Thermal Stress Analysis and Brazing Test for Design of a Frontend Pulse-by-pulse SR Beam Monitor

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Abstract

We have designed a frontend pulse-by-pulse synchrotron radiation beam monitor operated in photoemission mode. The detector head has a microstripline structure for fast response time. The candidates of the dielectric plates of the structure are aluminium nitride and silicon carbide. In order to establish a manufacturing process of the detector head, we have simulated residual stress of AlN and SiC dielectric plates after brazing on copper tungsten cooling blocks. Maximum and minimum principal stresses of various sizes of the dielectric plates were examined. Brazing tests have been also carried out for both AlN brazed on CuW and SiC brazed on CuW brazing. We report on details of thermal stress analysis and brazing test for design of the frontend pulse-by-pulse SR beam monitor.

1. Introduction

The present X-ray beam position monitors (XBPMs) for SPring-8 ID beamlines work in photoemission mode [1]. The detector heads having CVD diamond blades are mainly used in order to reduce the heat load. The XBPMs have high resolution and good stability even under severe heat load condition. However, they have long time constant, which is about 100 nsec. Therefore, we have developed a frontend pulse-by-pulse synchrotron radiation (SR) beam monitor operated in photoemission mode [2].

An important point for design of frontend components is consideration about high heat proof against extremely high power SR, especially in the third generation SR facilities, such as SPring-8. The frontend pulse-by-pulse SR beam monitor has the following mechanical structures for improving thermal properties, as shown in Figure 1. The detector head of the monitor has a metal line, which is made of OFHC copper, brazed to dielectric plates. The plates are connected to a metal cooling base by brazing. We chose aluminium nitride (AlN) for the dielectric plates, because AlN has the high heat conductivity (150 W/m·K). We chose copper tungsten (Cu10-W90, CuW) for the cooling base, because CuW has the high heat conductivity (180 W/m·K). The small thermal expansion coefficient of CuW (6.5×10^{-6}/K) is important for connecting a ceramics, such as AlN (4.6×10^{-6}/K).

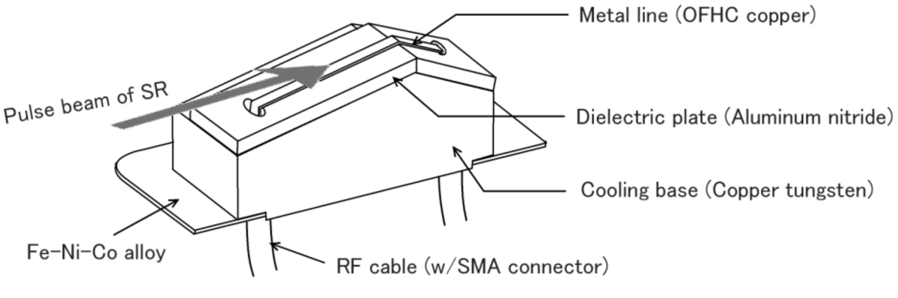


Figure 1: Schematic view of the detector head of the frontend pulse-by-pulse SR beam monitor. The copper line has the width of 1.5 mm and the length of about 60mm. The AlN plates have the thickness of 1.65mm. This monitor was manufactured by KYOCERA Corporation.

2. Thermal Stress Analyses

The typical temperature of brazing is 780 degree C. Thermal stress during cooling down to the room temperature may cause crack of ceramics, such as AlN and SiC. Therefore, we have simulated residual stress of AlN plates after brazing on CuW cooling blocks. Maximum and minimum principal stresses of various sizes of the plates were examined. The analysis model is indicated in Figure 2. The AlN plate is brazed on the CuW base plate. The model has rotation symmetry. Figure 3 indicates simulation results of the direction of the maximum principal stress in the AlN plate. The direction of the maximum principal stress near the axis of rotation symmetry is perpendicular to the contact surface of brazing, but the stress near the edge is orientated toward the center. Using the AlN with small diameter, the stress is low and distributed uniformly. But using the large diameter, the stress is high and distributed mostly near the edge. It is characteristic that there is no stress near the center of the large disc.Figure 4 indicates simulation results of the maximum principal stress and the minimum principal stress of AlN plates brazed on the CuW base plate. SiC has been also simulated as shown in Figure 5. SiC is another candidate for the dielectric plate. SiC can reduce electrification on the surface of the detector head because of the low electric resistivity.

