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ARTICLE

Microstructure and Dielectric Properties of Chopping SiC_f/LAS Composites

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Abstract: The chopping SiC_f/LAS composites were prepared by the hot-pressing method. The effects of hot-pressing time and pressures on the microstructures and the dielectric properties of the composites were researched. Compared with the LAS matrix and the SiC fibre, the results of dielectric constant testing in the range of 8-12 GHz indicate that the dielectric constant real part, imaginary part and dielectric dissipation of all samples increase by 1-3 orders of magnitude, and show obvious frequency dispersion effect. Their real parts increase while their imaginary parts and dielectric dissipations decline with the increase of the hot-pressing time or pressures. The SEM fractographs show that the composite interfacial films between the fibre and the matrix are thickened with the increase of the hot-pressing time or pressures.

Key words: chopping SiC_f; LAS glass-ceramic; dielectric properties

The SiC fibre reinforced oxide matrix composites are developed rapidly in recent years[1,2], but the related researches are mainly concentrated on the mechanical properties at room temperature and high temperature, and the purpose of the researches is to supply a type of structural materials for high temperature environment. However, there are few reports about other properties of the composites, and their applications have been restricted to some extent.

The melting point of the LAS glass, the main crystal phase of which is β-spodumene, generally exceeds 1300 °C, but its coefficient of thermal expansion is relatively low (9×10^{-7} K^{-1}) [3]. The LAS glass can bear high temperature and match the SiC fibre's coefficient of thermal expansion. It was indicated that the continuous SiC fibre can distinctly increase the fracture strength and the fracture toughness of the LAS glass[4-7], but only the mechanical properties were studied in these literatures. Moreover, the mechanical and other properties of the continuous fibre reinforced glass-ceramic matrix composites display strong anisotropy, so the applications of the composites are limited in some fields. There are a few research reports on chopping SiC fibre reinforced glass-ceramic matrix composites, which possess characteristic of isotropy, but only their mechanical properties were studied[8]. Their dielectric properties are not available. Therefore, this paper presents the microstructure and dielectric properties of the LAS glass-ceramic matrix composites reinforced with chopping SiC fibers.

1 Experimental

The LAS glass-ceramic composites reinforced with chopping SiC fibers were prepared by the hot-pressing method.

The average diameter of the SiC fibre was 10 μm, its density was 2.4-2.45 g/cm^3, its average tensile strength was 2200 MPa, and its elastic modulus was 200 GPa. The mol ratio of the LAS powder's elements was Li_2O:Al_2O_3:SiO_2= 1:1:4, its average particle size was about 5 μm, and its density was 2.54 g/cm^3.

The process of the experiment was divided into three steps. At first, the SiC fibre was cut into short fibers of 3 mm length and soaked in acetone, then the short fibres in acetone was mixed round to remove the glue on the surface. The short fibres and the matrix powders (their ratio by volume was 36:64) were added into the water solution (6%-7% mass fraction) of the polyvinyl alcohol and the glycol[8], and

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separated for 30-45 min with electric mixer (D90)[8]. Secondly, the mixed slurry was spread on thin sheets and dried, then the sheets were cut into round flakes (about 46 mm in diameter). The flakes were stacked into the graphite die to obtain the composites samples by hot-pressing. At last, the chopping SiC_f/LAS glass-ceramic composites were sintered in the atmosphere of nitrogen. The hot-pressing conditions are shown in Table 1.

Archimedes drainage was used to test the density of the composite samples.

The sequence network analyzer (E8362B, the measuring range from 10 MHz to 20 GHz) was used to test the dielectric properties of the composite samples in 8-12 GHz range. The dimension of the sample for testing was 10.14 mm×22.86 mm×2 mm.

SEM was used to observe the microstructure and fractography of the composite samples.

2 Results and Discussion

As shown in Fig.1a and Fig.1b, the dielectric constant real parts ε' of the prepared SiC_f/LAS composite samples 1, 2 and 3 increase with the hot-pressing time prolonging while their imaginary parts ε'' decline. Fig.2 shows their dielectric dissipations tgδ decline with the hot-pressing time prolonging.

