Introduction

- Superconducting RF cavity requires high thermal conductivity
- RRR is the first indicator for the performance of SRF Cavity
- RRR and thermal conductivity (Λ) have direct correlation
- RRR gives a direct indication of the purity of the niobium
- Usual method is 4-wire electrical resistance measurement
- 4-wire RRR measurement is destructive and local in nature
- Once RF cavity is fabricated, no way of measuring RRR
- AC methods for RRR measurements are the only solution

Abstract

A clear indicator of purity of niobium (Nb) used for fabricating Superconducting Radio Frequency (SRF) cavity is the Residual Resistivity Ratio (RRR) of the bulk Nb. Usual methods of determining the RRR is by Four-probe resistance measurement techniques. This process is destructive in nature and provides an average value of the RRR of the sample that is being used. It has already been shown in other literature’s that the RRR of the Nb changes as the RF cavity moves through various fabrication processes. In order to characterize the RF cavity through different stages of fabrication, a local, non-contact method for measuring RRR is required. This paper discusses one such non-destructive, non-contact method for RRR estimation using planar inductive sensor. Whenever a conductor is brought in the presence of an inductive sensor which is excited by an AC signal, the impedance associated with the sensing coil varies. This variation is a function of eddy current penetration depth (δ), the electrical conductivity (σ), the frequency of excitation (f) and the series inductance term (Ls) of the impedance of the sensing coil. The frequency response of the Ls term of the sensor will have an inflection point whenever the eddy current penetration depth becomes equal to the thickness of the sample. By determining the inflection point on the Ls graph close to the critical temperature (Tc) and at room temperature (Tr), the RRR can be estimated.

 Principle of Operation

- The penetration depth for eddy currents is given by,

\[ \delta \approx \sqrt{\frac{\mu_0 f}{\sigma}} \]  

(1)

- Assuming the thickness of the target remains constant, the series inductance Ls vs frequency plot will have an inflection point when

\[ \delta \approx \frac{\pi}{2} \sqrt{\frac{\mu_0 f}{\sigma}} \]

(2)

From equation (1),

\[ \delta \approx \sqrt{\frac{\mu_0 f}{\sigma}} \]  

(3)

here, CT is cryogenic temperature and RT is room temperature

From equation (2) and (3) we have,

\[ RRR = \frac{\sigma_{CT}}{\sigma_{RT}} \]  

(4)

Multilayer planar coil design

Experimental Procedure

- Four samples of different RRR values (1) 3.21; (2) 58.2; (3) 259 and (4) 367 was used in the experiment
- RRR for each sample was determined by 4-wire resistance measurement
- Each sample was mounted in a Hylam sample holder and kept at 1mm separation from the sensing coils by using SS washers
- Temperature was reduced and measurements (Ls and Rs) were acquired at specific temperatures (290K and 10K)
- Temperature control was done through heater and temperature sensor (Cernox/combination)
- The schematic of the experimental setup is shown in figure 4

Experimental Results

- A technique for measuring RRR and conductivity of Nb using planar multilayer inductor was tested for a samples of unknown RRR
- The method was confirmed with existing RRR measurement technique (4-probe electrical resistance measurement)
- Inflection point method was found to be less data intensive than dual slope methods for RRR measurement
- Percentage errors for different RRR values were determined and found to be around 5%
- Higher errors can be eliminated by considering the co-efficient of thermal expansion of the material into consideration

Acknowledgment

This work was carried out using the funds provided by Science and Engineering Research Board (SERB) under Department of Science and Technology (DST), India. This author would also like to acknowledge Dr. T. S. Datta from IUAC, Delhi for providing the reference Nb samples that was used to calibrate the sensor.

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