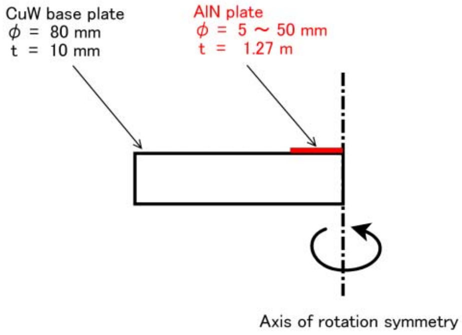


Figure 2: Model of analysis. Finite element method has been performed.

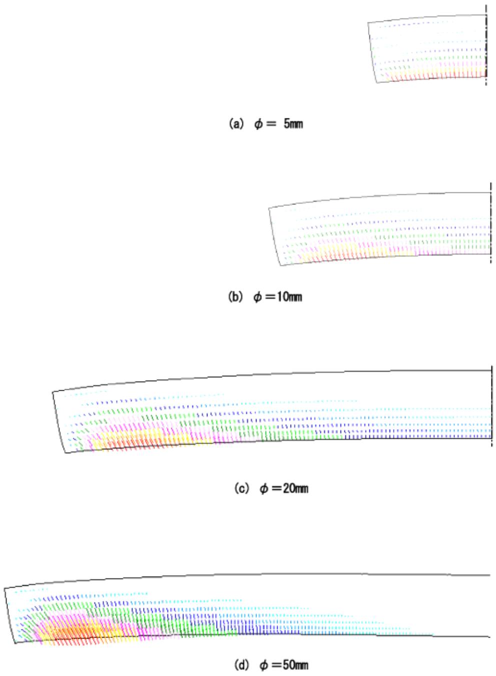
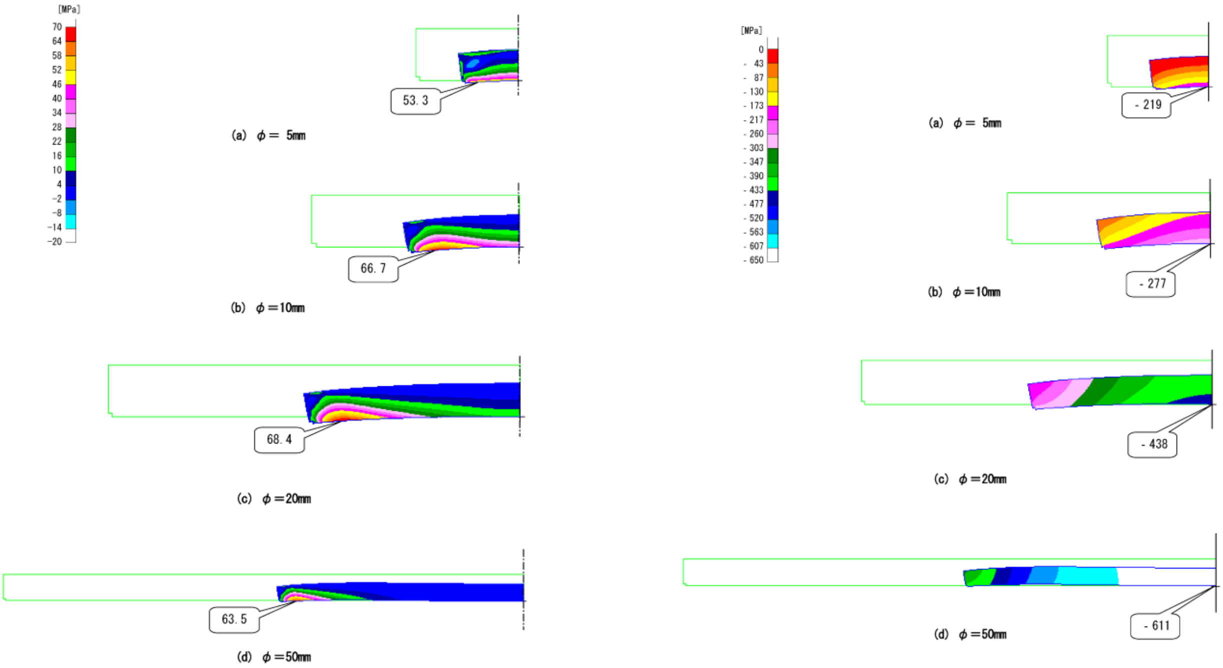


