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Microstructure and reaction phases in Si_3N_4/Si_3N_4 joint brazed with Cu–Pd–Ti filler alloy

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Abstract

Si_3N_4 ceramic was self-jointed using a filler alloy of Cu–Pd–Ti, and the microstructure of the joint was analyzed. By using a filler alloy of Cu76.5Pd8.5Ti15 (at.%), a high quality Si_3N_4/Si_3N_4 joint was obtained by brazing at 1100–1200 °C for 30 min under a pressure of 2×10^{-3} MPa. The microstructure of the Si_3N_4/Si_3N_4 joint which was observed by EPMA, XRD and TEM, and the results indicated that a reaction layer of TiN existed at the interface between Si_3N_4 ceramic and filler alloy. The center of the joint was Cu base solid solution containing Pd, and some reaction phases of TiN, PdTiSi and Pd_2Si found in the Cu [Pd] solid solution.

Keywords: A. Joining; B. Microstructure; C. Si_3N_4

1. Introduction

Si_3N_4 ceramic is a special and attractive material in engineering applications because of its lower density, higher thermal resistance and excellent wearing resistance without lubricants. It has become an ideal material for manufacturing the rotor of jet turbines. However, it is difficult to manufacture the Si_3N_4 ceramic workpieces with lager dimensions and complicated shapes due to its poor workability and lower ductility. Therefore, the engineering application of the Si_3N_4 ceramic greatly depends on the development of the bonding techniques of the Si_3N_4 ceramic. In recent 30 years, many studies have been focused on the joining techniques of the Si_3N_4 ceramic.

Active metal brazing has been widely investigated and used for joining the Si_3N_4 ceramic because it is a simple process to obtain high strength ceramic joints with different shape and size [1–3]. For active brazing of the Si_3N_4 ceramic, filler alloys containing some active metals such as Ti, Zr, Hf, etc. are usually used, and a high strength ceramic joint can be obtained by reaction between the active metals and the Si_3N_4 ceramic. Cu–Ag based alloys containing various amount of Ti have been widely adopted as the filler alloy for the brazing of Si_3N_4 ceramic [4,5]. This kind of filler alloys has a good wettability to almost all the ceramics. However, the ceramic joints using these filler alloys have lower thermal and oxidation resistance, and cannot be used at temperatures above 500 °C. Therefore the Cu–Ag–Ti filler alloys are not suitable for brazing the Si_3N_4 ceramic which is usually used at high temperature environment.

In order to improve the thermal and oxidation resistance of the Si_3N_4 ceramic joint, it is important to develop new filler materials with higher melting point and oxidation-resistance. It has been reported that by using Y–Al–Si–O–N glass filler a Si_3N_4/Si_3N_4 joint with the microstructure and properties similar to the bulk Si_3N_4 ceramic was obtained, and such a joint is suitable for high temperature applications [6–8]. It was also reported that the Si_3N_4/Si_3N_4 joints with high thermal and oxidation resistance have been obtained using active filler alloys with higher melting point and oxidation-resistance, which were developed by adding metals such as Au, Pd, Pt, V, Co, etc. into the filler alloys [9–13]. In this investigation, a Cu–Pd–Ti alloy was used as the filler alloy for brazing the Si_3N_4 ceramic. Tillmann [9,10] reported that Pd improves the heat resistance of the active filler alloy. However, the influence of Pd in the filler alloy on its microstructure still has not been clarified. In the present work, the reaction between the filler alloy and the Si_3N_4 ceramic and the resulting microstructure of

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the Si_3N_4/Si_3N_4 joint were investigated and the metallurgical behavior and bonding mechanism of the joint were analyzed.

2. Materials and experimental procedures

The Si_3N_4 ceramic used in this investigation was made by a hot-pressure sintering process. The content of MgO and Al_2O_3 in the ceramic is less than 5 wt.%. The raw materials of the filler alloy are Cu, Ti and Pd foils with the thickness of 10, 20 and 10 μm, respectively. By adjusting the amount of the three kinds of foils, an alloy with a composition of 76.5Cu–8.5Pd–15Ti (at.%) is formed during brazing.

The Si_3N_4 ceramic sample with a size of Ø6 mm × 4 mm was polished to a surface finish of $R_a = 30$ μm, and then was cleaned together with the metal foils in a super sonic device. The cleaned metal foils were placed between two pieces of Si_3N_4 ceramic samples and a small weight was put on the upper ceramic sample to obtain a pressure of 2×10^{-3} MPa. The brazing of the Si_3N_4 ceramic was carried out in a vacuum of 1.33×10^{-3} Pa at 1100–1200 °C for 30 min. The microstructure of the joints was observed and analyzed by EPMA, XRD and TEM.

