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Ceramics International 30 (2004) 813–815

CERAMICS INTERNATIONAL

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Short communication

SiC/TiC laminated structure shaped by electrophoretic deposition

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Received 1 September 2003; received in revised form 17 September 2003; accepted 2 October 2003

Available online 9 April 2004

Abstract

A SiC/TiC laminated structure was fabricated by electrophoretic deposition (EPD) from acetone-based suspensions. The formation rate of SiC is almost twice of that of TiC at the same deposition voltage and solid loading. The laminated material was then pressureless sintered. Without sintering additives, the composites cannot be densified by pressureless sintering even at 2000 °C.

Keywords: A. Shaping; A. Sintering; D. SiC

1. Introduction

Laminar ceramic composites are synthesized by tape casting [1,2], slip casting [3], centrifugal casting [4], dough rolling [5] and self-propagating high temperature synthesis [6]. In the nineties of last century electrophoretic deposition (EPD) has gained interest in the production of laminar ceramic composites.

EPD is a colloidal processing technique for ceramics [7]. It has been employed to fabricate coatings, thin films [8,9]. Laminar materials can also be produced via EPD. When the desired thickness of the first layer is reached, the deposition electrode can be moved to a second suspension for deposition of a layer of different composition. By changing back and forth, a layered material is readily obtained. Sarkar and Nicholson [7] have produced ZrO_2/Al_2O_3 laminates with alumina layers as thin as 12 μm and zirconia layers of 2 μm from ethanol-based suspensions. Ferrari et al. [10] and Fischer et al. [11] produced alumina/zirconia laminates from aqueous suspensions. Vandeperre and co-workers made a range of SiC-based laminates with graphite [12], and porous SiC interlayers [13]. In this study, the fabrication via EPD of SiC/TiC laminar ceramics was investigated using an acetone base suspension. The material was pressureless sintered at 2000 °C for 1 h.

2. Experimental

The following starting powders were used: (1) TiC powder (Zhuzhou, PR China) with a density of 4.93 g/cm^3, specific surface area of 4.8 m^2/g, and a mean particle size of 0.6 μm; (2) SiC powder (Norton, USA) with a density of 3.1 g/cm^3, specific surface area of 6.8 m^2/g, and a mean particle size of 0.6 μm. A suspension of 50 g/l TiC (or SiC) in acetone was prepared in an airtight glass container. It was placed in an ultrasonic bath for 15 min. The electrolytic cell is a glass beaker containing the counterelectrode stainless steel and the working carbon paper electrode. The effective surface areas of both cathode and anode were 6 cm^2 each. The distance between the anode and the cathode was constantly 3 cm. The schematic diagram of the cell and the circuit used for the electrical measurements are presented in Fig. 1. Layered composites were obtained by sequential deposition experiments alternatively changing both slurries to form deposits with different numbers of layers, up to 20. Each layer was formed after 1 min deposition. The layered deposits were left in a cabinet drier more than 5 h for drying.

3. Result and discussion

The voltage evolution along the 10 min EPD experiment for both slurries is plotted in Fig. 2. The voltage increases rapidly during the first minute of the deposition process and remains constant for longer deposition times. The measured voltage is always higher for the TiC slurry because of its

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0272-8842/$30.00
doi:10.1016/j.ceramint.2003.10.002

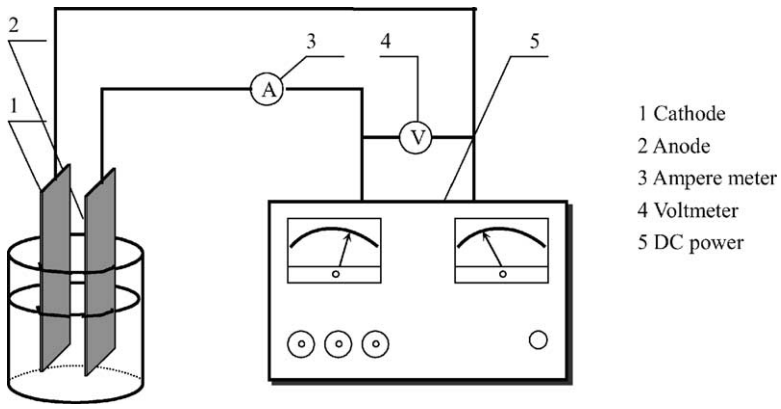

Fig. 1. Setup of EPD experiment.

