Low-k and High Reflectance Material as a Filler for Flat Panel Display Devices

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Abstract

The composites were fabricated with titania used commercially and calcite as a filler in BZB glass matrix and their thermal, optical and electrical properties were investigated. From our results, calcite may be the profitable and highly efficient reflectance material as a filler for flat panel display devices.

1. Introduction

In the flat panel display industry, the reflectance materials applied to the flat panel display components such as BLU (Back Light Unit) reflector for LCD (Liquid Crystal Display) and white dielectric for PDP (Plasma Display Panel) require the high reflectance, low dielectric constant and low price to acquire the competitive power such as the high brightness, high resolution and low power consumption [1, 2]. The low power consumption can be acquired by the low dielectric constant because the power consumption can be reduced with the decreased capacitance and the capacitance is directly correlated with the dielectric constant [3].

Commercially, titania is added to reflector as a filler due to its high reflectance [4]. However the titania added reflector has some problems such as high price of raw material and power consumption due to high price and dielectric constant of titania [5]. Calcite has relatively low price and dielectric constant despite its high reflectance [6, 7]. The purpose of this study is to confirm the possibility of developing the economic reflector by substituting calcite for titania.

2. Experimental

The BZB (B_2O_3-ZnO-BaO) glass system was prepared by mixing appropriate amount of each powder with a reagent grade. The batch was melted in an alumina crucible at 1200~1300°C for 20~50 min. The melt was quickly poured and quenched on a ribbon roller. The glass cullet was pulverized by using a sieve (140 mesh) and ball-milled by a planetary mono mill (Tesch, Germany) for 16h in wet condition. Ball milled frit (D_{50}:2.5um) were dried by a IR-oven. The glass transition temperature was determined with a differential thermal analyzer (TG-DTA, Thermo Plus TG-8120, Rigaku, Japan) under 10°C/min. The cylindrical glass bulk was prepared and determined dilatometric softening point and coefficient of thermal expansion by a dilatometer (PT-1600, Linseis, Germany). Three kinds of calcite were prepared with different sizes (Table 1). The thermal behavior of the filler was investigated by a differential thermal analyzer (TG-DTA, Thermo Plus TG-8120, Rigaku, Japan).

Table 1. Degree of filler size

Filler	Degree of size
C1	Fine
C2	Median
C3	Coarse

Calcite (C1~3) and titania were mixed with the BZB glasses by a turbula shaker mixer (Basel, Switzerland) for 24h with different contents (10, 20, 30 wt%) in wet condition. The mixed powders were dried by a IR-oven. The dried powder was milled with vehicle by a three roll mill and coated on the glass substrate by a die-coater. The coated films were fired at 550°C for 1h at the heating rate of 5°C/min. The reflectance was measured with an UV-visible spectrometer (Shimadzu, Japan) in the range of 300~800 nm of the wavelength. The crystal phase of thick films was analyzed by a thin film X-ray diffractometer (X'pert MPD, Philips, Netherlands). The microstructure of thick films was analyzed by a scanning electron microscope (SEM, S-4200, Hitach, Japan). To determine dielectric constant, the pellet was prepared with the mixed powder and fired at 550°C for 1h at the heating rate of 5°C/min. The dielectric constant of the sintered body was determined by a LCR meter (4284A, Agilent, USA) at 1MHz.

3. Results and discussion

The thermal properties of the BZB glass system are listed in Table 2. The glass transition temperature (T_g) was 457°C and dilatometric softening temperature was 402°C and coefficient of thermal expansion was 83.4×10^{-7}/k. The result suggests that the BZB glass can be fired at 550°C.

