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Fabrication and Characterization of Dielectric Materials of Front and Back Panel for PDP

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Abstract

The glass compositions of PbO-SiO_2-B_2O_3 system and P_2O_5-PbO-ZnO system for the transparent dielectric materials for front panel and P_2O_5-ZnO-BaO and SiO_2-ZnO-B_2O_3 for the reflective dielectric materials for back panel of PDP (Plasma Display Panel) were investigated. As a result, transparent dielectric materials for front panel showed good dielectric properties, high transparency, and proper thermal expansion matching to soda lime glass substrate. And the reflective dielectric layers for back panel were prepared from two series of parent glass and oxide filler. It was found that these glass-ceramics are useful materials for dielectric layers in PDP device, as they have similar thermal expansion to soda-lime glass plate, high reflectance, and low sintering temperature. In particular, the addition of BPO_4 and TiO_2 as fillers to SiO_2-ZnO-B_2O_3 system is considered to be the most effective for acquiring good properties of lower dielectric layer for PDP device.

Keywords : transparent dielectric materials, reflective materials, glass, PDP

1. Introduction

The transparent dielectric material for front panel in PDP is very important. As visible light emitted from phosphors pass through it, it affects the image quality. It covers the electrodes, thus affecting so the property of electrode. And dielectric property stabilizes the plasma discharge. To achieve these characteristics, transparent dielectric materials require high transparency, good thermal expansion matching to glass substrate, high breakdown voltage etc.

As it is very difficult to satisfy these requirements using single material, two kinds of dielectric layers are used. In this case dielectric materials contacting electrodes (bottom layer) act as an electrode protecting layer, and dielectric materials under the MgO layer (top layer) act as a high transparency layer[1].

Of a variety of glass-ceramics, especially high PbO content glass ceramics containing more than 40 % PbO have been broadly utilized in the past few years in PDP device because of its low sintering temperature of below 580 ℃ which is necessary to prevent deformation of glass plate[2]. However, due to environmental and human health problem as well as deterioration of properties by thermal process, high PbO content glass-ceramics are no longer suitable for dielectric layer in PDP device. We have couducted extensive studied on a promising alternative for non or low PbO-contained glass-ceramic, and consequently obtained a new glass-ceramic which is practical to dielectric layer in PDP device, satisfying the requirements for dielectric layer as previously mentioned.

2. Experimental Procedure

The ranges of compositions of PbO-SiO_2-B_2O_3 glass for clear dielectric materials are 60~80 PbO, 8.3~20 SiO_2, 8.3~20 B_2O_3, 0~15 ZnO, 0~10 Bi_2O_3, 0~5 CeO_2, 0~5 SrO,

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Table 1. Composition of parent glass and oxide filler employed in this study.

No	d_{50} (μm)	Composition (wt %)										
		SiO_2	P_2O_5	ZnO	B_2O_3	BaO	K_2O	PbO	Na_2O	Li_2O	CaO	Al_2O_3
G1	7.3	-	53	28	1	8	-	-	-	6	2	2
G2	6.9	20	-	35	18	-	7	7	5	2	3	3
M1	2.5	parent glass G1+ TiO_2 filler										
M2	2.2	parent glass G2+ TiO_2 filler										
M3	2.7	parent glass G2+ TiO_2 filler + BPO_4 filler										

D_{50} : average particle size (measured by particle size analyzer)

Table 2. The properties of PbO-B_2O_3-SiO_2 systems.

PbO-B_2O_3-SiO_2			
Tg (℃)	T_{dsp}(℃)	α ($\times 10^{-7}$/℃)	K
321 ~ 535	355 ~ 559	51.3 ~ 139	8.8 ~ 15.9

Tg : glass transition temperature, Tdsp : dilatometric softening temperature
α : coefficient of thermal expansion, K : relative dielectric constant at 1MHz

Table 3. Result of plasma discharging test in 7.5″ diagonal PDP panel.