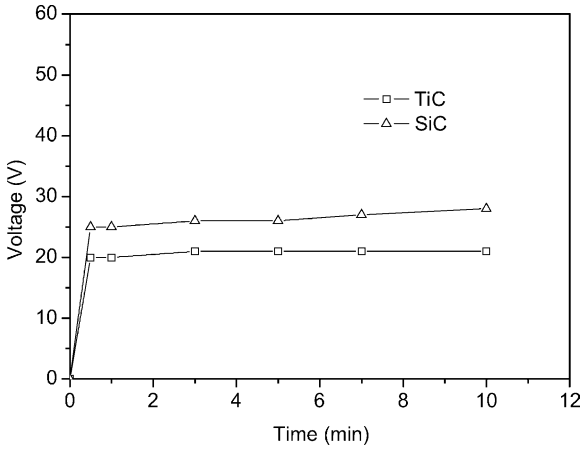

Fig. 2. Voltage variation of TiC and SiC suspensions during 10 min deposition experiments.

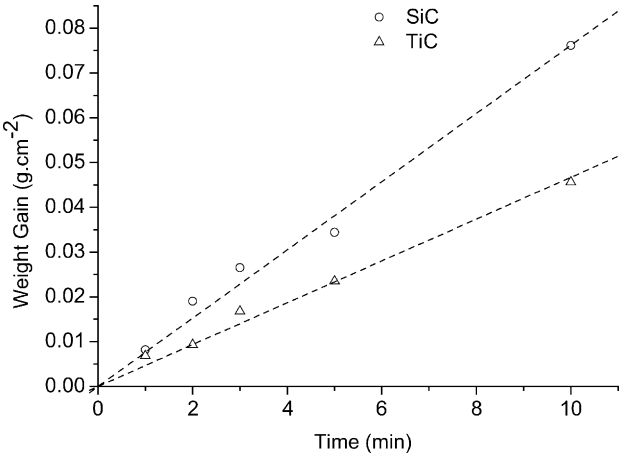

Fig. 3. Growth rates of SiC and TiC vs. time in same current density and suspension concentration.

lower conductivity. Deposits of both materials were prepared at different deposition times under similar conditions to evaluate the growth rates. The results can be seen in Fig. 3. As observed, a linear growth with time is obtained for both materials. The formation rate of SiC is almost twice of that of TiC at same condition. However, from Fig. 2 the voltage does not increase any more after the first minute of the deposition. This means that the resistance of the formed deposit is very low and the registered voltages must be related only to the electrical conductivity of the slips. The origin of this effect must be found in the nature of the electrode, consisting of an easily oxidizable substance, as Zn. During the EPD tests in aqueous media, Zn^{2+} cations are formed in the substrate, which can easily move through the deposit by either diffusion or migration phenomena [14].

Fig. 4 shows the scan electron micrographs of the pressureless sintering of the laminated structure. It is obvious that the silicon carbide was not sintered for there were no

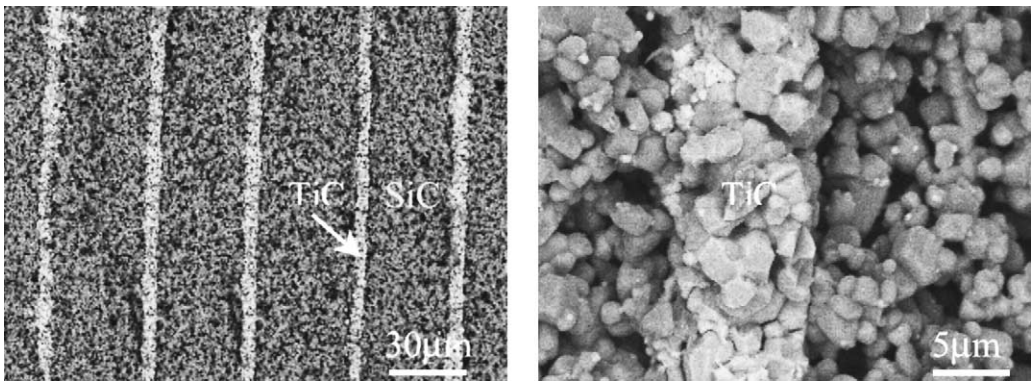

Fig. 4. The SEM morphology of the pressureless sintered SiC/TiC laminated structure.

