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1 Aim of the experiment

The HCPAF Group technological activity is dedicated to the construction of a 3 cells linear accelerating structures working at 11.424 GHz. Studies on the soft brazing bonding (or low temperature brazing) and sputtering Molybdenum material on the Copper have been carried out, too.

2 Technological activity

Soft brazing permits creating joints from similar or dissimilar base materials at temperatures below 450°C and at any rate such as to permit the fusion of the brazing alloy while maintaining the base materials integral if they are temperature sensitive.

Soft brazing is utilized for creating joints on copper tubing in heating and sanitary fitting plants, and in general plants that operate at maximum working temperatures of 100 - 120°C; higher temperatures require strong brazing.

The quality of the joint depends on various factors:

- joint design, normally spigot and socket joint;
- flow ability of alloy;
- appropriate activity of deoxidizer to be applied to joint surfaces;
- distance between the two surfaces to be brazed, recommended from 0.05 to 0.13 mm;
- stress studies, if necessary provide for expansion joints.

About the sputtering approach, the Molybdenum material deposition on the Copper one in order to improve the surfaces quality, some tests and checks using an Atomic force microscopy to understand the morphological aspect have been made.

Soft brazing bonding

In order to avoid mechanical stress and morphological one induced into the material during high temperature treatment (high temperature brazing) the soft brazing like is required. This method can be adopted when using metal for the RF accelerating structures construction which cannot be to sustain high temperature.

The alloy Sn/Ag 95/5 (melting point 230°C) is under investigation. The procedure is the same we adopt for the high temperature brazing replacing Cusil alloy with the Sn/Ag one.

Preliminary tests on COPPER have given good vacuum tight results but also some problems due to the fact that Sn/Ag alloy doesn't act like Cusil regarding capillarity; in other words the Sn/Ag diffusion is not homogeneous on each contact surface so in some tests we found an unwanted alloy diffusion inside the cells. For this reason, we also studied the possibility of using Sn, as gasket, to joint the cells.

The procedure is quite simple, by plating a Sn layer on one of the surfaces we want to joint, making a temperature treatment close to the Sn melting point in order to make a vacuum tight boundary layer between the cells. The deposition is so called "brush plating".

The electrolytic parameters can be used to estimate the thickness of the deposited material: in order to deposit 1 μm of Sn on 1 dm^2, we need 36 mAh and knowing the density of Sn, we can estimate the thickness.

By brazing bonding at temperature a little less than 230°C we obtain a good mechanical structure stability. Some tests (Fig.1) with copper OFHC remade with different shapes among the contact surfaces gave good results in term of helium vacuum leak.

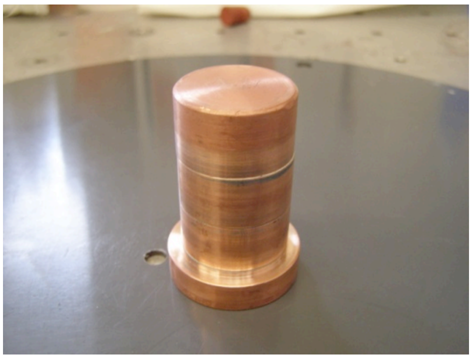

Fig. 1 : Soft brazed 3 cells Cu prototype

As a next step, the realization of the Cu-Zr three cells section, applying the above procedure, electrolytic plating plus temperature treatment, has been scheduled and is going to be completed in a couple of months.

If contact surfaces are machined at a very low roughness, in our case order of 70 nm, the thermal treatment after Sn deposition could be unnecessary. Vacuum tight of about $10^{-10}\frac{mbar*l}{\sec}$ has been obtained with a proper pressure applied to the structure with three bars (Fig. 2).

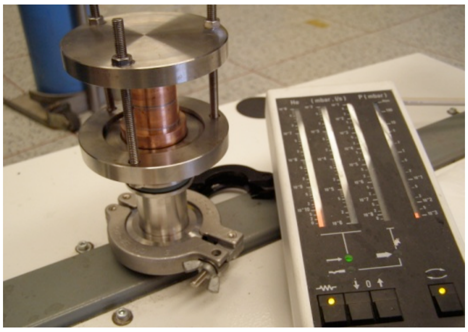

Fig. 2 : A Cu OFHC structure under vacuum leak test.

As a first prototype we use a soft brazing like with six bars, tight with a proper torque , in order to improve uniformly the pressure among cells. However we propose that standard model will be realized with the soft brazing bonding plus electroforming technique. In this case bolts will be replaced by electrolytic encapsulation.

Molybdenum sputtering

It is known that the Molybdenum material could be an interesting choice for making RF linear accelerating structure since its melting point is higher than the copper giving higher performances under RF higher power.

Unfortunately it is very difficult to be machined with a good roughness (not less of 350 nm can be obtained) and could trap residual gas by limiting the sections performances in terms of breakdown effects, as it was observed at SLAC during the high power tests on dedicated and brazed three cells section.

For this reason we started the study to make the cavity resonators in copper with an excellent roughness and then to deposit Molybdenum by sputtering technique in order to reduce the breakdown phenomena.