Sample	Voltage Margin (V)	Discharge Current [1] (mA)	Brightness [2] (cd/m^2)	Efficiency [3] (lm/W)
DD	60	27	199	1.55
Reference	47	31	204	1.38

* 1,2,3 - measured at 170V

DD : samples tested in this experiments
Reference : samples using commercial dielectric pastes

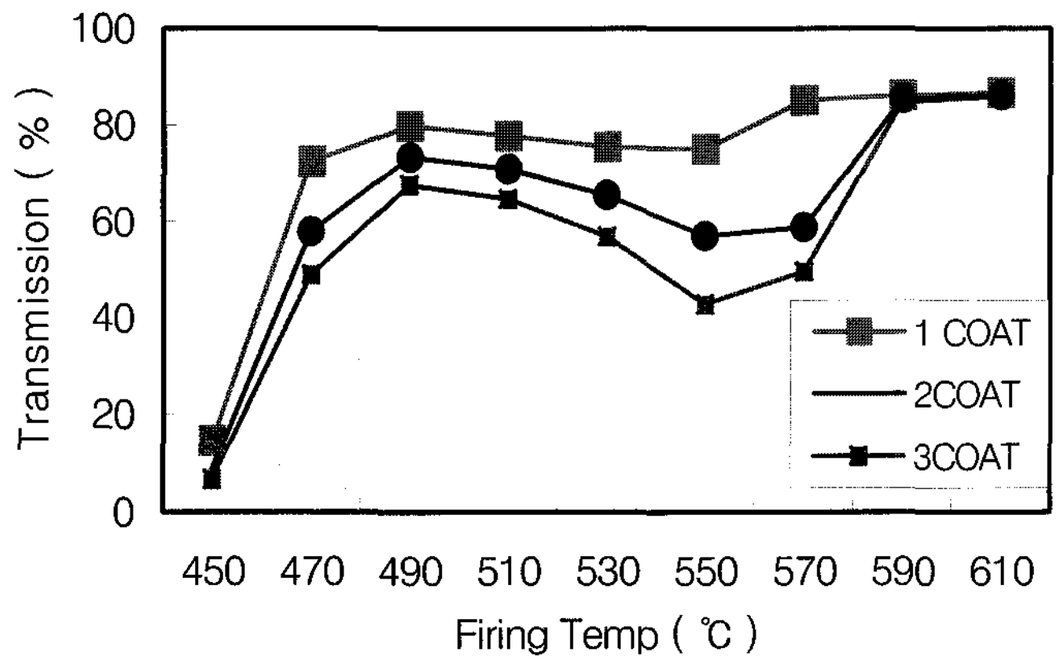


Fig. 1. The variation of transmission of clear dielectric materials with firing temperature and number of coatings.

0~2 Na_2O, 0~2 K_2O. Table 1 represents the compositions of the parent glass and oxide fillers used for reflective dielectric materials.

The mixture of raw materials was melted in a platinum crucible at 1200~1300 ℃ for 1 hour and the melt was quenched into stainless roller to make glass flakes. The glass flakes was pulverized in a ball mill to obtain glass powder. Differential thermal analysis (DTA) was conducted on parent glass and mixed powder. The coefficient of thermal expansion (CTE) of bulk glass and sintered glass ceramics with the dimension of 5×5×25mm was measured by dilatometer. The relative dielectric constant was measured by impedance analyzer using 10×10×1mm glass plate. The glass powder was mixed with an organic vehicle which consists of ethyl cellulose, α-terpineol and butyl carbitol acetate to make paste. The glass pastes with optimized rheology were coated onto a soda lime silicate glass substrate 2.8 mm thick by screen printing method and then dried at 130℃ for 10 minutes. The coated glass substrate was heated at a firing temperature for 30 minutes. Optical measurements were taken on sintered samples in the visible light range using a spectrophotometer with integrated sphere. Samples etched in 10 % HF solution were subsequently used in SEM to observe surface morphology and crystal shape within sintered samples.

