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Interface formation and strength of Be/DSCu diffusion bonding

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Abstract

Beryllium has been proposed to be used as a plasma facing material of the first wall for ITER, and will be bonded by HIP process to Dispersion Strengthened Copper (DSCu). Be/DSCu diffusion bonding tests in the range of temperature from 600°C to 850°C by hot pressing techniques have been conducted to identify the effect of bonding temperature and time on interface formation and joint strength. The bonded Be/DSCu joints were evaluated by microstructural analysis of the interface and shear strength tests at room temperature. The diffusion layer of directly bonded Be/DSCu joints and the joints with Be–Cu interlayer consisted of $Be_2Cu(\delta)$ phase on the Be side and Cu + $BeCu(\gamma)$ phase on the DSCu side. Cu + $BeCu(\gamma)$ phase generated remarkably fast at 800–850°C. The thickness of the diffusion layer was linear to a square root of bonding time. Shear strength of the joints bonded at 650–750°C are all around 200 MPa. Shear strength is dominated by the formation of the layer of $Be_2Cu(\delta)$ phase on the Be side.

1. Introduction

Beryllium has been proposed to be used as plasma facing material of the first wall in ITER. Dispersion Strengthened Copper (DSCu) is used as heat sink material because DSCu has high thermal conductivity and strength. In recent research of Be/Cu bonding, Be/Cu diffusion bonding tests using various interlayers were conducted to choose the suitable interlayer materials [1]. Out of-pile reactivity tests with diffusion couples between Be and Cu were conducted to clarify the generation of reaction products and growth of the reaction layer [2]. In order to obtain high strength and reliability for high heat flux, the control of the interface is an important technique. In this study, Be/DSCu diffusion bonding tests by hot pressing techniques have been conducted to identify the effect of bonding temperature and time on interface formation and joint strength.

2. Experimental

2.1. Specimens

Be specimens were hot pressed beryllium (S-65C) produced by NGK Insulators. DSCu were GlidCop® AL-25 produced by SCM Metal Products. Cylinders of Be and DSCu, 10 mm in diameter and 20 mm in length were bonded. Diffusion bonding of Be/DSCu was achieved by hot pressing at 50 MPa in vacuum with and without the insert metal of 50 μm thick Be–Cu alloy foil (Cu–1.8%Be). To make clear the effect of bonding temperature on strength and microstructure of the interlayer, a series of joints were manufactured at various temperatures in the range from 600°C to 850°C with the same bonding time of 1 h. At 700°C, a series of joints were manufactured with various bonding times in the range from 1 to 6 h.

2.2. Evaluation of Be/DSCu joint

Microstructural analysis was carried out for the interface of Be/DSCu joints by scanning electron microscopy. Mechanical testing for shear strength of the joints was carried out at room temperature.

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3. Results and discussion

3.1. Interface formation

Fig. 1 shows the SEM micrograph of the joint bonded at 700°C without the interlayer. The diffusion layer of this joint consisted of two layers. The nature of the diffusion layer was identified by X-ray diffraction. $Be_2Cu(\delta)$ phase of 6 μm thickness on the Be side and Cu + $BeCu(\gamma)$ phase of 27 μm thickness on the DSCu side were observed.

Fig. 2 shows the SEM micrograph of the joint bonded at 700°C with Be–Cu interlayer. At the interface of Be/Be–Cu, the diffusion layer had the same structure as the joint bonded at 700°C without the interlayer. The thickness of $Be_2Cu(\delta)$ and Cu + $BeCu(\gamma)$ phase layers were nearly equal to those of the joint bonded without the interlayer. At the interface of Be–Cu/DSCu, diffusion layers were not observed.

Fig. 3 shows the SEM micrograph of the joint bonded at 850°C without the interlayer. Diffusion layers have the same structure as in the joint formed at 700°C. The diffusion layer on the DSCu side was Cu + $BeCu(\gamma)$ phase and the thickness had increased to 260 μm. The growth rate of Cu + $BeCu(\gamma)$ phase layer was greater than that of $Be_2Cu(\delta)$ phase.

