STUDY OF NbTi WELDED PARTS

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Abstract

Due to its mechanical properties, niobium-titanium alloy is widely used to manufacture the flanges of superconducting niobium accelerating cavities. The material hardness is compliant to provide UHV-tight connections with aluminum gaskets or spring-type gaskets (Helicoflex). In addition, the alloy can be directly welded to the niobium. Because it is also superconducting, Nb55%Ti was used for the fabrication of the membrane of the original capacitive tuner of the IFMIF half-wave resonator. This paper will present surface analysis made on NbTi samples after the chemical treatment and on a Nb / NbTi weld, in order to better understand the experimental RF behavior of the cavity with this type of coupler.

INTRODUCTION

During the tests of the IFMIF half-wave resonator prototype with its capacitive tuner, unexpected quench appeared. The RF calculations performed to explain the test results pointed out that some watts were dissipating in an unknown area. A thermal simulation using the model described in [1] demonstrated that a weld between a niobium piece and a niobium-titanium one could be the cause of the quench [2]: if this one is not homogeneous, with the concentration of niobium on some areas lower than expected, a small dissipation in the weld could heat it up above the critical temperature as this one depends on the concentration of niobium in the NbTi alloy [3]. Indeed, variation of Tc along the welding seam of Nb55%Ti – Nb joint have already been observed on XFEL cavities [4]. We wanted to check if we find similar feature in our case.

EFFECT OF THE BCP TREATMENT ON A NbTi FLANGE

The IFMIF HWR prototype is made of high purity niobium with a titanium helium vessel. The cavity and the vessel are directly welded to the cavity flanges which are made of niobium-titanium [5]. The tuner port is also made of NbTi. Part of this flange as well as the weld connection to the main niobium cavity body is exposed to the RF field. Therefore this area is also treated with a buffered chemical polishing (BCP).

After the chemical treatment heavy pitting is observed everywhere on the NbTi flange. Moreover these pits have oblong shape, all directed from bottom to top.

A sample of the weld between the niobium-titanium flange and the niobium cavity body was observed with an optical microscope (Figure 1). The niobium-titanium close to the weld is not affected by the BCP treatment like the flange material.

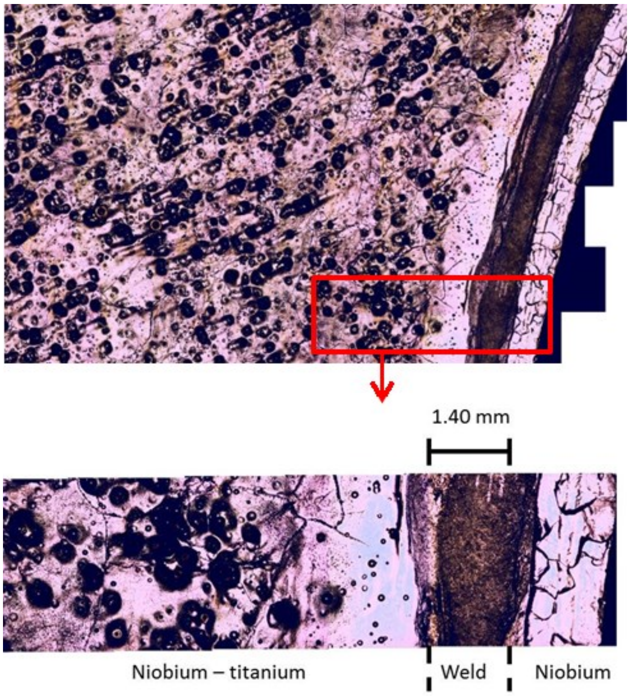

Figure 1: the weld between a niobium piece and a niobium-titanium one observed with a microscope.

A complementary test was performed to determine if the oblong shape of the observed pits is due to bubbles traces. A sample of NbTi was machined in the tuner flange which was previously removed from the cavity body. The already chemically treated surface was removed with a milling machine and polished. The piece was placed in the acid bath in such a way that the initially vertical surface was now placed horizontally.

The results are presented on Figure 2. The horizontally placed surface presents many pits which have the same size of the previously observed ones. But their shape is round and no more oblong. On the now vertical surface (initially horizontal), the pits are much smaller and fewer in number. Their shape is oblong with a vertical orientation.

It seems that thetexture and the grain orientation has an impact on the way the NbTi material reacts to the chemical treatment. Due to the lack of information about the metallurgical process - the NbTi material was supplied by the manufacturer of the cavity – complementary tests

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[#] Corresponding author: nicolas.bazin@cea.fr on reference samples would be performed to confirm these results.