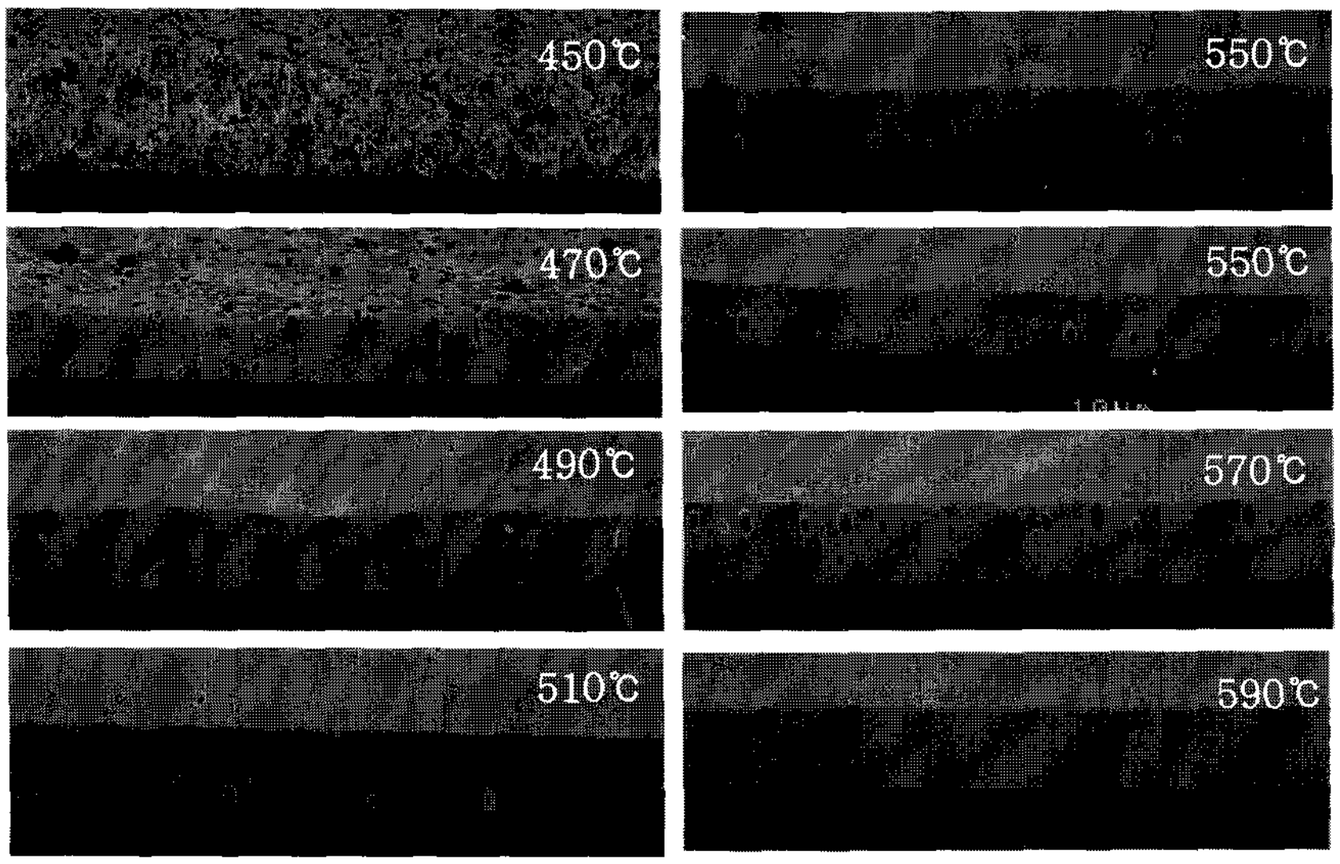
