SRF 2021

28 June 2021 – 02 July 2021

Main Highlights of ARIES WP15 Collaboration (Poster WEPFDV007)

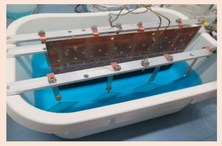
O.B. Malyshev[1], P. Goudket[1], R. Valizadeh[1], STFC/DL, Daresbury, Warrington, UK
G. Burt[1], D. Seal[1], B.-T. Singh Sian[1], D.A. Turner[1], Lancaster University, Lancaster, UK
C. Antoine, CEA-IRFU, Gif-sur-Yvette, France
A. Sublet, G. Vandoni, L. Vega Cid, W. Venturini Delsolaro, P. Vidal Garcia, CERN, Geneva, Switzerland
E. Chyhyrynets, C. Pira, O. Azzolini, F. Stivanello, G. Keppel, INFN/LNL, Legnaro, Padova, Italy
O. Kugeler, D. Tikhonov, HZB, Berlin, Germany
S. Leith, A.O. Sezgin, M. Vogel, University Siegen, Siegen, Germany
A. Medvids, P. Onufrijevs, Riga Technical University, Riga, Latvia
E. Seiler, R. Ries, Institute of Electrical Engineering SAS, Bratislava, Slovakia

ABSTRACT

An international collaboration of research teams from CEA (France), CERN (Switzerland), INFN/LNL (Italy), HZB and USI (Germany), IEE (Slovakia), RTU (Latvia) and STFC/DL (UK), are working together on better understanding of how to improve the properties of superconducting thin films (ScTF) for RF cavities. The collaboration has been formed as WP15 in the H2020 ARIES project funded by EC. The systematic study of ScTF covers: Cu substrate polishing with different techniques (EP, SUBU, EP+SUBU, tumbling, laser), Nb, NbN, Nb_3Sn and SIS film deposition and characterisation, Laser post deposition treatments, DC magnetisation characterisation, application of all obtained knowledge on polishing, deposition and characterisation, Laser post deposition treatments, DC magnetisation characterisation, application to the QPR samples for testing the films at RF conditions. The preparation, deposition and characterisation of each sample involves 3-5 partners enhancing the capability of each other and resulting in a more complete analysis of each film. The talk will give an overview of the collaborative research and will be an introduction to the detailed talks given by the team members.

COPPER SUBSTRATE PREPARATION

SUBU5 polishing

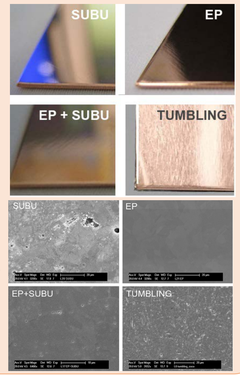


Electropolishing (EP)

For this project, small samples on copper substrate with a size of 53 mm × 53 mm were used as a standard. The objective was to investigate the effect of copper substrate polishing on Nb film. 50 planar copper samples were produced at CERN from the same copper sheet and polished with 4 different procedures: 25 samples were treated at CERN with chemical polishing (also known as SUBU5) solution and the other 25 samples were treated at INFN with SUBU5 solution, electropolishing (EP), SUBU+EP, and tumbling.

Following these results, two polishing techniques were adapted to QPR samples: SUBU5 and EP.

QPR sample after EP treatment

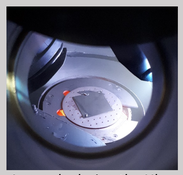


Optical and SEM images of Cu surface after different polishing treatments

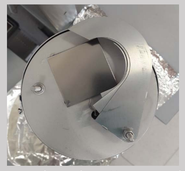
SUPERCONDUCTING THIN FILM DEVELOPMENT

Developing of Superconducting Thin Films is a core of the project. The substrates coated at INFN, Siegen and STFC with *Nb and non-Nb films as well as SIS structures.*

A sample and a Nb target in deposition facility at University Siegen.



