

## Dielectric properties of $\beta$ -SiAlON at high temperature using perturbation method

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**Abstract.**  $\beta$ -SiAlON with various z-values ( $z = 0.5\sim 4.0$ ) were produced by hot pressing. The dielectric properties (dielectric constant and tangent loss) of  $\beta$ -SiAlON were characterized by the post-resonator method at room temperature and by the perturbation method from room temperature to 1200 °C at 2.45 GHz, respectively. Effect of z-values and temperatures with  $\beta$ -SiAlON were investigated.

### Introduction

SiAlON shows superior mechanical properties and high-temperature stability than  $\text{Si}_3\text{N}_4$ , which enables SiAlON to be a promising material for high temperature structural applications. SiAlON has similar microstructure and properties with  $\text{Si}_3\text{N}_4$ , which is used for microwave applications due to microwave transparency [1]. Therefore, SiAlON is considered as a good candidate for electromagnetic window applications at microwave frequencies. As a result, it is important that both dielectric constant and tangent loss should be lower than the other microwave window materials [2]. However, in the literature only limited reports have been known on the microwave dielectric properties of SiAlON ceramics. Hence, it is important to study the properties of SiAlON ceramics at high temperatures where the permittivity may be changing rapidly with temperature. It is also possible, under some circumstance, to predict the dielectric behavior of a mixture of materials from the dielectric properties of the individual components and this can be of benefit when designing materials for microwave processing. There are a number of dielectric data gathered over a wide range of frequencies and temperatures can often give valuable information about the mechanisms responsible for the interaction between an electromagnetic wave and a material. [3-4] Therefore, this study has focused on the characteristic properties of  $\beta$ -SiAlON by a resonant cavity (perturbation) method, based on the work of Hutcheon [5], at 2.45GHz and temperature ranges to 1200 °C [6].

### Experimental Procedure

Commercially available  $\alpha$ - $\text{Si}_3\text{N}_4$  (UBE-SN-E10, Ube chemical, Japan),  $\text{Al}_2\text{O}_3$  (AKP-50, Sumimoto, Japan) and AlN (grade F, Tokuyama, Japan) were used in the preparation of the materials.  $\beta$ - $\text{Si}_{6-z}\text{Al}_z\text{O}_z\text{N}_{8-z}$  with various z-values (0.5, 1.0, 2.0, 3.0, and 4.0) was prepared in five different batches

of powders. To reduced the particle size and increase the homogenous nature, the powders were ball milled in 2-propanol for 24 h using the alumina balls. All powder mixtures were dried in convection oven at 80 °C for 24 h and granulated. Thus, obtained powders were hot-pressed (Thermal Technology Inc, Astro Hot Press) in BN-coated graphite dies under N<sub>2</sub> to 1800°C with an average heating rate of ~20 °C/min and maintained at that temperature for 2h under a uniaxial load of 25MPa.

Dielectric properties of β-SiAlONs were characterized by the post-resonator method (Hakki-Coleman method) at room temperature and by perturbation method at high temperature. The dimensions of β-SiAlONs were 3.5φ x 12mm. The pellets were heated in box furnace to 1200 °C and dielectric properties were measured in steps of 100 °C at 2.45GHz. Dielectric constant and tangent loss were calculated using eq. 1.

$$\varepsilon_r' = 1 - 2C'' \frac{f_1 - f_0}{f_1}, \quad \varepsilon_r'' = C'' \left( \frac{1}{Q_2} - \frac{1}{Q_1} \right)$$

$f_0$  : the resonant frequency of empty holder,

$f_1$  : the resonant frequency of holder within specimen

$Q_1$  : the quality factor of empty holder,

$Q_2$  : the quality factor of holder within specimen

$C'$ ;  $C''$  : the permittivity of specimen (Hakki-Coleman)

Eq.1.Equation of dielectric measurement was used and characterize by perturbation method