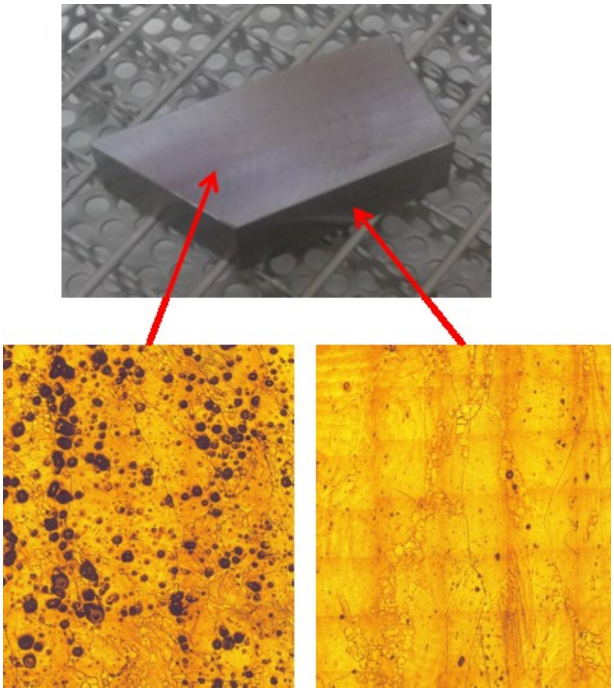

Figure 2: chemical treatment of the NbTi sample.

LIBS MEASUREMENTS ON THE WELD AREA

The Laser Induced Breakdown Spectroscopy (LIBS) was used to study the materials of the weld area. LIBS is a technique for qualitative and quantitative elemental analysis of any matter [6,7]. The principle is shown on Figure 3: a pulsed laser beam is focused onto the material to be analysed creating very hot plasma. Upon desexcitation, the plasma emits an emission spectrum characteristic of the composition of the material. This emitted light is collected and coupled to a spectrometer and detector for analysis. The positions of the lines in the resulting spectrum obtained gives the elemental composition, the intensity of these lines gives the quantitative information.

A portable version exist that can operate in the air, and is applicable to large objects [8].

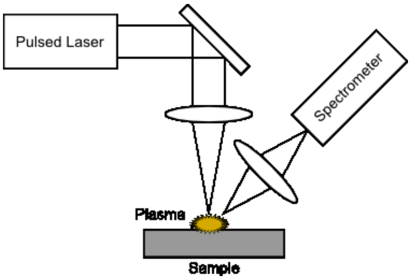

Figure 3: principle of the Laser Induced Breakdown Spectroscopy (LIBS).

Only qualitative measurements were realized. To make a quantitative measurement several NbTi calibration etalons with well-known concentrations of niobium and titanium are required.

Measurements on NbTi Matrix

A first set of measurements was performed on the NbTi part of the sample. The material was analysed at 25 spots forming a 5x5 matrix. The size of each spot is 50 µm corresponding to the size of the laser beam. The analysis of the results was performed on the emission peak at 410 nm for niobium and the one at 625 nm for titanium. The emission peaks for each material was chosen in the material spectrum in such a way that it does not interfere with a ray of the other material spectrum. The results are presented in Figure 4: the intensity of each peak is plotted as the intensity ratio of the titanium peak over the niobium peak. Small variations in the local composition are observed in the NbTi matrix.

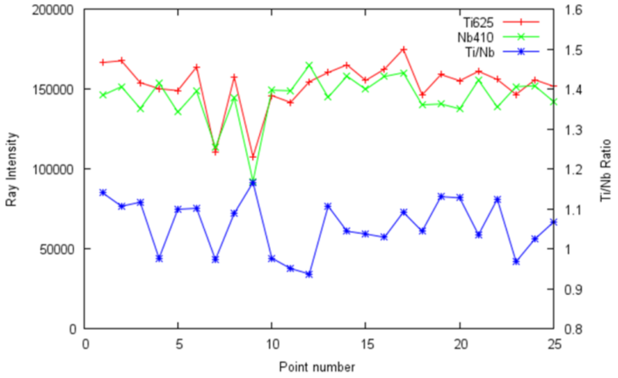

Figure 4: measurements on the NbTi matrix.

Measurements on the Weld

Two kinds of analysis were performed: two matrices on the weld to determine if this one is homogeneous, and two lines starting from the niobium part, crossing the weld and finishing in the niobium-titanium part (Figure 5).

