QUALITY CONTROL OF WELDING, BRAZING JOINTS AND CU DEPOSITION ON EU-XFEL COUPLER PARTS

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Abstract

In frames of EU-XFEL Project the quality control of fundamental 1.3GHz power couplers is very important task. The power coupler consists of a several of parts including itself the different types of welding and brazing joints between ceramic, copper and stainless steel components. The quality of these joints is subject to be investigated and controlled according to EU-XFEL coupler specification taking into account the different coupler manufacturers involved. The quality of Cu deposition on some EU-XFEL coupler parts is also the issue to be qualified according to specs. The number of microscope images of different types of joints and Cu deposition on some EU-XFEL 1.3GHz coupler parts are presented.

INTRODUCTION

The superconducting architecture of EU-XFEL linear accelerator imply the producing the beam of electrons with energy of between 10 and 20 GeV. The EU-XFEL linear accelerator includes itself the number of cryogenic accelerator modules equipped with 8 superconducting cavities. As the fundamental power coupler is the object providing the vacuum and thermal interface between the cavity and wave guide components at room temperature transferring the RF wave from electromagnetic sources (klystrons) to the superconducting cavities for achieving the high accelerating gradients of electron beam, the task of producing and conditioning of high quality RF couplers becomes to be important [1-5]. Due to its complex design and rather critical operation conditions the quality control of different parts including the number of welding and brazing seams as well as the copper deposition quality have to be controlled according to EU-XFEL power coupler specification. The number of microscopic images of different coupler parts welding and brazing joints as well as copper deposition is presented.

DESCRIPTION OF COUPLERS TECHNICAL ASPECTS

Generally the EU-XFEL power couplers have a complex structure including the 2 main assemblies: warm and cold one (Fig.1a, b). Every part has a number of different welding and brazing joints between ceramic (Al_2O_3), copper (Cu-c2 or Cu-OFHC) and stainless steel (AISI 316L). Some stainless steel parts of coupler including some bellows have a copper deposition.

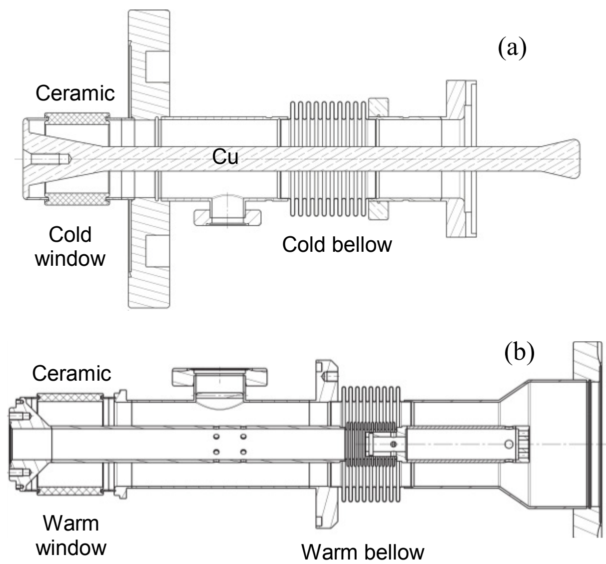

Figure 1: Main power coupler assemblies: Cold part (a), Warm part (b).

The samples for quality control and further analysis of welding and brazing seams were sectioned from the parts to be considered for investigation using linear precision saw. Taking into account the fragility of ceramic-copper brazing joints the parts before sectioning were fixed using epoxy resin. The samples for copper deposition control were cut out with special cutting blades preventing overheating the material. Each sectioned part was embedded with epoxy resin, grinded and polished thoroughly accordingly till the high quality final surface appears. In some cases the welding and brazing joints were etched in corresponding acids and its mixes (nitric acid, hydrochloric acid, hydrogen peroxide).

The measurements of thickness and quality control of copper surface deposition was done on Digital Microscope Keyence VHX-500F. The analysis of quality of welding and brazing seams was performed on inspection microscope Olympus MX-40. Hardness of copper of cold window part was done on Micro Hardness Tester Shimadzu HMV-2000. The surface roughness measurements are done using Mitutoyo ® SJ-301 surface roughness tester.

QUALITY CONTROL

Cold part as well as warm one of EU-XFEL coupler reveals itself the number of important welding, brazing parts and surfaces with copper depositions important from RF point of view. According to specification these critical

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parts should have be conditioned carefully with certain parameters (particularly smooth and clean RF surfaces, regular welded and brazed, copper deposition of a constant thickness etc.) to be used in critical conditions such as extremely low temperatures, high vacuum state and high RF power. Thereby the quality of the coupler assemblies is crucial.

