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FIRST RESULTS ON A 500 MHz Superconducting TEST CAVITY FOR TRISTAN

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Summary

First results on measurements of a 500 MHz superconducting cavity for TRISTAN are reported. The cavity of spherical shape has been built from 2.5 mm niobium sheet of 99.6 % purity by spinning, the main impurity being 1700 ppm of tantalum. Electropolishing and oxipolishing techniques have been applied for surface treatment. No high temperature degassing has been carried out. A Q-value of $Q_0 = 3.4 \times 10^9$ and an accelerating gradient of Eacc = 4.1 MV/m have been obtained at 4.2 K. At 1.9 K the Q-value has been improved to 1.1×10^{10}.

Gas condensation and degassing effects on the cavity are also reported.

Introduction

During the past several years the research on superconducting cavities at KEK has been carried out at C-band-frequencies around 6 GHz. The major effort was devoted to studying fabrication and surface treatment techniques for single and multi-cell cavities aiming at high Q-values and accelerating gradients.[1] In single cell cavities best values of $Q_0 = 2 \times 10^{10}$ and Eacc = 10 MV/m have been obtained. In a 9-cell structure Eacc = 3 MV/m could be maintained during an electron acceleration test.

From the end of 1979 the efforts at KEK have been focused on the development of superconducting prototype 500 MHz cavities to study the possibility of inserting them into the TRISTAN[2] electron ring which is at present expected to obtain the energy of ∿ 30 GeV with normal conducting rf structure. It is anticipated to eventually replace the normal conducting cavities of TRISTAN by superconducting ones, which would increase the available energy of e^+, e^- beyond 35 GeV, if an accelerating gradient of 3 MV/m could be obtained.

A 500 MHz niobium test cavity has been built and tested. The results of the first measurements are reported in the following.

Cavity fabrication and surface treatments

The cavity was chosen to be of spherical shape taking advantage of ease of fabrication by spinning and avoiding electron multipacting.[3]

Design parameters calculated by LALA[4] are listed in Table I, the peak surface electric field Ep was decreased by adopting an elliptical cross section at the beam hole edge.[5]

Table I

Design parameters of 500 MHz cavity.

Frequency	500.3 MHz
Q(Cu, 300 K)	48000
ZT^2/L (Cu, 300 K)	25 MΩ/m
Ep/Eacc	1.74
Hp/Eacc	34 Gauss/MV/m
Geometry Factor	277 Ω

At the time of purchase only niobium of 99.6 % purity with the major impurities as listed in Table II was available in a limited time. The cavity was fabricated by spinning out of 2.5 mm thick sheet of this material.

Table II

Major impurities in the niobium used for the 500 MHz cavity.

Tantalum	1700 ppm
Tungsten	800 ppm
Zirconium	800 ppm
Silicon	500 ppm

During the spinning process three annealing steps at 650 ∿ 750°C were carried out.

The next fabrication steps included the welding of 12 radial reinforcement ribs to each half of the cavity and the individual electropolishing of the cavity halves and the beam pipes. About 80 μm were removed from the surface by repeating 3 minutes polishing and 3 minutes agitating the solution.

Electron-beam welding of the cavity parts was done both from inside and outside by partial penetration welds with overlapping. Only the last weld at one of the beam pipes was done from outside with 95 % penetration.

Prior to electropolishing the welded cavity, it was stress annealed at 900°C and 10^{-5} torr for 1 hour. The electropolishing was done as shown in Fig. 1, the cavity was placed vertically in the electropolishing bath with the inner surface being shielded against hydrogen bubbles emerging from the center aluminum cathode during the polishing by a porous teflon tube**, which surrounded the cathodes at a distance of ∿ 2 cm.

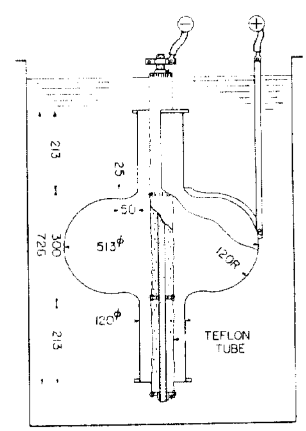

Fig. 1 Set up of the electropolishing.

