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Usefulness of Alumina-coated SiC Whiskers in the Preparation of Whisker-reinforced Alumina Ceramics

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Abstract: Alumina coated SiC whiskers were used as the starting material for the fabrication of SiC-whisker-reinforced alumina ceramics. Sintering density and the dispersion state of SiC whiskers were improved by using alumina coated SiC whiskers. Mechanical strength increased 1·5 times by using alumina coated SiC whiskers.

1. INTRODUCTION

In order to increase the strength and reliability of whisker-reinforced ceramics, it is important to disperse the whiskers uniformly in the matrix. When whiskers coated with the matrix substance are used as a raw material, it is expected that the agglomeration of whiskers in the matrix can be reduced and a more uniform dispersion can be obtained. Furthermore, in the case where the substance of the whiskers is different from that of the matrix, the pre-coating of the whiskers with the matrix substance provides the same surface properties for them as for the matrix substance, thus reducing the difficulties in powder handling during wet molding.

Based on these viewpoints, the authors have studied the method to coat whiskers with the matrix substance with the intention to use them as a raw material for whisker-reinforced ceramics.[1,2] Recently, Kapolnek and Dejonghe[3] reported that in the production of whisker-dispersed ceramics, the use of matrix-coated whiskers was effective for the uniform dispersion of whiskers.

In the present study, SiC-whisker-reinforced alumina ceramics were prepared by using alumina-coated whiskers. Mechanical strength values were also determined.

2. EXPERIMENTAL PROCEDURE

Commercial SiC whiskers (TWS-400, average diameter: 1·2 μm, average length: 40 μm, Tokai Carbon Co., Ltd.) were coated with alumina hydrate from aluminum sulfate aqueous solution by homogeneous precipitation techniques.[2] The coating was carried out at 70°C under the following conditions: suspension of SiC whiskers = 9·0 g/l, $[Al_2(SO_4)_3]$ = 0·075 mol/l, [urea] = 10·8 mol/l, stirring rate of the reacting solution = 850 rpm. The coated particles were calcined at 1150°C for 1 h in an Ar atmosphere. By this calcination the alumina hydrate changed to α-Al_2O_3. The ratio of coated alumina/SiC whisker was 40/60 (in vol). The calcined powder is shown in Fig. 1.

Alumina-coated or uncoated SiC whiskers were mixed with fine α-Al_2O_3 powders (AKP-50 of Sumitomo Chemical Co., Ltd., >99·99% purity, Mg < 10 ppm, particle size 0·1–0·3 μm, surface area 10·7 m^2/g) in ethanol to give the volume ratio SiC/Al_2O_3 = 1/9 or 3/7. The preparation of SiC whisker–Al_2O_3 powder mixtures was carried out as follows:

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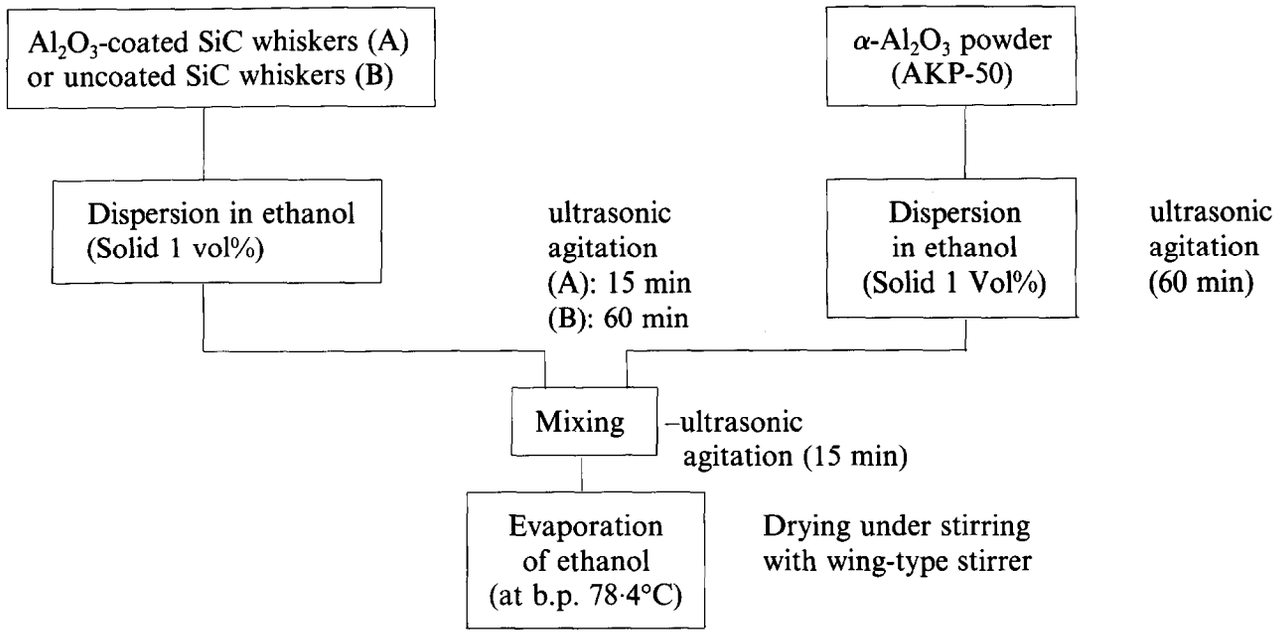

The powder mixtures prepared are shown in Table 1.

