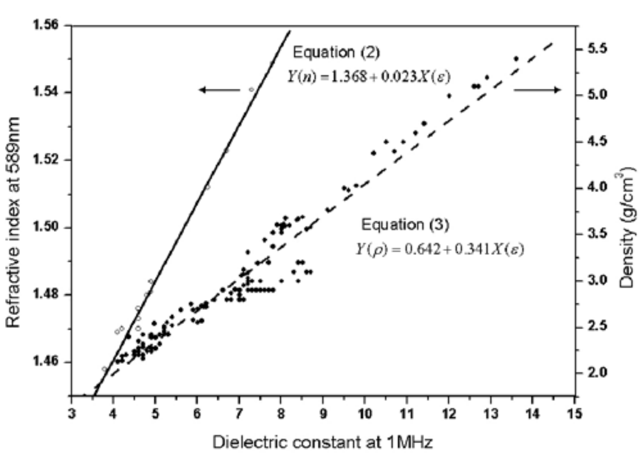

Fig. 6. Refractive index and density of various glasses with dielectric constant and the trend line of the relationship of each groups.

The relationship between the dielectric constant and the refractive index at 589nm, and the density is shown in the equations (2, 3). We calculated the dielectric constant by two equations with the refractive index and density for the experimental glasses which were determined. Table 1 listed the various dielectric constants for the glasses with increasing the ratio of SiO_2/B_2O_3.

Table 1. Dielectric constant of glasses with SiO_2/B_2O_3 ratio by several methods.

Glasses with SiO_2/B_2O_3	Dielectric constants				
	$^a\varepsilon$	$^b\varepsilon$	$^c\varepsilon$	$^d\varepsilon$	$^e\varepsilon$
1/4	7.78	9.07	7.17	5.55	7.00
3/7	5.81	8.95	3.41	5.65	8.04
2/3	5.82	8.90	5.22	5.57	7.98
1	5.83	8.77	6.48	5.69	7.62

$^a\varepsilon$: calculated by the equation (2) with the Appen's refractive index.
$^b\varepsilon$: calculated by the equation (2) with the experimental refractive index at the wavelength of 589nm .
$^c\varepsilon$: calculated by the equation (2) with the refractive index at 589nm, which was observed by the reflectance.
$^d\varepsilon$: calculated by the equation (3) with the density.
$^e\varepsilon$: the experimental dielectric constants at 1MHz.

The dielectric constants of the glasses calculated by various methods were different. It should be limited by the glass composition and the range of the previous results. For the photolithographic process of barrier-ribs, we suggest that the glasses based on B_2O_3-Al_2O_3-SiO_2 glass system should be a candidate with optimal refractive index and low dielectric constant.

4. Summary

We investigated the optical and electrical properties of glasses based on the B_2O_3-Al_2O_3-SiO_2 glass system with the ratio of SiO_2/B_2O_3. The glass consisted of the ratio of SiO_2/B_2O_3: 3/7 has lowest refractive index, reflectance and highest dielectric constant in the experimental glasses. It should be related to the glass composition. However, increasing the ratio of SiO_2/B_2O_3 (>3/7) in the glass system was contributed to the increase of the reflectance and refractive index and to the decrease of the dielectric constant.

5. Acknowledgements

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6. References

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