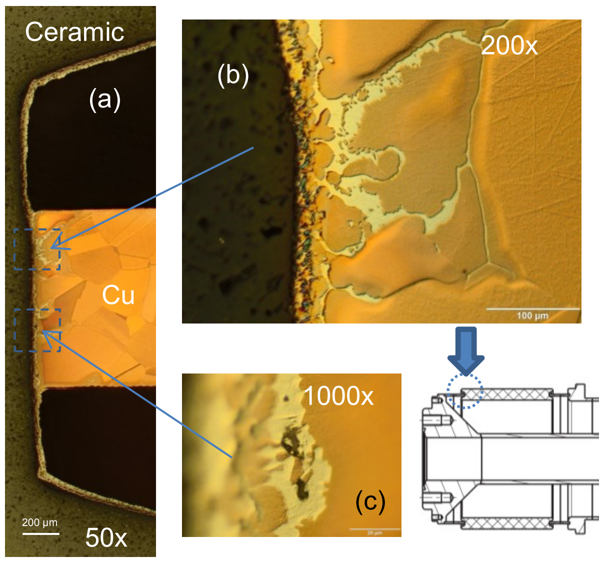

Figure 2: Warm window. Ceramic-Cu brazing joint. Fa. CPI.

Brazing & Welding Joints

As shown on Figures 2, 3 the cold and warm parts have a multiple different important joints to be controlled. One of this part is cold (warm) window includes the ceramic-copper brazing joint and copper-copper welding joints. The microscopic pictures of one side of ceramic-copper brazing joint of coupler cold and warm windows are presented (see Fig. 2a, 3a). Ceramic-Cu brazing joint of both connections shows the diffusion of brazing material (type of CuAg) into the Cu bulk along the grain boundaries as visible on Figures 2b, 3a. Contact surface between ceramic and copper over the brazing material is irregular with different thickness of Cu-ceramic affected brazing layer. The observed defect has size of ~15 µm^2.

Copper-copper welding joint shows clearly of not fully through welded joint as shown as a gap-like border welding line separate the 2 Cu parts up to the middle of the Cu bulk. This line is standing out also by the rupture of Cu grain structure up to the middle of affected part. Beginning of the welded through part is marked with blue dashed line (see Fig. 3b). The similar structure of Cu-Cu welding joint observed on other parts of cold and warm windows. Some defects in the welding seam area are also presented (see Fig. 2c, 3c).

Measurements of hardness profile of copper part of cold window show the hardness by Vickers in range of 95÷104 in 2 mutual perpendicular directions with respect to the center of the part.

