Fabrication of Nano-laminar Glass Composite Using Thin Flake

Hideki Kakisawa[a], Kazumi Minagawa[b] and Kohmei Halada

Ecomaterials Center, National Institute for Materials Science
1-2-1 Sengen, Tsukuba, Ibaraki 305-0047, JAPAN
[a]Kakisawa.Hideki@nims.go.jp, [b]MINAGAWA.Kazumi@nims.go.jp,
[c]HALADA.Kohmei@nims.go.jp

Abstract

Fabrication of a nano-laminar ceramic composite by sintering thin ceramic plates was examined. Silver-coated glass flakes with a thickness of less than 1μm were consolidated by pulsed current sintering or hotpressing to obtain model composites. The samples sintered at the optimum conditions were fairly dense, and the flakes were aligned by uniaxial press. The metal coating remained on the flakes through the sintering process, and became an interface layer between the flakes. No crack propagation through the transverse direction of the lamellar was observed in the indentation test. The possibilities of high resistance against crack propagation was suggested.

Keywords : nano-laminar composite, fracture behavior

1. Introduction

Laminated ceramics composites have been attracting attention because of their apparently high fracture toughness[1-3]. The reduction of the structural dimension of the composite will contribute to the combination of strength and toughness. The objective of this study is to fabricate a "nano" laminar ceramic composite with high fracture resistance, which consists of thin ceramic plates of submicrometers and interface layers between them.

Recent developments in thin film processing can produce nanometer-thin layers, via self-assembly by biomimetic processing[4], chemical and physical vapor deposition (CVD and PVD) [5], spin coating,[6,7] etc. These all have the potential to form very thin, uniform films. However, it becomes difficult to fabricate a bulk material for structural use. In this paper, a processing with a simple powder metallurgical technique is examined for fabricating such a nano-laminar ceramics composite. Specifically, a laminar glass composite is fabricated by sintering glass flakes coated with an interface material.

2. Experimental Procedure

Almino-silicate glass flake powder with silver coating was used as the raw material. The mean diameter and thickness of the flakes were 20μm and 0.7μm, respectively. Silver was coated on the flakes by electroless plating, and the thickness of the coating was about 50nm. The properties of the glass and silver are shown in Table 1.

The powder was put into a graphite die. Then it was sintered using either a pulsed current sintering (PCS) or hotpress. The sintering temperature, sintering time, and applied pressure were changed to find the optimum sintering condition.

A Vickers indentation test was carried out on the polished surfaces with an indentation load of 49-196N for 40s, using a standard pyramidal indenter. The indentation was oriented so that one of the diagonal lines of the permanent impression would be parallel with the lamination direction. After indentation the crack propagation behavior near the indent was observed.

Table 1. Properties of the glass and silver

	Glass	Silver
Young's modulus (GPa)	73	71
Density (g/cm^3)	~2.6	10.5
Glass transition temperature (K)	961	-
Melting Temperature (K)	-	1235

3. Results and Discussion

High sintering temperature resulted in a good densification of the powder but caused the silver coating cohered in a spherical form and the glass flakes bonded with each other. The temperature where the densification occurred and the silver coating remained at the flake surface was investigated; the optimum temperature was found 943K in PCS and 1023K in hotpress, respectively. High pressure helped rapid densification; typically 30MPa of uniaxial press was applied. PCS need shorter sintering time than hotpress but the difference of sintering method was not essential. Figure 1 shows the cross-sections of the samples sintered at 943K by PCS with a pressure of 30MPa. The flakes in the sample sintered at 943K were flexibly bent and filled the spaces.

The alignment of the flakes clearly had a lamellar tendency. The longitudinal direction of the lamellar was perpendicular to the loading direction; the lamellar alignment was achieved by uniaxial compression. The silver coating remained on the flake surface and formed an interface layer.

Figure 2 shows the Vickers indent on the sample sintered at 943K by PCS. In general, Vickers indentations on brittle materials cause cracking from the corner of the indent according to the indentation load[8-10]. In this experiment, no crack passing through the lamellar from the corner A was observed in optical microscopy at any load up to 196N. The absence of cracks in the transverse direction suggests a high resistance to crack propagation across the laminated structure. The absence of cracks in the transverse direction suggests a high resistance to crack propagation across the laminated structure. Along the lamellar direction, cracks propagated from the sides of the rhombus as well as from the corners oriented in the lamellar direction (corner B).

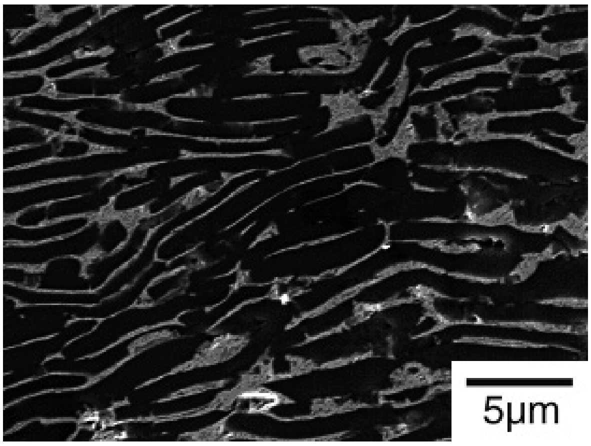

Fig. 1. Microstructure of the samples sintered at 943K with an applied press of 30MPa by PCS.

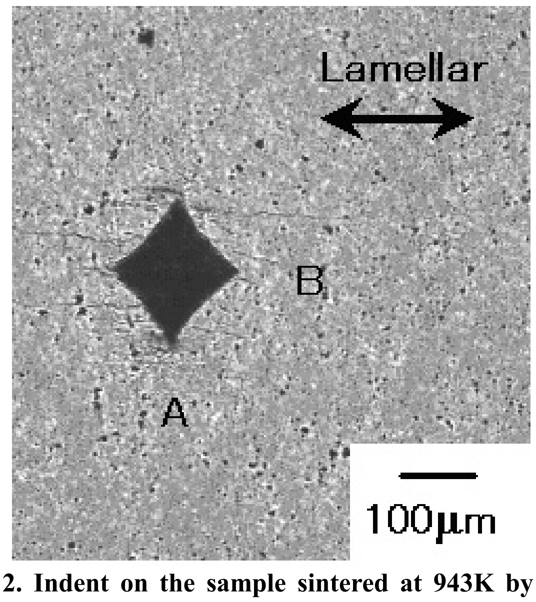

Fig. 2. Indent on the sample sintered at 943K by PCS (indentation load: 49N).

4. Conclusion

1) A nano-laminar composite was successfully fabricated from glass flakes coated with silver by sintering processes.
2) In the Vickers indentation test, no crack propagated from the corner of the indent in the transverse direction, suggesting the possibilities of good fracture resistance.

5. Acknowledgement

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6. References

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