Student workshop on superconductivity and applications

Thursday 8 October 2020 - Friday 9 October 2020

CNR-Spin

Book of Abstracts

Contents

Session 1 - Day 1 - AM / **2**

Invited Talk - The Future Circular Collider (FCC) Project: goals and challenges

Corresponding Author: patrizia.azzi@cern.ch

Session 5 - Day 2 - AM / **14**

Invited talk - Superconducting materials for the fusion magnetic confinement coils

Session 3 - Day 1 - PM / **27**

On the Use of the Lossy Transmission Line Theory for the SRF Characterization

Author: Pablo Vidal Garcia[1]

[1] *CERN*

Corresponding Author: pablo.vidal.garcia@cern.ch

In this work, an alternative method to compute the effect of losses on superconductors based on the *Lossy Transmission Line Theory* is introduced rigorously. In contrast to the application of the well-known perturbative methods at the dielectric-superconductor interface to obtain the equivalent surface currents, this new approach lies in analyzing the decaying propagative waves along the superconductive media by means of a lossy transmission line equivalent circuit. This kind of analysis becomes crucial when trying to characterize rigorously the EM behavior of *Superconducting RadioFrequency* (SRF) devices, in particular SRF cavities, turning out to be a possible way to generalize SRF studies. Thus, the characteristic effects of both good conductors and superconductors could be described all at once by means of this approach as particular cases. In order to illustrate all these aspects, some basic examples are presented while emphasizing the graphical capabilities of this analysis when representing the underlying theory using resources of Complex Analysis, as well as its usefulness to uncover possible practical uses of SRF.

Session 1 - Day 1 - AM / **28**

Deposition parameter effects on the superconducting performance of HiPIMS Nb thin films deposited on copper

Author: Stewart Bristow Leith[None]

Co-authors: Xin Jiang [1]; Michael Vogel [1]; Jiaokun Qiao [1]

[1] *University of Siegen*

Corresponding Authors: michael.vogel@uni-siegen.de, xin.jiang@uni-siegen.de, stewart.leith@uni-siegen.de

Future particle accelerators require performance figures which push the boundaries of what is achievable with current SRF technologies. In this light, research has been completed into the creation of

HiPIMS Nb thin films deposited onto copper as a means of achieving these performance figures.
The results from the parametrical investigation into HiPIMS Nb thin films deposited onto copper substrates is presented. The copper substrates were prepared using an electropolishing process. The HiPIMS Nb films were prepared in a large scale commercial coating system by adjusting a number of deposition parameters.
As part of the optimisation process, the films have been characterised using various characterisation methods, including surface, crystallographic and superconducting analysis, to determine the effects of the deposition parameters during the film growth process. The effects of the HiPIMS duty cycle were also elucidated from the results.

Acknowledgement
The EASITrain project has received funding from the European Union's Horizon 2020 research and innovation programme under grant No 764879. The information herein only reflects the views of its authors and the European Commission is not responsible for any use that may be made of the information.

Session 6 - Day 2 - PM / **29**

A Study of the Effect of a Strand Breakage on the Operating Margin of a Nb3Sn Cable

Authors: Giovanni Succi[1]; Luca Bottura[1]; Marco Breschi[2]

[1] *CERN*

[2] *Università di Bologna*

Corresponding Authors: luca.bottura@cern.ch, marco.breschi@unibo.it, giovanni.succi@cern.ch

Current and temperature distribution and re-distribution phenomena in multi-strand superconducting cables are a topic of research since the beginning of this technology, and can be of major relevance for the operating margin and performance of accelerator magnets. My work at the MSC Group at CERN is based on the problem of current distribution in a Nb3Sn Rutherford cable subjected to a local strand breakage and it is conducted by modeling the coil cable and joints by means of the THEA software (Cryosoft package).

The main aim of the study is to evaluate the effect of local strand breakages, which could be originated as an example during coils and magnets fabrication process, on the operational margin of the magnets themselves. This is to understand, ultimately, if the presence of such defects is acceptable for the use of non-conform coils in magnets, and in particular for the High-Luminosity LHC project.

