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Technological issues and high gradient test results on X-band molybdenum accelerating structures

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ABSTRACT

Two 11.424 GHz single cell standing wave accelerating structures have been fabricated for high gradient RF breakdown studies. Both are brazed structures: one made from copper and the other from sintered molybdenum bulk. The tests results are presented and compared to those of similar devices constructed at SLAC (*Stanford Linear Accelerator Center*) and KEK (*Kō Enerugī Kasokuki Kenkyū Kikō*). The technological issues to build both sections are discussed.

1. Introduction

The high gradient RF breakdown phenomena is still an open problem and dedicated research and development in this field has been launched within the linear-collider community in order to understand the breakdown mechanisms, which limit the high gradient performance [1].

The activity of designing, constructing and experimental testing of short 11.424 GHz high power standing wave (SW) sections began at INFN-LNF in the framework of a collaboration with SLAC and KEK laboratories [2]. The goal of the collaboration is to assess the maximum sustainable gradients in normal-conducting RF powered particle beam accelerators with extremely low breakdown probability. An intense technological activity is therefore committed to making X-band, accelerating structures, using different materials and methods [3–8]. Presently, the main processes under investigation are the following:

- high temperature brazing (800–1000) °C;
- soft bonding (250–300) °C;
- electroplating;
- molybdenum (Mo) sputtering on copper.

Single cell X-band standing wave structures operating at 11.424 GHz have been made with copper and sintered molybdenum bulk using a high temperature brazing procedure. High power tests for both structures have been conducted at SLAC. We report on the comparison of the breakdown rate probability in these two with structures of same geometry built at SLAC and KEK. The brazed Mo structure had a higher breakdown rate than the copper structures. We also report on the technological techniques for fabricating both structures and the possible effects that impacted the molybdenum brazed structure performance.

Issues concerning soft bonding, electroplating and molybdenum sputtering on copper techniques will be discussed in other papers.

2. Copper section construction and characterization

The device under study is a single cell in a 3-cell structure fed by a circular waveguide, as shown in Fig. 1. The central cell is the cell of interest and operates at high gradient, while the adjacent cells are used to match the RF power from the input circular waveguide and to balance the electric field in order to have the maximum intensity in the central one. This scheme is that used at SLAC to represent the performance a long accelerating structure composed of cells like the central cell in the test structure [9].

The π-mode accelerating electric field on axis and the reflection coefficient obtained from HFSS simulations [10] are shown in Fig. 2. They show a good match at the nominal RF frequency of $\sim$11.424 GHz and the maximum field intensity in the central cell doubles that of the adjacent cells.

The relevant cell dimensions for the copper structure are shown in the mechanical drawing in Fig. 3. The section has been made of oxygen free Cu (OFHC) using a numerical controlled

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lathe; each cell has been checked with a quality control test of the geometrical dimensions and the obtained machining precision is about ± 1.3 μm while the smoothness is about 70 nm The surface finishing was obtained directly by mechanical machining with custom cutting tools (diamond mono-crystal), avoiding any polishing technique. The machining was done at constant temperature (by means of a proper fluid) in order to maximize the uniformity of the mechanical dimension of the cells as much as possible. The standard cleaning procedure after the machining consists of two steps, the first with a 3% alkaline solution at 50 °C and the second with a 3% citric acid solution at 50 °C; each step is followed by a rinse first in tap water and then in distilled water. The pieces were dried in a dust free oven.

The brazing of the structure requires two different steps: the brazing of the copper–copper cells and the brazing of the stainless steel flanges on the copper beam pipe. Different composition of PALCUSIL (palladium–copper–silver) alloys with different melting points were used for the two different brazing procedures. In the subsequent brazing of the tuners one has to consider the effect of the gravitation; as shown in Fig. 3, they are placed in opposite sides of the structure and therefore they have been brazed in two different steps using the PALCUSIL alloy with decreasing melting temperature. After extensive tests, we have concluded that better brazing with PALCUSIL was obtained when the structure was brazed in vertical position since the presence of palladium in the alloy reduces the diffusion for capillarity.