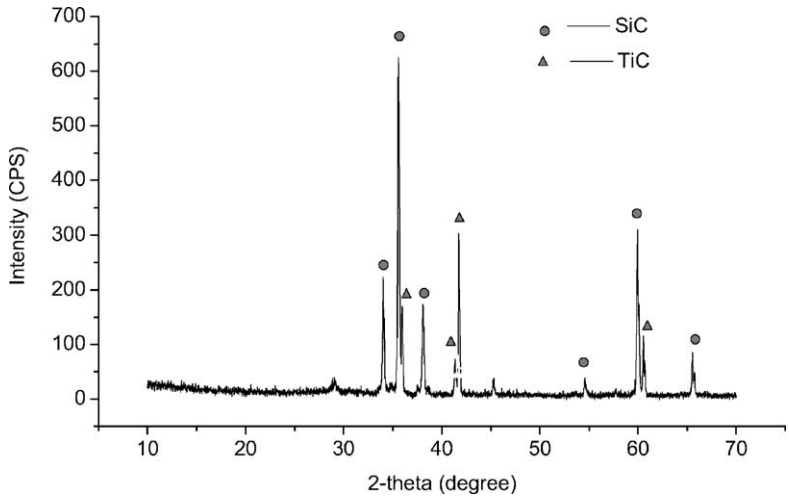

Fig. 5. XRD analysis of the SPS SiC/TiC laminated structure.

Table 1
The densities of the green deposits and sintered composites

Samples	Green SiC deposit	Green TiC deposit	Pressureless sintered SiC/TiC
Relative density (%)	60.1	59.6	90.2

additives. The pressureless sintering of pure silicon carbide is very difficult. The sintering of TiC is easier relatively. More denser TiC can be observed in Fig. 4.

The densities of the green deposits and sintered composites were measured by Archimedes' method are shown in Table 1. The green density of the SiC and TiC deposits were measured respectively. Without sintering additives, pressureless sintered sample has a very low density. Further research on the densification of the material should be carried out later. The XRD analysis of the sample is shown in Fig. 5. There are only SiC and TiC phase in the composites.

4. Conclusions

EPD was demonstrated to be an effective technique in synthesizing laminated structure ceramics. SiC particles have bigger formation rate than TiC particles at the same deposition voltage and solid loading. Pressureless sintering cannot densify the SiC/TiC laminated structure without sintering additives.

References

[1] P. Boch, T. Chartier, M. Huttepain, Tape casting of Al_2O_3/ZrO_2 laminated composites, J. Am. Ceram. Soc. 69 (1986) C-191.
[2] T. Chartiful, J.L. Besson, P. Boch, Mechanical properties of ZrO_2–Al_2O_3 laminates composites, in: Advances in Ceramics, vol. 24B, Science and Technology of Zirconia III, 1988, p. 1131.
[3] J. Requena, R. Moreno, J.S. Moya, Alumina and alumina/zirconia multilayer composites obtained by slip casting, J. Am. Ceram. Soc. 72 (1989) 1511.
[4] D.B. Marshall, J.J. Ratto, F.F. Lange, Enhanced fracture toughness in layered microcomposites of Ce-ZrO_2 and Al_2O_3, J. Am. Ceram. Soc. 74 (1991) 2979.
[5] W.J. Clegg, K. Kendall, N. McN. Alford, T.W. Botton, J.D. Birchall, A simple way to make tough ceramics, Nature (London) 347 (1990) 455.
[6] M. Koizumi, Recent progress of functionally gradient materials in Japan, Ceram. Eng. Sci. Proc. 13 (1992) 333.
[7] P. Sarkar, P.S. Nicholson, Electrophoretic deposition (EPD): mechanisms kinetics and application to ceramics, J. Am. Ceram. Soc. 79 (1996) 1987–2002.
[8] L. Gal-Or, S.R. Chaim, Electrolytic ZrO_2 coatings, J. Electrochem. Soc. 138 (1991) 1939–1946.
[9] J. Mizuguchi, K. Sumi, T. Muchi, Highly stable nonaqueous suspensions for the electrophoretic deposition of powdered substances, J. Electrochem. Soc. 130 (1983) 1819–1825.
[10] B. Ferrari, A.J. Sanchez-Herencia, R. Moreno, Aqueous electrophoretic deposition of Al_2O_3/ZrO_2 layered ceramics, Mater. Lett. 35 (1998) 370–374.
[11] R. Fischer, E. Fischer, G. De Portu, E. Roncari, Preparation of ceramic micro-laminates by electrophoresis in aqueous system, J. Mater. Sci. Lett. 14 (1995) 25–27.
[12] L. Vandeperre, O. Van der Biest, W.J. Clegg, Silicon carbide laminates with carbon interlayers by electrophoretic deposition, Key Eng. Mater. 127 (1997) 567–574.
[13] L. Vandeperre, O. Van der Biest, SiC laminates with porous interlayers produced by EPD, Presented at 100th Annual Meeting of the American Ceramic Society, Cincinnati, OH, 1998.
[14] B. Ferrari, R. Moreno, Zirconia thick films deposited on nickel by aqueous electrophoretic deposition, J. Electrochem. Soc. 147 (2000) 2987–2992.