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Effect of Joining Conditions on Joint Strength of Barium Titanate Brazed by Pure Molten Aluminum

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The effects of joining conditions on the joint strength of barium titanate brazed by pure molten aluminum were examined. Higher shear strength was obtained with the fracture of barium titanate for brazed specimens under longer holding times. This suggests that the joint strength is greater than the shear strength of barium titanate. On the other hand, lower shear strength with the interfacial delamination was obtained for the specimens under shorter holding times. Observations of the delaminated surface under longer holding times showed that fractured barium titanate pieces and grains were strongly bonded to the aluminum layer. Here, the cross-sectional oxygen distribution in the vicinity of the joint interface indicated the existence of a thicker alumina layer between barium titanate and pure aluminum under longer holding times. Therefore, interfacial bonding may be achieved through the progress of oxidation of molten aluminum during joining.

Keywords: *joining, pure metal, aluminum, ceramic, barium titanate*

1. Introduction

Positive temperature coefficient (PTC) ceramics such as barium titanate are used as electric heating elements in electric vehicles [1]. However, the use of electric heaters reduces the driving range of the vehicles. In conventional heaters, PTC ceramics contact heat diffusers through insulating layers and thermal grease. Direct bonding of the ceramics and pure aluminum diffusers by cast-in insertions would enable the manufacture of highly efficient heaters [2]. In this study, the effects of joining conditions on the joint strength of barium titanate brazed by pure molten aluminum were examined.

2. Experimental procedure

Brazed specimens were prepared by heating in a muffle furnace under several conditions and then cooling in air, as shown in Fig. 1 [3]. The joint strength of the specimens was evaluated using a shear test, as shown in Fig. 2 [4]. The fracture surface of the specimens was observed using an optical microscope and a scanning electron microscope (SEM). The cross-sectional distribution of the elements was also analyzed by an electron probe microanalyzer.

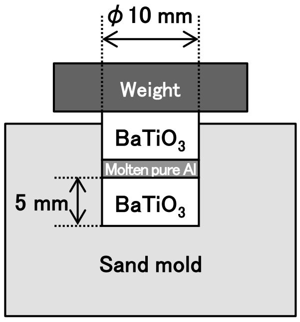

Fig. 1 Illustration of specimen preparation.

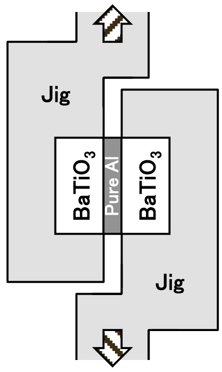

Fig. 2 Illustration of shear test.

3. Results and discussion

Figure 3 shows the relationship between the holding time and the shear strength at 780°C. For the specimens under longer holding times, higher shear strengths of more than 10 MPa were obtained with the fracture of barium titanate. This result suggests that the joint strength is greater than the shear strength of barium titanate. On the other hand, lower shear strength with interfacial delamination was obtained for the specimens under shorter holding times. This result suggests that the shear strength reflects the joint

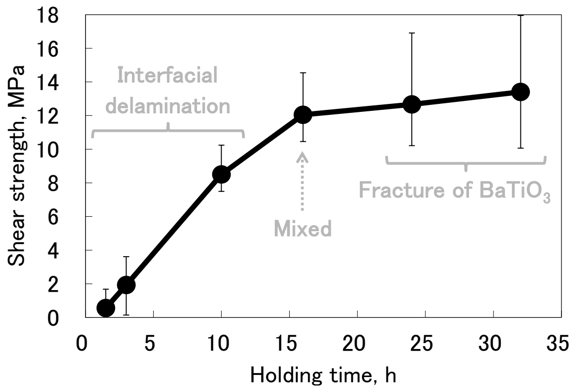

Fig. 3 Relationship between holding time and shear strength (Temp: 780°C, pressure: 12.7 kPa).

strength. Furthermore, the joint was not obtained at 720°C. Therefore, both joining conditions of a longer holding time and a higher temperature are necessary to obtain a higher joint strength.

Figures 4 and 5 show the comparisons of the macrostructure and microstructure of the delaminated surface of the specimens, respectively. Adhesion of fractured barium titanate pieces to the aluminum layer was observed for the delaminated surface near the periphery under the holding time of 16 h [Fig. 4(b)]. In addition, significant adhesion of the fractured micro grain was observed [Fig. 5(b)]. Here, Fig. 6 shows the comparison of the cross-sectional oxygen distribution in the vicinity of the joint interface near the periphery. An oxygen-rich layer was observed at the joint interface between barium titanate and pure aluminum under a holding time of 16 h [Fig. 6(b)]. This result indicated the existence of the thicker alumina layer due to a longer holding time and a higher temperature during joining [5,6]. Therefore, interfacial bonding

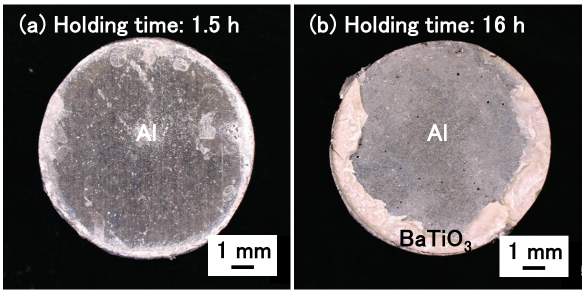

Fig. 4 Appearance of delaminated surface of the specimens (Temp: 780°C, pressure: 12.7 kPa).

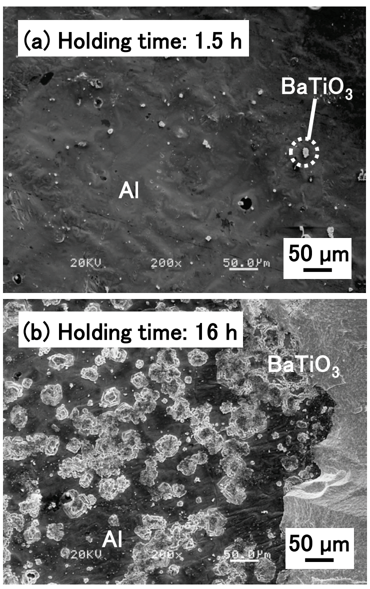

Fig. 5 SEM images of delaminated surface near the periphery (Temp: 780°C, pressure: 12.7 kPa).

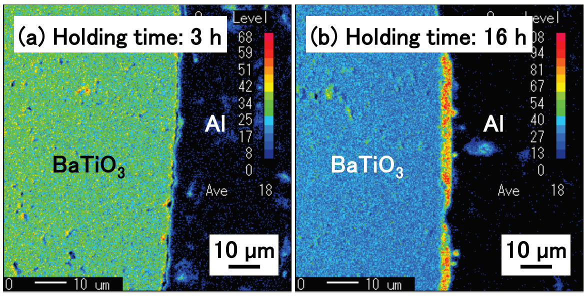

Fig. 6 Cross-sectional O distribution in joint interface near the periphery (Temp: 780°C, pressure: 12.7 kPa).

may be achieved through the progressive oxidation of molten aluminum [7,8].

4. Conclusions

(1) Higher shear strengths of more than 10 MPa was obtained with the fracture of barium titanate under longer holding times. Lower shear strength with interfacial delamination was also obtained under shorter holding times.

(2) Significant adhesion of fractured barium titanate pieces and grain to the aluminum layer was observed on the delaminated surface under a holding time of 16 h.

(3) The existence of a thicker alumina layer between barium titanate and pure aluminum in the joint interface was indicated under a holding time of 16 h.

Acknowledgements

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