Session 4 - Day 1 - PM / **30**

Update on Nb thick films on Cu for 6GHz cavities

Authors: Vanessa Garcia Diaz[1]; Eduard Chyhyrynets[2]; Cristian Pira[3]; Fabrizio Stivanello[4]; Zanierato Matteo [5]

[1] *INFN-LNL, Università degli Studi di Ferrara*

[2] *INFN - National Institute for Nuclear Physics*

[3] *LNL-INFN*

[4] *INFN-LNL*

[5] *Università degli studi di Padova*

Corresponding Authors: cristian.pira@lnl.infn.it, fabrizio.stivanello@lnl.infn.it, matteo.zanierato@lnl.infn.it, eduard.chyhyrynets@lnl.infn.it, vanessa.garcia@cern.ch

One of the well-known difficulties concerning the performances of the Nb coated Cu cavities, is the reproducibility of the results. Two cavities fabricated by the same method and sputtered with the same deposition parameters, may present different performances during the RF characterization. Two main approaches are taken into consideration for this research: substrate and film reproducibility. In order to improve the substrate reproducibility, the standard mechanical grinding of the 6GHz cavities, that leads to defects on the inner surface of the cavities that can remain even after chemical treatments, has been replaced for Vibrotumbling technique in order to improve the inner surface of the cavities. For the film reproducibility, a Nb thick film between 40 and 70 microns is deposited to reproduce the bulk niobium superconducting properties. On the other hand, we report the experimental results concerning a material study (Nb bulk, Nb on Cu thin film and Nb on copper thick film) under the effect of the magnetic flux trapped in 6 GHz cavities.

Session 6 - Day 2 - PM / **31**

State of the art of Bi2212 PIT wires made with GDG process

Author: Andrea Traverso[1]

Co-authors: andrea malagoli [2]; Riccardo Musenich [3]; Pasquale Fabbricatore [3]; Alessandro Leveratto ; Stefania Farinon [3]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *CNR-SPIN*

[3] *INFN e Universita Genova (IT)*

Corresponding Authors: stefania.farinon@ge.infn.it, andrea.traverso@ge.infn.it, riccardo.musenich@ge.infn.it, alessandro.leveratto@gmail.com, andrea.malagoli@spin.cnr.it, pasquale.fabbricatore@ge.infn.it

The first step towards high critical currents in Bi-2212 wires was the comprehension that the supercurrent is blocked over long lengths by filament-diameter bubbles growing from the porosity of the powders during the partial melting phase. The Over Pressure (OP) process led to the realization of dense Bi-2212 wires with a J_E performance far beyond the minimum application requirements, but not easily scalable to real coils. Researchers at CNR-SPIN are developing a standard and scalable process based on mechanical deformation to realize dense Bi-2212 wire with performances useful for applications. Initial evidence of the effectiveness of the process has already been reported. Now we are able to realize wires with a J_E satisfying the application requirements.
One of the challenges we are facing is trying to understand if GDG Bi-2212 wires can be arranged into a Rutherford cable, whose fabrication process could lead to wire properties degradation.
Here I report, through finite-element simulation and transport properties characterization, about the effects of the mechanical deformation on the wires brought by such process.

Session 5 - Day 2 - AM / **32**

Proceedings on 2.6T-77K M-Scanner

Author: Johannes Gnilsen[None]

Co-authors: Alexander Usoskin ; Michael Eisterer [1]

[1] *Vienna University of Technology (AT)*

Corresponding Authors: alexander.usoskin@bruker.com, michael.eisterer@tuwien.ac.at, johannes.gnilsen@cern.ch

Several present and future-relevant technologies are based on high magnetic fields provided by the superior current carrying properties of high temperature superconductors (HTS) at low temperatures. Up to 600 m long YBCO coated conductors are commercially produced. Defects, material faults and magnetic fields suppress the critical current, Ic, and determine the maximum loss-free current throughput of the tape. Manufacturing processes require efficient Ic measurement tools for reliable Ic(x) evaluation.
In this study a measurement tool (M-Scan) for continuous 4-probe Ic(x) determination at 77 K in 2.6 T flux density was developed and HTS-tapes <100 m were scanned. The measurement setup, the model to calculate Ic from the measured voltage signal and results of scanned long samples are reported. The impact of "artificial"and "natural"defects on Ic is shown and physical interpretations discussed. Comparison with an independent technique of continuous Ic evaluation via magnetic shielding shows intrinsic disagreements.