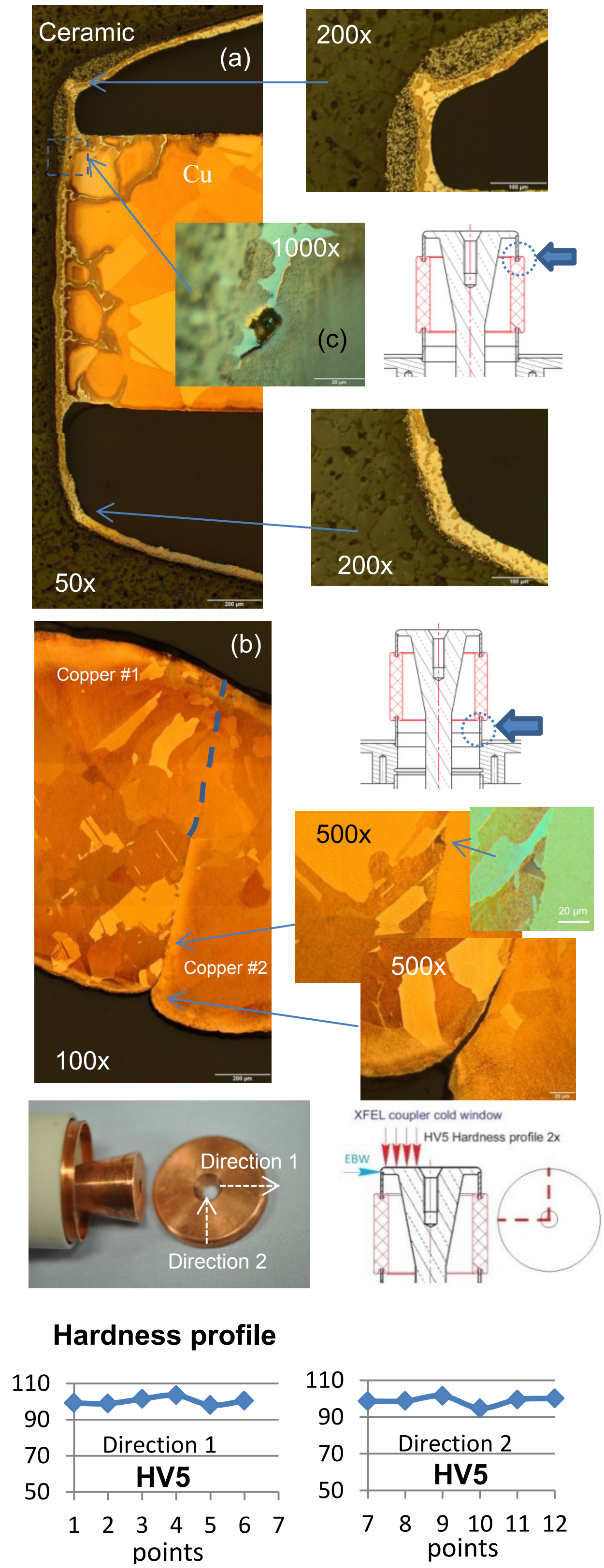

Figure 3: Cold window part. Ceramic-Cu brazing joint (a). Cu-Cu welding joint (b). Hardness profile. Fa. CPI.

Taking into account the typical hardness values for such types of material (high purity copper of Cu-c2 or OFHC type) used and uniformly Cu hardness values distribution one can say that high temperature electron beam welding conditions didn't affect the structure of the copper of this coupler part.

Copper-stainless steel brazing joint (see Fig.4a) shows the regular copper-brazing material interface. The defect in the shape of small cavity with size of ca. 25 μm^2 in

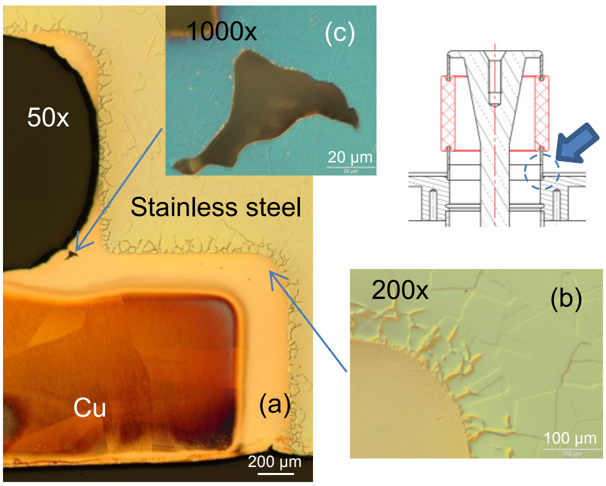

Figure 4: Cold window. Copper-stainless steel brazing joint. Fa. CPI.

bulk of brazing material is presented (Fig. 4b). The partial diffusion of brazing material (type of CuAu) into the stainless steel bulk along the grain boundaries is observed (see Fig. 4b).

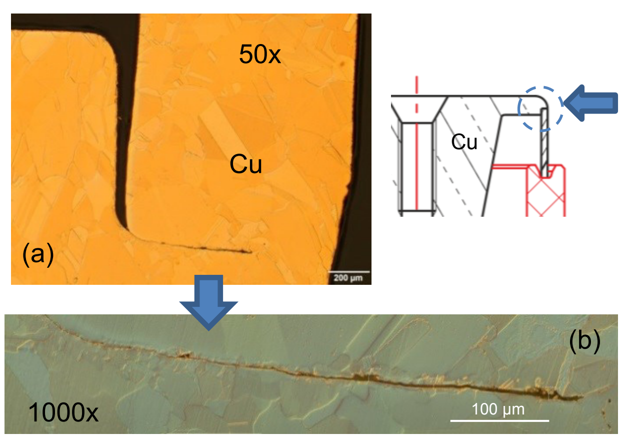

Figure 5: Cold window. Cu-Cu welding joint. Fa. CPI.

