Title	Non-oxide Ceramics (Si_3N_4,SiC) Joint Made with Amorphous $Cu_{50}Ti_{50}$ and Ni_<24.5>Ti_<75.5> Filler Metals
Author(s)	Naka, Masaaki; Tanaka, Tasuku; Okamoto, Ikuo; Arata, Yoshiaki
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TECHNICAL NOTE

Non-oxide Ceramics (Si_3N_4, SiC) Joint Made with Amorphous $Cu_{50}Ti_{50}$ and $Ni_{24.5}Ti_{75.5}$ Filler Metals†

Masaaki NAKA*, Tasuku TANAKA*, Ikuo OKAMOTO** and Yoshiaki ARATA****

KEY WORDS: (Brazing) (Joining) (Si_3N_4) (SiC) (TiN) (Amorphous Filler Metals) (Copper-Titanium) (Nickel-Titanium)

Silicon-based structural ceramics such as Si_3N_4 and SiC are under active consideration for structural use in hot machinery such as gas turbines. Joining ceramics to ceramics is important in many applications. Construction of large ceramic structures requires joining smaller structures because physical and economical limitations of producing ceramics limit the size of components. Some ceramics can only be made in relatively simple shapes, so fabrication of more complex shapes requires extensive joining. Recently, the present authors have reported the simple ceramic joining method using amorphous filler metals quenched from the liquid state[1]. The objective of the present paper is to present the joint strength of Si_3N_4/Si_3N_4 and SiC/SiC joints using $Cu_{50}Ti_{50}$ and $Ni_{24.5}Ti_{75.5}$ quenched from liquid state.

The materials used were Si_3N_4 sintered at ordinary pressure and sintered reaction-bonded SiC (86 wt%SiC, 13 wt%Si, 1 wt%SiO_2). The amorphous fillers were prepared by impinging the molten alloys on a rotating wheel through a quartz orifice[1]. The filler metals were 5 cm in width and 50 μm in thickness for $Cu_{50}Ti_{50}$ and 5 mm in width and 45 μm in thickness for $Ni_{24.5}Ti_{75.5}$. The amorphous structure of the filler metals were confirmed by X-ray diffractometry. Si_3N_4 or SiC of 15 mm in diameter and 3 mm in thickness, and Si_3N_4 or SiC of 6 mm in diameter and 3 mm in thickness were used for a lap joint. Prior to brazing the specimens were polished mechanically with silicon carbide paper to No. 1000. The brazing was conducted in 5×10^{-5} torr at 980° to 1300°C. The heating rate up to brazing temperature was 19°C/min, and the cooling rate after brazing was about 20°C/min up to 600°C, and 1°C/min up to room temperature. Joint strength of the lap joint was determined by fracture shear loading using a crosshead speed of 1 mm/min at room temperature. Microstructures of specimen joined were determined by scanning electron microscopy and X-ray microanalysis.

At constant brazing time of 30 min the brazing temperature dependence of shear strength of Si_3N_4/Si_3N_4 joint exhibits a maximum value of 18 kg/mm^2 at 1100°C and the strength decreases markedly up to 1.4 kg/mm^2 at 1200°C with higher brazing temperature as shown in **Fig. 1**. **Fig. 2** shows the brazing temperature dependence of shear strength of SiC/SiC joint made with $Cu_{50}Ti_{50}$ filler metal at constant brazing time of 1 min. The strength exhibits a maximum value of 3.1 kg/mm^2 at 1025°C. Compared with the strength of Si_3N_4 joint the value SiC joint is relatively low. In joining of SiC using $Ni_{24.5}Ti_{75.5}$ filler metal the joint strength possesses a maximum value