## Result and discussion

The bulk densities were measured for the hot pressed β-SiAlON pellets and the result showed 3.106 g/cm<sup>3</sup> (z = 0.5), 3.098 g/cm<sup>3</sup> (z = 1.0), 3.070 g/cm<sup>3</sup> (z = 2.0), 3.056 g/cm<sup>3</sup> (z = 3.0), 3.025 g/cm<sup>3</sup> (z = 4.0), respectively. In comparison with the theoretical density, the prepared pellets revealed > 98% of relative densities. Fig. 1 shows the XRD patterns of the β-SiAlON pellets. The patterns clearly revealed the solid solution fabricated at 1800 °C. The increase in the z-values of β-SiAlON has been evidenced by the shift in the peak positions.

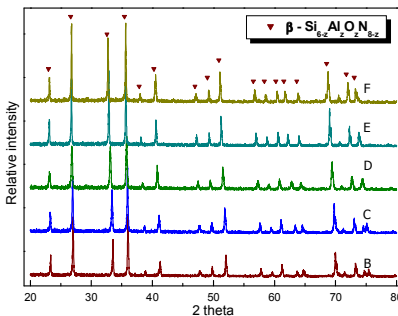


Fig.1 XRD patterns of β-SiAlON with various z-values

Fig.2 shows plot of dielectric properties as a function of temperatures. From Fig. 2, it is clear that at room temperature dielectric constant of all the pellets were around 7.5 - 7.8 and tangent loss were  $1 \times 10^{-3}$  -  $3 \times 10^{-3}$ . These values are lower than those of Si<sub>3</sub>N<sub>4</sub>. It is noticeable that as the temperature increases dielectric constant also increased. Likewise, dielectric loss of β-SiAlON increased with increase in temperatures. The pellet with z = 1.0 has revealed high dielectric constant and z = 4.0, has showed high dielectric loss.

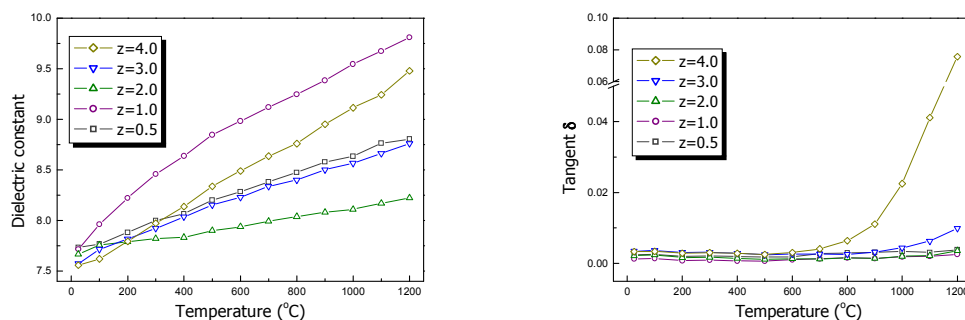


Fig.2 Dielectric properties of  $\beta$ -SiAlON with various z-values

## Summary

Fully dense and single phase  $\beta$ -SiAlON with various z-values was prepared by hot-press method. The dielectric properties (dielectric constant and tangent loss) of  $\beta$ -SiAlON were characterized by the post-resonator method at room temperature and by perturbation method from room temperature to 1200°C at 2.45 GHz, respectively. In all cases of  $\beta$ -SiAlON, as temperature increased, dielectric constant and dielectric loss increased. In case of  $z = 1.0$ , dielectric constant showed higher value than the other z-values of  $\beta$ -SiAlON, whereas  $z = 4.0$  showed dielectric loss as much higher value than the other z-values of  $\beta$ -SiAlON at high temperature. The dielectric properties of  $\beta$ -SiAlON with various z-values showed limitation in the high temperature region. Hence, the relationship study between dielectric properties and various z-values at high temperature are under progress and will be communicated in future.

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**SiAlONs and Non-oxides**

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