Session 2 - Day 1 - AM / **33**

Microstructural characterization of advanced superconducting materials for different components of the CERN Future Circular Collider (FCC-hh)

Author: Alice Moros[1]

Co-authors: Michael Stöger-Pollach [2]; Johannes Bernardi [3]

[1] *Technische Universität Wien*

[2] *TU Wien*

[3] *Vienna University of Technology (AT)*

Corresponding Authors: alice.moros@tuwien.ac.at, johannes.bernardi@tuwien.ac.at, stoeger@ustem.tuwien.ac.at

The microstructural characterization represents an essential aspect for helping the enhancement of the material superconducting properties. Within the huge CERN project related to the realization of the FCC-hh, we focused on the microstructural analysis of superconducting materials envisioned as suitable candidates for some of its fundamental components: Nb₃Sn for the bending magnets, MgB₂ for the superconducting links and Tl-1223 for the beam screen. For each of these materials, produced by different manufacturers, we received several prototype samples, which differ from each other due to some specific changes brought to the manufacturing process. A key point of this work is to understand how the parameters involved in such processes influence the material microstructural features, in order to give a contribution in terms of producing wires and films with optimized superconducting performances. For this purpose, different electron microscopy techniques were employed with both Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM).

Session 5 - Day 2 - AM / **34**

Development of Superconducting MgB2 Wires

Author: Paola Mauceri[1]

Co-author: Daniele Magrassi [1]

[1] *ASG Superconductors*

Corresponding Authors: magrassi.daniele@as-g.it, mauceri.paola@as-g.it

The Magnesium Diboride (MgB2), is a material known since early 1950's, but, whose superconducting (SC) properties were defined in 2001, positioning this as a High-Temperature superconductor

material (Tc= 39-40 K). The absence of weak-link and the simple crystalline structure allows to produce wires using the powder in tube (PIT) technique, allowing the industrial development and application. Currently, the MgB2 wire technology is making a significant progress, due to the continuing research and industrial development. Nowadays, the MgB2 is a good candidate to replace NbTi in liquid helium-free magnetic resonance imaging (MRI) magnet. In addition, the MgB2 is used in rotating electrical machines, wave-energy converters and in high current cables for powering devices. Columbus MgB2 wire unit (ASG Superconductors Spa), is working into improve the uses and performance of the MgB2 and MgB2 wires production, using a technology, which allows to produces MgB2 multi-filamentary wires with unit length exceeding 2-4km in a single piece. In order to obtain and qualify a high performance Mgb2 wire, in Columbus, it is carrying out the characterization of MgB2 wires, through SEM, mechanical Test, critical current analysis, critical temperature and residual-resistance ratio (RRR) Test.

Session 4 - Day 1 - PM / **35**

Turbocompressor test facility operating with light gases: architecture, operation and preliminary results with air

Author: Maxime Pierre Podeur[None]

Corresponding Author: maxime.pierre.podeur@cern.ch

To better understand the challenges and opportunities associated with the design and operation of radial compressors with light gases, a closed loop test facility has been designed, built and commissioned at the ITSM. The test facility has been developed to operate with air as well as with helium-neon gas mixtures of varying mixing ratios ranging from pure neon to pure helium.

The test facility includes a preconditioning unit, in which the operating gas is first prepared. The preconditioned gas is then admitted to a closed test loop, where a high-speed motor supported by gas bearings directly drives a radial compressor impeller. The test rig architecture allows to adjust the gas mass inside the test loop as well as compressor inlet temperature and pressure as desired. After having designed a first exploratory compressor stage at low tip Mach number, the main objective of this test rig is to validate its aerodynamic performance experimentally for different gas composition before moving to other designs in a next step.

This presentation gives an overview of the test rig and describes its architecture, components and operation. Moreover, the aerodynamic performance of a newly designed centrifugal compressor stage is validated with air.

