Fabrication of the high power input coupler for BEPCⅡ superconducting cavities*

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Abstract The BEPCII storage ring adopts two 500 MHz superconducting cavities (SCC). Each one is equipped with a 500 MHz input power coupler. The coupler is to feed 150 kW power in continuous wave (CW) mode with both standing and traveling wave modes. Due to high power feeding and high frequency of the coupler, its fabrication is a big challenge. The fabrication started with two key components，the window and the antenna. Up to now, two sets including windows and antennas have been made by IHEP. And a 270 kW RF power in CW has passed through the coupler during the high power test. The fabrication details are presented in this paper.

Key words high power input coupler fabrication, superconducting cavity

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1 Introduction

The BEPCⅡ 500 MHz SCC input coupler is designed with use of the KEKB 508 MHz SCC input coupler as the main reference. Fig. 1 shows the general layout of the whole input coupler[1]. Considering the difference of the central frequency with that of the KEKB, there are some slight modifications in the BEPCⅡ coupler structure[2]. Due to high power feeding and the compact structure, the fabrication is considerable difficult.

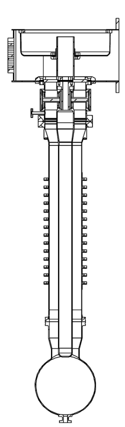

Fig. 1. General layout of the whole input coupler[1].

2 Key components fabrication

All coupler components have been carefully studied by electromagnetic and thermal simulation in the designing stage. The fabrication started with two main components, the window and the antenna. The coaxial alumina window assembly consists of four complicated choke structures, two water cooling pipes and three ports for vacuum, arc and electron current monitoring. The antenna is an OFHC copper tube with a length of 872 mm. It also has two water cooling channels. The fabrication of the window and the antenna has been proved to be particularly challenging.

Figure 2 gives the whole fabrication process of the window and the antenna.

2.1 Welding process

The window and antenna are made up of more than 30 parts. These parts are welded by different methods. Fig. 3 shows all the weld joints.

Braze welding techniques were adopted in window parts connections. It was a major difficulty to braze the window for the big dimensions, high purity of the planar ceramic (42 mm×170 mm×10 mm, 99.5% alumina ceramic) and the complicated choke structure.

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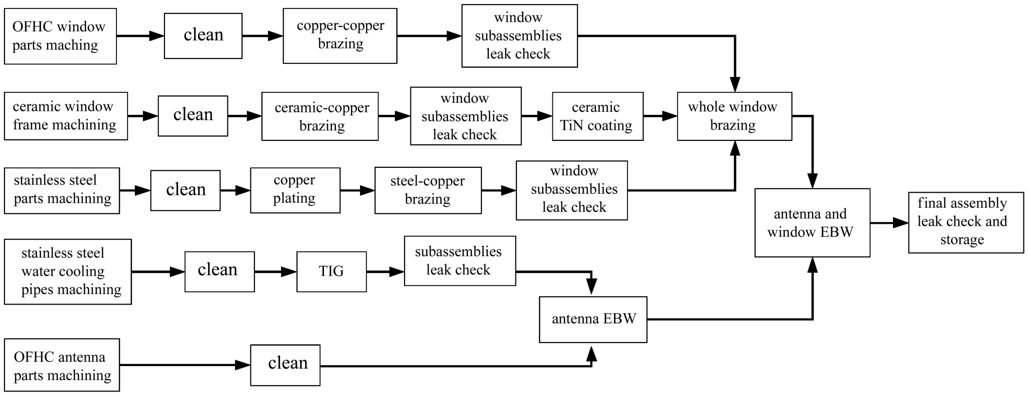


Fig. 2. Fabrication process of the window and the antenna.

After several experiments, we developed a series of methods to improve the brazing. The outer window was tied with a molybdenum strip and thread to restrain the expanding. The solder wires were carefully selected and arranged to improve the solder creeping. Also, temperature increment should be slow enough to keep the brazed parts being heated uniformly and to ensure a successful brazing. Fig. 4 gives the temperature increment and the vacuum change curve during the window brazing. The 'temperature_Real' should be adjusted to be equal to the 'temperature_Design'; and the vacuum pressure should be around 3.0×10^{-3} Pa. The braze welding was processed in vacuum furnace to protect the TiN film.

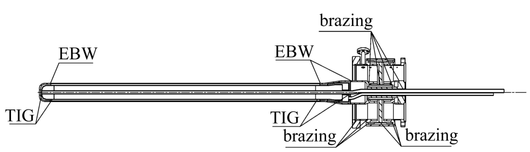


Fig. 3. Weld joints drawing of the window and the antenna.

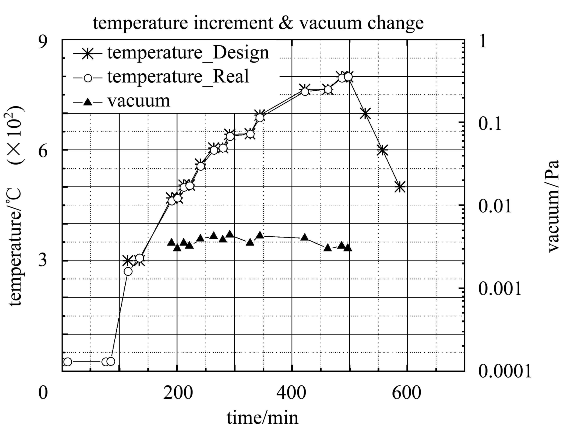


Fig. 4. Temperature increment and vacuum change curve during the entire window brazing.

