RF PROPERTIES AT 6 GHZ OF ULTRA-HIGH VACUUM CATHODIC ARC FILMS UP TO 450 OERSTED

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Abstract

Several films of niobium were deposited on copper plates via the ultra-high vacuum cathodic arc (UHVCA) deposition method as described by R.Russo et al. (see [1], [3]). We attached these end plates to a 6 GHz cavity operating in the TE_{011} mode for characterizing the film quality by measuring the Q vs surface magnetic field.

INTRODUCTION

Thin films of niobium on copper are one of the promising alternatives to bulk niobium since the thermal conductivity of copper is higher than that of niobium thus allowing higher surface fields without quench of the cavity. Different film deposition techniques have been studied elsewhere [4]. In this paper we present recent results on the RF surface resistance of cathodic arc films of niobium on copper.

SAMPLE FABRICATION

Circular copper plates of the dimensions, which fit our apparatus used for RF measurements, were used as a substrate for an ultra-high vacuum cathodic arc film deposition at INFN-LNL, Italy. The details of the copper plate preparation and cathodic arc deposition are given in [1]. The picture of one of the niobium-coated plates and atomic force microscope (AFM) picture of its surface are shown in Fig.1.

EXPERIMENTAL SETUP

Niobium cavity operating in the TE_{011} mode at the frequency of f = 5.96 GHz was used as a host cavity for the measurements. This cavity is described in [5, 6]. The bottom plate of the cavity can be replaced by the Nb/Cu end plate for the evaluation of the sample's RF properties. The schematic of the cavity design and the picture of the cavity are shown in Fig.2. The presence of the groove on the surface of the sample is intended for removing the degeneracy between TE_{011} and TM_{111} modes.

Measurements were made in liquid helium at T = 2 K.

Figure 1: Nb-coated copper plate.

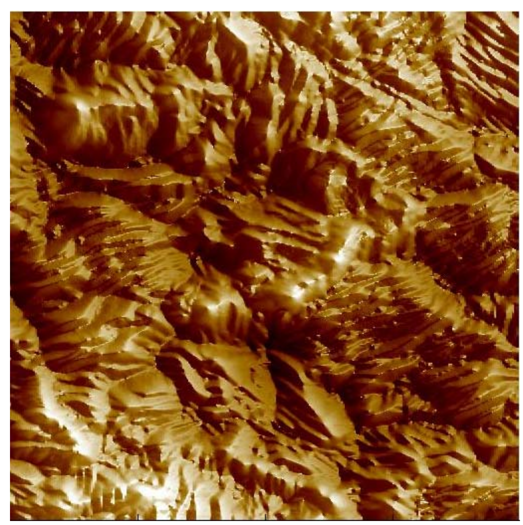

Figure 2: Atomic force microscope picture of the sample surface (2x2 μm area). The surface roughness is about 400 nm as compared to EP bulk Nb (200 nm) and BCP bulk (2 μm).

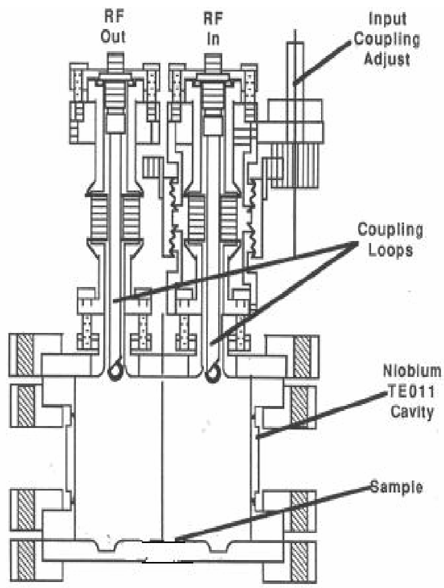

Figure 3: TE cavity schematic diagram.

CST Microwave Studio was used to simulate the field distribution for the TE_{011} mode and to obtain the peak magnetic field at the sample surface for the given stored energy. Surface currents at the bottom plate are shown in Fig. 4.

