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Influence of nickel ion implantation on the inactive braze joining abilities of Al_2O_3 ceramics

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Abstract

Multi-crystalline Al_2O_3 ceramics were implanted with 130 keV Ni^+ ion beams at 225 °C in a vacuum of 1.33×10^{-3} Pa. The inactive braze joining abilities of the implanted ceramic to 1Cr18Ni9Ti (AISI 321) stainless steel with $Ag_{34}Cu_{16}Zn_{50}$ (wt%) brazing material were investigated. The relationships between the joining abilities and the surface compressive stresses produced by the ion implantation were studied for the first time. The results showed that when the fluence was less than 5×10^{16} ions/cm^2, the surface properties including wetting ability, braze joining ability and produced surface compressive stresses, increased with ion implantation fluence, and reached the maximum value at a point of 5×10^{16} ions/cm^2. After this point, the properties decreased upon further increasing the ion implantation fluence.

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Keywords: Ion implantation; Joining; Surface treatment; Ceramics

1. Introduction

The joining of ceramic to metal and to itself, which is useful to the application of the structural ceramics, is a very important surface and interface engineering research problem in recent years. High energy ion beams possess both surface and interface modification effects, and how to use this advanced technology to improve the joining ability of ceramics is a worthy problem to investigate. According to Batfalsky [1], C^+ ion implantation of SiC ceramics can surely enhance the strength and fracture toughness of the SiC ceramic-to-metal brazing joints. Another relevant work was conducted by Baba and Hatada [2]. Their results

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showed that the electric conductivity and wetting ability of Cu–Ag brazing material to the Al_2O_3 ceramics increased with the fluence of Ti^+ ion implantation. In the present paper, we studied the braze joining abilities of Ni^+ ion implanted Al_2O_3 ceramics, and the relationship between the surface stresses and braze joining abilities of the ceramics.

2. Experimental

The ceramic samples used in this study were Al_2O_3 multi-crystalline ones, which were first annealed, and then implanted with different fluences of 130 keV Ni^+ ion beams at 225 °C in a vacuum of 1.33×10^{-3} Pa. The surface residual stresses of the ion implanted ceramic samples were measured by 2904 AL X-ray stress measure device.

The brazing tests of the ion implanted ceramics to 1Cr18Ni19Ti (AISI 321) stainless steels were carried out. The brazing material used was Ag_{34}-$Cu_{16}Zn_{50}$ (wt%) provided by Peking Electrician Material Factory, with the thickness of 100 μm, and the liquid phase line temperature of 775 °C. The size of the joining surface is 4 mm × 8 mm. The braze joining processes were conducted in vacuum with a pressure applied onto the joining interface of about 1 kPa. The braze joining temperature versus time curve is shown in Fig. 1. The shear strengths of the ceramic–metal brazing joints were tested on the Instron1251 Electro-hydraulic Servo material experimental machine. And the SEM images of the fracture surfaces of the broken joints were taken by S360 scanning electron microscope.

Moreover, the same braze joining tests of the ceramic samples, which were not ion implanted, but vacuum vapor plated with 40 nm active metal Ti thin film, were also performed, in order to perform analyses comparatively with the ion implanted ceramics.

3. Results

3.1. Surface residual stresses

Fig. 2 shows the fluence dependence of surface residual stress, which increases with the fluence until the fluence was reached 5×10^{16} ions/cm^2, and then decreases. This phenomenon had also been reported by Hioki [3], who explained that the reason why the residual stress decreased later was that the excessive fluences had made the surface layer amorphous, and the amorphous layer resulted in the release of surface stresses. Chai [4] considered that as the fluence increased, the crystal surface layer gradually changed into an amorphous state upon creation of more lattice defects and broken ionic bonds of the crystal. Thus the compressive residual stresses were released. The electron diffraction patterns, which showed amorphous rings, supported this hypothesis.

3.2. Braze joining

3.2.1. Configuration of brazing joints

During the brazing process, large amount of melted brazing materials between the joining surfaces were squeezed out, and solidified as droplets

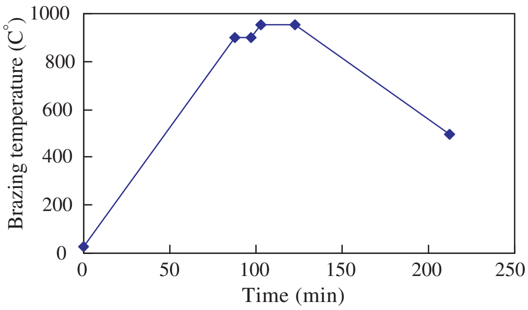

Fig. 1. Brazing temperature versus time.

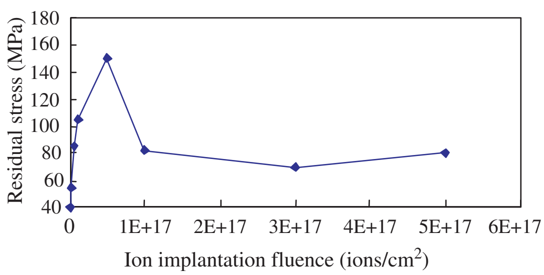

Fig. 2. The fluence dependence of surface compressive residual stress.