A sample during the Nb deposition at STFC



A sample and sputter assembly for the Nb deposition at INFN

DC Superconductivity evaluation

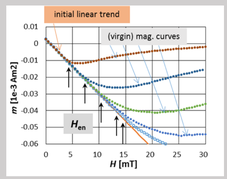
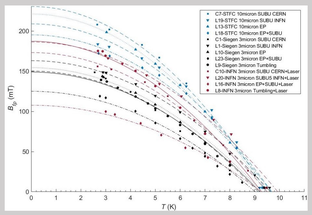
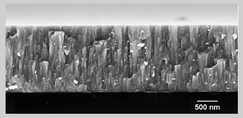


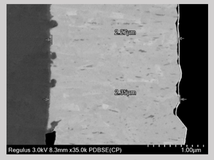
Illustration of determination of the characteristic field Hen from the virgin magnetization curves



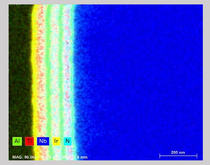
Overview of the field of full flux penetration (B_{jp}) measured at STFC for the Nb films deposited at INFN, Siegen and STFC on Cu.



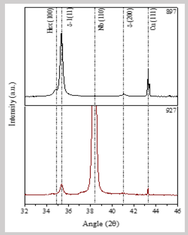
X-sections SEM of NbN deposited on Si at high pressure at Siegen



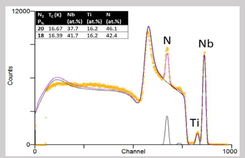
X-sections SEM of Nb_3Sn deposited on Cu at STFC



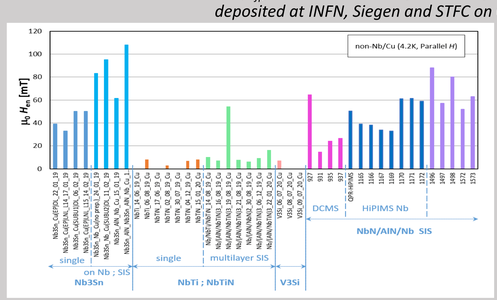
EDS of a triple multilayer NbTiN in SIS structure (depicting each layer composition) deposited on Cu at STFC



XRD patterns of single layer sample 897 and ML sample 927 completed in Bragg-Brentano configuration Cu (Kα) radiation at Siegen.



RBS of NbTiN film deposited on Si at STFC

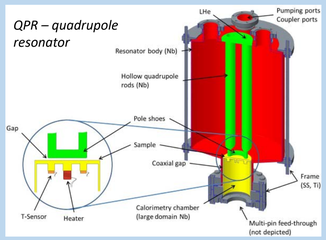


Overview of the first flux entry fields B_{en} for the non-Nb films on Cu substrates measured in VSM at IEE.

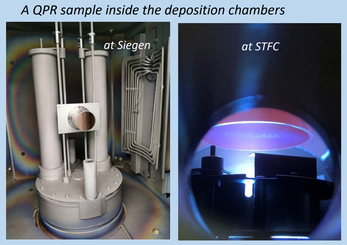
RF TESTING WITH QPR

The SRF measurement are used to validate or disprove all the results with small samples, to demonstrate what are the correlations between the RF performance and all information obtained on small samples. Thus, the objectives for the RF testing are (a) QPR sample manufacturing, (b) cases for sample transfer, (c) sample polishing with EP and SUBU5, (d) Nb film deposition, (e) Nb film laser treatment, (f) SIS deposition, (g) SRF testing of all samples.

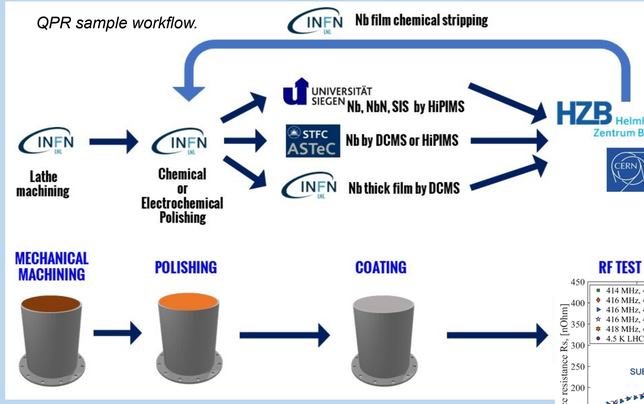
QPR – quadrupole resonator



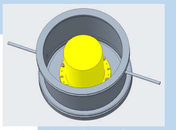
A QPR sample inside the deposition chambers



