FIRST RESULTS ON CORNELL TE-TYPE SAMPLE HOST CAVITIES *

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Abstract

In order to measure surface resistance of new materials other than niobium such as Nb_3Sn and MgB_2, two sample host niobium cavity systems operating at TE modes have been developed at Cornell University. The first one is a 6GHz pillbox TE_{011} cavity modified from older visions enabling testing 2.75 inch diameter flat sample plates. The second one is an optimized mushroom-shape niobium cavity operating at both 5GHz TE_{012} and 6GHz TE_{013} modes for 3.75 inch diameter flat sample plates. First results from the commissioning of the two TE cavities will be reported.

INTRODUCTION

In the past three decades, different types of TE sample host cavities were designed and used to test niobium or alternative materials for superconducting cavities [1], [2], [3], [4]. However, most of them has only achieved magnetic field under 200Oe on the sample, and often the sensitivity in surface resistance is well above the desirable nΩ range. In the other hand, niobium is rapidly approaching its theoretical superheating field around 2000Oe, a sample host cavity which can reach relatively high field and has high sensitivity is highly desirable for studying various field-dependent loss phenomena in niobium. Also since the alternative materials such as Nb_3Sn and MgB_2 are theoretically predicted to have a very high superheating field [5], a sample host cavity can reach above niobium superheating field is especially needed to test those materials.

At Cornell University, two sample host TE cavity system have been designed and successfully commissioned. In the following sections, rf design considerations, the cavity preparation apparatus and RF test results using baseline niobium bottom plates will be presented.

TE-TYPE SAMPLE HOST CAVITY DESIGN AND FABRICATION

TE Pillbox Cavity

Various versions of TE pillbox cavities have been used at Cornell University to study surface resistance of high temperature superconductors $YBa_2Cu_3O_7$, ultra-high vacuum cathodic arc films coated samples and MgB_2 [3], [4], [6]. For the first Cornell TE pillbox cavity, the sample was introduced into the cavity by a sapphire rod through a niobium cutoff tube aligned along the cavity axis. A thermometer was attached to the sapphire rod near the sample and a heater was attached to the bottom of the sapphire rod. The heater and both thermometers were placed well beyond RF cutoff. This cavity was used to measure $YBa_2Cu_3O_7$ rf surface resistance at various temperatures with magnetic field on the sample of 1 Oe [3]. The highest magnetic field reached on the sample surface was around 11 Oe. Later the bottom plate of the cavity was replaced by the Nb/Cu end plate with a groove on the surface of the sample which was intended for removing the degeneracy between TE_{011} and TM_{110} modes. This cavity had a very high residual resistance above 1$\mu\Omega$ and the maximum surface field on the sample ever achieved was around 200Oe. Therefore, two new TE pillbox cavities were designed to enable testing flat surface samples and were aimed to reach high surface magnetic field by using carefully treatments and improved rf designs.

In order to test a flat sample, the groove was moved to the top plate near the coupler ports as reported previously [8]. This TE pillbox cavity design has achieved 300Oe magnetic field on the sample plate. Later we discovered that only by increasing the diameter of the input power coupling port, the port itself is efficiently break the modes degeneracy between TE_{011} and TM_{110}. And the fabrication process is greatly simplified by not using dies to make grooves. Fig.6 shows the magnetic field contour plot in a cross-section view of the new design. The new design also employs only one coupler port instead of two ports. Thus we will only use reflected power to phase lock the cavity during cryogenic rf tests. In addition, another non-flat sample plate was designed which introduced two symmetric ports as reported before [8]. The design parameters of this TE pillbox are shown in Table.1.

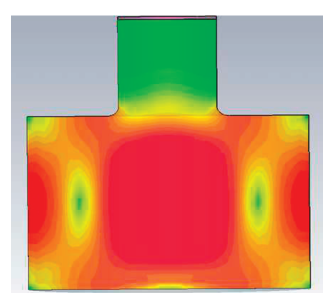

Figure 1: Magnetic field contour plot of the TE_{011} mode of TE pillbox cavity. Red color indicates higher magnetic field region.

The TE pillbox cavity is made of RRR300 niobium. It consists three separate niobium part: top plate with coupler port, cavity tube, the flat sample plate (baseline niobium). Then they were assembled together by non-magnetic standard steel type 316 clamps as shown in Fig.2.

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Table 1: The Design Parameters of the TE Pillbox Cavity

	Big flat sample plate	Small round sample
f(GHz)	5.88	5.88
$\frac{H_{max,sample}}{H_{max,cavity}}$	0.77	0.65
Sample diameter (cm)	7.0	1.0

Figure 2: The TE pillbox cavity with SS316 flanges and pumping adapter tubes.

TE Mushroom Cavity

As reported before, The mushroom shape TE cavity operates at both TE_{012} and TE_{013} modes [7]. The input coupler port is located at the center top of the mushroom type cavity and the pickup probe and pumping probe are distributed symmetrically at the input coupler port. During rf test, the pickup coupler is not used because we only use reflected power to phase lock the cavity.

This cavity is fabricated with RRR300 niobium and has received a 120μm heavy BCP as show in Fig.3. A flat sample plate has also been made and they are assembled together by non-magnetic standard steel type 316 clamps.

COUPLER DEVELOPMENT

As discussed before, a typical ”Saclay” style input coupler tip plane is always parallel to magnetic field line planes of the TE_{0mn} monopole modes no matter what direction of the tip is positioned if loop/hook is at cavity axis [9]. Therefore we use an off-center hook tip coupler which can be seen from Fig.4 to increase magnetic field coupling.