Like in the NbTi matrix, the composition along the welding seam also presents small variations in the local composition. On the other hand, when looking from the seam towards the NbTi matrix, the thermally affected zone (TAZ) close to the weld presents a higher concentration of niobium than the rest of the NbTi matrix, coherent with a thermal diffusion front.

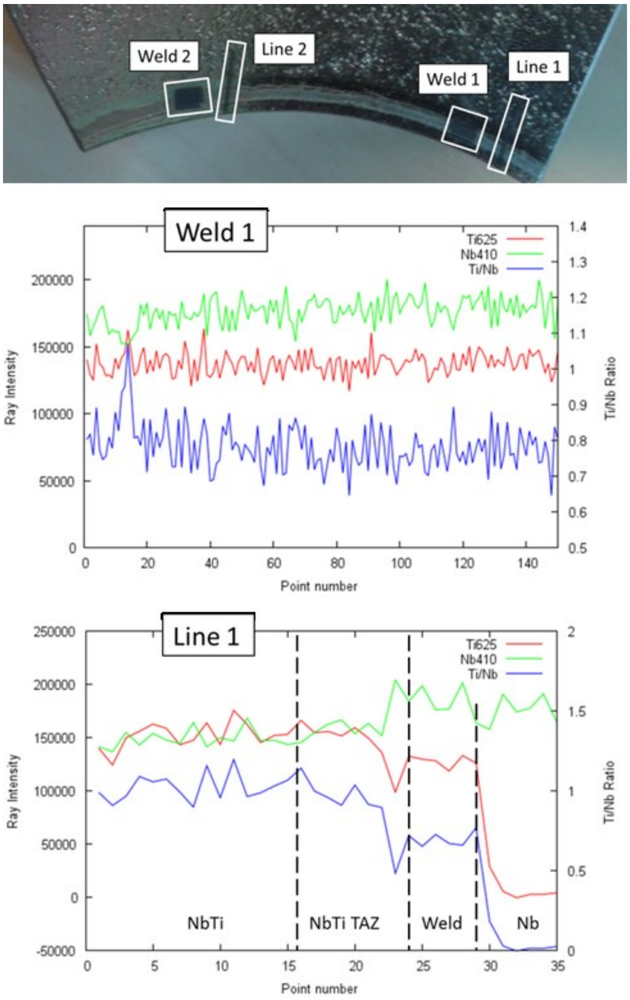

Figure 5: LIBS measurements on the weld area.

EDX MEASURMENTS

To have a resolution better than 50 µm – resolution of the used LIBS apparatus – energy-dispersive X-ray spectroscopy (EDX) measurements were performed on the sample. A SEM view (x25) and EDX analysis of the weld area are presented on Figure 6. The same results with a higher magnifying power (x12000) are presented on Figure 7 for the middle of the weld, on Figure 8 for the NbTi TAZ, and on Figure 9 for the NbTi matrix far from the welding seam.

These results confirm the variation of composition across the welding seam, with a diffusion of Nb in the TAZ. This variation of composition is expected to influence the local T_C similarly to what was observed in [5].

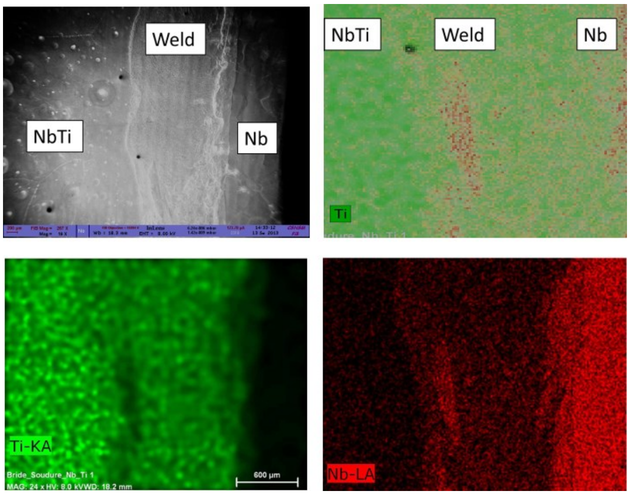

Figure 6: SEM view (upper left) and EDX analysis on the weld area (x25). In red: niobium. In green: titanium.

In addition, a change of the repartition of the Titanium was evidenced: it gathers in the shape of small nodules ~ 0.5 µm x 0.2 µm large.

