**学術論文**

**ロッド形状を有するSiCと酸化物(SiO2, Al2O3)混合体の複合誘電率とマイクロ波加熱挙動 (English title, MS Gothic、16points)**

**Complex Permittivity and Microwave Heating Behavior of Rod-Shaped SiC and Oxide (SiO2, Al2O3) Mixtures （Japanese Title, Times New Roman 16 points）**

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**Abstract** ( Bold, Times New Roman 10 points )

Permittivity measurement and microwave heating characteristics of rod-shaped SiC (fragmented SiC fiber) mixed with SiO2 or Al2O3 were investigated, comparing with the mixtures of other two kinds of SiC materials. Rod-shaped SiC mixtures had larger permittivity (both real and especially imaginary parts) than the other SiC mixtures, and a broad peak of loss factor (r") appeared around 1GHz. Effective permittivity of mixtures was not successfully fitted by Maxwell-Garnett mixing law to the rod-shaped SiC mixtures but well fitted to other kinds of SiC mixtures. The microwave heating ability of rod-shaped SiC mixtures were much superior to that of other SiC mixtures, as expected from the larger loss factors. However, differences were observed between the mixture of rod- shaped SiC with SiO2 and with -Al2O3 in heating behavior and in the mixture permittivity. Interactions of the rod SiC are considered different between SiO2 and -Al2O3 and influenced the experimental heating data.

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1. **Introduction** ( Bold, Times New Roman 10 points )

Microwave heating application to ceramic materials has been studied by many researchers [1-3] both in academia and in the industry, considering its specific features, such as rapid, internal and selective heating [4]. And so-called non-thermal effect has been attracted attention for promoting the solid state reaction kinetics [5] and for obtaining the non-equillibrium phases [6] possessing superior properties.

On the other hand, it has been clarified that the microwave heating has serious disadvantages of causing thermal runaway, which is known to be detrimental aspects in ceramic sintering, especially of oxides [7]. One of the factors related to this phenomenon is a large temperature dependence of microwave loss factor of the oxide materials [8]. Low absorbing characteristics at room temperature changes into very large absorbing characteristics at high temperature. Once high temperature region is formed such as by thermal fluctuation, microwave heating is concentrated in this region, and results in hot spot formation.

In order to avoid the thermal runaway, it is possible to take advantage of a microwave susceptor [9], which enables to aid preferable and stable heating of oxide ceramics from room temperature. One of the proposed sintering methods is that a susceptor heats the object at the initial stage, then the susceptor is removed and the object is concerted to microwave absorber.

SiC ceramics is known to be one of good microwave susceptors\*1 and there are many reports on the microwave heating of SiC [10-12]. And it is also possible to heat the powder mixtures consisting of some oxide and SiC. The SiC/oxides’ heating process has been applied to microwave fabrication of SiC composite materials, and several experimental attempts are previously reported [13,14]. Therefore, it is of significance that microwave heating behavior of SiC ceramics composites to be discussed by relating with its average permittivity.

**2. Experimental procedure**

Two types of microwave irradiation devices were used to investigate the spinodal decomposition of TiO2–VO2. Figure 1 shows the schematic views of each of the devices. One of the devices was a single-mode type microwave irradiation device. The device was composed of a magnetron (IMP-15ENA IDX Co., Ltd., Tochigi, Japan), an isolator, three stub tuners, a plunger, and a TE102 cavity, which specially divided the maximum point of E-field and H-field intensity. The sample was inserted into a test tube composed of quartz and sealed in a vacuum. The sample temperature was measured by a radiation thermometer through a hole at the side of the cavity. The other device was a multi-mode type microwave irradiation device, μReactor Ex (Shikoku Keisoku Co., Ltd., Takamatsu, Japan), as shown in Fig. 1 (b). In this device, microwaves were uniformly irradiated to a sample. The sample was also sealed in a test tube, and the test tube was surrounded by SiC, which acted as a susceptor. We measured the susceptor temperature, as it is close to the sample temperature given the susceptor absorbs most of the microwave energy.

\*1: SiC has large dielectric loss factor (imaginary part of permittivity, ε”) and is known suitable for the susceptor. On the other hand, there are other materials.

**3. Results and Discussion**

3.1 SEM observation (Time New Roman 10 point)

The SiC powder particles are observed with SEM, and the micrographs are shown in Fig.2. The regent SiC has smaller size than the other two. The rod SiC possesses the various length, the aspect ratio ranges between about 1 and 20.

Table 1: Impedance and electric conductivity of SiC.





Fig. 1: Impedance (real part) of three kinds of SiC.

One of the most general mixing equation for composite dielectric materials is Maxwell-Garnett law [21], as expressed in Eq. 1, and the effective permittivity m is given by.

 (1)

, where εh is the relative permittivity of a host material, εi is the relative permittivity of the ith inclusions, fi is the volume fraction occupied by the inclusions of the ith type, Nik are the depolarization factors of the ith inclusions, and the index k = 1, 2, 3 corresponds to x, y, and z cartesian coordinates.

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