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Dissimilar laser brazing of single crystal diamond and tungsten carbide†

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KEY WORDS: (Laser brazing) (Single crystal diamond) (Tungsten carbide)

1. Introduction

The brazing technology is commonly used for the bonding of ceramic to metals [1-3]. Although, there are some problems such as joint defects that due to thermal stress in the joint field and material deterioration by heating in these dissimilar joints [4].

Diamond has various functional characteristics. Especially single crystal diamond has a good wear resistivity and thermal conductivity. Besides, tungsten carbide - cobalt alloy made by powder metallurgy has low thermal expansion coefficient and high rigidity good for a counter structural material to ceramics.

Among brazing processes, laser brazing [3] has good characteristics for dissimilar joining because of the possibility of short heating times and small heating areas, and suppression of damage to the base materials without furnace in comparison with conventional furnace brazing. This method is suitable for brazing of diamond, which has a tendency to graphitization at high temperature. So, this study describes dissimilar laser brazing of single crystal diamond and tungsten carbide using Ag-Cu-Ti alloy braze.

2. Experimental method

Commercially available WC-Co alloy classified as ISO K10 grade and artificial single crystal diamond were used in this work, whose sizes were 10mm × 10mm × 2mm and 4mm × 4mm × 2mm, respectively. The crystal plane (100) of the single crystal diamond was used as the interface. 70.26mass%Ag-28.06mass%Cu-1.68mass%Ti alloy braze sheet included Ti as major active ingredient for direct ceramic brazing and its thickness was 0.1mm.

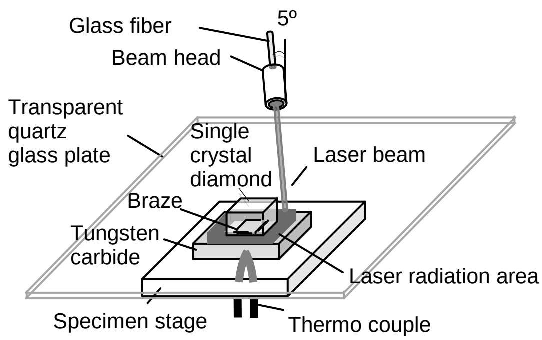

Fig. 1 Schematic illustration of laser brazing.

A braze sheet was sandwiched with a diamond block from top side and a tungsten carbide plate from bottom side in a vacuum chamber as shown in **Fig. 1**. The topside of the specimen was covered with a transparent quartz glass plate, which also served to fix the specimen. This chamber was evacuated to less than 10^{-1} Pa after samples had been loaded, and substitution of the atmospheric pressure with 99.999% Ar gas was done after the evacuation. This evacuation and substitution cycle was done at least three times before brazing. During brazing, Ar gas continued to flow, with a flow rate of about 5L/min.

The generated YAG and LD lasers were radiated through the transparent quartz glass plate to the topside of the WC-Co. Scanning of laser was done on the WC-Co around the single crystal diamond block. Laser brazing condition is summarized in **Table 1**. Scanning speed of laser was determined in order to heat the specimen efficiently in a circle around it.

Table 1 Laser brazing condition.

Pulsed YAG Average Output (kW)		0.134
Pulsed YAG wave length (nm)		1064
CW LD Output (kW)		0.02
CW LD wave length (nm)		808
Pulse frequency (Hz)		100
Scanning speed (mm/s)	(1st run)	0.6
	(2nd run)	1.0
	(3rd run)	1.0
	(4th run)	1.0
Laser beam diameter (mm)		0.5

Cross sectional observations and elemental analyses of the interface were performed using an electron probe micro-analyzer. Interfacial observation and estimation of interface area were performed using a scanning acoustic microscope. Shear strength was calculated from maximum load divided by interface area estimated from scanning acoustic microscopy.

3. Results and discussions

Figure 2 shows a cross sectional SEM observation of a single crystal diamond / Ag-Cu-Ti braze / WC-Co interface with low magnification. The interface between single crystal diamond and Ag-Cu-Ti braze is smooth and no

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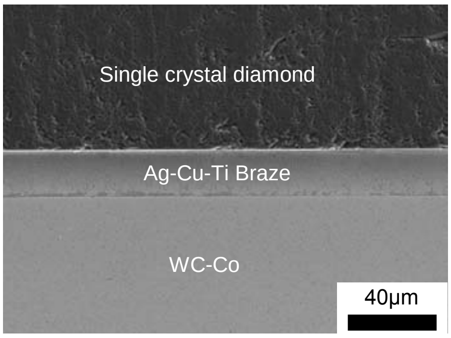

Fig.2 Cross section of a single crystal diamond / braze / WC - Co interface.

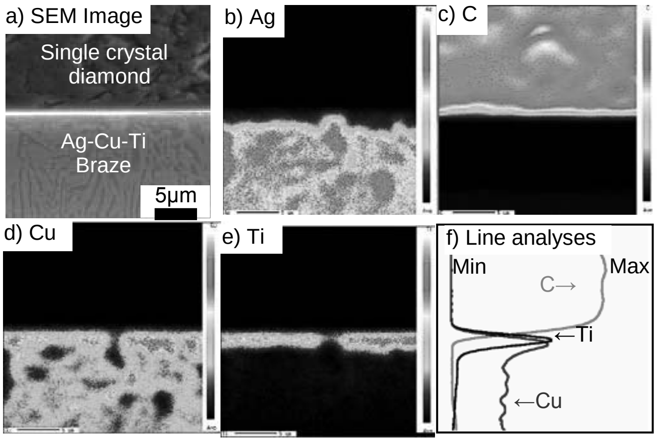

Fig. 3 Map analysis of a single crystal diamond / braze interface.