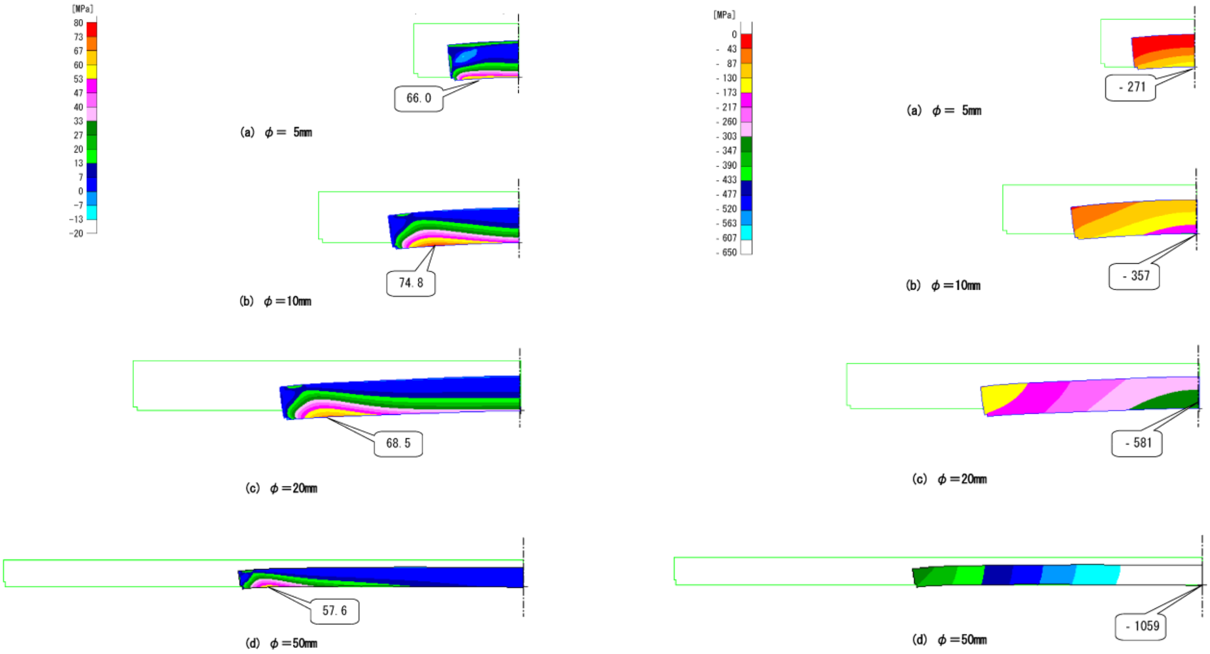
Figure 3: Simulation results of the direction of the maximum principal stress in the AlN plate.



