ISIS@MACH ITALIA

Science and Technology Facilities Council
ISIS Neutron and Muon Source

Experiment Proposal

Experiment number GP2023020

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Experiment title	Iron Based Coated Conductors (ICON)	
MRF Instrument	**High Resolution TEM**	**Days requested:** 3
Access Route	Direct Access	**Previous GP Number:** no
Science Areas	Chemistry, Materials	**DOI:** -
Sponsored Grant	Yes	**Sponsor:** Other
Grant Title	EUROfusion Researcher Grant	**Grant Number:** 101052200
Start Date	01/03/2022	**Finish Date:** 29/02/2024
Similar Submission?	-	
Industrial Links	-	

Non-Technical Abstract

This project focuses on the application of chemical techniques to the design of an iron-based flexible conductor, Fe (Se1-xTex) which can be grown on metallic substrates with different techniques. We plan a detailed investigation of the microstructure of the metal/buffer/ superconductor system at atomic level to assess the efficiency of this proposed architecture for coated conductors. This information will be coupled with transport properties, to investigate the structure/properties correlation, already characterised via X-ray diffraction. We plan to cahraterise the structural features at nanoscale by a combination of probe-corrected atomic resolution BF/ADF/HAADF-STEM imaging, HR-TEM together with EDX mapping.

Publications

ISIS neutron and muon source

IM@IT E-platform: No

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Sample record sheet

Principal contact Dr Laura Piperno, ENEA, ITALY
MRF Instrument **High Resolution TEM** **Days Requested:** 3
Special requirements:

SAMPLE

Material	Ni-W; CeO2, Fe(Se,Te)	Fe, FeSe	-
Formula	Fe(Se,Te)	FeSe	-
Forms	Solid	Solid	
Volume	0.05 cc	0.05 cc	
Weight	mg	mg	
Container or substrate	Ni-W	Fe	-
Storage Requirements	-	-	-

SAMPLE ENVIROMENT

Temperature Range	- K	- K	-
Pressure Range	- mbar	- mbar	-
Magnetic field range	- T	- T	-
Standard equipment	Do Not Know	Do Not Know	-
Special equipment	none	-	-

SAFETY

Prep lab needed	Yes	Yes	-
Sample Prep Hazards	no	no	-
Special equip. reqs	The TEM lamellae need to be prepared	The TEM lamellae need to be prepared	-
Sensitivity to air	No	No	-
Sensitivity to vapour	Yes	Yes	-
Experiment Hazards	no	no	-
Equipment Hazards	-	-	-
Biological hazards	no	no	-
Radioactive Hazards	no	no	-
Additional Hazards	-	-	-
Additional Details	-	-	-
Sample will be	Returned to user by instrument scientist (when inactive)	Returned to user by instrument scientist (when inactive)	-

Title of the proposal: Iron Based Coated Conductors

Acronym of the proposal: I_BCON

Background and Context

In view of the exploitation of nuclear fusion as a sustainable energy source, the late efforts of the scientific community are aimed at increasing the magnetic field strength of magnets and the operating temperature of a tokamak device. In this view, great expectations rely on iron-based superconductors (IBSCs). The high magnetic critical fields and critical current densities (J_c), coupled to small anisotropy and large critical grain boundary angle for J_c, make the IBSCs ideal for the fabrication of multilayered flexible structures known as coated-conductors (CCs), suitable to be assembled in cables. Moreover, in view of large-scale applications, the integration of low-cost, chemical methodologies in the preparation process of IBSC-based coated conductors could be a game changer.

The EUROfusion-funded I_BCON project, chemical techniques are applied to the fabrication of growth Fe(Se,Te) coated conductors. More in detail, it focuses on the growth of CeO_2-based buffer layers on metallic substrates such as Ni-W and on the electrochemical deposition of FeSe on metallic flexible templates. As regards buffers, the transfer of the buffer layer knowledge gained on single crystals to buffered metallic tapes represents a development with respect to previously published results[1,2], and their efficiency as template for an IBSC is tested through the physical deposition of a superconducting Fe(Se,Te) film, which will be thoroughly characterized as regards structural and transport properties. Electrochemical deposition of FeSe, instead, represents a novelty in this field since few attempts were made to obtain superconducting films with this technique[3]. Should it prove effective in the production of superconducting FeSe, it would be a substantial simplification of the process, in view of large area production of iron based coated conductors.

Proposed Experiment

The aim of the experiment is to investigate the structure/properties correlation in iron-based films samples. Detailed investigation of the microstructure of the NiW/CZO/Fe(Se,Te) at atomic level is essential to assess the efficiency of this proposed architecture for coated conductors. The quality of the superconducting film, the presence of defects, the interfaces and oxygen diffusion from the buffer are all parameters that influence the material's performances. This information will be coupled with transport properties, measured as a function of the applied magnetic field intensity/direction and of the temperature. In particular, the proposed experiment should focus on the analysis of two samples with the same nominal composition, one of which exhibits a superconducting transition while the other does not. The origin of this behavior was investigated with structural e microstructural measurements, but no meaningful difference was found between the two samples, which is why a TEM analysis is required.

As regards electrochemically deposited FeSe, to our knowledge, no TEM analysis of the deposit is available in the literature. The produced samples show optimal structure, evaluated via X-ray diffraction, but show no superconducting transition. The origin of this behavior needs to be clarified. The present proposal will contribute to elucidate the potentiality of chemical techniques for the fabrication of an all-chemical Fe-based coated conductor. To visualize the structural features of interest at nanoscale a combination of probe-corrected atomic resolution BF/ADF/HAADF-STEM imaging, HR-TEM

together with EDX mapping is necessary, and this analysis can be provided from the HR-TEM facility from ISIS@MACH ITALIA

Summary of previous instrument time or characterisation

No previous characterization with ISIS@MACH ITALIA were performed. However, structural and microstructural characterization such as X-Ray diffraction and Scanning electron microscopy were performed to assess the quality of the films, as well as DC resistivity measurements to evaluate the critical temperature transition. All this data can be shared prior to or during the proposed experiment in order to efficiently plan the experiment itself.

Justification of instrument time request

The HR-TEM facility from ISIS@MACH ITALIA is provided with the equipment necessary to perform the proposed experiment. After preparing the lamellae from the 3 samples, the cross sections of the 3 samples should be analyzed. The time request of 3 days was made as a rough estimate considering the number of samples (3) and the time required for the sample preparation before the analysis.

References

[1] L. Piperno, A. Vannozzi, A. Augieri, V. Pinto, A. Angrisani Armenio, F. Rizzo, A. Mancini, A. Rufoloni, G. Celentano, V. Braccini, M. Cialone, M. Iebole, N. Manca, A. Martinelli, M. Putti, G. Sotgiu, and A. Meledin, IEEE Trans. Appl. Supercond. **32**, 1 (2022).

[2] A. Vannozzi, S. Prili, G. Sylva, A. Masi, A. Angrisani Armenio, A. Mancini, V. Pinto, A. Rufoloni, L. Piperno, A. Augieri, F. Rizzo, P. Manfrinetti, V. Braccini, M. Putti, E. Silva, and G. Celentano, Supercond. Sci. Technol. **33**, 9 (2020).

[3] A. Yamashita, R. Matsumoto, M. Tanaka, H. Hara, K. Iida, B. Holzapfel, H. Takeya, and Y. Takano, Solid State Commun. **270**, 72 (2018).