SOME FABRICATION ISSUES ON THE SPARE HIGH POWER INPUT COUPLER FOR BEPCII SUPERCONDUCTOR CAVITIES

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Abstract

The BEPCII storage ring adopted two 500MHz superconducting cavities (SCC). The input coupler for the SCC is required to feed high RF power up to 150kW under continuous wave mode (CW). Considering the high power feeding and the compact structure of the coupler, the input coupler fabrication is challenged. Up to now, two units including windows and inner conductor (antennas) have been made by IHEP for the spare parts of BEPCII SCC input couplers. Some fabrication issues will be presented in this paper.

INTRODUCTION

The BEPCII 500MHz SCC input coupler is based on the KEKB 508MHz SCC input coupler. Considering the difference of the operation frequency, there are some slight modifications in structure compared with KEKB SCC coupler [1]. Two couplers in operation were manufactured by Toshiba co. Japan. Considering the necessary of the spare input coupler, we are trying to make two spare input couplers for BEPCII SCC by ourselves. The input coupler fabrication is challenged due to the high power feeding and the compact structure. There are many difficulties in the coupler fabrication.

- The high RF power is up to 150 kW under CW with beam operation, which is leading internationally. So the requirements about vacuum, clean and materials are strict.
- Tristan type window is adopted, which has the following characters: big dimension coaxial planar ceramic, with chock structure and water cooling pipes. Therefore, the window brazing is a key technology.
- The length of the inner conductor (antenna) is so long up to 872mm, also with water cooling pipes. So keep the concentric of the window and the antenna during EBW is difficulty and vital.

This paper summarizes the fabrication issues of the window and inner conductor (antenna).

MATERIALS SELECTION

The materials specifications of the SCC input coupler are listed in Table 1[2].

The materials such as stainless steel, OFHC copper and ceramic were selected according to the above materials specifications. The stainless steel is 0Cr18Ni9Ti, which is a high austenitic steel and the relative magnetic permeability is <1.005. The OFHC copper is TU1, which have high electrical conductivity close to $58Sm/mm^2$ and the content is >99.97%. The metalized 99.5% Al_2O_3 coaxial planar ceramic is adopted, which bought from Morgan Advanced Ceramics. Table 2 gives the physical properties of the ceramic.Fig1 gives three subassemblies made from the above different materials.

Table 1: Material specifications

Physical or technology requirement	**Material specification**
Superconducting	Low magnetic field
Low static cryogenic losses	Low thermal conductivity
low dynamic losses	High electric conductivity on RF surface
Use of standard vacuum seals	Hard sealing surfaces (knives)
Good vacuum and short processing time	Low H_2 content
Bridge the gap between room-and cryogenic-temperature	Withstand thermal cycles without properties change

Table2: The physical properties of the ceramic

Physical properties	**Value**
Grain size, um	10
Compressive strength, MPa	2000
Flexural strength, MPa	330
Thermal conductivity, W/m.K @20 ^oC	25.6
Thermal conductivity, W/m.K @400 ^oC	12.5
Dielectric constant @ 1MHz	9.7
Dielectric constant @ 9.4GHz	10.0

Fig1. Materials: stainless steel, OFHC copper and coaxial planar ceramic.

COPPER PLATING AND TIN COATING

The steel parts which have to be connected with copper need to be processed copper plating before brazing. Two methods can be used: spattering and electroplating. We did the copper plating with electroplating. Special care of current value should be taken during the copper electroplating. If the current is too high, there will be many bubbles on the plated surface. Fig2 shows a good sample and a bad sample of copper plating. There were bubbles on the plated surface of the bad sample and the good sample was free of bubbles. Turning the workpiece with an even interval and velocity is also helpful for decreasing bubbles. After the electroplating, the plated parts were heated in hydrogen furnace with temperature up to 500 ^{o}C in order to improve the adhesiveness and the electrical conductivity of the copper layer.

Fig2. A good sample (left) and a bad sample (right) of copper plating: There are bubbles on the plated surface of the bad sample and the good sample is free of bubbles.

Since the secondary emission coefficient of TiN over a wider range of impact energy is less than unity, TiN coating on the ceramic window is necessary to cure multipacting. The TiN coating was processed before the chock structure brazing considering the ceramic might be shielded by the chock structure in the TiN coating. After the vacuum was pumped up to $4\times10^{-5}\,Pa$, nitrogen–argon mixed gas (nitrogen: argon =15.4%:84.6%) was filled into the vacuum chamber keeping the pressure 6.5 Pa. A plate shape Ti target acted as anode and the outer conductor of the window as the cathode. High voltage up to 2kV was added between the anode and the cathode. The nitrogen–argon mixed gas was ionized by the high voltage field and the accelerated ion bombarded the Ti target. In the end, Ti+ and N- generated TiN, deposited on the surface of the ceramic. The desired film thickness is about 80 $\overset{o}{A}$, which was satisfied by controlling the spattering time. The Plate shape Ti target helped the film thickness uniform comparing to a pole shape Ti target.

BRAZING AND WELDING

Fig3 shows the brazing and welding drawing of the window and the inner conductor (antenna). The stainless steel water cooling pipes were connected by TIG. The antenna was welded by EBW considering the demanding requirement of the antenna surface condition. The other joints were all connected by brazing using different solders.

