SUPERCONDUCTING CAVITY DEVELOPMENT AT LOS ALAMOS NATIONAL LABORATORY*

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Abstract

A capability to design, fabricate, and test superconducting cavities has been established at Los Alamos Natinal Laboratory. Chemically treated single-cell niobium cavities are being tested at high fields (805 MHz and 3 GHz). Because the accelerating gradients achieved in these cavities are usually limited by field emission, conditions affecting field emission and cavity loss are being investigated by making changes in the established cavity-processing sequence. This paper discusses one of those changes and results.

Introduction

Single-cell, 3 GHz cavities are being tested to refine cavity processing and assembling procedures. These cavities are high-RRR niobium, spheroidal in shape, and use indium seals between the beam tubes and stainless steel flanges. Part of the testing program is the development of a distribution of cavity performance as measured by peak electric field in the cavity. The results of measurements made over more than a year are summarized in Fig. 1. Certain of these results indicated a cavity contamination problem, especially after high-field operation. Addressing this problem led us to make a change in the chemical polishing procedure.

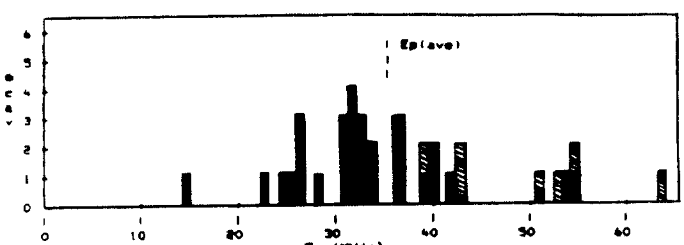

Fig. 1. Distribution of 3 GHz cavity tests related to the maximum peak electric field achieved. ▨ = runs with modified chemistry, █ = standard 1,1,1 chemistry. For the cavity geometry, $E_{peak}/E_{accel} = 3.64$. Cavity $Q_0 = 4\text{-}10 \times 10^9$ at 1.8 K. Total of 36 runs on 9 cavities.

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Observations

Figure 1 shows that the average peak electric field achieved is 35 MV/m, which corresponds to an average accelerating gradient of 9.7 MV/m. It also shows that one out of five cavity runs resulted in a fairly low peak electric field, around 26 MV/m. Usually, this occurred after a cavity had first run at a higher field level. Attempts to improve performance by rinsing the cavity with water and methanol proved futile. In addition, the majority of cavities that fell in the 26 MV/m cluster also showed a bump at 3.4 K in their $1/Q_0$ vs T_c/T plots. A typical example of such a plot is shown in Fig. 2.

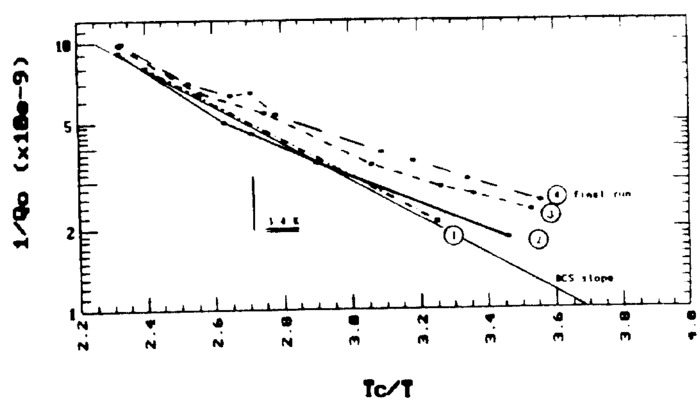

Fig. 2. Plot showing non-BCS behavior around 3.4 K in Final Run 4

Because indium is a superconducting metal, and T_c of indium is 3.4 K, we speculated that the bump in the $1/Q_0$ curve had something to do with indium contamination. The presence of the bump could be explained by the fact that indium is a normal conducting contaminant above 3.4 K (which would cause the $1/Q_0$ curve to approach a constant value above this temperature) and that at 3.4 K, when the indium becomes superconducting, the loss caused by the contaminant becomes negligible and the overall cavity behavior returns to conformance with BCS theory.

