A 1500 MHZ NIOBIUM CAVITY MADE OF ELECTROPOLISHED HALF-CELLS*

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Abstract

A 1500 MHz niobium cavity has been fabricated with two half-cells, which are pre-electropolished with a very simple and compact system. In this paper, we present half-cell electropolishing, cavity fabrication and first test results.

INTRODUCTION

Electropolishing of niobium cavities is proving to yield consistently better performance than chemical polishing thanks to the persistent effort by KEK [1]. However, an electropolishing system for a multi-cell structure can become complicated and expensive. An alternative, economic way is to electropolish half-cells or dumbells before they are welded into a cavity. This method has been tried at DESY [2], but the results were reported to be unpromising. The cavity surface was compromised by the niobium vapor and spatter during electron beam welding. We have taken a second look at the principle of half-cell electropolishing by improving the electron beam welding procedure with an EB welder in our facility. A 1500 MHz niobium cavity has been fabricated with two half-cells, which are pre-electropolished with a very simple and compact system.

HALF-CELL ELECTROPOLISHING

1500 MHz cups were formed by deep drawing with $1/8''$ thick RRR250 niobium sheets with MK-III dies. The inside surface of these cups was electropolished for a surface removal of 160 μm (This was done in March, 2000). The electropolishing set-up is similar to the one illustrated in Fig. 1. The cup is filled with a mixture of HF(49% wt.) and H_2SO_4(96% wt.) at a volume ratio of about 1:10. The mushroom-shaped cathode is made of aluminum. A voltage-regulated DC power supply is used. The normal voltage across electrodes is 10 - 15 V. The cup is cooled by bath water. Acid was agitated through a magnetic stirrer driven spin bar placed inside the acid and at the bottom of the cup. A laminar circulating acid flow is formed when the spinning speed is adjusted to the optimal value [3]. A continuously oscillating current is obtained and can be maintained for more than 2 hours. It is believed that in this CW current oscillation mode, a dynamic balance is reached between the niobium oxidization and dissolution of the oxide.

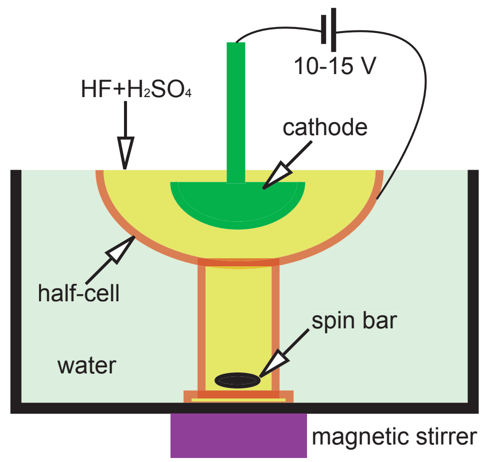

Figure 1: Sketch of the half-cell electropolishing setup.

After electropolishing, the cups were trimmed at its iris and equator and then beam tubes were welded to the half-cells.

HALF-CELL PURIFICATION

The two beam-tube-welded half-cells were paired together and Ti purified in our furnace. The outside surface of the half-cells is taken care of by the Ti liner of the furnace and the inside surface by a cylindrical-shaped Ti box centered inside the cell.

An optimal heat treatment recipe [4] was used, namely 2 hours at 1300°C followed by 4 hours at 1200 °C. This recipe allows gettering of oxygen with limited Ti diffusion (< 16 μm) into the bulk of niobium. The RRR is boosted to over 500 from 250, as measured with the witness samples treated in the same batch as the half-cells.