As shown in Fig.3, the interface reaction between the SiC fibres and the LAS matrix, which forms carbon-rich graphite layer[6,7], is intensified with the prolonging of the hot-pressing time, and the interfacial layers are thickened. Therefore the graphite contents in the composites are increased. It is well-known that the graphite, like the metals, has characteristic of high dielectric constant and dissipation. So these should be some of the reasons for the dielectric constant variation of the composite samples.

Fig.4a shows that the dielectric constant real parts ε' of the SiC_f/LAS composite samples 2, 4 and 5 increase with increasing of the hot-pressing pressures, and Fig.4b shows their imaginary parts ε'' decline with increasing of the hot-pressing pressures. Their dielectric dissipations tgδ decline with increasing of the hot-pressing pressures, as shown in Fig.5.

In addition, as shown in Fig.1 and Fig.4, the ε' and ε'' of all samples decline with increasing of the microwave frequency, which is entitled frequency dispersion effect. Their preferable frequency dispersion effects show their potential for broad band microwave dissipation.

Fig.6 shows the interface reaction between the SiC fibre and the LAS matrix is intensified with increasing of the hot-pressing pressures, which is the same as the results of Ref. [9], and the interfacial films are thickened, so the graphite contents of the composites are increased. These should to be some of the reasons for the dielectric constant variation of the composite samples.

Table 1 Hot-pressing condition of the SiC_f/LAS composites

Sample number	1	2	3	4	5
Hot-pressing temperature/℃	1200	1200	1200	1200	1200
Holding time for hot-pressing /min	10	20	30	20	20
Hot-pressing pressure/MPa	20	20	20	27	34
Density/%	88	90	89	93	96

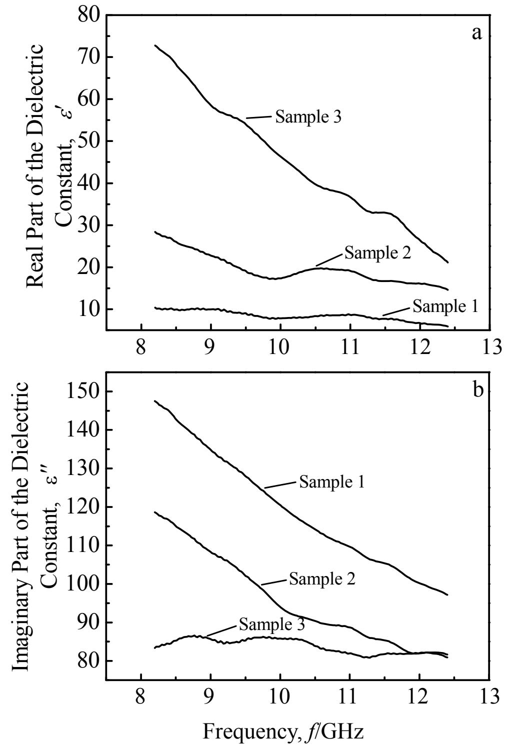

Fig.1 Hot-pressing time effect on ε'(a) and ε''(b) of samples 1, 2 and 3

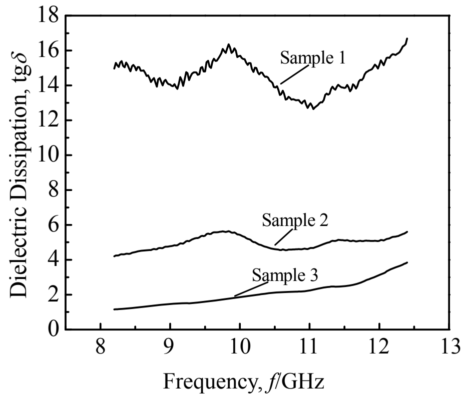

Fig.2 Dielectric dissipation of samples 1, 2 and 3

The SiC fibre used here is a type of semiconducting material: $\varepsilon'\approx 9.20$, $\varepsilon''\approx 3.50$, tg$\delta\approx 0.38$ (in the range of 8-12 GHz). The fibre has few microwave dissipation properties[10].