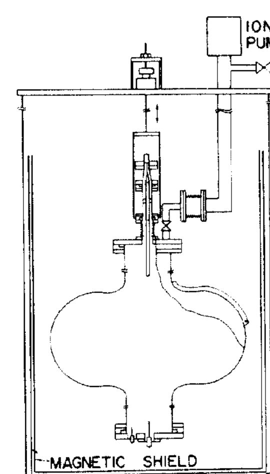

Fig. 2 Cavity assembly in the dewar.

* Guest from KfK, Karlsruhe.

** Commercial name is GORE TEX.

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After the removal of 30 μm the cavity was twice oxipolished up to 80 volts, thoroughly rinsed in deionized water and methanol, wet assembled with an adjustable input coupling probe and two pickup probes and evacuated to a vacuum of < 10^{-7} torr, before being placed in a magnetically shielded cryostat as shown in Fig. 2.

Results of the first measurements

At low fields Q-values of $Q_0 = 3.4 \times 10^9$ at 4.2 K and 1.1×10^{10} at 1.9 K were observed as shown in Fig. 3. When increasing the field level in the cavity, no multipacting barriers were encountered, degradation of Q_0 due to the electron loading started at Eacc $\gtrsim$ 2.8 MV/m. Electronic activities as measured by pickup probes and X-rays outside the cryostat were observed at Eacc $\gtrsim$ 2.9 MV/m. Above a field level of Eacc = 4.1 MV/m the cavity was breaking down.

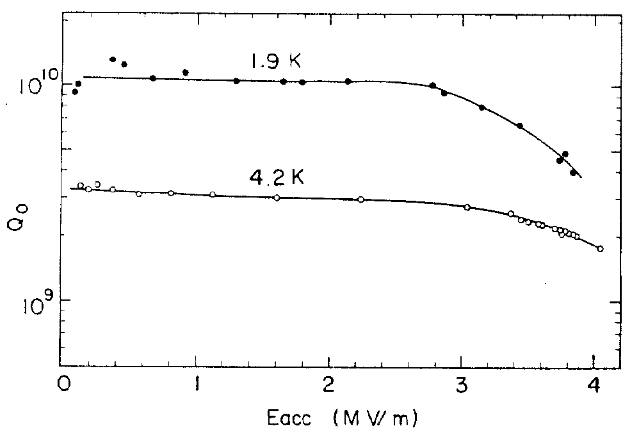

Fig. 3 Q_0 with increasing field at 4.2 K and 1.9 K.

Temperature rise of the cavity wall was measured by 384 carbon resistors distributed almost uniformly on the cavity wall. At the breakdown field heating was observed at a point on the equator of the cavity as shown in Fig. 4. Below the breakdown field level, only moderate heating corresponding to temperature rise of 15 ∿ 30 mK was observed at about one half of total surface area as shown in Fig. 5. Due to the rather large mesh size of the resistor network, no evident trace of electron trajectories as in the CERN[6] cavity was observed.

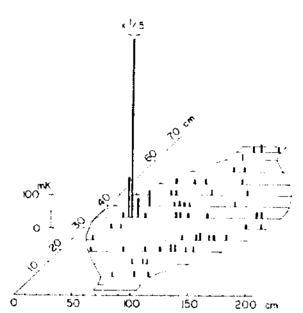

Fig. 4 Temperature rise of the cavity wall at breakdown field of Eacc $\approx$ 4 MV/m.

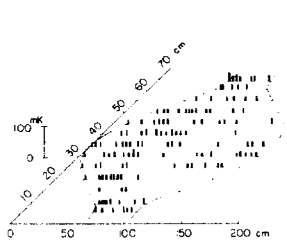

Fig. 5 Temperature rise of the cavity wall at Eacc = 3.71 MV/m.

Fowler-Nordheim plots[7] taken for electron current at a biased probe and X-ray intensities yielded microscopic field enhancement factor β of 660 and 790 which is comparable to DORIS[8] and CERN[6] cavities.