Hot-pressing was used for densification. The resulting powders were packed in a graphite mold, pressed at 30 MPa, then heated at around 60°C/min to 1800°C for 30 min and allowed to cool after the pressure was released. The size of the sintered specimen was approximately 20 mm × 40 mm × 5 mm.

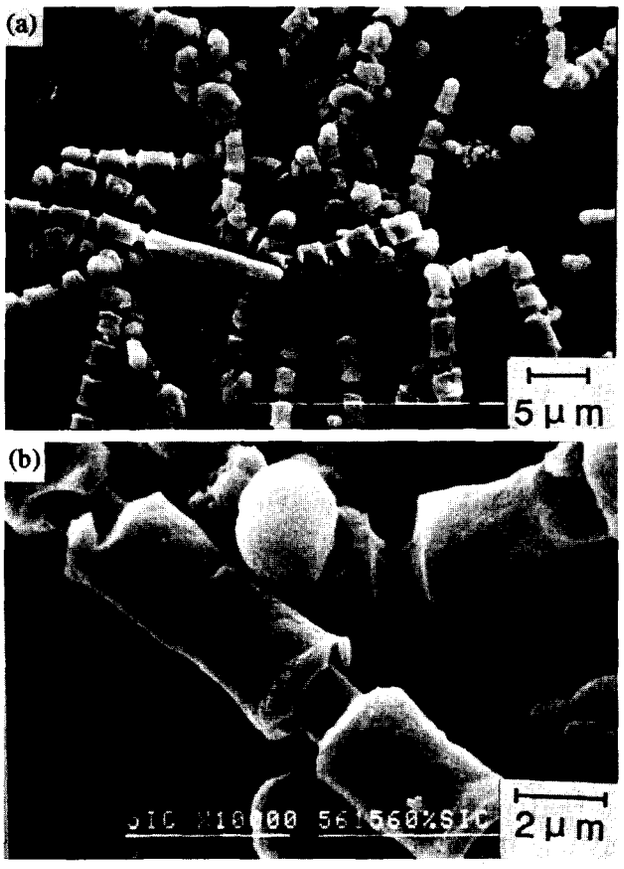

Fig. 1. Calcined product. Reaction condition: [SiC] = 9 g/l, $[Al_2(SO_4)_3]$ = 0·075 mol/l, [urea] = 10·8 mol/l, Temp.= 70°C, Stirring rate = 850 rpm, volume of reaction solution = 500 ml. Calcination condition: 1150°C, 1 h in Ar.

Table 1. Raw powders for SiC-whisker-reinforced alumina ceramics

No.	SiC whisker (vol%)	Constituent of raw powders
1	10	α-Al_2O_3 powder + uncoated SiC whiskers
2	10	α-Al_2O_3 + Al_2O_3-coated SiC whiskers
3	30	α-Al_2O_3 + uncoated SiC whiskers
4	30	α-Al_2O_3 + Al_2O_3-coated SiC whiskers

Hot-pressed disks thus prepared were polished with a # 200 diamond wheel and their densities were measured by the Archimedes method. Hot-pressed disks were cut into bars with nominal dimensions of 3 mm × 4 mm × 40 mm. The bars were prepared for flexure tests by grinding three surfaces and beveling the edges (to be in tension) with a # 800 diamond grind plate. Room-temperature flexural strength was measured in a three-point-bending mode, with a span of 30 mm, at a loading rate of 0·5 mm/min. The measurement was carried out on four bars from each hot-pressed disk.

3. RESULTS AND DISCUSSION

Figure 2 shows the Si distribution on the surface perpendicular to the hot-press axis of the sintered bodies. From this picture, one can observe that the use of alumina-coated SiC whiskers improves the dispersion state of SiC whiskers.

