SUPERCONDUCTING RF ACTIVITIES AT LANL*

T. Tajima*, G.V. Eremeev, F.L. Krawczyk, LANL, Los Alamos, NM 87545, U.S.A.

Abstract
Activities related to superconducting RF at LANL in the last 2 years are presented. They include developments of a full cavity thermometry system for standard 1.3 GHz 9-cell cavities, a surface inspection system and high-gradient SRF cavities at 805 MHz, the frequency at which LANL’s 800-MeV proton accelerator operates, in order to boost the energy to ~1.2 GeV with only 2 cryomodules. Additionally, we have been studying thin-film superconductors coated on Nb separated by an insulator to increase achievable surface magnetic field for very high accelerating gradient (hopefully ~100 MV/m or higher) to realize a compact accelerator system. High gradient SRF cavities would benefit such applications as the International Linear Collider (ILC), XFELs and cargo interrogation systems using proton or muon beams.

INTRODUCTION
LANL has been involved in 4 activities in the last 2 years: 1) development of a fixed-type full temperature mapping system for 1.3 GHz 9-cell “standard shape” cavities, 2) development of cavity surface inspection system, 3) development of high-gradient 805 MHz cavities, and 4) study of thin film superconductors aiming at future enhancement of cavity accelerator gradients. In the following sections, each activity will be briefly summarized with references for detailed descriptions elsewhere.

1.3 GHZ 9-CELL CAVITY T-MAPPING SYSTEM
We have developed and commissioned a full T-map system for standard shape 9-cell cavities. A total of 4608 temperature sensors made of 100 Ω Allen Bradley carbon resistors surround the entire cavity at every 10 degrees azimuthally, except for the end parts where part of He vessel is installed. The details of the system and some T-map results are described in Refs. [1] through [4].

The advantages of this full T-map system are 1) fast mapping of the entire cavity (within a few seconds), 2) detection of RF losses on the surface before quench, and 3) detection of the heating caused by the electrons generated at other cells.

CAVITY SURFACE INSPECTION SYSTEM
We have developed a system consisting of a cavity holding and moving mechanism and a scope based on a Karl Storz 6.2 mm diameter video scope having a working distance of 7-40 mm and an 80-degree field of view with remote articulation. The image is captured on a 1/10-inch CCD chip installed in the tip having 250,000 pixels in an aspect ratio of 16:9. Figure 1 shows the cavity surface inspection station located in a class 100 clean room.

HIGH-GRADIENT 805 MHZ CAVITY DEVELOPMENT
We are studying the possibility of producing very high gradient (40-50 MV/m) Nb cavities in order to shorten the length of accelerator. The reasons for choosing 805 MHz are its compatibility with LANL’s LANSCE proton linac frequency, larger beam pipe aperture, fewer cells, less BCS losses for the same energy gain and operating temperature compared to popular 1.3 GHz cavities.

The disadvantage would be larger diameter and surface area, making the cavity surface quality control more difficult and would lead to larger-diameter cryostats. On the other hand, reducing the number of cells per cavity might lead to a better yield of high-quality cavities and depending on the application, the cryostat diameter can be reduced.

We optimized the cavity design parameters with a constraint of the beam pipe inner diameter of 100 mm. Following the recent trend of reducing the ratio of $B_{\text{peak}}$ to $E_{\text{acc}}$, we get higher gradient, we designed 3 types, i.e., standard, low-loss and re-entrant shapes [6]. By “standard”, we mean a cell shape with inclined walls to facilitate easy draining of rinsing water in a vertical
position. The optimized $B_p/E_a$ ratios for standard, low-loss and re-entrant cavities are 3.75, 3.60 and 3.57 mT/(MV/m), respectively. Compared to the ILC standard shape $B_p/E_a = 4.15$, we were able to obtain significantly better ratio.

In collaboration with JLab, we have fabricated 3 standard-shape single-cell cavities and tested one of them so far. See the detail of test results in Ref. [6]. Unfortunately, the 150 μm buffered chemical polishing (BCP) performed at LANL created a number of bubble traces on the cavity surface, causing a lot of field emissions. However, the achieved accelerating gradient of ~22.5 MV/m, limited by available power as shown in Fig. 2, was not so bad. The other 2 cavities will be tested after BCP by the end of 2009, and we might add electropolishing (EP) later to see the difference in the result.

**STUDY OF THIN FILM SUPERCONDUCTORS COATED ON Nb**

The hard limit on accelerating gradient for Nb cavities in standing wave mode seems to be ~50 MV/m due to the RF critical field of ~200 mT for Nb, assuming the $B_p/E_a$ ratio of ~4 mT/(MV/m).

In 2005, Gurevich suggested a way to increase this limit using multi-layer coating of a different superconductor that has higher $T_c$ than Nb [7]. One of the key elements of this proposal is the fact that the lower critical magnetic field $H_{c1}$ that is parallel to the material surface significantly increases if the film thickness gets less than its London penetration depth.

Following this idea, we tested a sample of MgB$_2$(100 nm)/B(10 nm)/Nb at SLAC using TE$_{013}$ mode Cu host cavity. Here, the Nb substrate was a single-crystal bulk of 2 inches in diameter and ~1 mm thick. The details of coating method and results are described in Refs. [8] and [9].

Figure 3 shows $Q_0$ as a function of temperature at low power for the coated and uncoated Nb samples. The effect of MgB$_2$ layer is clearly seen as the increase of $Q_0$ starting from ~37 K where superconducting transition of MgB$_2$ occurred. After the Nb transition at ~9 K, the $Q_0$ seems to become dominated by the resistance of host copper cavity. To know the detail of surface resistance at 4 K or 2 K, the host cavity needs to be made of Nb.

Figure 4 shows cavity $Q_L$ as a function of peak surface magnetic field on the sample for Nb and MgB$_2$ coated Nb. It was found that, for this sample, the breakdown field was significantly lower (~40 mT) than Nb sample. Since this is the only one sample tested, we do not know if this is caused by the coating or some defects on the Nb.

Figure 5 shows cavity $Q_L$ as a function of temperature at different peak fields. The drop of $Q_L$ at 42 mT at T<9...
K suggests that the breakdown occurred in Nb, not in MgB$_2$.

We plan to increase the field to see at what level MgB$_2$ quenches. Also, we plan to test thicker MgB$_2$ film to determine the characteristics and quality of MgB$_2$ film that we are depositing as well as identifying the reason of early quench in the Nb substrate.

Figure 5: Cavity loaded Q as a function of temperature of the MgB$_2$/B/Nb sample for different peak surface fields.

ACKNOWLEDGMENTS

We would like to thank the following people for their help, collaboration and cooperation.

- LANL: A. Bhatty (now at a company), A. Burrell, A. Canabal (now at U. Maine), A. Burrell, Q. Jia, G. Zou (NbN coating), P. Chacon, J. Sedillo (T-mapping hard and software), Vacuum team members (assembly, etc.)
- JLab (805 MHz cavity fabrication, etc.): W. Clemens, P. Kneisel, R. Manus, R. Rimmer, L. Turlington
- FNAL (commissioning of T-map system, etc.): M. Champion, S. Mishra, C. Ginsburg
- ORNL (superconductor testing): I. Campisi
- SLAC (superconductor testing): S. Tantawi, V. Dolgashev, D. Martin, C. Nantista, C. Yoneda
- STI (MgB$_2$ coating): B. Moeckly

REFERENCES