From Q values at low field, BCS surface resistance R_{BCS} at 4.2 K is 81 nΩ, residual loss resistance R_{res} is 25 nΩ and from the data with decreasing temperature Δ/kT_c is 1.6.

Gas condensation and degassing effects

After the first measurements, a 20 ℓ/sec ion pump evacuating the cavity continuously as seen in Fig. 2 was once overheated by some reason and hot gas went into the cavity which was cooled down to ∿ 1.7 K. Degradation of both Q_0 and maximum field was observed. By rf processing of a few hours the cavity was recovered to some degree. Then the cavity was taken out of the cryostat and baking at ∿ 80°C for degassing the absorbed gas was carried out for three days. Q_0 and maximum field were completely recovered. Fig. 6 shows Q_0 and Eacc for these three different stages.

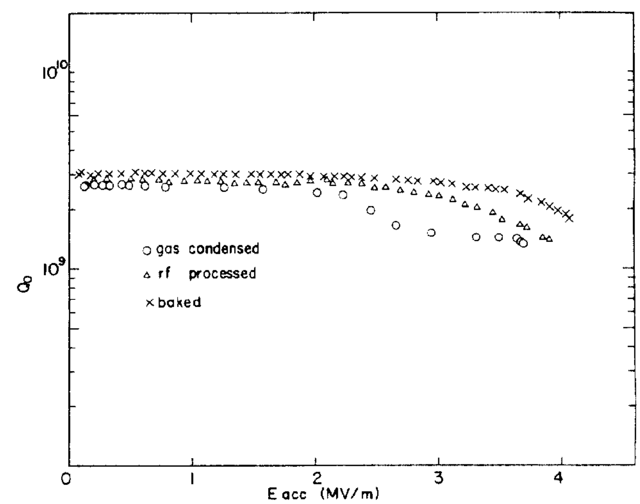

Fig. 6 Q_0 and Eacc for three different surface states.

In Fig. 7, $1/Q_0$ corresponding to the cavity losses are plotted against E_p^2. From the linear part of these curves at low field, losses due to the heating proportional to E_p^2 are estimated and from a relation of $Q_0\ \Delta(1/Q) = \gamma(H/H_c)^2$, γ was obtained as 35 for gas condensed and rf processed surface and 20 for baked surface.

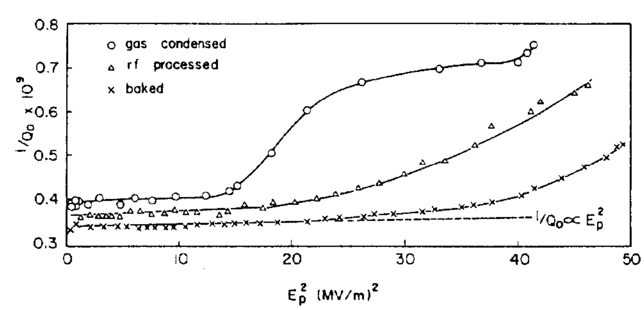

Fig. 7 Losses against square of peak field as calculated from Fig. 6.

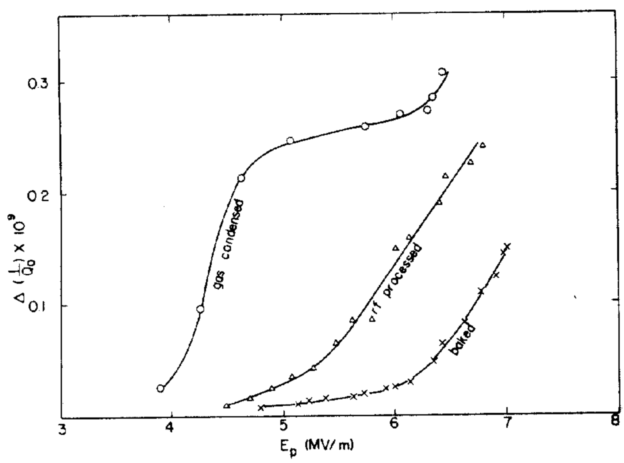

Fig. 8 Losses as a function of peak field Ep after subtracted the heating losses.