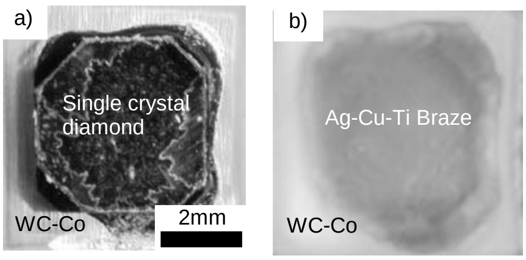

Fig. 4 a) Appearance of specimen and b) interfacial observation using scanning acoustic microscopy.

voids were observed. Also the interface between WC-Co and Ag-Cu-Ti braze is smooth.

Figure 3 shows the result of map analysis of a single crystal diamond / Ag-Cu-Ti braze interface. Figure 3(a) shows enlargement of the single crystal diamond / Ag - Cu - Ti braze interface in Fig. 2. Figure 3(b) shows the distribution of Ag near the interface in the same area of Fig. 3(a). Fig. 3(c), (d) and (e) show the distributions of C, Cu and Ti, respectively. From these distributions of elements, the concentration of Ti near the interface was observed and its thickness was about 2µm.

Figure 3(f) shows line analyses of C, Ti and Cu in the same area of (b) to (e). The distribution of C is decreased sharply at the interface. Meanwhile, the peak of the

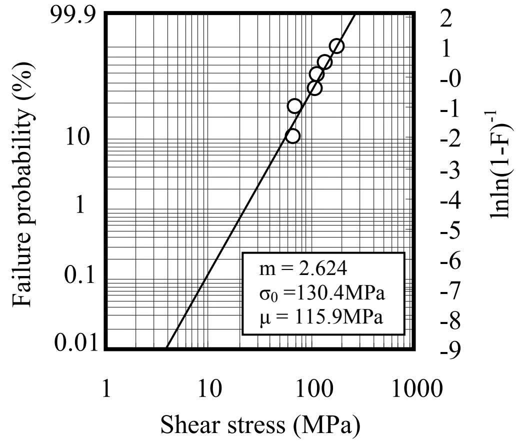

Fig. 5 The Weibull distributions of shear strength test.

distribution of Ti was located at the interface. The distribution of Cu is similar to that of Ti, but its peak shifted to the braze side and the concentration of Cu in the braze away from the interface was high. This shows the existence of interface layers of C-Ti and Cu-Ti. These results strongly suggest the formation of reacted layers like TiC and Cu-Ti like Cu_3Ti at the interfaces of single crystal diamond / Ag-Cu-Ti braze, respectively [5, 6].

Non-destructive test by scanning acoustic microscopy was done to evaluate how the melted braze filler spread at the interface between single crystal diamond and WC-Co plate. **Figure 4** (a) shows appearance of the specimen and (b) shows the image of scanning acoustic microscopy at the interface of the single crystal diamond / Ag-Cu-Ti braze / WC-Co. The black area in the center of (b) is Ag-Cu-Ti braze which was melted at the joint interface and partly spread out on the interface onto the WC-Co plate. There were no big voids in the black area where melted braze existed at the joint interface. So the wettability of these braze fillers and single crystal diamond or WC-Co seemed to be good.

Figure 5 shows the Weibull distribution of shear strength test of single crystal diamond / Ag-Cu-Ti braze. In the case of all tests, fracture occurred at the single crystal diamond side of the specimen. Average shear strength was 115.9MPa. This suggests that the fracture occurred at the base material of single crystal diamond and that the interface of brazing joint has the strength enough to connect single crystal diamond and WC-Co.

4. Conclusions

The conclusive remarks of this study are summarized as follows.

(1) At the interface of single crystal diamond / Ag-Cu-Ti braze, a concentration of Ti and C was observed. It was presumed that the reacted phase existed at the interface between single crystal diamond and braze.

(2) No large voids or cracks in the braze area existed from non-destructive observation of the interface using scanning acoustic microscopy.

(3) Fracture occurred at single crystal diamond side of each specimen after a shear strength test. This suggests that

the shear strength indicates the bulk strength of single crystal diamond and this brazing joint has strength enough to connect single crystal diamond and WC-Co.

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References

[1] Y. Nakao, K. Nishimoto and K. Saida: Trans. of Japan Welding Soc., 20 (1989), pp.66-76.
[2] M. Nicholas, D. Mortimer, L. Jones and R. Crispin: J. Mat. Sci., 25 (1990), pp.2679-2689.
[3] Y. Sechi, T. Tsumura and K. Nakata: Mat. and Des., 31 (2010), pp.2071-2077.
[4] W. Wlosinski: Fueg. Keram. Gla. Met., (1985), pp.22-36.
[5] A.Palavra, A. Fernandes, F. Costa, R. Silva, C. Serra, L. Rocha: Dia. and Rel. Mat., 10 (2001), pp.775-780.
[6] Y. Sechi, A. Takezaki, T. Matsumoto, T. Tsumura and K. Nakata: Mat. Trans., 50 (2009), pp.1294-1299.