To estimate the surfaces quality some tests under an Atomic force microscopy to understand the morphological aspects or the topic ones was used.

Studies on the molybdenum sputtering on the copper surfaces are in progress.
The pictures 3-4 obtained with Atomic Force Microscopy show the surfaces of the machined copper with a very low roughness, of the 70 nm order, after and before the molybdenum sputtering.
In Fig.4 one observes the undulations of the surface due to the step of lathe machine , about 700nm , with a lots of spikes overlapped , spikes that disappear when a layer of about 100 nm molybdenum is deposited on. It seems to be that molybdenum on the copper surface acts like a smooth layer, in other words the roughness improves. Further studies are in progress in order to verify this statement.

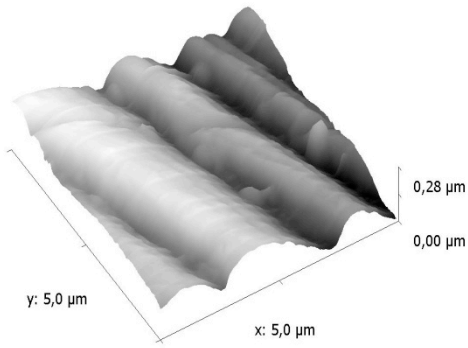

Fig. 3: AFM image of deposited Molybdenum on copper cell by sputtering technique

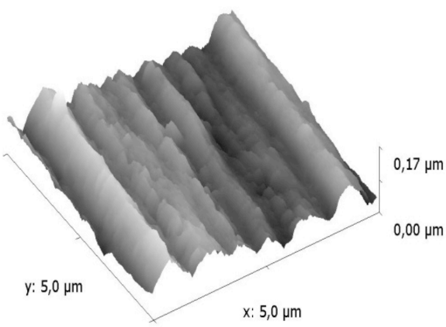

Fig. 4 : AFM shows surface of copper cell before molybdenum sputtering

Since the materials have different thermal coefficients, the deposited molybdenum on the copper could be not stable rising temperature. One possible solution consists in depositing a film and make a thermal treatment, about 800 Celsius degree, in order to fix the film on the substrate (a similar treatment has been adopted for other applications). We scheduled this activity and we believe to get these results in a couple of weeks.

Other materials.

Presently some other materials, in addition to the Copper, are under study: essentially Molybdenum and alloy Copper – Zirconium. Regarding Molybdenum some electroformed multicell structures with Mo irises have already been made with good results. These prototypes were made only to check the procedure. For these special materials the Electroforming technique could be used as a way to "encapsulate" the components of the multi-cell structures, making something like a "cold brazing" of the multi-cell elements, as well as the end flanges. The above procedure will have the advantage to avoid the high thermal stress of these metals during the brazing. In particular this is valid for the Cu/Zr because it loses its RF properties above a 300 °C treatment. Finally the way to obtain electroformed multi-cell structures with the presence of two tuners per cell will be considered as soon as a proper tuner structure designed for this procedure will be tested.

X-band sections working at 11.424 GHz

A Cu three cells electroformed section realized with no brazing procedure has been tested for the electromagnetic characterization at room temperature and helium vacuum leak checks [Fig. 5].

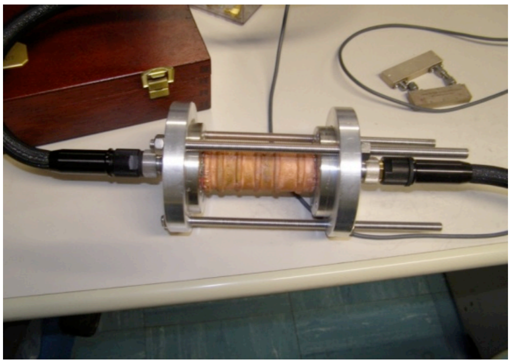

Fig. 5 : Electroformed Cu three cells section

X-band copper and molybdenum structures have been constructed at LNF using the brazing technique and have been tested at high power at SLAC. Results of the first high gradient test done at SLAC on brazed Cu and Mo LNF structures are discussed in another dedicated paper [5].

Summary and future work

A first method to make the soft brazing has been obtained. For practice opportunity reasons, a Cu/Zr three cells section using the soft brazing bonding and with six bars is under construction. Vacuum and electromagnetic tests at room temperature have been scheduled to be carried out within two weeks.

Another Cu/Zr three cells section realized with the soft brazing bonding and the electroforming procedure has been scheduled to be realized in a month. We believe this model will represent the standard solution for the construction of next accelerating sections.

Additional investigations about the sputtering technique are in progress, too.

In addition, it has been seen that the microscopic surface status plays an important role on the maximum gradient limiting for Cu X-Band RF accelerating structures (Sami Tantawi private communication), and not only from a point of view of surface roughness or cleanliness but also considering the metallurgical behavior of the material.

As known interaction of intense radiation with solids can change essentially its surface characteristics. We have discussed [6] the first results of our studies on irradiation of the Cu RF structures by dense X-ray beams. X-ray micro-beam shaped by means of poly-capillary semilens has been applied as a probe in a number of specified stripes on a surface. The indentation depth analysis has shown the change in surface hardness in correspondence to the applied radiation dose.

References

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