The geometric factor of the cavity operating in TE_{011} mode is 750 Ω. Under assumption that the losses are dominated by those at the sample surface, the surface resistance of the sample can be estimated (see [2]) as:

$$R_s = G / Q_0, \tag{1}$$

Bulk niobium end plate with the cut-off tube was used to get a baseline Q_0 of the cavity.

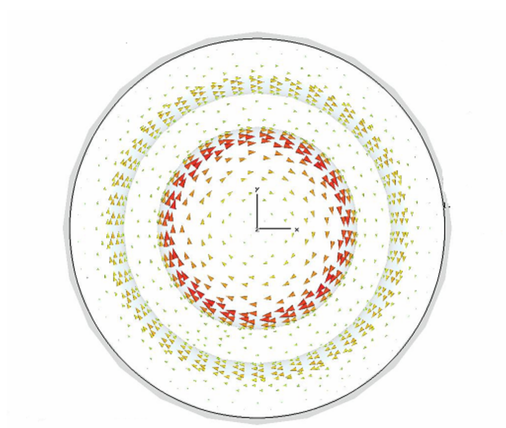

Figure 4: Currents at the bottom plate surface when the cavity is operated in TE_{011} mode. Red arrows correspond to a larger current – high magnetic field region.

RESULTS AND DISCUSSION

Results of the experiments for four different samples and the bulk Nb end plate are summarized in Fig.5.

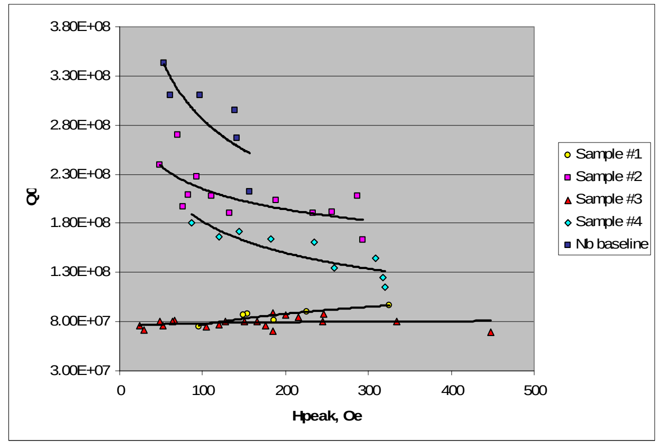

Figure 5: Q_0 versus peak magnetic field for different Nb/Cu end plates and a bulk Nb end plate.

Maximum achieved fields were limited by the available power (36 Watt) or quench in some cases.

At low field, the Q values for the arc films were (1-2) * 10^8 corresponding to a surface resistance of 3-6 μΩ. The calculated BCS surface resistance for RRR ≈ 50 Nb films is 0.23 μΩ at 2 K and 6 GHz.

No Q-slope was observed at the achieved field levels, but this is most likely due to the fact the residual resistance is still high. The Q remained constant up to a field of 450 Oe for one of the samples where the power available was 36 Watt. Slight decrease in Q for some samples might be attributed to the heating of the end plate.

A baseline Q of 3.5 * 10^8 (2 μΩ) was determined for the host cavity by attaching the original bulk Nb end plate (not shown) which has a sample port electron beam welded on to the center of the plate (RRR ≈ 40). We expect the BCS resistance to be 0.2 μΩ for the end plate and cavity material. Therefore the host cavity has 1.8 μΩ of residual losses. The quench limit for this end plate may be due to the presence of a defect on the weld between the end plate and the sample port. The film resistance appears to be two times higher than the residual resistance of the host bulk Nb cavity.

The presence of the groove on the surface of the sample might result in the inhomogeneous distribution of the film thickness. If the film is thinner inside the groove, the losses in the underlying copper may be a contributing factor. As a first measurement on the cathodic arc films, coming within a factor of two of the BCS resistance is encouraging.

One of the future improvements for the cavity is to make a groove on the top end plate to allow testing flat bottom end plates. We also intend to make new end plates with shallower grooves to get a uniform film thickness.

Origin of a high residual resistance of the host cavity is also unclear, but could arise from current flowing through the indium joint between the end plate and the cavity. Future efforts will focus on reducing the residual resistance of the host cavity to get a better baseline.

ACKNOWLEDGEMENTS

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