

Shrinkage Free Sintering of Low Temperature Cofired Ceramics by Glass Infiltration

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Abstract

The shrinkage variation of Low Temperature Cofired Ceramics(LTCC) limits the size of the substrates that impose limitations on embedded passive components. This paper focuses on the method of minimizing or controlling planar shrinkage and reducing distortion during firing. The laminated sheets of alumina and glass were sintered at varying temperature, and depending on the amount of the glass ceramics. When the sintered of multi-layer structure with Al_2O_3 /Glass/ Al_2O_3 , the glass infiltrated entirely into Al_2O_3 layer at the temperature of about 950 °C or higher.

Keywords : shrinkage, LTCC, Glass, Infiltration

1. Introduction

Following the recent highlighted importance of developing the embedded-related technology for higher integration technique for built-in devices and the technique responsive to high density mounting, expectation for LTCC (Low Temperature Co-fired Ceramics) has also increased. LTCC enables passive devices to be integrated with the substrate, which could not be materialized in the polymer substrate or HTCC (High Temperature Co-fired Ceramics) substrate.[1] Furthermore, it enables high level performance to be achieved using Ag and Cu conductor.

This ceramic substrate, however, has one critical weak point which is the shrinkage problem when fired. Therefore, to achieve high integration inside the substrate, it is a critical technical requirement that the size is accurate. Therefore, high integration of passive components and other functional parts using ceramic substrate can be achieved by control the ceramic shrinkage rate using ceramic substrate.[2,3,4] Therefore, in this study, we attempted to find a way to control the shrinkage in x-y planes by utilizing the Al_2O_3 layer and glass layer by the glass infiltration method.

2. Experimental and Results

Al_2O_3 (Sumitomo chemical) and glass powder of ZnO-PbO-B₂O₃-SiO₂ system were used as starting materials. The particle size of Al_2O_3 powder was 1.63 μm and density was 3.97g/cm³, The particle size of glass powder was 2.53 μm the density was 4.87g/cm³ and the Tg(°C) was 455°C. The Al_2O_3 and glass powders were mixed with resin (polyvinyl butyral), plasticizer (di butyl phthalate) and solvent (toluene and ethanol) for 24 hours. The resultant

slurry was then tape-casted to green sheet with thickness of 41 μm (Al_2O_3) and 38 μm (glass) using comma caster system. The laminated green sheets were prepared as shown in Fig.1. They were pre-laminated by uniaxial press and finally laminated by warm isostatic press at 250bar. The laminated tapes were cut into square by 15 x 15mm. Following a binder burnout at 450°C the samples were sintered at different temperature of 800 ~ 1000°C for 15 min.[5] The shrinkage of the green and sintered tapes for the samples in Fig. 1 (a) and (b) were measured by geometrical method. The microstructure and phase purity were analyzed by Field Emission Scanning Electron Microscope (FE-SEM) and X-ray powder diffraction (XRD), respectively.

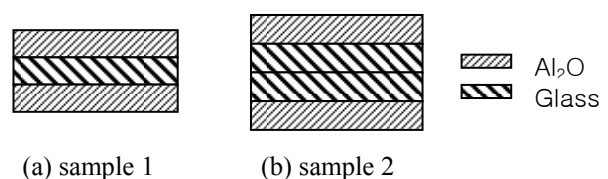


Fig. 1. Schematic cross section of laminated Green Sheets.

Al_2O_3 powder was pressed in pellet type, where glass powder was added. Then its wetting angle was measured using a high temperature electron microscope. This wetting angle data is shown in Fig. 2. The angle value of Glass started to increase from 550°C, and it reached its peak of 102 degree at 700°C, beyond which point, it began to rapidly drop. From 800°C, the decreasing range of wetting angle smoothened, but still decreased. That is, glass started to melt at around 700°C, and became completely melted at around 800°C.

