CERN-based Tc Measurement Station for Thin-film Coated Copper Samples and Results on Related Studies

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Introduction

The development of SC thin-film coated copper cavities at CERN implies the synergy of the Vacuum, Surfaces and Coatings, Radio Frequency, Cryogenics and Mechanical and Materials Engineering groups:

- $T_c$ as first assessment of the film quality, can be costly in terms and financial resources;
- the station provides a free service with fast feedback in the initial part of the production process;
- inductive technique sensitive to the magnetic field expulsion occurring in the film when it turns superconducting, due to Meissner effect.

Critical temperature measurement station

The quality of the substrate is of utter importance when it comes to the performance of niobium-coated copper SRF cavities [1]. The presence of seams and welds cannot be completely avoided with standard cavity fabrication methods, but it has been shown that the electroforming of seamless copper cavities is a real possibility [2]. Based on the idea of electroforming copper vacuum chambers with integrated NEG film coating [3], the following shows the same production steps reproducible to explore the possibility of integrating the niobium film in the electroformed cavity. The idea consists in:

- building the cavity by copper electroforming around a sacrificial aluminium mandrel;
- coating the mandrel via bi-polar HiPIMS with a niobium layer, then with a copper layer;
- chemically etching the aluminium mandrel so that only the electroformed cavity with the integrated niobium film is left.

A successful outcome of this process would lead to better adherence of the SC film to the copper substrate and make the chemical treatment of the substrate in preparation to the coating no longer be needed.

Reverse coating study

The development of thin-film coated superconducting radio-frequency (SRF) cavities capable of providing higher accelerating fields (10 to 20 MV/m) at high current density is expected in the framework of the Future Circular Collider (FCC) Study. $T_c$ Measurement Station: commissioned at the Central Cryogenic Laboratory (Cryolab) at CERN for the inductive measurement of the critical temperature ($T_c$) of SC thin-film deposited on copper samples for SRF application. Reverse coating: study of an alternative forming method for seamless copper cavities with niobium layer integrated in the production process, based on new studies for the production of Non Evaporable Getters (NEG) coated chambers.

Results

FIB-SEM pictures - Two distinct cases:

1. the sample was removed as soon as the etching process finished (Fig. 10). The Nb layer shows a smooth surface reproducing the machining lines from the surface of the aluminium disk. The film cross section appears regular too, with the columnar growth pattern typical of physical vapour deposited (PVD) niobium.

2. the sample stayed longer (~1 hour) in the solution after the end of the etching process (Fig. 11), leading to the formation of a NBO layer. The surface (indicated by the arrow in Fig. 11) appears rough and the section presents damaged structures and voids in correspondence of the Nb film.

After the etching of the Al disk, the SC transition appears to be degraded suggesting damage to the Nb film. This is confirmed by the FIB-SEM pictures of two samples etched for different times. Next iteration: deposit a protective Cu layer on the Al disk before the deposition of the Nb film to prevent the etching of Al from attacking the Nb layer. The final Cu will then be electroplated on the resulting Al-Cu-Nb-Cu sandwich [3].