A COMPARISON OF LARGE GRAIN AND FINE GRAIN CAVITIES USING THERMOMETRY

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Abstract

An important limitation for SRF niobium cavities is the high field Q-slope. To investigate this phenomenon we compare the behavior of large grain and fine grain cavities using thermometry. Thermometry allows us to distinguish between different problems which occur in cavities, and to distinguish between different areas showing high field Q-slope. We looked for the difference in heating between grain boundaries and inside grains. We have found interesting differences between the heating of high field slope regions and the heating of point-like defects.

INTRODUCTION

In this contribution we discuss recent results with large grain cavity and compare results with previous tests on fine grain cavities. We use thermometry mapping system to look for any correlations between the pattern of grain boundaries and the heating pattern of the wall. We also did some quantitative analysis of thermometry data and compared results with small grain cavity results.

EXPERIMENTS

The large grain cavity is elliptical shape 1.5 GHz cavity with 3 mm wall thickness which was made of 300 RRR material purchased from OTIC, China. Before each test, the cavity was rinsed for two hours in the clean room with high purity water under 1000 psi high pressure. Assemblings and disassemblings from the test stand were done in the clean room class 100. The description of test stand, cryogenic and RF setup can be found in [1]. Temperature mapping system [2] was used to see heating distribution on the cavity surface. Baking was done by hot air flow, where heater was controlled by computer. The temperature distribution around the cavity was within $5°$C. The following experiments were carried out:

- The cavity was tested at the helium bath temperature of $1.5°$K.
- The cavity was chemically treated with BCP(1:1:2) for 200 μm and then anodized for 50 Volts to remove the defect.
- The cavity was tested at the helium bath temperature of $1.5°$K.
- The cavity was baked at $100°$C for 48 hrs.
- The cavity was tested at the helium bath temperature of $1.5°$K.

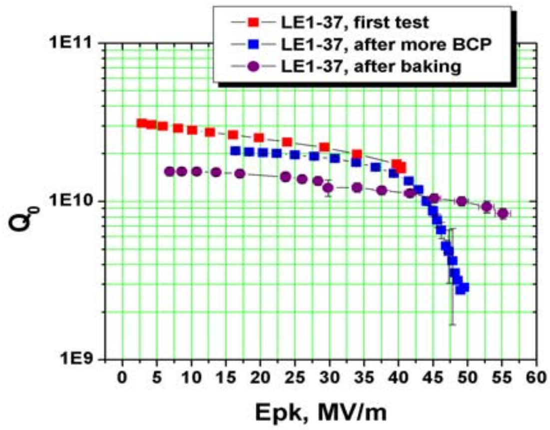

Figure 1: Results for the large grain cavity.

RESULTS

In Fig.1 the results of all tests are presented. In first test the cavity quenched at 40 MV/m peak electric field. The thermometry map (Fig.2) showed a point like heating at a singular spot, which suggested a defect on the cavity surface. After removal from the test stand and inspection of the inside surface we found a small pit right under thermometer that showed high signal. We assumed that cavity quenched because of sharp edges of the pit and we decided to remove more material chemically in order to remove sharp edge. In second test the cavity reached higher

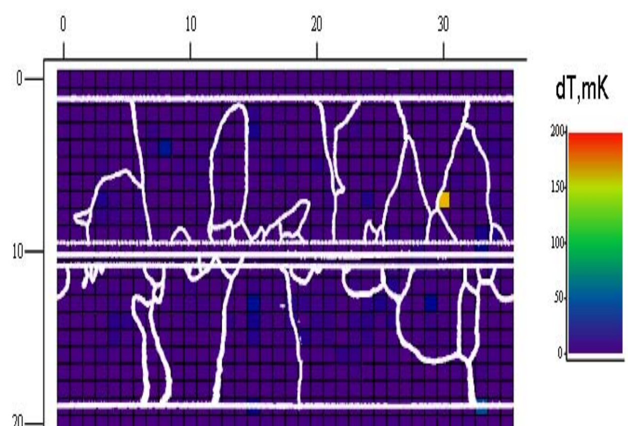

Figure 2: Temperature map for first test at Epk = 40 MV/m.

field and showed a high field Q-slope. The temperature map at the highest field is shown in Figure 3. It shows several regions heating up. The original defect site also showed up as one of the several hot spots in the temperature map of (Fig.3). Finally after baking the high field Q-slope was removed. The temperature map showed that the cavity quenched at new defect-like spot. And again we found a pit-like irregularity on the inside surface of the cavity.