Fig. 4 shows the changes of the thickness of diffusion layer with bonding temperature. As the bonding temperature increased, the thickness of Cu + $BeCu(\gamma)$ layer increased. For the joints at 800–850°C without the interlayer, Cu + $Be_2Cu(\gamma)$ layer generated at remarkably high rates, i.e. 150 μm for bonding temperature of 800°C and 270 μm for 850°C. For the joints with the interlayer, the thicknesses of Be_2Cu layer were under 50 μm even for 850°C.

In diffusion controlled processes the thickness of diffusion layer is expressed as a parabolic law. Fig. 5 shows the changes of the thickness of diffusion layer with bonding time for a bonding temperature of 700°C. The thickness of the diffusion layer in both cases was proportional to the square root of bonding time [2].

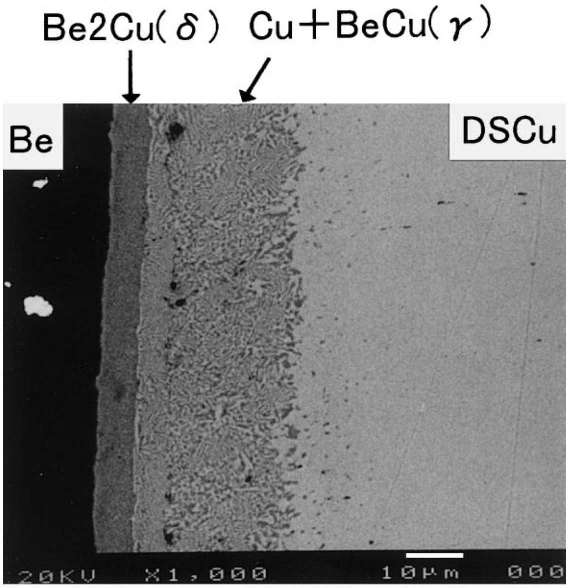

Fig. 1. SEM micrograph of joint bonded at 700°C without the interlayer.

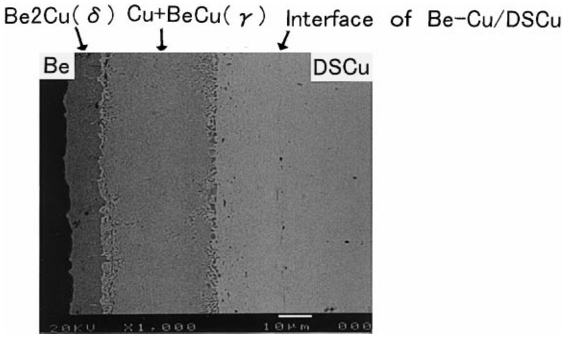

Fig. 2. SEM micrograph of joint bonded at 700°C with Be–Cu interlayer.

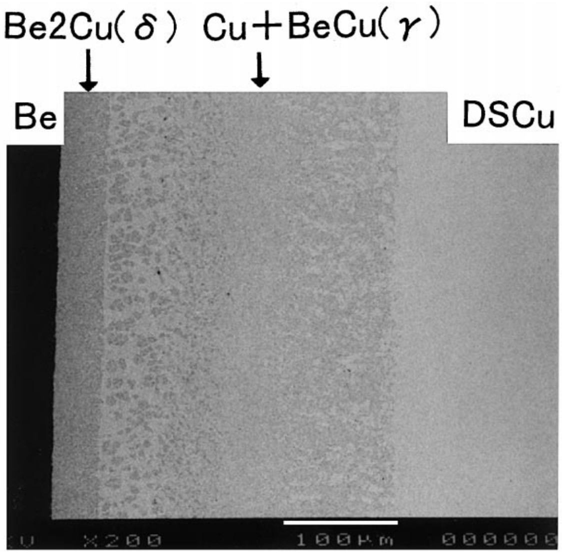

Fig. 3. SEM micrograph of joint bonded at 850°C without the interlayer.