Further, the roll-off of the cavity Q_0 at 26 MV/m appeared qualitatively more precipitous than a roll-off due to field emission. A 26 MV/m peak electric field gives a peak magnetic field level in the cavity of 303 Gauss. For indium at 1.8 K, H_c is 211 Gauss. Assuming indium contamination was not uniform in the cavity, it seemed plausible that the cavity magnetic field was driving the indium normal, leading to a lower cavity Q_0.

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Test Results

Because this roll-off behavior at 26 MV/m was not necessarily removed by a 2-minute dip in 1,1,1 hydrofluoric, nitric, and phosphoric acids, we conducted to a qualitative study of the dissolution rates of niobium and indium in different acids. We found that in the 1,1,1 acid mixture, niobium dissolved more quickly than did indium. This means that a 2 minute polish in 1,1,1 could leave indium on the cavity surface, if the acid could not completely dissolve the niobium underneath to release it. The tests also showed that pure nitric acid would readily dissolve indium, but had no effect on niobium. Further research indicated that pure nitric acid would not hydrogen-impregnate the niobium and thereby degrade the Q_0.

Figure 3 shows the results of three high field tests run on one cavity. The first test was the initial one run after fabrication and after the removal of 57 microns with a 1,1,1 acid mixture. The second test was done after another 18 microns had been removed with 1,1,1. This run exhibited a 25 MV/m roll-off, indicating that something had contaminated the cavity; either the 18 micron polish did not remove the contamination from the first run or it occurred after the polishing step. For the third test, the cavity was dipped only in pure concentrated nitric acid for 10 minutes, then rinsed. In this run, the cavity achieved the same peak electric field as in the initial run, but at a lower Q_0. This test suggested that whereas a moderate (2 minute) 1,1,1 polish would not remove indium contamination, a pretreatment with pure nitric acid would.

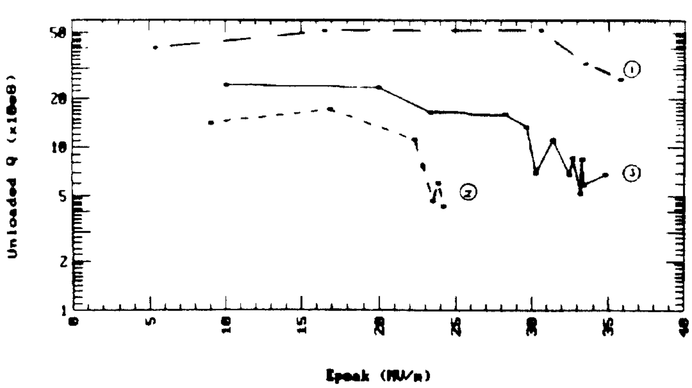

Fig. 3. Comparison of tests after different acid treatments
1 - 57 um removed with 1,1,1 initial run
2 - 18 um removed with 1,1,1, second run
3 - 10 minutes in conc nitric acid only, third run

We consequently changed our chemical polishing procedure from one using only the 1,1,1 mixture to one that incorporates a 10 minute pretreatment in pure concentrated nitric acid before the cavity is polished in 1,1,1. The intent is to remove any indium, or other foreign metal contaminant, from the niobium surface before the 1,1,1 niobium polish.

Though more data is needed, the five cavity tests done so far, using the new procedure, have not shown the symptoms postulated to be due to indium contamination. The cavities also had higher than average fields see (Fig. 1).

Discussion

Indium contamination may be a significant problem with the Los Alamos 3 GHz cavity design, because the width of the indium sealing flange on the cavity is 0.188 inches and the indium wire used is 0.020-0.030 inch. This makes it likely that indium will protrude into the cavity, potentially causing contamination . Using a wider flange may mitigate the problem, or make it less frequent, but as long as indium is used as the flange sealing material, the cavity interior will always be exposed to it to some degree.

Summary

Contamination of superconducting cavities is always a problem. In this instance, the observed behavior of poorly performing cavities indicated that indium contamination may be responsible. The standard chemical polishing treatment was modified to include a 10 minute pretreatment with pure concentrated nitric acid before the standard 2 minute dip in 1,1,1. Preliminary results from five cavity tests indicate that this modification may decrease the number of cavity tests that fall in the lower lobe of the performance distribution.

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