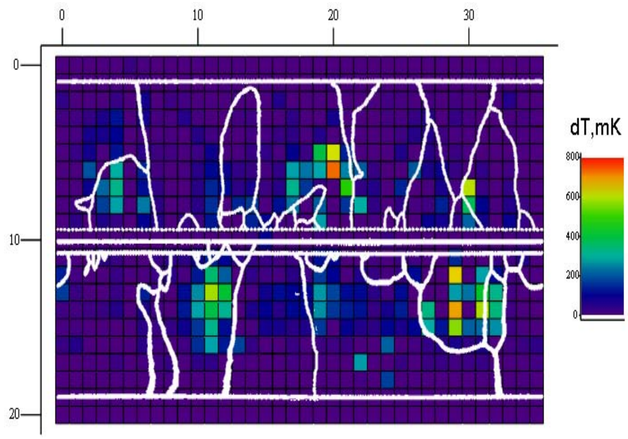

Figure 3: Temperature map for second test at Epk = 49 MV/m.

DISCUSSION

We want to compare high field behavior of large grain cavity to small grain cavity. In Fig.4 we plot results for both cavities when they showed high field Q-slope before baking. The large grain cavity has a slightly higher Q at all fields, though this improvement is within experimental error. The high field Q-slope onset fields and Q-slope strength are similar. One the other hand the temperature map(Fig.5 [3]) of the small grain cavity looks different from the temperature map of the large grain cavity at high fields. By comparing Fig.5 and Fig.3 we see that in case of large grain cavity the hot spots are more localized than for small grain cavity.

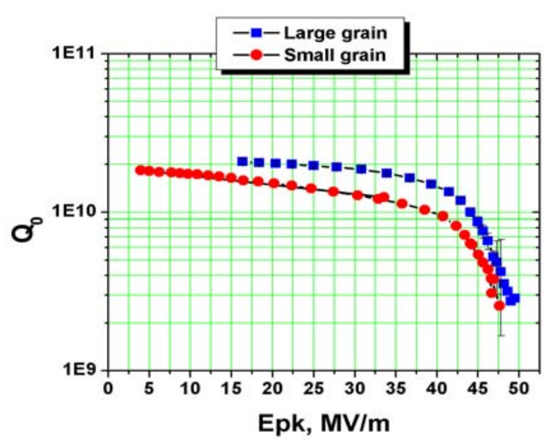

Figure 4: Results for the large grain cavity and small grain cavity before baking.

The advantage of large grain material is that grain boundaries are easily distinguished and can be superimposed on the temperature map. In Fig.3 you can see grain boundaries as white lines over the temperature map. We failed to find a definite correlation between grain boundaries and hottest spot distribution. The hottest spots are clearly not on the grain boundaries.

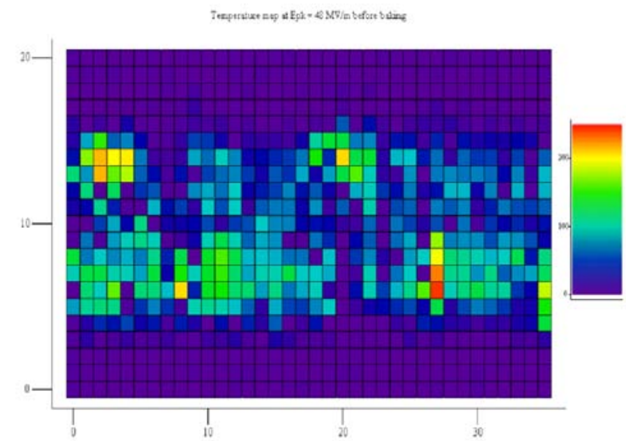

Figure 5: Temperature map for small grain cavity.

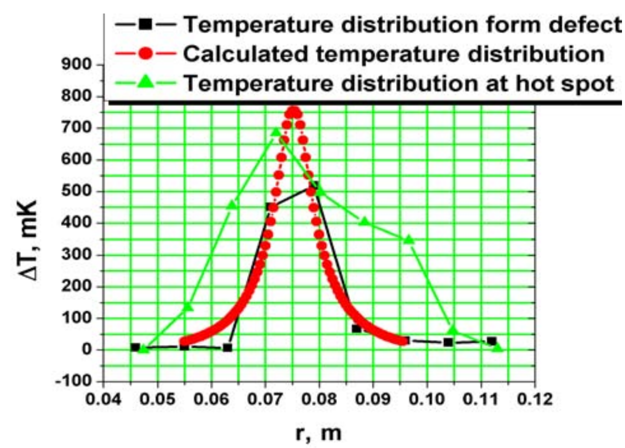

Figure 6: Spatial distribution of hot spots.