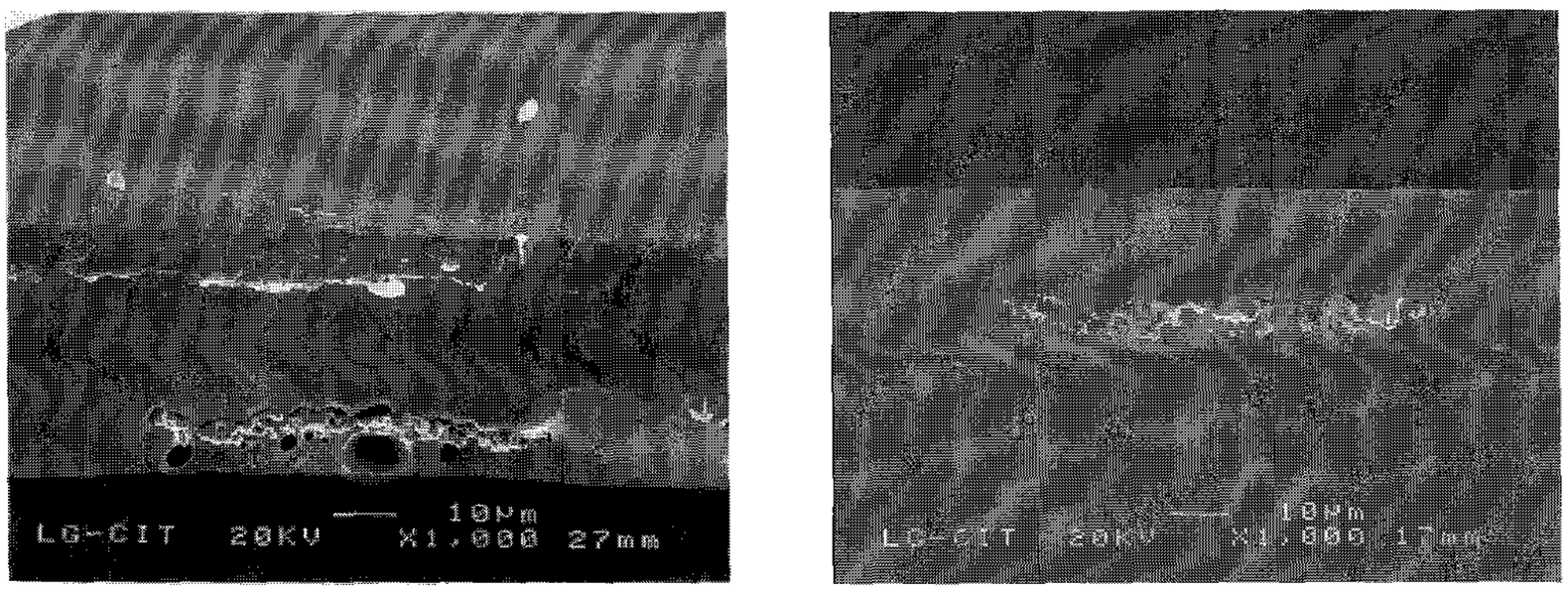