Table 2 Thermal properties of mother glass

Glass transition temperature (T_g)	457°C
Dilatometer softening point (T_{dsp})	502°C
Coefficient of thermal expansion (CTE)	83.4×10^{-7}/k

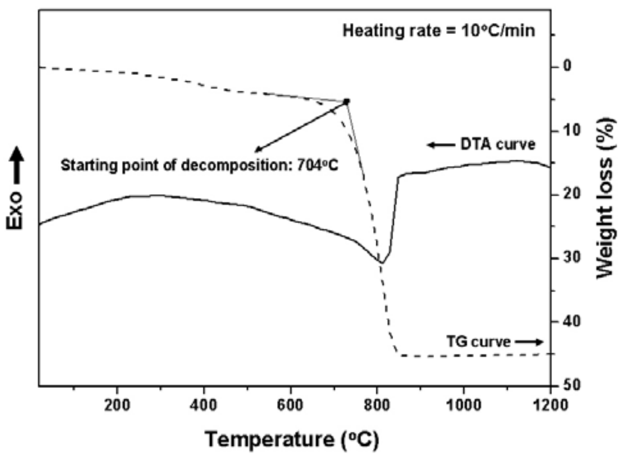

Fig. 1. TG-DTA result of calcite with increasing temperature at the heating rate of 10°C/min.

Thermal behavior of calcite is shown in Fig. 1. The starting temperature of decomposition of calcite is 704°C. The decomposition of calcite is given by the following chemical equation;

$$CaCO_3 \rightarrow CaO + CO_2$$

Calcite may maintain a steady state of chemical structure in the glass matrix after firing at 550°C because the firing temperature is under the decomposition temperature of calcite.

As shown in Fig. 2, the crystal phase (JCPDS No. 72-1214) of calcite exists in the glass matrix. Increasing the intensity of XRD patterns for calcite should be resulted by the increasing amount of calcite added as a filler in the glass matrix. These XRD patterns suggest that calcite should maintain its crystal phase in a BZB glass matrix as a filler. From the thermal properties and XRD analysis, the calcite can be stable to fire at 550°C in the glass matrix.

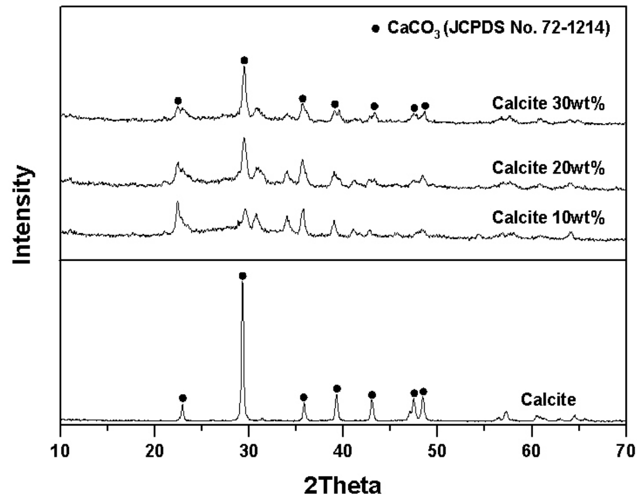

Fig. 2. XRD results of thick films fabricated with contents of calcite (10, 20, and 30 wt%) in glass matrix and Calcite.

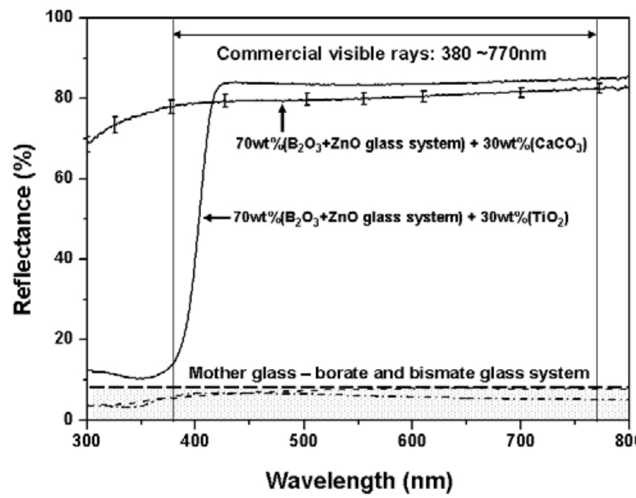

Fig. 3. Reflectance of thick films fabricated with calcite and titania (30wt%) in the glass matrix.

The reflectance of the composites used titania and calcite as a filler compared in the range of the commercial visible rays (Fig. 3). As the addition of the filler, the reflectance of the thick film dynamically increased. Comparing between the reflectance of both thick films, the thick film used calcite as a filler was more uniform distribution of reflectance in the range of the commercial visible rays. Therefore, the calcite may be good alternative material instead of titania as a filler for improving the reflectance.