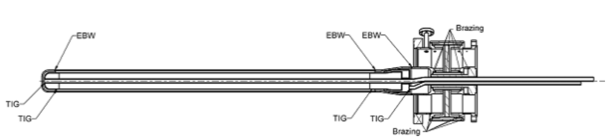

Fig3. The brazing and welding drawing of the window and the inner conductor (antenna)

The ceramic copper brazing used Ag at 962 ^{o}C. The molybdenum strip and molybdenum thread was used to restrain the expanding of the outer window frame. During the brazing, the temperature increasing had to be slow enough to keep the brazed parts heated uniformly. Before the steel copper brazing, the steel parts were nickel or copper plated since the stainless steel parts can't be brazed with OFHC copper directly. The steel copper brazing used AuCu(65%) at 1020 ^{o}C. Copper parts were also brazed with AuCu(65%) at 1020 ^{o}C. All the subassemblies brazing without TiN coated ceramic were processed in hydrogen furnace.Fig4 shows various subassemblies brazing pictures.

Fig4. Ceramic copper brazing, steel copper brazing (middle, copper copper brazing

Since brazing in hydrogen furnace would damage the TiN film, the whole window brazing including the TiN coated ceramic was processed in vacuum furnace. The whole window brazing used AuCu(20%) at 889 and AgCu(28%) at 779 in two steps. The molybdenum strip and molybdenum thread were applied to restrain outer conductor expanding. Also a special fixture was used to fix the whole window to keep the concentric. Fig5 is the whole window brazing picture.

Fig5. The whole window brazing: before brazing (left) and after brazing (right)

All the stainless steel water cooling pipes were welded with TIG. One TIG joint didn't finish in one step. First, welding was just processed with several points. Then the pipe alignment was made. After making sure the pipe alignment, one TIG joint could be finished in the end. The last weld on coupler was EBW of antenna. Considering the length of the antenna is so long up to 872mm a special fixture was fabricated to keep concentric of the window and the antenna. Also a piece of polyimide was applied as the shield to protect the ceramic during the EBW. Fig6 gives the pictures about TIG and EBW. Fig7 shows the polyimide shield before EBW and after EBW. It can be seen that a large amount of copper vapor spattering and condensed on the shield during EBW. So ceramic shielding is vital during EBW.

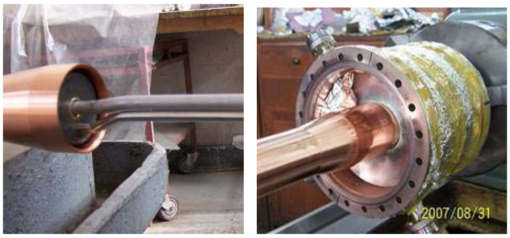

Fig6. TIG and EBW picture


Fig7. The ceramic shield before EBW (left) and after EBW (right).

LEAKAGE CHECKING AND SURFACE CLEANING

Leakage checking is important for every brazing and welds which referring vacuum sealing. Black vacuum cream was used for sealing during the leak checks of subassemblies. However, it might bring contamination to the ceramic surface. So the black vacuum cream should be cleaned carefully with aerial gasoline and acetone. Furthermore, preparing the specific tooling for sealing is necessary to decrease the use of the black vacuum cream. The final assembly leak checks including three EBW welds were processed in a special storage container and sealed with vacuum flange. Fig8 shows the subassemblies and final assembly leak checks.

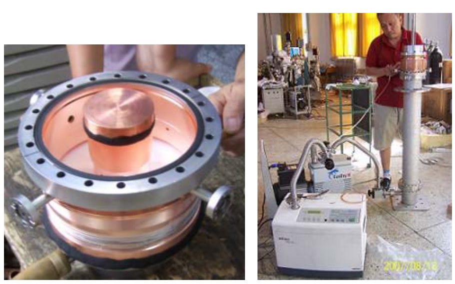
Fig8. Subassemblies (left) and final assembly (right) leak checks

The cleaning is demanding and important for SCC high power input coupler since its ultra high vacuum and high power requirements. The parts cleaning flow is as follows:

- Degreasing in warm liquor with metal decontamination power;
- Rinsing with tap water to remove the detergent;
- Soaking with strong acid to deoxygenization;
- Rinsing with tap water to remove the acid;
- Soaking with chromium acid;
- Rinsing with tap water to remove the acid;
- Rinsing with de-ionized water;
- Soaking in alcohol to dehydration;
- Drying in warm clean atmosphere.

Experientially, keeping the ceramic surface not contaminated is vital because it is hard to clean the polluted ceramic. Only sandblasting and silk cloth wiping can be adopted to clean the ceramic. All the subassemblies were stored in the hot vessel to avoid oxygenation and the assembly was processed in a class 100 clean room. After final assembly, the coupler was put into a special container filled with nitrogen.Fig9 shows the final storage of the window and antenna.


Fig9. The window and antenna stored in a special container filled with nitrogen

SUMMARY

Though we encountered many difficulties in the fabrication due to the lack of experiences and technology, two sets of windows and antennas has been finished in the end. 150kW CW high power input coupler represents the top level of coupler fabrication in China up to now. A lot of experiences have been accumulated through the fabrication.

- Close communication with the manufacturer all the time is important.
- The mechanical tolerances should be optimized for brazing and welding.
- Ceramic protection is vital in every step.
- It is necessary to prepare special fixture tooling for brazing, leak check, assembly and so on.
- The high power test will be processed soon.

REFERENCE

[1] J. Zhong, W.M. Pan, "Study on the performance of the Input Coupler for the BEPCII Superconducting RF Cavity", 2006, 30 (10):1014—1017

[2] Wolf-Dietric Moeller, "Fabrication issues on the high power couplers for TTF," ERL-mini worshop at Beijing university