Session 3 - Day 1 - PM / **36**

RF characterization: From QPR samples to 1.3 GHz cavities

Authors: Lorena Vega Cid[1]; Pablo Vidal Garcia[1]; Walter Venturini Delsolaro[2]; Guillaume Jonathan Rosaz[2]; Giovanna Vandoni[2]

[1] *Centro de Investigaciones Energéti cas Medioambientales y Tecno*

[2] *CERN*

Corresponding Authors: lorena.vega@cern.ch, giovanna.vandoni@cern.ch, guillaume.rosaz@cern.ch, walter.venturini@cern.ch, pablo.vidal.garcia@cern.ch

This work will provide an insight into the CERN R&D programme on superconducting thin films. The aim is to find coating techniques and/or new materials with enhanced RF performance applicable to SRF cavities. The main lines of research at CERN consist of Nb on Cu technology, historically used in our accelerators, and A15 on Cu, to find new superconducting materials with potential application to SRF. The methodology used for characterizing a new thin film will be exposed, starting from testing

small flat samples with the Quadrupole Resonator. Then, the thin films showing good results in the QPR are applied to 1.3 GHz copper cavities to determine their reproducibility in a bigger, non flat surface. Examples will be given to describe this process and results will be discussed. Finally, the current lines of work will be reported, with the ultimate goal of producing SRF thin film cavities competitive with the bulk niobium ones in terms of RF performance.

Session 4 - Day 1 - PM / **37**

Development of the neon-helium Turbo-Brayton cryogenic refrigerator for the FCC-hh

Authors: Sofiya Savelyeva[None]; Steffen Kloeppel[1]; Christoph Haberstroh[1]; Hans Quack[1]

[1] *TU Dresden*

Corresponding Authors: quack@sunrise.ch, sofiya.savelyeva@cern.ch, christoph.haberstroh@tu-dresden.de, steffen.kloeppel@tu-dresden.de

The proton-proton Future Circular Collider (FCC-hh) is a concept of the high energy accelerator being considered as a successor of the Large Hadron Collider. It is being designed to reach the centre-of-mass energy of 100 TeV in the ring with the circumference of 100 km, which is approximately 7 times higher than the energy of the Large Hadron Collider. To build this accelerator, the existing technologies have to be improved in many fields including cryogenics. Thus, the state-of-the-art cryogenic system has to be upgraded. A new efficient system is required to provide cooling of the beam screen and thermal shield at the temperature level between 40 and 60 K. The neon-helium Turbo-Brayton cryogenic refrigerator has been designed at the TU Dresden for this purpose and improved within the EASITrain project.

Within the workshop, the requirements for the cryogenic system of the FCC-hh will be summarized. The basics of the cryogenic refrigerator design will be introduced. The improved design of the Turbo-Brayton refrigerator and the developed strategies of the efficient part-load and cool-down operation will be demonstrated.

Session 6 - Day 2 - PM / **38**

AntiCoincidence detector for ATHENA X-IFU

Author: Lorenzo Ferrari Barusso [1]

[1] *Unige - INFN*

Corresponding Author: lorenzo.ferrari@ge.infn.it

Transition edge sensors (TES) play a key role in current projects of future X-rays space telescopes as are foreseen as detectors for the focal plane instrument. In order to full exploit their sensitivity in the space environment, they need an active cryogenic anticoincidence detector (CryoAC) to reject the background due to cosmic charged particles. As signal given by the interaction of high-energy protons (> 150 MeV) and other charged particle with the X-ray calorimeter cannot be distinguished from the one given by the scientific photons, thus degrading the instrument performance. It will be reported the CryoAC design and, in detail, the last prototype based on TES calorimeter where a 1-cm^2 silicon chip is used as both substrate and absorber. The readout is made of 96 iridium/gold TESs uniformly distributed on its surface and connected in parallel. Focusing on the production of the detector and its potentialities.