Fig. 2. The Variation of surface morphology and shape of inner pores of clear dielectric materials with firing temperature(2 coatings).



(a) (b)

Fig. 3. SEM Image of cross section of dielectric layer on electrodes with different Tg(Fired at 590 ℃) (a) upper : Tg 402 ℃ under : Tg417 ℃ (b) upper : Tg 385 ℃ under : Tg 432 ℃.

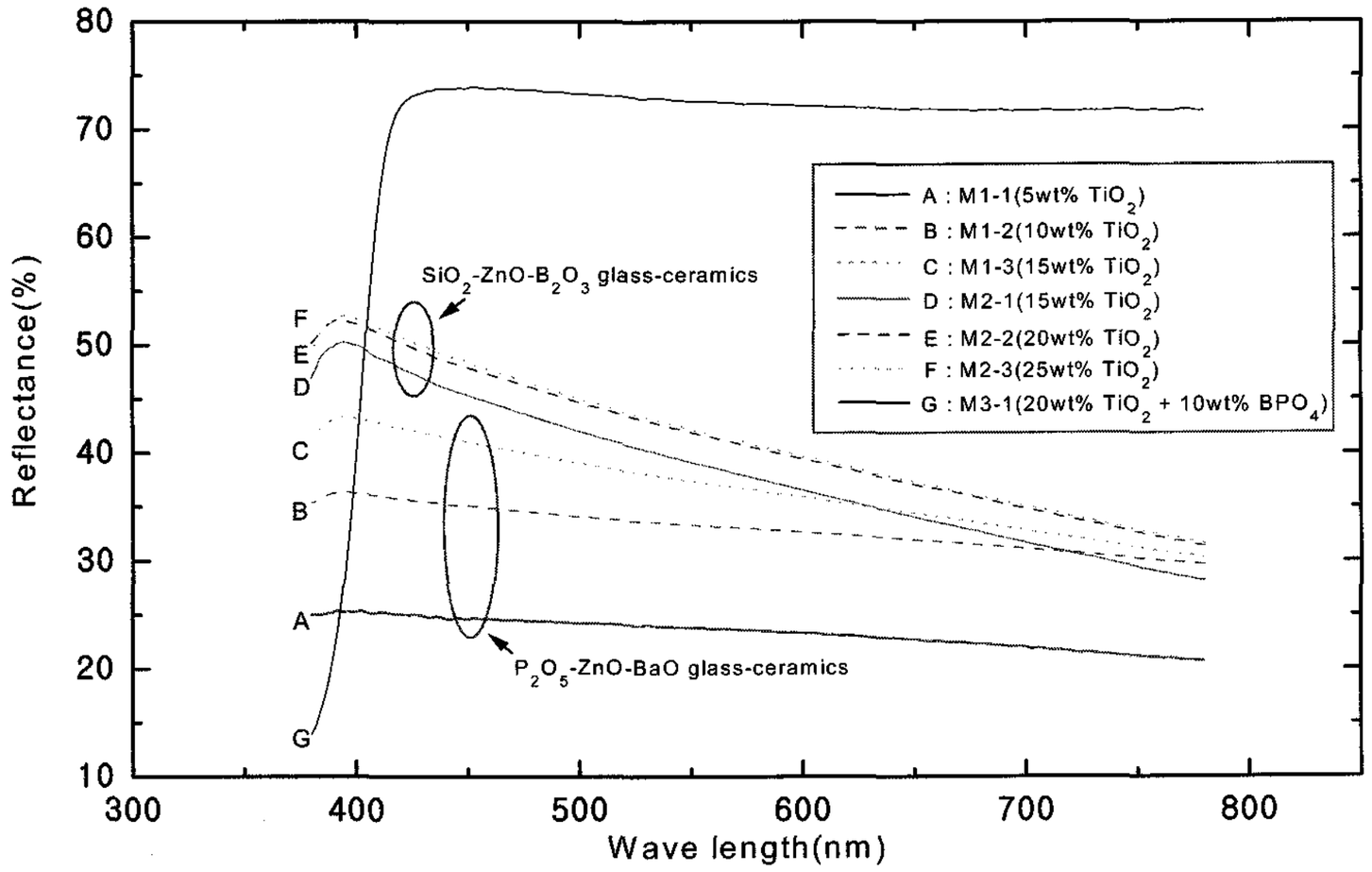


Fig. 4. Reflectance of M1,M2 and M3 samples as a function of wavelength.