3.2. Shear strength

Fig. 6 shows the dependence of shear strength on bonding temperature. Shear strengths of the joints bonded at 600–750°C with and without the interlayer, except the joint bonded at 600°C with the interlayer, are

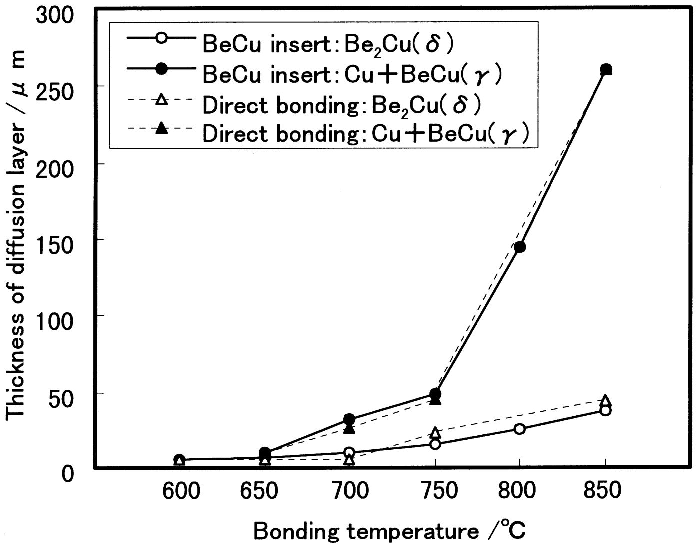

Fig. 4. Changes of the thickness of diffusion layer with bonding temperature.

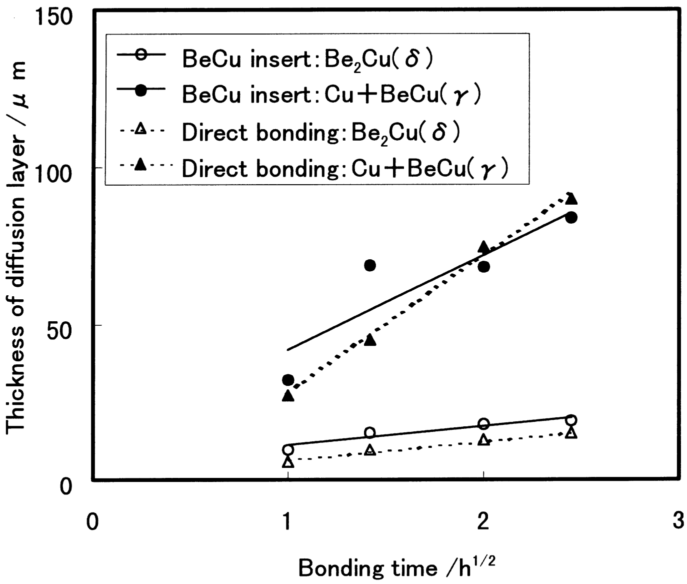

Fig. 5. Changes of the thickness of diffusion layer with bonding time (bonding temperature: 700°C).

of the same level: 200 MPa, even though the thickness of Cu + BeCu(γ) layer increased with increasing bonding temperature. Fracture originated near the interface of Be/Be_2Cu(δ) phase. Therefore the shear strength does not depend on the thickness of Cu + BeCu(γ) layer. Shear strength degradation of the joints bonded at 800–850°C is thought to be due to the increase of residual stress at the bonded interface with increasing bonding temperature.

Fig. 7 shows the dependance of shear strength of joints bonded at 700°C on bonding time. The joint bonded with the bonding time of 6 h did not show the large degradation of shear strength even though the thickness of Cu + BeCu(γ) layer increased with increasing bonding time.

From the above it may be concluded that the shear strength is affected mainly by the formation of the layer of Be_2Cu(δ) phase on the Be side of the interlayer.