The strength of coupling depends both on tip penetration depth and the angle/the direction of hook. The input coupling coefficient Q_{ext} was calculated by both Omega3P and MWS and agreed well. Since rf surface resistance of new superconducting material may vary a lot, the coupler is designed to enable a large range of coupling from 10^6 to 10^{11}. The inner conductor consists of three section hollow copper tubes which length can be adjusted for different coupling requirements. A fully 3-dimensional multipacting simulation was performed to check the possible existence of multipacting barriers. Numerical simulation using SLAC's parallel computing EM codes ACE3P was used [10].

Table 2: The Design Parameters of the TE Mushroom Cavity

	TE_{012}	TE_{013}
f(GHz)	4.78	6.16
$\frac{H_{max,sample}}{H_{max,cavity}}$	1.24	1.74
Sample diameter (cm)	9.525	9.525

Figure 3: TE mushroom cavity after a heavy BCP.

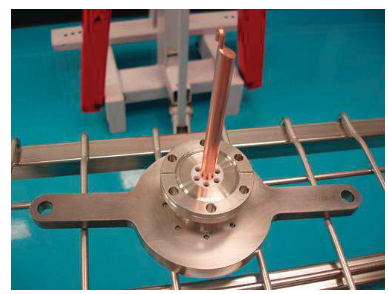

Figure 4: An off-center hook coupler for TE sample cavity test.

TEST INSERT, THERMOMETRY SYSTEM AND CAVITY PREPARATIONS

The old Cornell pillbox cavity system was tested inside a small dewar with no radiation shielding. Also the adjustable coupling was done by mechanically gear system which is not easy to control. In order to make a dedicated TE sample host cavity testing system, a special rf test insert with electric motor controlled adjustable coupling was designed and built. It can accommodate both TE pillbox cavity and TE mushroom cavity with the same input coupler. The assembling process was done in class10 clean room despite the common belief that TE cavity have no field emission problem.

A ring of 8 thermometers(Allan-Bradley resistors) has been mounted near the highest magnetic field region at the bottom plate of the TE pillbox cavity and can successfully detect around 10 nΩ surface resistance. Fig.5 shows the thermometer setup.

After fabrication, the TE pillbox cavity and mushroom cavity both received a 120μm heavy BCP. High pressure rinsing attachments were also developed for the various

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Figure 5: TE cavity sample plate thermometry system.

components of the TE pillbox and mushroom cavity. After the initial heavy BCP, the cavity received 2 hours HPR in class 10 cleanroom and was baked 800C in a high temperature vacuum furnace. Another 20 μm light BCP was applied to this cavity. After a final HPR, the TE pillbox and mushroom cavity were available for rf test.

NIOBIUM BASELINE RF TEST RESULTS AND DISCUSSION

A dedicated 6GHz rf phase-lock-loop system was assembled in the Cornell rf test area. Since cable loss in the 6GHz range is relatively larger compared with the cable loss at 1.3GHz, special low-loss coaxial cables LMR600 were used for the signal transmission between amplifier and cavity. A pre-amplifer before the 250W TWT amplifier was used to enable delivering over 200W to the test dewar.

The rf test result of TE pillbox cavity is shown in Fig.6. The maximum field achieved on sample surface is around 450Oe and the maximum low field Q_0 is 6×10^9. The rf test result of TE mushroom cavity is shown in Fig.7. The maximum field achieved on sample surface is around 600Oe and the maximum low field Q_0 is 1×10^9. Both cavity quenched possibly due to global thermal instability of high rf frequency. Coupler loss also observed during both tests. Thermal feedback simulation indicates that lower bath temperature and 120C bake may improve the maximum surface magnetic field on the sample to more than 800Oe.

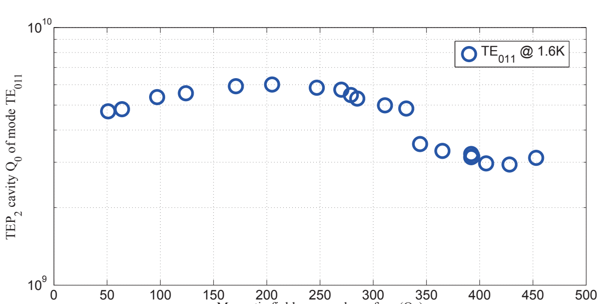

Figure 6: Baseline Nb sample plate for TE pillbox cavity.

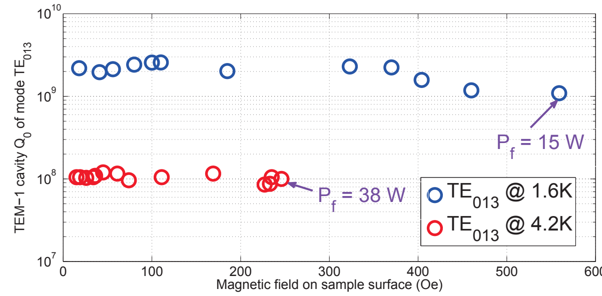

Figure 7: Baseline Nb sample plate for TE mushroom cavity.

CONCLUSIONS

Two TE-type sample host cavities have been successfully fabricated at Cornell University to systematically study niobium surface resistance and new alternative materials. The TE pillbox cavity has achieved over 450Oe magnetic field on the sample surface with a Q_0 6×10^9. The TE mushroom cavity has achieved around 600Oe magnetic field on the sample surface with a Q_0 1×10^9. Vertical electropolishing and 120C bake will be made to improve the maximum surface magnetic field.

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