3. Results and Discussion

3.1 Transparent dielectric material

Table 2 shows the properties of clear dielectric glasses. The transmittance of transparent dielectric glass varies with the firing temperature and thickness. According to this relation, the best condition for firing can be deduced. Figure 1 and Figure 2 shows the variation of transmission and microstructure of clear dielectric materials with firing temperatures and number of coatings. The firing process can be divided by 3 regions. At first stage the transmittance increases rapidly to 490 ℃ with firing temperature. Observation the SEM image of cross-section shows that the shape of pore is not round and condensation follows ceramic sintering mechanism. The surface is not flat and screen mesh mark is remained. Bottom layer is fired at this temperature because of high softening temperature. Next, the viscosity decreases as firing temperature increases. Due to the increase of surface fluidity, the path of pore removal is closed. As a result, the pores inside are trapped, causing the transmission decrease. Finally, as temperature increases the viscosity of glass drops and pores inside the glass can rise to the surface and disappear. Therefore, to protect electrodes under dielectric layer, it is recommended to fire the dielectric layer at first maximum temperature because the fluidity of glass is less than second maximum. The lower the fluidity of dielectric layer, the better the stability of electrodes.

In Fig. 3, comparing two kinds of glass with different Tg, it can be concluded that bottom dielectric layer of higher Tg (B) gave less damage than that of lower Tg (A). It is suggested that to avoid damage of electrodes during firing Tg of dielectric material is higher than 430 ℃.

The results of discharge test on 7.5″ diagonal panel showed some favorable results, which are shown in Table 3.

3.2 Reflective dielectric material

The P_2O_5-ZnO-BaO system has higher dielectric constant than SiO_2-ZnO-B_2O_3 system, which increased proportionally with increasing TiO_2 content. It is assumed that this result is attributable to the increase in newly formed crystal and remnant TiO_2(anatase) crystal in glass matrix[3,4]. In P_2O_5-ZnO-BaO system, the micro crack occurred due to considerable differences in thermal expansion coefficient, approximately $10X10^{-7}$/℃, with soda-lime glass substrate under sintering at 550 ℃. The P_2O_5-ZnO-BaO system exhibited 5 % lower reflectance than SiO_2-ZnO-B_2O_3 system (Fig.4), and it can be deduced that this result arose from the difference at reflective index of parent glass. In particular, P_2O_5-ZnO-BaO glass-ceramics showed monotonous increase with

Table 4. Result of plasma discharging test in 7.5″ diagonal PDP panel.

No	Brightness (Cd/m^2)	Back-scattering (Cd/ m^2)
M3	103	1.4
Reference	80 - 100	4 - 6

Table 5. The properties of dielectric glasses.

No	Tg(℃)	T_{dsp}(℃)	α ($\times 10^{-7}$/℃)	K(at 1MHz)	T(%)
Lower	432	474	83.7	12.1	85.5
Upper	385	416	83.4	14.1	85.2
G3	443	476	78.9	6.81	-

increment of TiO_2 filler, whereas SiO_2-ZnO-B_2O_3 glass ceramics, irrespective of TiO_2 content, showed no remarkable change. This can be speculated from the fact that the fraction and size of crystal phase containing Ti rose proportionally with increase of TiO_2 content in P_2O_5-ZnO-BaO layer, but remained constant without any remarkable changes in SiO_2-ZnO-B_2O layer. In sharp contrast, M3 sample exhibited high reflectance over visible light range because of dense structure and ZnO crystal phase precipitated in glass-ceramic matrix by heat treatment for sintering. As the results of discharge test on 7.5″-diagonal panel, some favorable results were obtained in the panel with sample M3 as shown in Table 4.

4. Conclusion

We investigated the glass forming ranges of PbO-B_2O_3-SiO_2 system. As a result of this investigation, we developed transparent dielectric material for bottom layer and top layer, and reflective dielectric material G3 for back panel. Table 5 shows the summary the result.

It was concluded that the glass-ceramics composed of SiO_2-ZnO-B_2O_3 glass and oxide filler are potential candidates for lower dielectric layers in PDP device. In particular, it is notable that the addition of TiO_2 (20 wt %) and BPO_4(10 wt%) as fillers to SiO_2-ZnO-B_2O_3 glass played a major role in acquiring lower dielectric layer with good properties in PDP device.

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