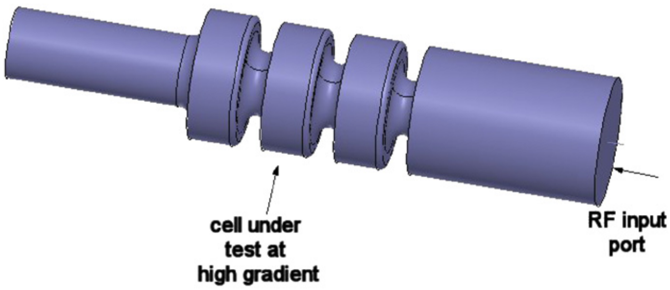

Fig. 1. Sketch of the cells structure to be tested at high power.

We also investigated the brazing with CUSIL (copper–silver) alloy, resulting in optimal results for copper–copper brazing. To achieve the same high quality also for steel–copper brazing, the steel flanges were covered by a few μm layer of nickel or copper. The advantage of the CUSIL alloy is its independence from the whole structure orientation in the brazing oven.

The tuners are designed for plastic wall deformation, i.e. they are copper cylinders of 2.3 mm diameter acting on a copper surface 0.9 mm thick; the maximum allowed (measured) elastic deformation is of 0.6 mm height. Tuners are brazed in order to allow a push–pull tuning with a frequency dependence of 1.6 MHz/mm^3 of wall deformation. Each tuner by itself can recover the frequency shift due to mechanical machining tolerances and each cell is equipped with two tuners to double tuning range.

To identify structures we use abbreviations derived from the properties of the structure, the manufacturer and the serial number. As an example, the name 1C-SW-A5.65-T4.6-Cu-Frascati-#2 refers to a single standing wave high gradient cell (1C-SW) with a 5.65 mm

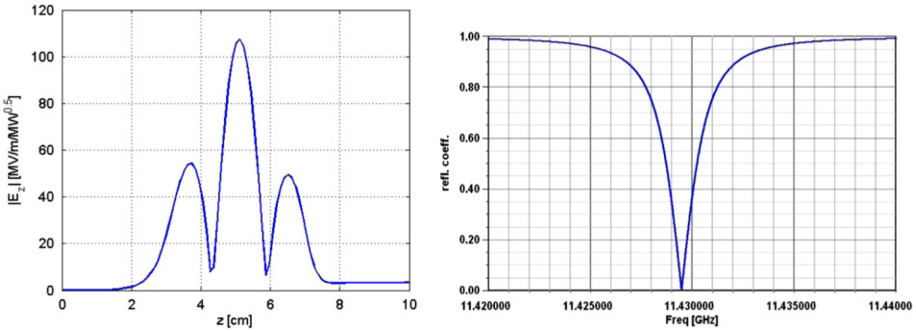

Fig. 2. Electric field profile on axis and reflection coefficient at the RF input port for the π-mode (HFSS simulations).

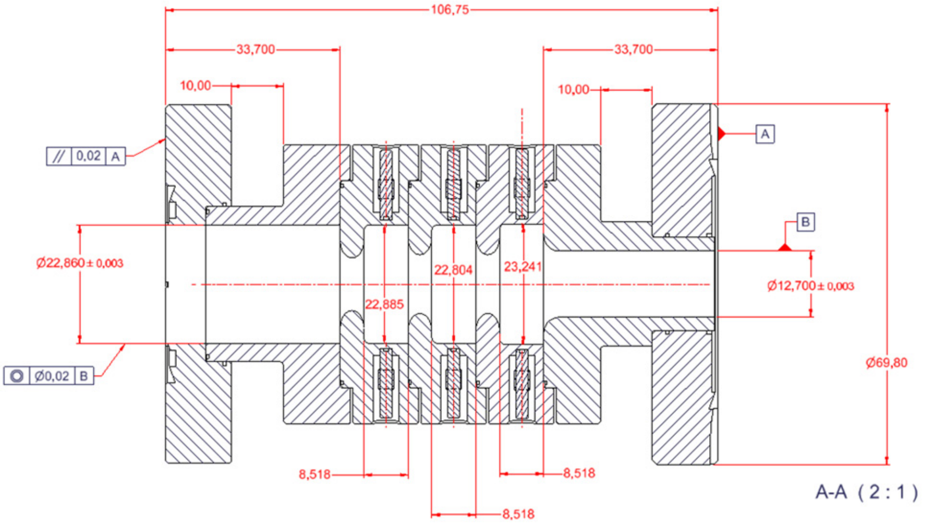

Fig. 3. Mechanical drawing of copper structure with dimensions.