3. Results

Fig. 1 shows the morphology and elemental analysis results of the joint brazed at 1100 °C. It can be seen that a continuous TiN reaction layer with an average thickness of 5 μm exists between the Si_3N_4 ceramic and filler alloy as shown in Fig. 1(d) and (f). The matrix in the central part of the joint is Cu base solid solution containing 5 at.% Pd. There are two phases in the Cu [Pd] solid solution as shown in Fig. 1(a). It was determined by the elemental analysis results that the white, large, is PdTiSi phase as shown in Fig. 1(c)–(e), and the small black one is TiN phase as indicated for the results shown in Fig. 1(d) and (f).

Fig. 2(a) shows the morphology of the joint brazed at 1200 °C. Two phases were found in the Cu [Pd] solid solution. Elemental analysis results indicated that one of them with the grey phase is PdTiSi and white one is Pd_2Si. From the results of Figs. 1 and 2(a), the microstructure of the Si_3N_4/Si_3N_4 joint brazed using the 76.5Cu–8.5Pd–15Ti filler alloy at the brazing conditions of this work is schematically shown in Fig. 2(b). It shows that the microstructure of the joint is "Si_3N_4 ceramic/TiN reaction layer/filler alloy". The base of the filler alloy is Cu [Pd] solid solution, in which there are TiN, Pd_2Si and PdTiSi phases.

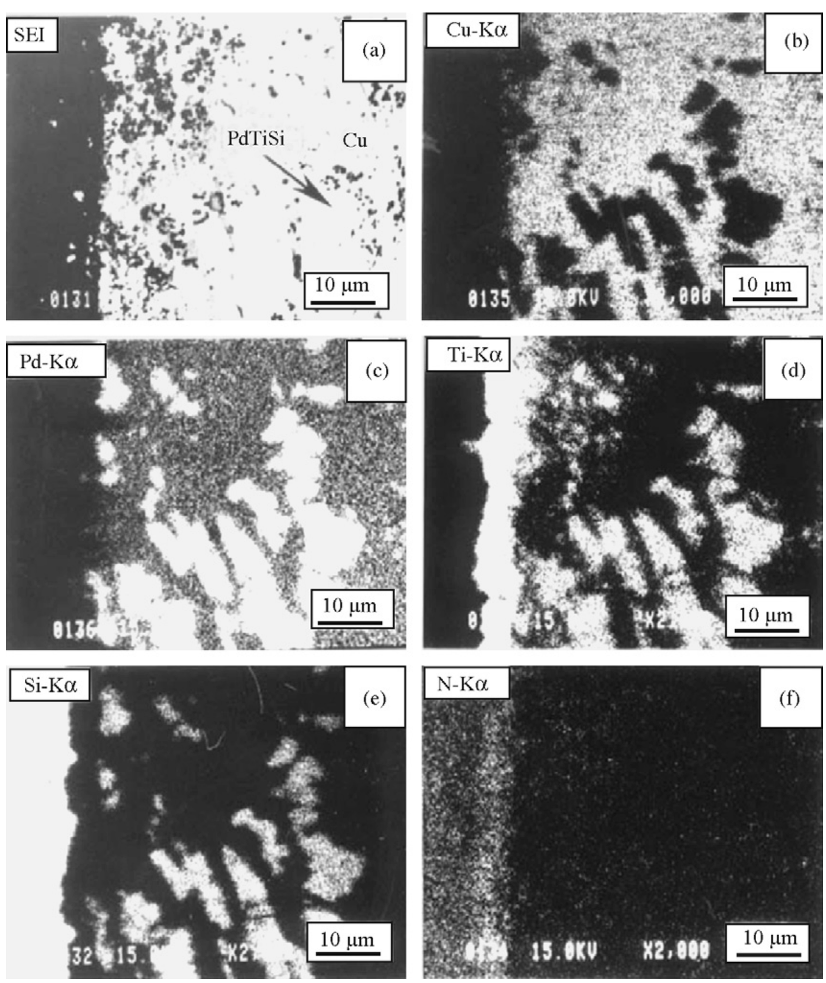

Fig. 1. Morphology and elemental analysis results of the Si_3N_4/Si_3N_4 joint brazed using Cu76.5Pd8.5Ti15 filler alloy at 1100 °C for 30 min.