Copper-copper welding joint clearly shows the boundary between the two welded copper bulks with welded through part from the right side of about 400 µm (Fig. 5a). The Cu grain structure in this melted area has no irregularities. Not smooth coupling (contact) interface of not welded down Cu parts on the rest of welding seam (length is ca. 500µm) is observed (see Fig. 5b). The gap between the not welded parts in some areas reaches few micro meters.

The welding joint of stainless steel of tube and bellow of warm internal conductor is shown on Fig. 6.

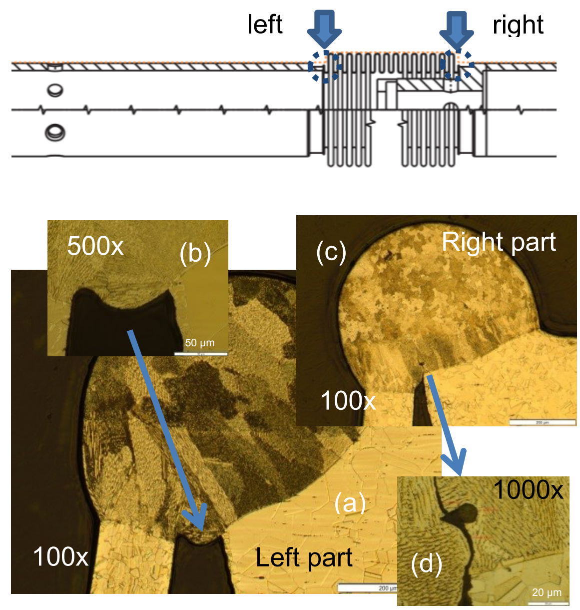

Figure 6: Warm internal conductor: Pipe-bellow stainless steel welding joint. Fa. CPI.

The observed microstructure in welding seam interface shows the partial spreading of stainless steel grain structure over the heating zone of welding seam to the welded part –top cone (see Fig. 6a, c). The area between the bellow and tube part of left welding joint is wider and has no visible cracks. As opposed to left part the right one of bellow-tube joint between the bellow and tube part has a crack spreading inside the welded top cone up to 50 µm with hollow in between with diameter of ~ 9 µm (see Fig. 6d).

Copper Deposition

According to general specification of the couplers all RF surfaces should be smooth and ultra-clean implying, particularly, the copper deposition of constant thickness and free from any defects. On Figure 7, 8 & 9 are given the results of copper deposition investigation done on bellow and tube parts of warm external and internal conductors provided by few producers (Fa. Collini, CERN & Galvano T).

Particularly, the investigation of copper deposition on some areas of tube parts of warm internal conductor shows the relatively constant Cu thickness 32,4 ÷ 42,7 µm. On samples sectioned from bellow the copper layer thickness has a bigger range: 65,7 ÷ 87,1 µm (see Fig. 7). According to specification the variation of Cu thickness in bellow parts should not be than 30%. It is necessary to emphasize that in most cases and particularly in data given below for another coupler parts the thickness of copper deposition in bellow part marked ***B*** is bigger.

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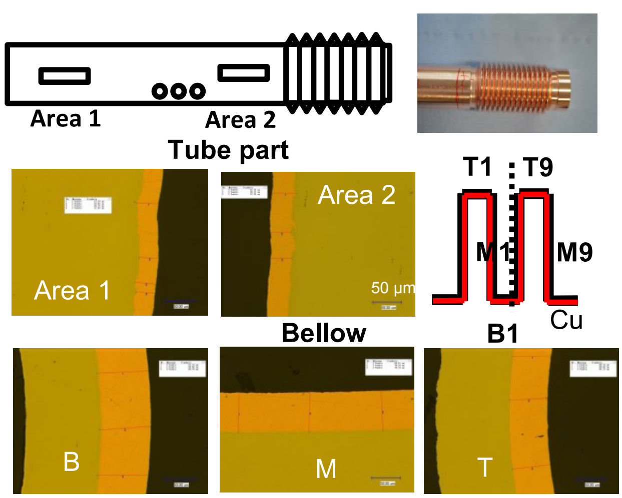

Figure 7: Warm internal conductor. Copper deposition quality control. Fa. Collini {scale 50µm}.

The microscopic pictures with variation of Cu thickness in some tube parts of warm external conductor given on Fig. 8. The Cu layer thickness changes as 9,8 ÷ 18,9 µm in tube part and as 3 ÷ 20,1 µm in bellow area. For samples from tube parts the copper covers the stainless steel surface with relative constant thickness taking into account the wave shape of the stainless steel surface. The parts marked ***T*** and ***M*** in bellow area the thickness of Cu layer is significantly lower than the thickness in ***B*** areas.