Sintered density and mechanical properties of the four samples are summarized in Table 2. The

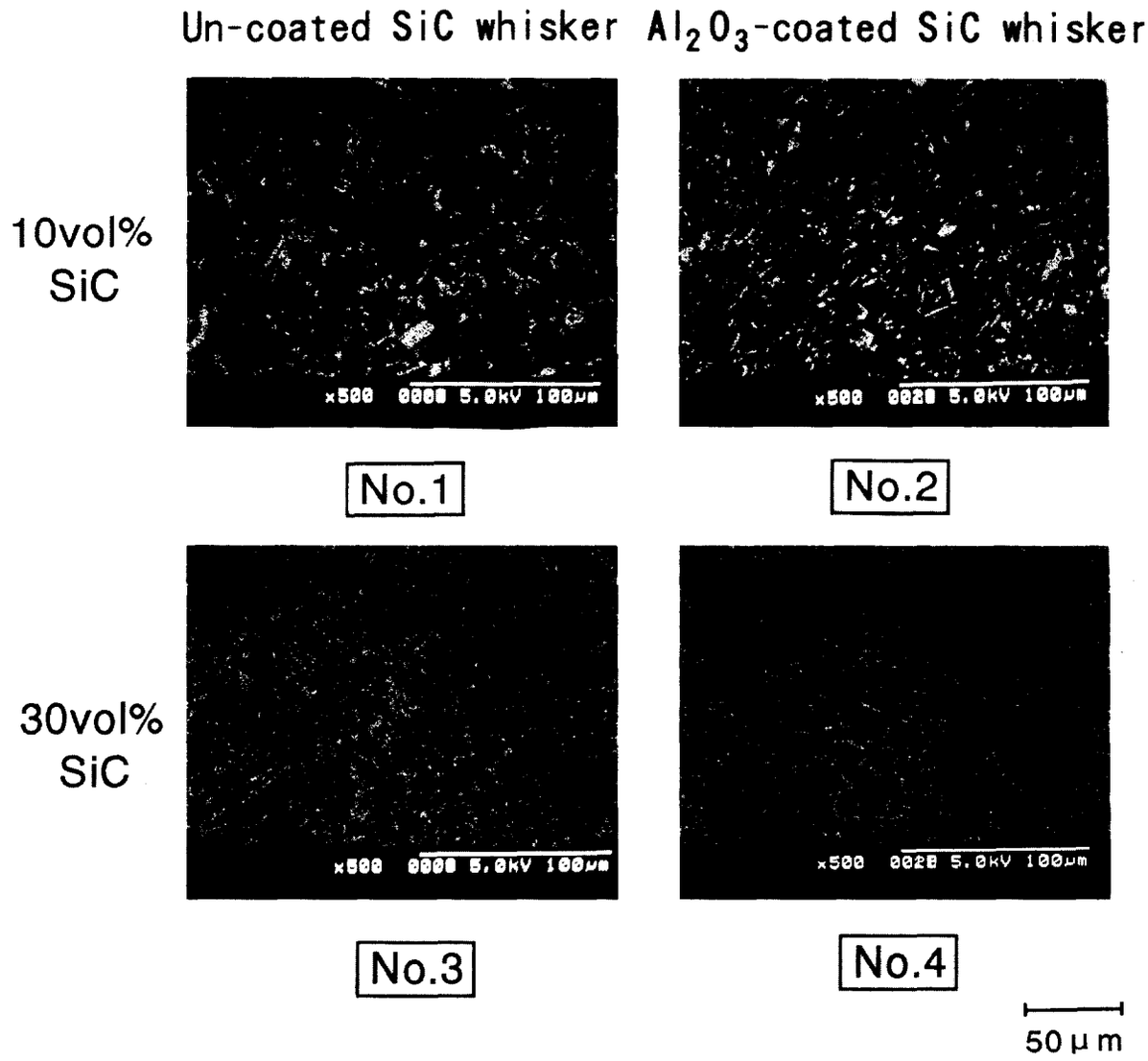

Fig. 2. Distribution of Si element of sintered body. (XMA mapping of Si K_α.) (Surface perpendicular to hot press axis.)

strength of the SiC-whisker-reinforced alumina prepared from alumina-coated SiC whiskers are comparable with those of SiC-whisker-reinforced alumina prepared by conventional powder processing method from finer SiC whisker and alumina powder containing 0·25 wt% MgO.[4] The strength of whisker-reinforced ceramics is affected by many factors including the bonding strength at the alumina–SiC interface, the morphology and size of the whiskers, the orientation state of the whiskers, sintering aid, etc. Thus, further investigations are needed to get stronger composites. However, Table 2 shows that the use of alumina-coated SiC whiskers gave a higher sintered density when the SiC content was 30 vol% and significantly higher flexural strengths. These improvements may be due to the more uniform dispersion of SiC whiskers which was described above and shows the advantage of the use of alumina-coated SiC whiskers as a starting material.

Table 2. Density and mechanical properties of SiC-whisker-reinforced alumina

Sample no.[a]	Density[b] g/cm^3(% T.D.)	Flexural strength (MPa)
1	3·899 (99·9 %)	289
2	3·911 (100 %)	369
3	3·638 (97·0 %)	400
4	3·734 (99·6 %)	568

[a] see Table 1.
[b] % T.D. was calculated on the basis of theoretical densities 3·21 g/cm^3 for SiC and 3·98 g/cm^3 for Al_2O_3.

4. CONCLUSIONS

In the preparation of whisker-reinforced ceramics, the use of matrix-coated whiskers is effective in improving the dispersion of whiskers in the resulting composite and hence improving the mechanical properties.

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