Session 2 - Day 1 - AM / **39**

The Next Generation Materials for Superconducting Radio-Frequency (SRF) Cavities of Modern Particle Accelerators

Author: Ayse Özdem Sezgin[1]

Co-authors: Michael Vogel [1]; Xin Jiang [1]; Isabel Gonzales Diaz-Palacio [2]; Robert Zierold [2]; Stewart Bristow Leith [1]

[1] *University of Siegen*

[2] *University of Hamburg*

Corresponding Authors: igonzale@physnet.uni-hamburg.de, xin.jiang@uni-siegen.de, robert.zierold@chyn.uni-hamburg.de, michael.vogel@uni-siegen.de, oezdem.sezgin@uni-siegen.de

While unbounded collective human mind continues to push beyond the boundaries in uncovering myriad mysteries of our universe, highly performing particle accelerators become indispensable tool to conduct successful experiments to shed light on such fundamental scientific inquires. On the path towards more efficient and sustainable particle accelerators, overcoming performance bottleneck of the current niobium-based SRF cavities is crucial. Hence, advanced material structures such as mono- and/or multi-layer structured superconducting thin films seem to promise increasing the maximum accelerating field set by pure niobium while decreasing RF losses for high quality factors (Q) in such resonators leading to high performance in SRF cavities. Therefore, our initial research endeavors have been focused on systematic experimental investigations of niobium nitride (NbN)-based superconducting thin films coated by reactive-direct current (DC) magnetron sputtering and the subsequent material characterizations of the coated thin films, whose preliminary results are discussed in detail, in order to address the key challenges such as obtaining stoichiometric films with low defect densities yielding to high crystalline quality along with establishing reproducible thin film deposition methods with up-scaling capacities to be used in industrial applications too so that paving the way to the next generation materials and their associated state-of-the-art production technologies.

Session 1 - Day 1 - AM / **40**

Effect of strain rate on the tensile mechanical properties of high–purity Nb single crystals and EB welded sheets for SRF applications

Author: Jean Francois Croteau[None]

Co-authors: Eureka Pai Kulyadi [1]; Marco Peroni [2]; Chaitanya Kale [3]; Derek Siu [4]; Di Kang [1]; Ana Teresa Perez Fontenla [5]; Elisa Garcia-Tabares Valdivieso [5]; Thomas R. Bieler [1]; Philip Eisenlohr [1]; Kiran N. Solanki [3]; Daniel Balint [4]; Paul A. Hooper [4]; Said Atieh [5]; Nicolas Jacques [6]; Elisa Cantergiani [7]

[1] *Michigan State University*

[2] *JRC Ispra*

[3] *Arizona State University*

[4] *Imperial College London*

[5] *CERN*

[6] *ENSTA Bretagne*

[7] *I-Cube Research*

Corresponding Author: jean.francois.croteau@cern.ch

Seamless SRF cavities have been proposed to improve performances (i.e. higher quality factor at high accelerating gradients) and reduce the risk of a quench in the vicinity of the equatorial weld. However, the anisotropic mechanical properties of high–purity niobium tubes with large grains or

the low ductility of small-grained tubes remain important limiting factors during forming.
An investigation of the mechanical properties of differently oriented high–purity niobium single crystals and electron beam welded polycrystalline Nb deformed in tension at strain rates between 10^{-4} to 10^{3} s^{-1} is presented. Specimens were respectively cut from a large grain niobium disk used for the manufacturing of SRF cavities and welded polycrystalline sheets. The effects of strain rate on the mechanical properties, the microstructure and the ductility are presented. For single crystals, different crystallographic tension directions exhibit significantly different softening and hardening behaviors. Such anisotropy is reduced at high strain rates. The effect of activation of multiple slip systems and adiabatic heating on the tensile split Hopkinson results is discussed. An attempt is made to explain the influence of those properties in high-speed sheet forming of SRF cavities with electro-hydraulic forming.

Session 2 - Day 1 - AM / 41

Development of a Station at the CERN Central Cryogenic Laboratory for the Measurement of the Critical Temperature of Superconducting Thin Films Deposited on Copper

Author: Dorothea Fonnesu[1]

[1] *CERN*

Corresponding Author: dorothea.fonnesu@cern.ch

The FCC Study is an international collaboration established, in the search for physics beyond the Standard Model, to investigate the feasibility of a new circular collider having LHC as main injector. To this end, the development of ad-hoc SRF cavities represents a major challenge, for which superconducting (SC) film coated copper cavities are one of the pursuable solutions. Among the several options, A15 compounds are being explored as coating materials, in particular Nb3Sn and V3Si. To assess the quality of the SC films on their substrate and to investigate how the condition of the substrate can cause deviation of their behaviour from what is observed in bulk materials, it is important to study their physical and thermal properties such as the critical temperature T_c. For A15 in particular, the achievement of the literature values of T_c still represents a non-trivial goal. In this work, we present the development of a dedicated test stand commissioned at the CERN Central Cryogenic Laboratory for the contactless, inductive measurement of the T_c of SC thin-film samples deposited on copper, and discuss the results from the first measurements performed with it.

