STUDY ON MULTILAYER THIN FILM COATING ON SUPERCONDUCTING CAVITY

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Abstract

Multilayer thin film coating to enhance performance of superconducting cavities is under investigation. We proposed a method to deduce a set of the parameters to exhibit good performances. In order to verify the scheme, characteristic measurement setup using the third order harmonic detection method for superconducting thin foil is under preparation.

INTRODUCTION

Multilayer thin film coating is a promising technology to enhance performance of superconducting cavities (see Fig.1). Figure 1 shows the simplest case of two layers of an insulator and a superconductor. The magnetic field B_0 applied from the left vacuum space is partially shielded by the first superconducting thin layer denoted by SC1, where SC1 would have higher $Bc1$ than SC2 (assumed as Nb in the paper) such as NbN or Nb3Sn. Then the magnetic field level felt by the bulk part can be less than B_0, hence the B_0 can be higher than $Bc1$ of SC2. Until recently, principal parameters to achieve the sufficient performance had not been known, such as the thickness of each layer [1]. Reference. 1, however, derived the enhancement factor of the amplitude of the applicable magnetic field as a function of the thicknesses of the insulator and the superconductor layers assuming the characteristics of the superconductor layers. Using the theory, the optimum thickness set of the layers can be found.

In order to verify the scheme, we are trying to make $Bc1$ measurements of thin film coatings at Kyoto University. The third order harmonic detection seems a first choice for that purpose [2,3].

EXPERIMENTAL SETUP

A coil located on a superconducting sample generates magnetic field (see Fig.2). The magnetic field more than the critical field $Bc1$ causes penetration of flux into the superconducting material. By detecting a third order harmonic voltage component in the electromotive force of the coil that is driven by AC current source, the $Bc1$ will be evaluated. While an external DC field could optionally be applied, it also was not adopted in our case as the same as Ref. 3. At the temperature just below the critical temperature, the flux penetration starts at the less magnetic field (see Fig.3)

A rough sketch of the cryogenic stage is shown in Fig. 4. A sample plate is put between the two Cu plates, where the top plate has an exciting coil at the center. The two plates clamp the sample with three coil springs to
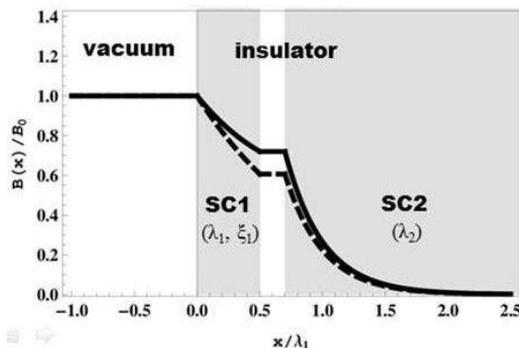

Figure 1: The multilayer thin film coating on superconducting bulk surface. The simplest case of two layers of an insulator and a superconductor is shown. The solid line shows the RF magnetic field amplitude as a function of the coordinate along the axis normal to the surface (see Ref. 1).
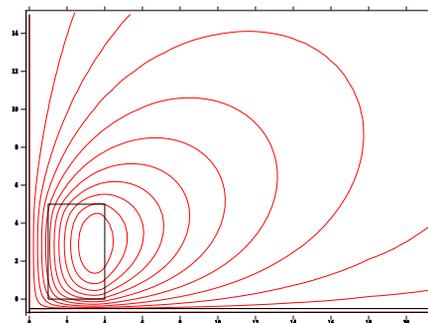

Figure 2: Superconducting material does not allow for a magnetic flux to penetrate when the magnetic field B is less than the critical field Bc1.
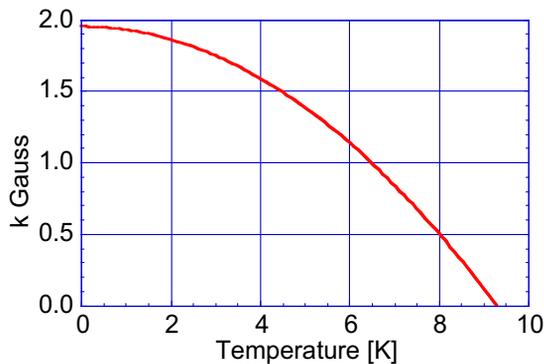

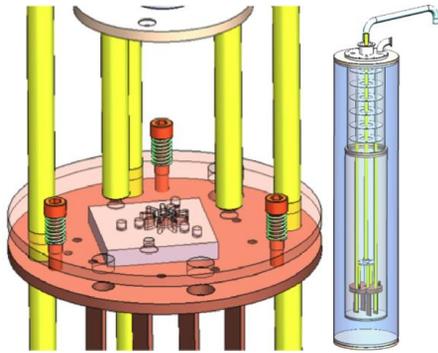Figure 3: Temperature dependence of a critical field.

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Figure 4: Rough sketch of the cryogenic stage (left) and that in our cryostat (right).

keep the distance between the coil and the sample. The coil height and diameter are 5 mm and 8 mm, respectively. The conductivity of Cu at the low temperature less than 10 K can be expected to be at least hundred times higher than that at the room temperature [4], which seems depending on the quality of the material. Assuming the conductivity $\sigma=6\times10^9$ [S/m] and i=30 [A/mm^2], the power loss density p in the coil would be $p=i^2/\sigma=150\times10^3$ [W/m^3]. The heat generation of about 40 mW is expected for that coil, which can be reduced by a pulse operation. The coil is fixed on the top plate and the heat will be removed through the top plate. Assuming the excitation frequency of 2 kHz, the skin depth of Cu is about 0.2 mm at room temperature. Although the skin depth at the cryogenic temperature would be about 20 μm, a test coil was wound with 0.2 mm Cu wire (see Fig. 5). While this effect may increase the heat dissipation in the coil, the pulse operation will cut down it. The long tabs fixed on the top plate downwards will be immersed in the liquid He and cooled down the top plate. The bottom plate has a smaller tabs and a heater to control the temperature during the measurement.

Figure 5: Test coil put in a Cu plate of the cryogenic stage.

Figure 6 shows the cryostat and the heat exchanger for He gas return system on the wall. The assembled cryogenic stage is shown in Fig.7. The cold experiment is expected in this year.

Figure 6: The cryostat and the heat exchanger for He gas return system on the wall (left).

Figure 7: The cryogenic stage hanged by FRP rods (left) and its overview (right) in front of the cryostat.

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