Another interesting topic is to compare the heating pattern of a high-field Q-slope dominated region (e.g. see Fig.3) with the heating pattern of a defect dominated region (e.g. see Fig.2). It is clear that hot spots that appear due to the high field Q-slope are not caused solely by defects: In fig.6 we compare spatial distribution for this hottest spots with that for a point-like defect. We also show the results of calculations[4] which suggest that for known thermal conductivity, Kapitza resistance[5] and wall thickness of niobium cavity the width of a hot spot on the outer surface from a point-like defect on the inner surface should be about 1 cm. The distance between thermometers is also about 1 cm. So for point-like defect one would expect to see 1-2 hot thermometers along one axis. This what we see in our first and last test, which were both limited by a quench at a defect. But in the test when we had a high

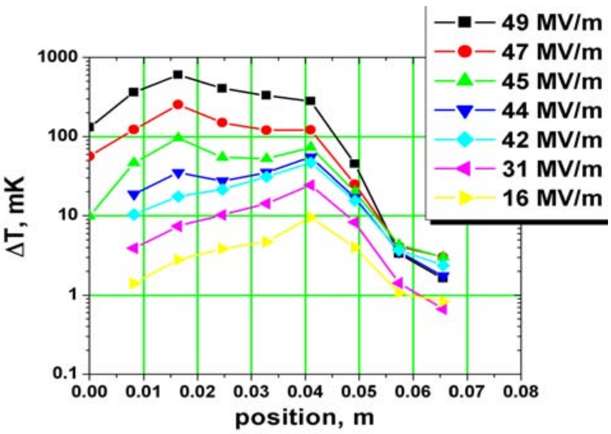

Figure 7: Spatial distribution as function of field for high field Q-slope region.

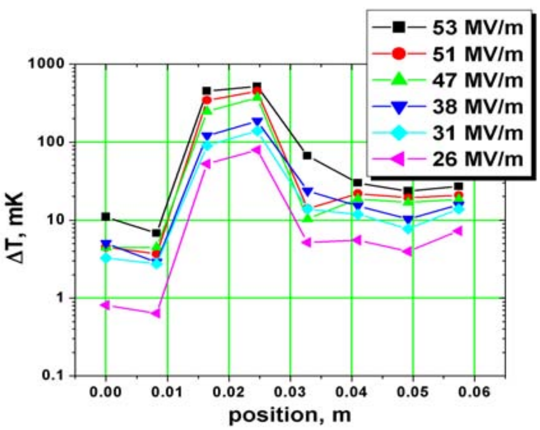

Figure 8: Spatial distribution as function of field for defect region.

field slope, the spatial distribution was more than 1-2 thermometers (Fig.3). We compared the evolution of the defect's temperature distribution (Fig.7) with field to the evolution of the temperature distribution corresponding to the high field Q-slope region (Fig.8). While defect site dominates at all fields, the high field Q-slope region is quite different: the hot spot is centered at one spot at low field, but as field increases a different spot overcomes the initial hot spot.

CONCLUSION

Large grain cavity shows Q-slope with onset comparable to that of small grain cavity. The Q-slope heating in a small-grain cavity is spread out over a larger area than the Q-slope heating in a large grain cavity. But the hottest spots on the large grain are not on the grain boundaries. The spatial distribution of Q-slope is broader then spatial distribution for point-like defect. Therefore Q-slope is not due to the expansion of the hot spots. We are going to carry out more experiments with this cavity and another large grain cavity.

ACKNOWLEDGMENTS

We would like to thank Professor James P. Sethna for inspiring discussions.

REFERENCES

[1] H. Padamsee, J. Knobloch, T. Hays, "RF Superconductivity for Accelerators", John Wiley and Sons, 1998.

[2] J. Knobloch, "Advanced Thermometry Studies of Superconducting RF Cavities", PhD thesis, Cornell University, 1997.

[3] G. Eremeev, H. Padamsee, M. Liepe, R. Roy, "A Pleasant Surprise: Mild Baking Gives Large Improvement for the Q-Slope of a BCP Cavity", 11th Workshop on RF Superconductivity, Germany, 2003.

[4] J.C. Amato, "Spatial resolution of residual resistance using thermometer arrays", SRF-840506, 1984.

[5] H. Padamsee, "Heat transfer and models for breakdown", CLNS 80/469, 1980.