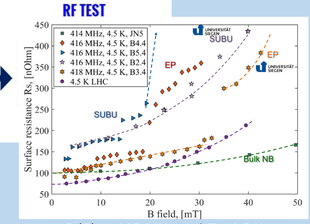
QPR sample workflow.



10 samples has been polished, deposited with Nb films and SIS structures, and tested at QPR.



A QPR sample transfer case



$R_s(B)$ at 415 MHz and T = 4.5 K

CONCLUSIONS

The main achievement over 4 years of ARIES are:

- ✓ Five polishing techniques for Cu have been tested with Nb films,
- ✓ Development of superconducting films on small samples establishes a capability of depositing
  - NbN, Nb_3Sn, NbTiN films
  - as well as SIS structures,
- ✓ Evaluation of Nb films at the RF conditions enables:
  - Routine sample transport between the labs;
  - QPR sample polishing developed and applied to the samples at INFN;
  - A number of QPR samples has been deposited at INFN, Siegen and STFC with Nb and SIS structures;
  - Comparative testing of QPR facilities at CERN and HZB;
- ✓ ARIES enabled developing new technologies for the thin film SRF:
  - Laser treatment of Cu substrate and Nb films and
  - Magnetic field penetration facility;
- ✓ Finally, ARIES helped to set up more intense and coordinated collaboration, involving new partners, enhancing capabilities of every partner, frequent discussions and joint publications.

FUTURE PLANS

ARIES WP15 went to the end by 30th April 2021.

A H2020 funded collaboration has started on the 1st May 2021 for 4 years:. IFAST (Innovation Fostering in Accelerator Science and Technology) WP9 - Innovative superconducting. The team has grown to 15 partners from 9 Countries. It will continue all activities started with ARIES on further development of various superconducting thin films. In addition to Physical Vapour Deposition methods, an Atomic Layer Deposition will be explored. However, *the main emphasis* will be shifted on applying the result of ARIES to the deposition and testing of the half-wave RF cavities at 6, 3 and 1.3 GHz.

For more details in this conference:

[1] Pira, C., et al., "Plasma Electrolytic Polishing as A Promising Treatment Replacement of Electropolishing in The Cu and Nb Substrate Preparation for SRF"THOTEV06.
[2] Turner, D., et al., "A Facility for the Magnetic Characterisation of Planar Thin Film Structures", SUPFDV007.
[3] Valizadeh, R., et al., "Synthesis of Nb and Alternative Superconducting Film to Nb for SRF Cavity as Single Layer", FROFDV06.
[4] Lockwood Estrin, F.B, et al., "Using HiPIMS to Deposit V_3Si Superconducting Thin Films", WEPFDV009.
[5] Sezgin, A.O., et al., "Low Tc Superconducting Thin Film-Based Multilayer (S(I)S) Structures for SRF Cavities", SUPFDV005.
[6] Leith, S., et al., "The Development of HiPIMS Multilayer SIS film coatings on Copper for SRF Applications", SUPFDV012.
[7] Leith, S., et al., "HiPIMS NbN Thin Film Development for Use in Multilayer SIS Films", SUPFDV013.
[8] Chyhyrynets, E., et al, "Application of Plasma Electrolytic Polishing onto SRF Substrate SUPTEV002.
[9] Chyhyrynets, E., et al, "Cu/Nb QPR Surface Preparation Protocol in the Framework of ARIES Project", SUPTEV003.
[10] Tikhonov, D., et al., "Investigation of SIS multilayer films at HZB", SUPFDV006.
[11] Seal, D., et al., "A Low Power Test Facility For SRF Thin Film Testing With High Sample Throughput Rate", SUPFDV016.