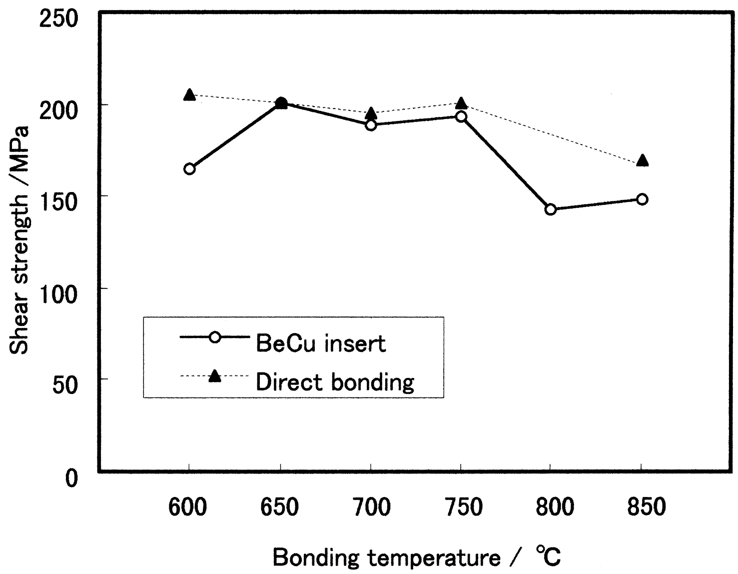

Fig. 6. Dependance of shear strength on bonding temperature.

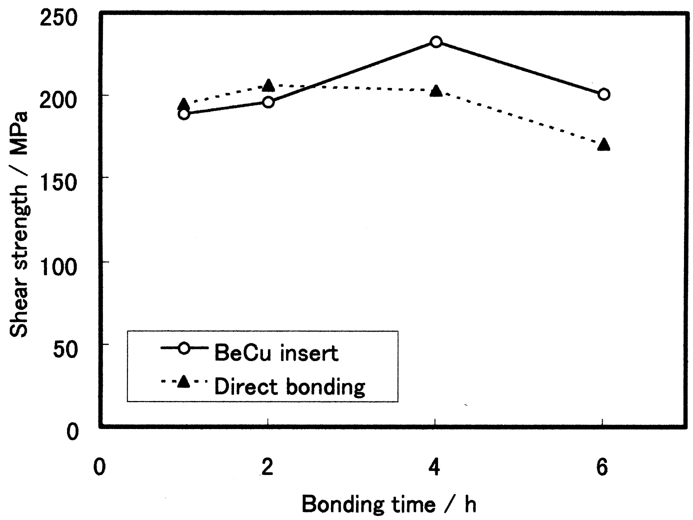

Fig. 7. Dependance of shear strength of joints bonded at 700°C on bonding time.

4. Conclusions

Be/DSCu diffusion bonding tests using a Be–Cu alloy interlayer or direct bonding in the range of temperature from 600°C to 850°C have been conducted to identify the effect of bonding temperature and time on interface formation and strength. The following conclusions are derived.

1. The diffusion layer of directly bonded Be/DSCu joints consisted of $Be_2Cu(\delta)$ phase on the Be side and Cu + $BeCu(\gamma)$ phase on the DSCu side of the interlayer. Cu + $BeCu(\gamma)$ phase generated rapidly at 800–850°C.
2. The diffusion layer of the joint with Be–Cu interlayer at the interface of Be/Be–Cu has the same structure as directly bonded Be/DSCu joints. At the interface of Be–Cu/DSCu, diffusion layers were not observed by SEM.
3. The thickness of diffusion layer was linear with the square root of bonding time.
4. Shear strengths of the joints bonded at 600–750°C with and without the interlayer, except the joint

bonded at 600°C with the interlayer, are of the same level: 200 MPa. It may be concluded that the shear strength is affected mainly by the formation of the layer of $Be_2Cu(\delta)$ phase on the Be side of the interlayer.
5. Bonding temperatures of 650–750°C are recommended. Bonding time and interlayer are unimportant.

References

[1] E. Visca et al., in: Proceedings of 12th Topical Meeting on the Technology of Fusion Energy, USA, 1996.
[2] N. Sakamoto et al., in: Fifth International Workshop on Ceramic Breeder Blanket Interactions, Rome, 23–25 September 1996.