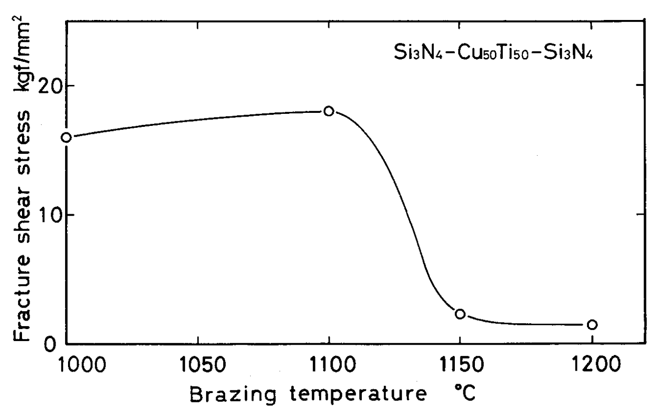

Fig. 1 Change in shear strength of Si_3N_4/Si_3N_4 joint using $Cu_{50}Ti_{50}$ filler with brazing temperature at brazing time of 30 min.

† Received on October 31, 1983
* Associate Professor
** Professor
*** Graduate Student

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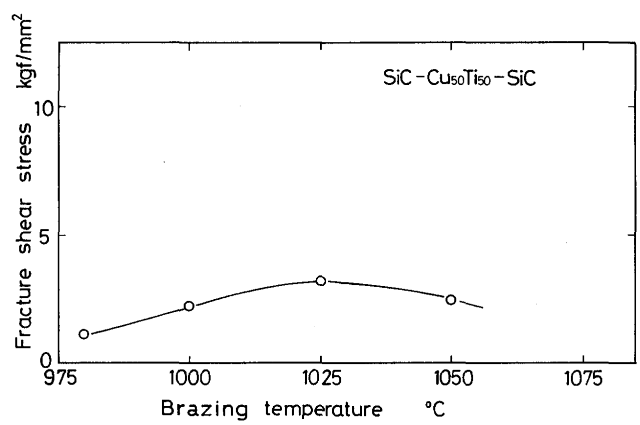

Fig. 2 Change in shear strength of SiC/SiC joint using $Cu_{50}Ti_{50}$ filler with brazing temperature at brazing time of 1 min.

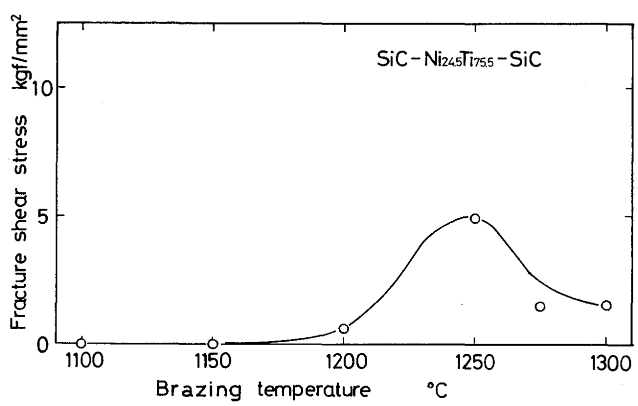

Fig. 3 Change in shear strength of SiC/SiC joint using $Ni_{24.5}Ni_{75.5}$ filler with brazing temperature at brazing time of 30 min.

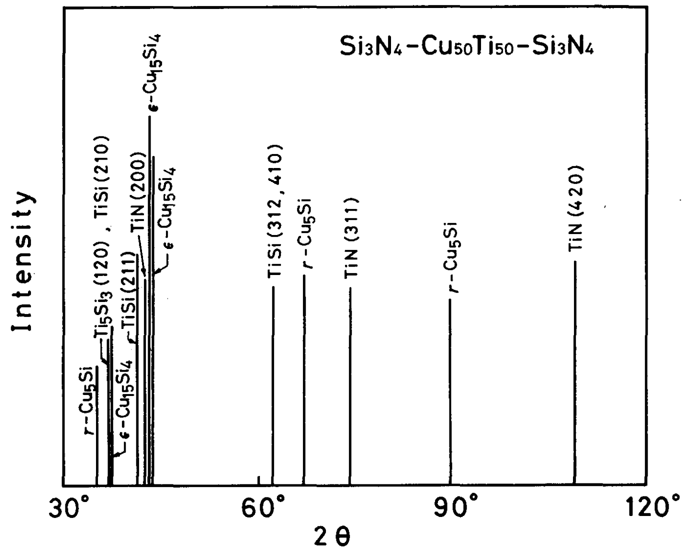

Fig. 4 X-ray diffraction pattern of fracture surface of Si_3N_4/Si_3N_4 joint made with $Cu_{50}Ti_{50}$ filler brazed at 1100°C for 30 min.