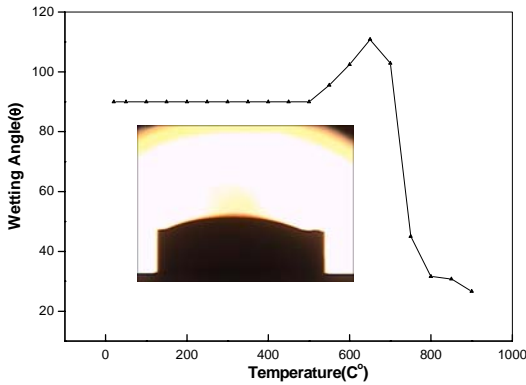


Fig. 2. Wetting angle of Glass Powder.

The x-y shrinkage for all tapes was not more than about 0.2%, while z axis shrinkage was increased dependent on firing temperature. Fig. 3 shows density and Z axis shrinkage rate of the sample 2 after firing. In this case, it shows the tendency to increase in Z axis shrinkage rate and density as the temperature increases. The maximum value of sample 2 having 37.9% of Z axis shrinkage rate and 3.95 g/cm³ of density was obtained at sintering temperature of 1,050°C.

Fig. 4 shows the SEM images of sample 2 at various temperature after firing. Pores are observed in the glass layer until 900°C, but glass infiltrates into Al₂O₃ at 950°C. Then, the pores in the glass layer disappears, and the thickness of the sheet decreases. This is attributed to the fact that Al₂O₃ layer can be sintered at a high temperature and no sintering occurs when sintered at low temperature. Instead, the pores inside the Al₂O₃ layer are filled with liquid phase of the glass making its densification, and then the glass layer disappears after sintering.[6] In Fig. 2, it can be seen that the glass melted at around 800°C, and this continued even at higher temperatures. It is also noteworthy that as glass flow is improved with increasing temperature. Accordingly, after glass infiltration into Al₂O₃ at 950°C, the densification continues until 1050°C.

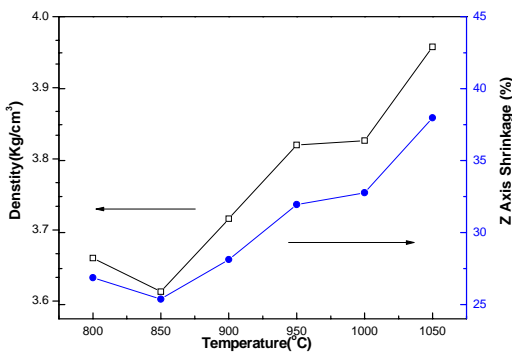


Fig. 3. Density and Z axis shrinkage of sample 2.

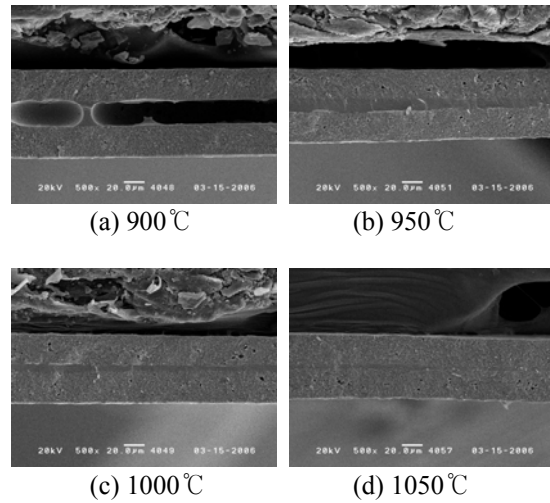


Fig. 4. Scanning Electron Micrograph of sample 2 with various cofired temperature.

3. Summary

To adjust the X and Y axis shrinkage rates of LTCC sheets, an exploratory survey was performed against glass infiltration method using Al₂O₃ and PbO-B₂O₃-SiO₂ glass. The survey was conducted within the temperature ranges of 800°C and 1050°C. When the proportion of Al₂O₃ and glass was set up at about 100:93, glass was infiltrated entirely into Al₂O₃ layer at the temperature of about 950°C or higher. Therefore, to produce a more improved sample with higher sinterability, the contents of Al₂O₃ and glass must be adjusted.

4. References

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