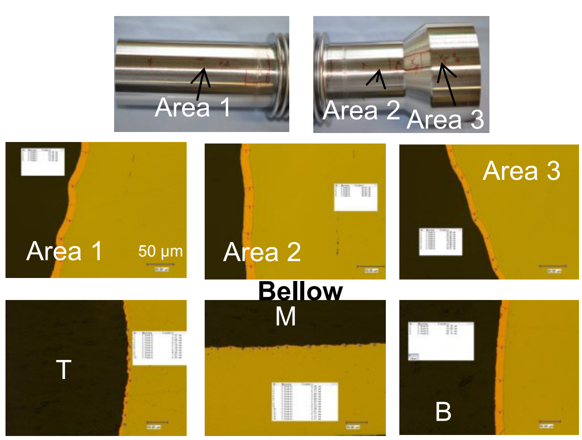

Figure 8: Warm external conductor. Copper deposition. Fa. Collini {scale 50µm}

The thickness of copper samples taken from area 1 & 2 of external conductor (Fig. 9) show the relative constant values: 32,9 ÷ 41,2 µm. The Cu layer observed in areas 3 & 4 shows the thinner layer with clear shape wave surface profile with wave amplitude of about 21 µm and wave length ~ 107 µm.

The similar surface profile (copper / stainless steel) observed also for same tube parts from another producer as well as a thickness distribution of Cu layer in bellow parts. The samples taking from area 5 show the

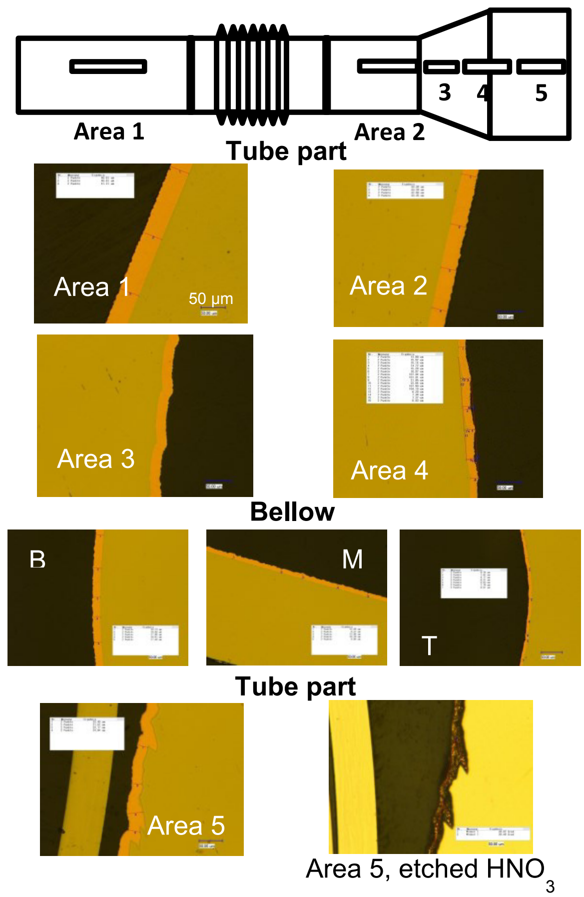

Figure 9: Warm external conductor. Copper deposition quality control Fa. CERN (tube part, bellow), Fa. Galvano T (tube part, area 5) {scale 50µm}.

inhomogeneous Cu layer with pronounced defects penetrating inside the stainless steel bulk up to 50 µm and having the angle of inclination of ca. 30° to the surface. Surface roughness parameter Ra for this area changes as 0,79 ÷ 0,96 µm. For all other areas of warm external conductor including bellow parameter Ra changes as 0,82 ÷ 1,52 µm that agreed with specified values.

SUMMARY

The numbers of different parts of EU-XFEL power coupler assemblies provided by few producers were investigated. The quality of different welding and brazing joints as well as the copper deposition were analysed. Obtained results of quality control show that some of Cu-Cu and stainless steel-stainless steel welding joints have to be improved to be qualified according to specifications. In some cases the quality of Cu deposition, its thickness and Cu surface profiles on tube parts and in bellow areas is also the issue to give a feedback to the coupler producers.

ACKNOWLEDGMENT

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