of 4.9 kg/mm² at 1250°C for constant brazing time of 30 min as shown in **Fig. 3**. The temperature that gives the maximum strength of SiC/SiC joint made with $Ni_{24.5}Ti_{75.5}$ filler is higher than that of SiC/SiC joint made with $Cu_{50}Ti_{50}$ filler.

In order to characterize the reactions between ceramics and filler metals, X-ray diffraction analyses of fracture surfaces of the joints were conducted. **Fig. 4** shows X-ray

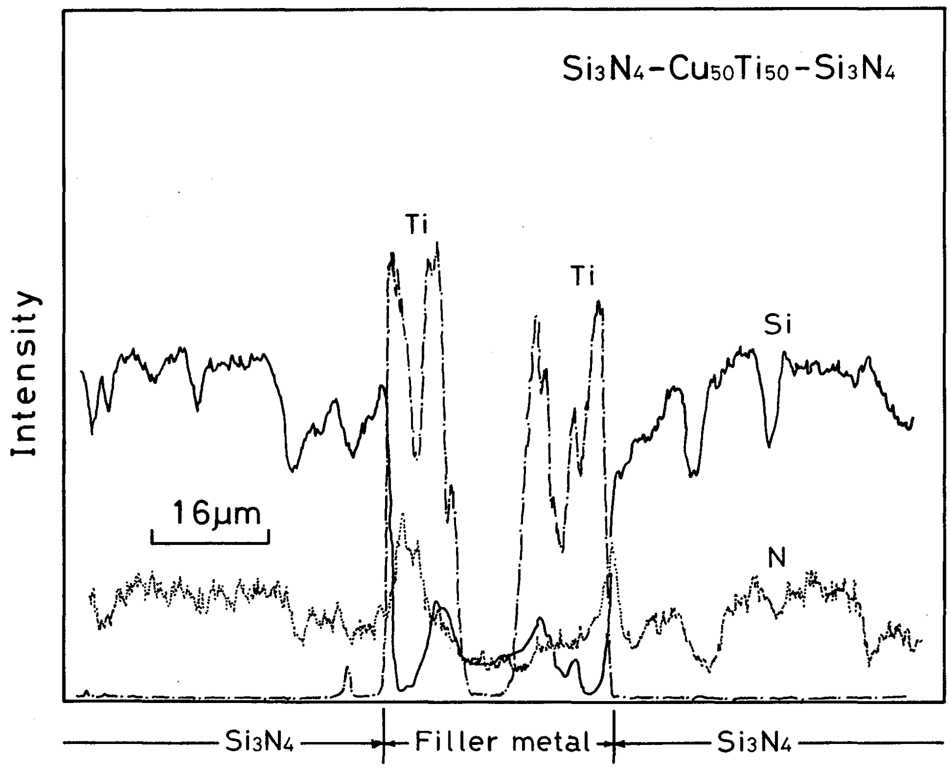

Fig. 5 Electron microprobe analyses for Ti, Si and N in Si_3N_4/Si_3N_4 joint brazed at 1100°C for 30 min.