(A) Maximum principal stress

(B) Minimum principal stress

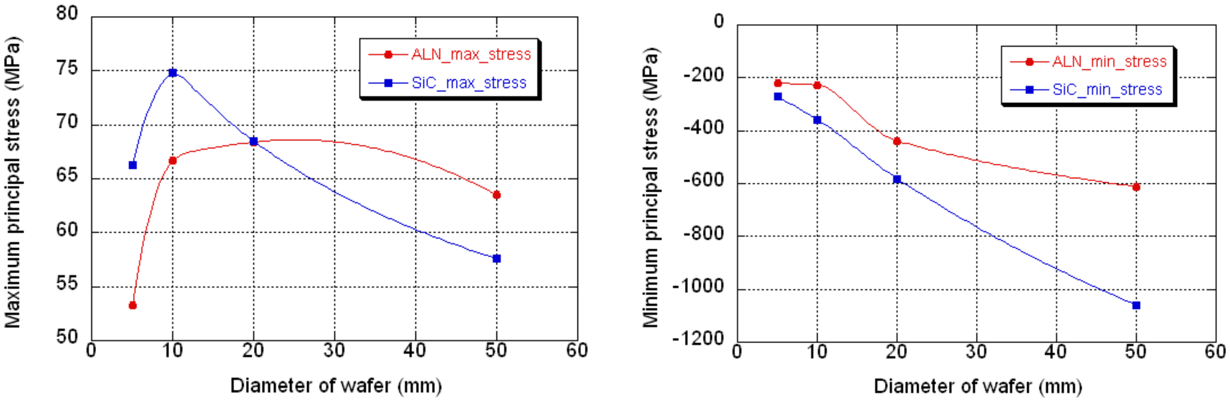
Figure 4: Simulation results of (A) the maximum principal stress and (B) the minimum principal stress of AlN plate brazed on the CuW base plate. Green lines indicate initial shapes of AlN at brazing temperature (780 degree C).



(A) Maximum principal stress

(B) Minimum principal stress

Figure 5: Simulation results of (A) the maximum principal stress and (B) the minimum principal stress of SiC wafer brazed on the CuW base plate.



(a) Maximum principal stress (b) Minimum principal stress

Figure 6: Dependences of (a) the maximum principal stress and (b) the minimum principal stress of AlN and SiC wafer brazed. The horizontal axis indicates the diameter of AlN or SiC wafers.

Simulation data of the maximum principal stresses and the minimum principal stresses are summarized in Fig. 6. The maximum principal stresses of AlN and SiC have peak values at the diameter of 20 mm and 10 mm, respectively, but do not increase any more. Contrarily, the minimum principal stresses of AlN and SiC get decrease, as the diameters increase. Generally, the maximum principal stress is considered for evaluation of durability, but the minimum principal stress is not. In this tests the absolute value of the minimum principal stress, however, is well over the maximum principal stress 10 times. Therefore we considered so that the size of ceramic pates might not become large.

3. Brazing Tests

We do not have experience brazing ceramic plates, such as AlN and SiC, on the CuW base plates. Therefore, brazing tests have been carried out. Figure 7 shows the test samples for (a) AlN brazed on CuW and (b) SiC brazed on CuW brazing. The contact planes of the CuW base plates are flat, but the ceramic plates have various shapes. The sizes and shapes are shown in Table 1. Figure 8 shows the test sample, where AlN plate was brazed on CuW having slits on a joint plane. The width of slits is 1 mm, and the depths are various. Basically most of brazing procedures have been successfully performed. The SiC plate comes off partially, because of the void in the brazing area. The simulation results mentioned above agree with theses results of brazing tests.

Table 1: Size of AlN plates and SiC plates indicated in Figure 7.

	Size, mm	Thickness, mm	Shape
A	40 × 10	1.65	flat plane
B	20 × 10	1.65	flat plane
C	10 × 10	1.65	flat plane
D	40 × 10	1.65	flat plane with snap lines

(a) AlN on CuW

(b) SiC on CuW

Figure 7: Photographs of brazing test samples. (a) AlN and (b) SiC were brazed on CuW base plates, respectively. The thickness of the ceramic plates is 1.65 mm. The SiC plate with snap lines comes off partially, because of the void in the brazing area.

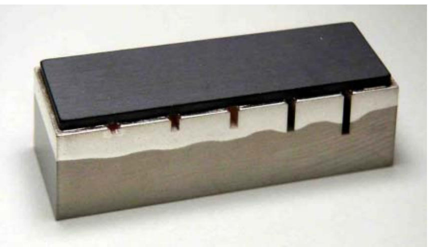


Figure 8: Photographs of brazing test samples. AlN plate was brazed on CuW having slits on a joint plane.

4. Conclusions

In order to establish a manufacturing process of the detector head a frontend pulse-by-pulse SR beam monitor, we have simulated residual stress of AlN and SiC dielectric plates on CuW cooling blocks, and carried out brazing tests for both AlN brazed on CuW and SiC brazed on CuW brazing. We have found that this brazing method can be utilized for manufacturing of the newly designed monitor.

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References

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