Another difficulty encountered was the antenna welding. In addition to the length of the antenna itself (872 mm), the 4 water cooling pipes are 500 mm long. So the total length is about 1.4 m. It's difficult to find such a large vacuum furnace, which made the brazing welding unavailable. Besides, considering the high requirements about the smoothness and cleanness of the antenna surface, electron beam welding (EBW) was selected. During the antenna welding, a bowl-shaped fixture with a centre hole was designed to keep the concentricity of the long antenna (see Fig. 5). Meanwhile, Teflon® was applied as a shield to protect the ceramic. Fig. 6 shows the shield before and after EBW. It can be seen a large amount of copper vapor spattered and condensed on it.

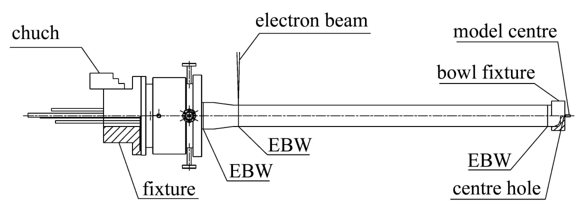


Fig. 5. EBW drawing.

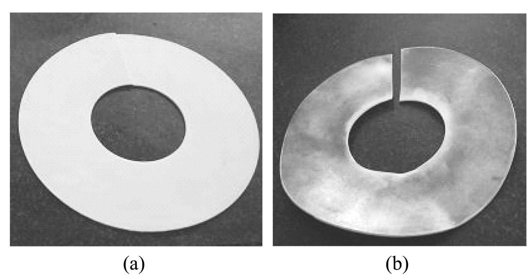
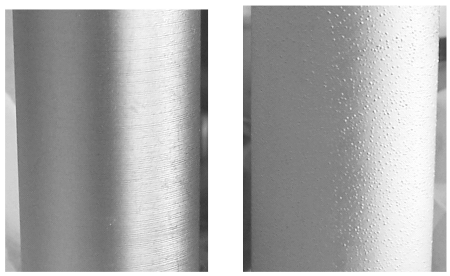


Fig. 6. Ceramic shield before (a) and after (b) EBW.

The stainless steel water cooling pipes were connected by TIG.

2.2 Copper plating and TiN coating

Some parts were made of stainless steel for high mechanical strength, but a 40 μm of copper plating is adopted to minimize RF losses. Special care of current value should be taken in the copper electroplating. Fig. 7 shows a good and a bad sample of copper plating. There were many bubbles on the surface of the bad one due to the over current. The current should be controlled according to the size and geometry of the plated parts. In our case, the current value was 4 A with a voltage of 1 V. Turning the plated piece with uniform interval and velocity was also helpful for reducing bubbles. After the electroplating, the plated parts were heated in a hydrogen furnace with a temperature up to 500 ℃ to improve the adhesiveness and the electrical conductivity of the copper layer[3].



(a) (b)

Fig. 7. A good sample (a) and a bad sample (b) of copper plating.

Since the secondary emission coefficient of TiN is less than unity over a wider range of impact energy[4], TiN coating on the ceramic window is necessary to cure multipacting. To avoid being shielded by the choke structure, TiN coating was processed before the choke brazing. The desired thickness of the TiN film is about 80Å, which was satisfied by controlling the spattering time. Fig. 8 shows the TiN coating mechanism. The ceramic coated has a resistance of 2000 MΩ.

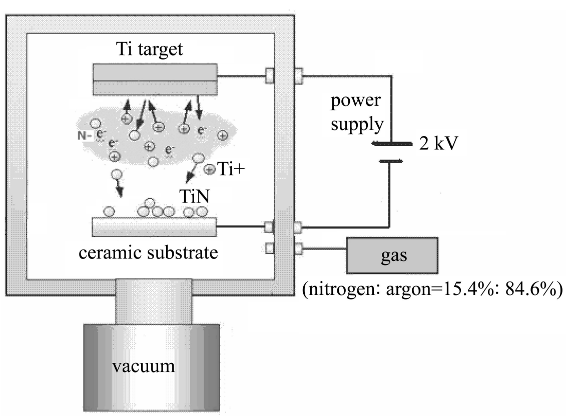


Fig. 8. TiN coating mechanism.

2.3 Cleaning procedure and leak checking

The cleaning is important for the SCC high power input coupler due to its ultra high vacuum and high power requirements. All parts were degreased and deoxidized carefully to assure the following welding quality.

Leak checking was performed after each welding to ensure that the part was ultra high vacuum tight before proceeding to the next step. During the leak checking of subassemblies, black vacuum grease was used for sealing. However the following welding shows that the grease residue might form the black stain deposited on the ceramic surface, which might cause the ceramic to crack. So the black vacuum grease should be cleaned carefully with aerial gasoline and acetone. As a matter of experience, the ceramic cleaning is difficult once polluted. Actually, only sandblasting and wiping with silk cloth can be adopted. So keeping the ceramic surface from contamination is important. The best method to reduce ceramic contamination is to prepare specific sealing tools to replace the vacuum grease. The final leak checking including three EBW welding joints was processed in a special storage container sealed with vacuum flange. No lead was found at a helium leak rate of 6×10^{-8} Pa·l/s.

All the subassemblies were stored in the vacuum desiccator to avoid oxidation. The final assembly was done in a class 100 clean room. After the final assembly, the coupler was stored in a special container filled with nitrogen.

3 Summary

Although there are many difficulties in the fabrication due to the high requirements of advanced technology and the lack of experiences, two sets of windows and antennas have been fabricated. A set of effective fabrication technologies has been developed; and a lot of experiences have been gained from the fabrication, which can be used in the future, for example.

1) The mechanical tolerance should be further reduced for better welding.

2) Ceramic protection is important in every step.

3) Special tools for brazing, leak checking and assembly are necessary and very effective.

High power test and conditioning of the above new coupler has been finished. A 270 kW RF power in CW has passed through the coupler. A detailed description about the test will be given in the future.

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