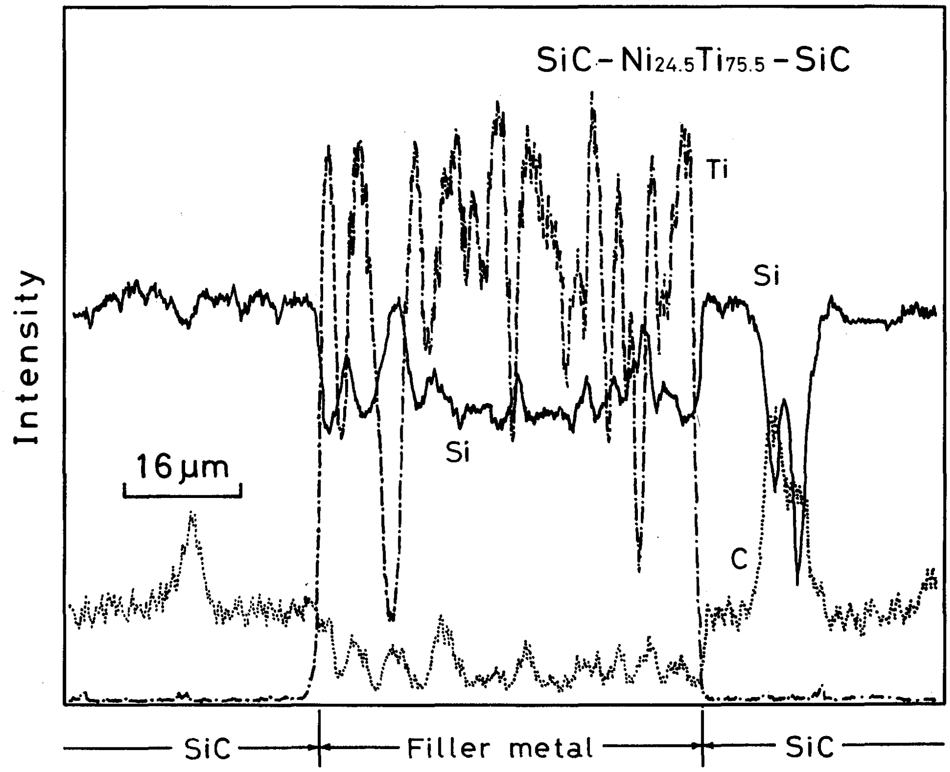

Fig. 6 Electron microprobe analyses for Ti, Si and C in SiC/SiC joint using $Ni_{24.5}Ti_{75.5}$ filler brazed at 1250°C for 30 min.

diffraction pattern of the fracture surface of Si_3N_4/Si_3N_4 joint brazed at 1100°C for 30 min with Cu·K_α radiation. Complex reactions took place, and TiN, TiSi, Ti_5Si_3, γ-Cu_5Si and ϵ-$Cu_{15}Si_4$ were formed in Si_3N_4/Si_3N_4 joint. **Fig. 5** illustrated electron microprobe analyses for Ti, Si and N in Si_3N_4/Si_3N_4 joint made with $Cu_{50}Ti_{50}$ filler brazed at 1100°C for 30 min. During brazing the filler metal was separated into Ti rich and Cu rich layers. Ti rich layer near the interface of the joint was composed of TiN, TiSi and Ti_5Si_3. Cu rich layer in the central layer of the joint was composed of γ-Cu_5Si and ϵ-$Cu_{15}Si_4$. The distribution of element for SiC/SiC joint made with $Ni_{24.5}Ti_{75.5}$ that was brazed at 1250°C for 30 min is represented in **Fig. 6**. Large amounts of silicon dissolve into the liquid filler. TiSi, Ti_5Si_3, a small amount of $TiSi_2$, Ni_3Si_2, δ-Ni_2Si, γ-Ni_5Si_2 and β_1-Ni_3Si were observed by X-ray diffraction analysis of the fracture surface of the joint. Compared with the braz-