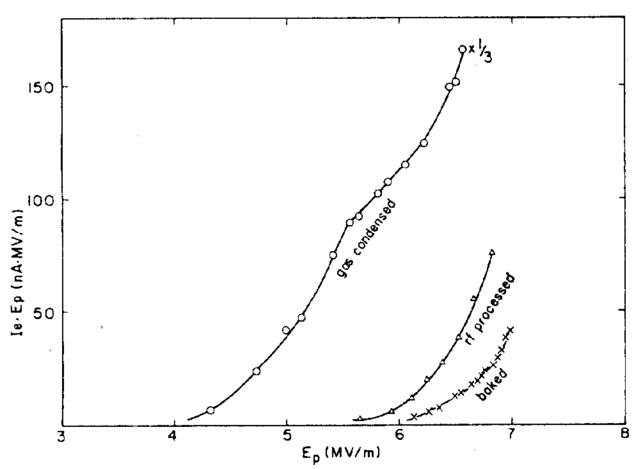

Fig. 9 Electron current I_e times peak field Ep as a function of Ep.

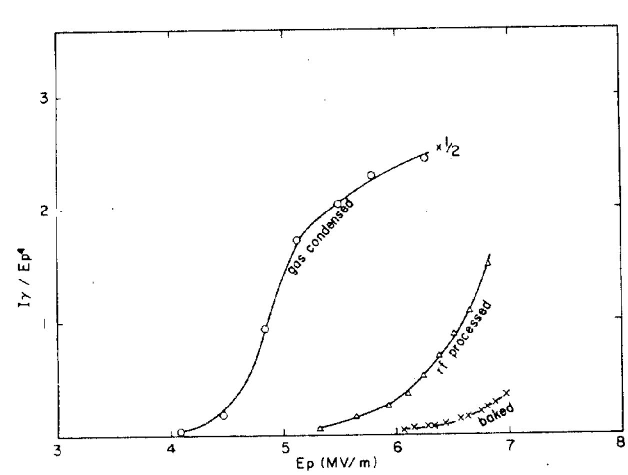

Fig. 10 X-ray intensities as a function of Ep.

After subtracted these heating losses, remaining part of the losses at higher field is plotted in Fig. 8 as a function of Ep. These losses are correlated with the electron loading as shown in Fig. 9 and Fig. 10. In these figures the electron current I_e times electric field Ep and X-ray intensities are plotted. X-ray intensities measured at the outside of the cryostat are divided by Ep^4 with assuming the energy dependence of X-ray absorption by the cavity wall, liquid He and N_2, magnetic shielding and cryostat walls.

Quantitative comparison between the cavity losses and electron loading or X-ray intensities is not examined, because these data were taken at the different runs so some rf processing might have occured among each run, also the electrons picked up by the probe are not exactly proportional to the electrons responsible to the cavity losses or X-ray production.

Some remarks can be exhausted from these experiments as following.

Gas condensation onto the surface plays an important role for electron emission and the loading of these electrons causes the cavity losses additional to the heating losses and lowers the attainable field.

By rf processing or baking at rather low temperature of ∿ 80°C, electrons or X-ray decrease and Q-value and Eacc are improved.

Conclusion

In a 500 MHz spherical cavity made out of niobium of 99.6 % purity, Q-value of $Q_0 = 3.4 \times 10^9$ and accelerating field of Eacc = 4.1 MV/m at 4.2 K have been obtained by electropolishing and oxipolishing surface treatment without high temperature firing. Up to the Ta-impurity of 1700 ppm there seems to be no deterioration of the cavity performance. At the design field level of 3 MV/m for the superconducting TRISTAN version, a Q-value of 2.8×10^9 was obtained and electron loading was very moderate.

Gas condensation and degassing experiments have shown the electrons and X-ray were enhanced by condensed gas causing the lowering of Q_0 and accelerating field.

Acknowledgement

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