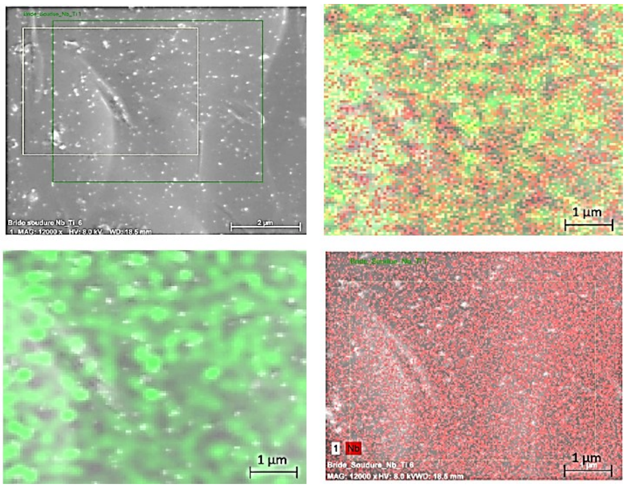

Figure 7: EDX analysis on the middle of the weld (x12000). In red: niobium. In green: titanium.

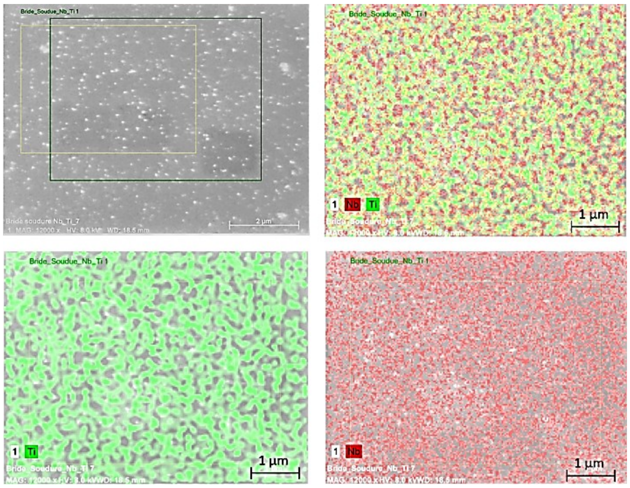

Figure 8: EDX analysis in TAZ (close to the welding seam) (x12000). In red: niobium. In green: titanium.

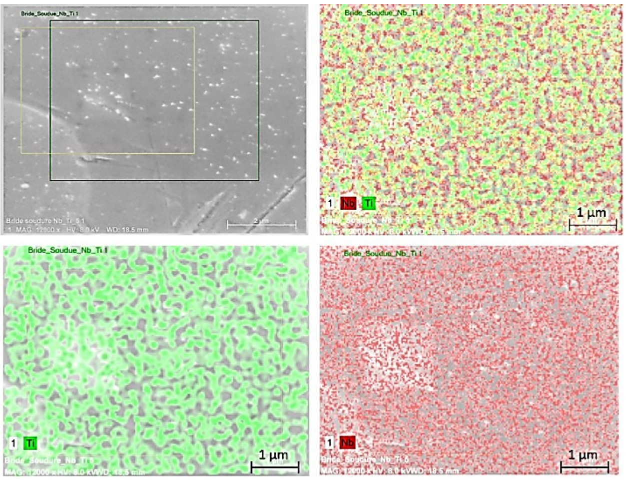

Figure 9: EDX analysis in the niobium-titanium matrix far from the welding seam (x12000). In red: niobium. In green: titanium.

SUMMARY

The LIBS and EDX measurements give the same results: the composition along the NbTi – Nb weld seam is relatively homogeneous at a large scale (> 50 µm). At smaller scale, nodules of pure Titanium are found (~0.5 µm x 0.2 µm large) that probably appeared during the solidification of the melted area. Pure Titanium is not superconducting and is liable to generate additional losses in RF.

In the thermally affected zone (TAZ) close to the weld presents a higher concentration of niobium than the rest of the NbTi matrix. This modification of the alloy composition is expected to modify locally the critical temperature, and can also affect the surface resistance.

These two phenomena could be the possible source of dissipation when the niobium-titanium flange and the NbTi – Ti weld seam are exposed to the RF field and explain the early quench observed on the IFMIF HWR prototype.

ACKNOWLEDGMENTS

The authors would like to thank L. Delbecq (CSNSM) for the EDX measurements, F. Eozenou (CEA) for the chemical treatment and cleaning of the NbTi samples, and the CEA staff of the mechanical workshop for the cutting of the samples from the cavity tuner port. We also thank W. and X. Singer for the access to their own experimental data.

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