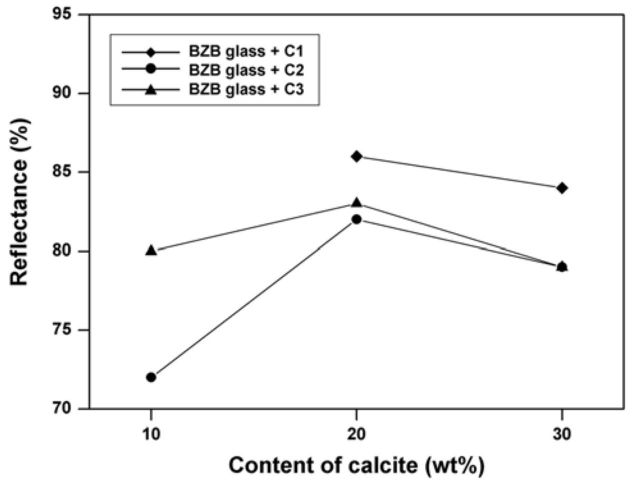

Fig.4. Reflectance of thick films used calcite (C1~3) as a filler with contents (10, 20, and 30 wt%) at 550nm of the wavelength

To compare the effect of the fillers, the reflectance of the thick films used three different sized calcite (C1~3) as a filler was determined (Fig. 4). The thick film used C1 with 20wt% of the content as a filler had the highest reflectance. The reflectance was different with the size of the fillers with the same content of the filler. The critical size and content of filler may exist for the reflectance.

Regarding the mechanism of light scattering in the composite, the short mean free path should be required to increase the light scattering. The mean free path $\ell \equiv (\sigma\ \rho)^{-1}$, where ρ is the number density of particles per unit volume, is the average distance that photon will transfer before being scattered by the filler [8].

Table 3 Dielectric constant of the sintered body used calcite and titania (20wt%) as a filler.

Samples	Dielectric constant at 1MHz
BZB glass + Titania (20wt%)	10.82±0.45
BZB glass + Calcite (20wt%)	3.75±0.06

The sintered body used calcite as a filler had much lower dielectric constant than the sintered body used titania as a filler (Table 3). The dielectric constant of thick film was conducted by the addition of the filler. Therefore, the composite with titania and calcite was 10.82±0.45 and 3.75±0.06 for dielectric constant, respectively. It should be resulted by the different crystal structure.

4. Summary

The optical and dielectric properties of the composites, titania and calcite ceramic fillers added in the B_2O_3-ZnO-BaO glass system with different sizes and contents, were investigated. The calcite added composite showed the similar reflectance to the titania added composite. The critical size and content of the filler existed for high reflectance. The calcite added composite showed much lower dielectric constant than the titania added composite. From our study, it is available to confirm that calcite is a promising material as a filler due to its high reflectance, low dielectric constant and low cost.

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6. References

1. D. Y. Lee, D. S. Kim, B. G. Kang, E. T. Kim, B. R. Kim, J. H. Kim, B. H. Lim and B. C. Ahn, *IMID'06 Technical Digest*, 290-293 (2006).
2. R. Veerasingam, R. Campbell and R. McGrath, *Plasma Sources Sci. Technol*, 6, 157-169 (1997)
3. C.X. Li, P.T. Lai and J.P. Xu, Microelectronic Engineering, 84, 2340-2343 (2007)
4. H. H. Shin, S. G. Kim, J. S. Park, J. S. An, K. S. Hong and H. S. Kim, *J. Am. Ceram. Soc.*, 89 (10), .3258-3261 (2006).
5. O. Carp, C.L. Huisman and A. Reller, *Prog Solid State Chem* **32** (1–2), 33–177 (2004).
6. C. T. Dervos, J.A. Mergos and A.A. Iosifides, *Materials Letters*, 59 (22), . 2842-2849 (2005)
7. A. Larena and M. A. Villar, *Optical Materials*, 17, p. 437-442 (2001)
8. A. Small, S. Hong and D. Pine, *J. Polymer Science, Part B: Polymer Physics*, 43 (24), 3534-3548 (2005)