Session 6 - Day 2 - PM / 42

Synthesis and study of Tl-1223 Superconducting Thin Films for the Future Circular Collider (FCC-hh) Beam Screen

Author: Aisha Saba[None]

Corresponding Author: aisha.saba@spin.cnr.it

The properties of thallium based superconductors are under exploration for the potential coating of the beam screen of the future circular collider (FCC). The FCC's (100 km in circumference) study revolves around achieving 100 T-eV center-of-mass energy through the collision of beams (steered by 16 T magnetic field produced by superconducting magnets). One of the most important tasks is beam stability, and a beam screen (40-60 K) with a high impedance might give rise to beam instabilities. Theoretical calculations show that the surface resistance of copper at the given temperature range might not be low enough for the anticipated performances. As a consequence, high-temperature superconductors have been proposed as potential low impedance materials that face the beam during operation to replace bare copper, which is the current state of technology in the LHC at CERN.
To contribute to this research, we process and analyze thallium based superconducting samples. We

will show the improvement made in Tl-1223 superconductors, their characterization, suitability for the demanding conditions, vacuum compatibility, and the secondary electron emission reduction to a significantly low level after the amorphous carbon coating.

This work is part of the Marie Sklodowska-Curie Training Network EASITrain (European Advanced Superconductivity Innovation and Training), funded by the European Union's H2020 Framework Programme under grant agreement no. 764879.

Session 2 - Day 1 - AM / **43**

Investigation of the influence of copper surface preparation methods on the srf performance of bulk niobium films

Author: Dmitry Tikhonov[1]

Co-authors: Sebastian Keckert [2]; Oliver Julius Kugeler ; Jens Knobloch ; Stewart Bristow Leith ; Michael Vogel [3]; Cristian Pira [4]; Eduard Chyhyrynetz [5]; Reza Valizadeh [6]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *Helmholtz-Zentrum Berlin*

[3] *University of Siegen*

[4] *LNL-INFN*

[5] *INFN-LNL*

[6] *STFC Daresbury Laboratory*

Corresponding Authors: stewart.leith@uni-siegen.de, eduard.chyhyrynets@lnl.infn.it, cristian.pira@lnl.infn.it, reza.valizadeh@stfc.ac.uk, michael.vogel@uni-siegen.de, oliver.kugeler@helmholtz-berlin.de, knobloch@bessy.de, sebastian.keckert@helmholtz-berlin.de, dmitry.tikhonov@cern.ch

The niobium-coated copper cavities are interesting candidates for replacing bulk niobium cavities in future facilities (e.g. FCC). Such cavities, ideally, should overcome some accelerator design problems related to bulk Nb cavities. However, Nb/Cu films tend to show more extreme "Q-slope"effect, and have other disadvantages compared to bulk-Nb cavities, which currently limit their application in high-gradient machines. It is known that the properties of the deposited niobium films depend on the surface topography of the Cu substrates. The Cu-Nb interface has also been proposed to cause a steeper Q-slope effect, due to thermal boundary resistance. This talk reports on the progress in study of the influence of the copper surface preparation methods on the SRF properties of bulk-like niobium films, deposited onto this surface, currently ongoing among HZB, INFN-LNL, University of Siegen and STFC. In this study the surface of several copper substrates was polished by different methods (chemical polishing "SUBU"and electropolishing), then coated with ˜3 μm Nb films at different facilities. In order to determine the SRF properties, the resulting Nb films were tested at HZB with the Quadrupole Resonator (QPR) at operating frequencies of the accelerating cavities.

Session 3 - Day 1 - PM / **44**

Invited Talk - Main objectives of the FCC feasibility study

Author: Michael Benedikt[1]

[1] *CERN*

Corresponding Author: michael.benedikt@cern.ch