ELECTRON BEAM WELDING

The equator end of half-cells was dipped in cold BCP for 20 minutes to remove possible Ti trapped along the corner of the weld-preps. This was followed by another cycle of electropolish (Fig. 1) for an inside surface removal of about 30 μm to remove the Ti diffused layer of the RF surface. EBW of the equator was done with a special jig, made of niobium, running across the two irises as shown in Fig. 2. The jig has a maximum allowable diameter to

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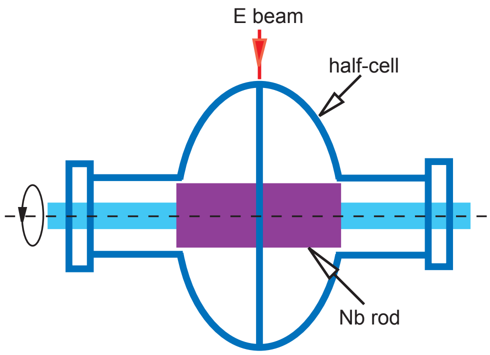

Figure 2: EBW pre-electropolished half-cells with a Nb vapor interceptor.

intercept niobium vapor and spatter so as to minimize contamination to the pre-electropolished surface.

The exterior surface of the welded cavity was etched with cold BCP for a surface removal of 3 μm to eliminate the titanized surface layer so as to improve heat transfer across the interface between the niobium and LHe during cavity test. The final step of the cavity treatment was a brief etching with cold BCP for a surface removal of 4.5 μm (inside and outside). Then the cavity was rinsed with high pressure water and mounted to the test stand.

CAVITY TEST RESULTS

First cavity test at 1.5 K yielded a Q_0 of 5×10^9 for Epk $\leq$ 15 MV/m as shown in Fig. 3. Above 15 MV/m, Q_0 dropped down to 6×10^8 at 20 MV/m. No x-ray was observed at the highest field and the limitation was due to the power from the amplifier.

Thermometry system revealed that there was a temperature rise within a band in the bottom half of the cavity. The boundary of the band is $1''$ and $3/4''$ away from the equator and the lower iris respectively. The center of the band does not corresponds to the peak magnetic field region. The nature of this increased losses is not fully understood yet. But residual Ti due to insufficient etching after purification is suspected.

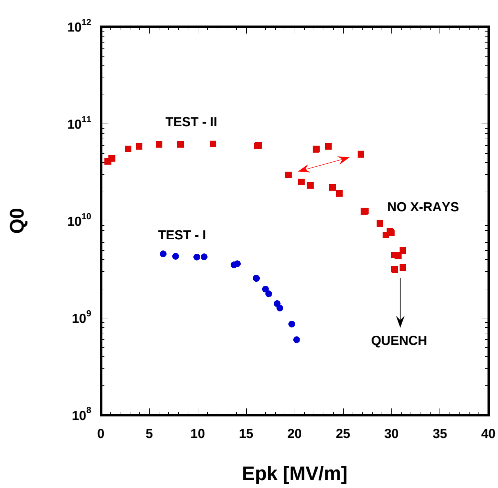

Figure 3: First test results.

The cavity was etched with cold BCP for another 7.5 μm of surface removal (inside and outside) and tested again. The overall BCP surface removal after EBW reached 13 μm for the inside surface and 16 μm for the outside surfacerespectively. This time, a surprising high Q_0 of 6×10^{10} was measured at low fields. This high Q is retained up to Epk = 25 MV/m. At this field, a Q-switch was observed. The Q_0 jumped to 2×10^{10} and Epk backed off to 20 MV/m. When the input power was raised further, Q started to drop down. Finally the cavity quenched at Epk = 30 MV/m. Again, no x-ray was observed for the entire field range. When the input power was decreased, Q switched back to 6×10^{10} at 20 MV/m.

Thermometry system revealed that at the switching field, a hot spot appeared near the equator. Also above 20 MV/m, the lower half of the cavity still showed relatively higher temperature rise within the same band observed during the previous test. The cause for the Q-switch at 20 - 25 MV/m is under investigation. A niobium blister from weld spatter is suspected.

REMARKS

Our first 1500 MHz half-cell electropolished has been fabricated and cavity test has started. First test showed encouraging high Q at low field and no field emission was observed up to a Epk of 30 MV/m. It is essential to remove a surface layer of at least 13 μm after EBW in order to achieve a high Q. Further investigations on Ti purification and welding procedures are needed to reach a higher accelerating field.

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