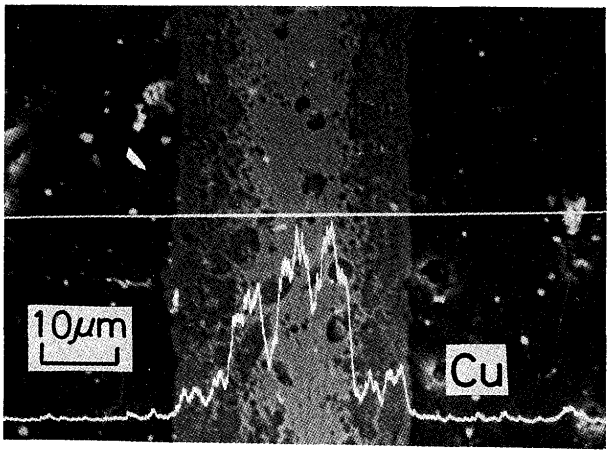

Fig. 7 Microphotograph and line analyses for Cu in Si_3N_4/Si_3N_4 joint using $Cu_{50}Ti_{50}$ filler brazed at 1100°C for 30 min.

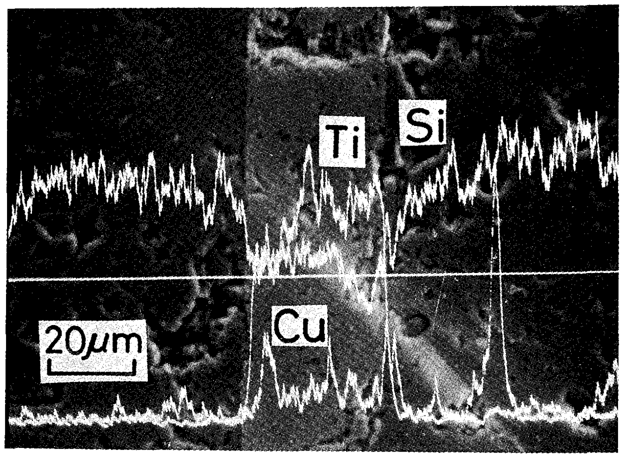

Fig. 8 Microphotograph and line analyses for Ti, Cu and Si in SiC/SiC joint using $Cu_{50}Ti_{50}$ brazed at 1100°C for 30 min.

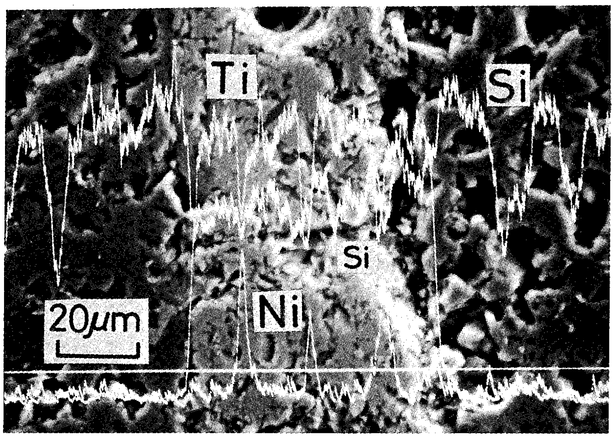

Fig. 9 Microphotograph and line analyses for Ti, Ni and Si in SiC/SiC joint using $Ni_{24.5}Ti_{75.5}$ brazed at 1250°C for 30 min.

ing of SiC with $Ni_{24.5}Ti_{75.5}$ filler the brazing of SiC with $Cu_{50}Ti_{50}$ can be conducted at low temperatures, and the reaction products are TiSi, $TiSi_2$, a small amount of Ti_5Si_3 and ϵ-Cu_5Si_4. As shown in **Figs. 7** to **9**, the elements in $Cu_{50}Ti_{50}$ filler reacts with Si_3N_4, but does not dissolve appreciably into the ceramics. On the other hand, SiC posseses large amounts of silicon as binding element and the element of Cu or Ni in $Cu_{50}Ti_{50}$ or $Ni_{24.5}Ti_{75.5}$ reacts with Si in the ceramics during brazing. The silicon, therefore, losses the role of binding SiC in the ceramics.

References

1) M. Naka, K. Asami, I. Okamoto and Y. Arata. Trans. JWRI, 12 (1983), No. 1, 145.