IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 55, January 2024

X-ray Absorption Spectroscopy as a Tool for Characterising Irradiation Damage in REBCO Coated Conductors

S. Speller[1], J. Lewis[1], K. Adams[1], J. Tufnail[1], R. Nicholls[1], C. Grovenor[1], S. Diaz-Moreno[2], F. Mosselmans[2], and W. Iliffe[3]

[1]Department of Materials, University of Oxford, United Kingdom
[2]Diamond Light Source, Harwell Science and Innovation Campus, Didcot, United Kingdom
[3]Culham Centre for Fusion Energy, Abingdon, United Kingdom

E-mail: Susannah.speller@materials.ox.ac.uk

***Abstract*—Predicting the behaviour of REBCO coated conductors under fusion-relevant irradiation conditions is a major challenge because of the lack of high flux sources of fusion spectrum neutrons and the complexities of performing neutron irradiation experiments, especially at cryogenic temperatures. Ion irradiation is a widely available, relatively cheap and quick alternative to irradiation in a nuclear fission reactor, and it does not activate the samples making them easier to characterise. A wide range of different ion species and energies are available, opening up a wealth of experimental opportunities. The question is: *can ion irradiation successfully emulate neutron irradiation using a suitable choice of ion?* T_c is found to decrease monotonically with neutron fluence for both neutron and ion irradiation [1], and this is attributed to the generation of point defects throughout the REBCO lattice. However, this damage cannot easily be observed with atomic resolution electron microscopy, even in samples that have been irradiated to a high enough fluence for superconductivity to have been entirely lost, because many of the defects are believed to be in the oxygen sublattice and oxygen atoms are not strong electron scatterers [2].**

X-ray absorption spectroscopy is a powerful technique that probes the local environment around specific atomic species. The near edge (XANES) gives information about the chemical and electronic environment and the extended edge (EXAFS) gives information about the structure. Here we will present a series of experiments using the I20-scanning beamline at Diamond Light Source that demonstrate the use of high energy resolution Cu K-edge XANES is sensitive to irradiation induced changes in the Cu-O bonding environment in REBCO. DFT simulations of spectra from pristine and defect structures have been used to simulate the spectra, enabling features from the Cu(1) chain site and Cu(2) plane site in the REBCO crystal structure to be distinguished. Initial experiments using 300 keV He^+ ions revealed that substantial changes occurred in the CuO_2 planes, even though earlier literature speculated that the chains were more likely to be affected [2]. More recently, we have performed the same experiments on coated conductors that

had been neutron irradiated as part of the Vienna study by Fischer et al [3]. Although the total damage level of these samples was lower than the He^+ irradiated samples, we found similar spectral changes, suggesting that the defect landscape is not entirely different, as shown in Figure 1 [1]. We will also present preliminary analysis of EXAFS data on the Cu K-edge and Ba L-edge, and discuss our plans for performing experiments on cold-irradiated samples.

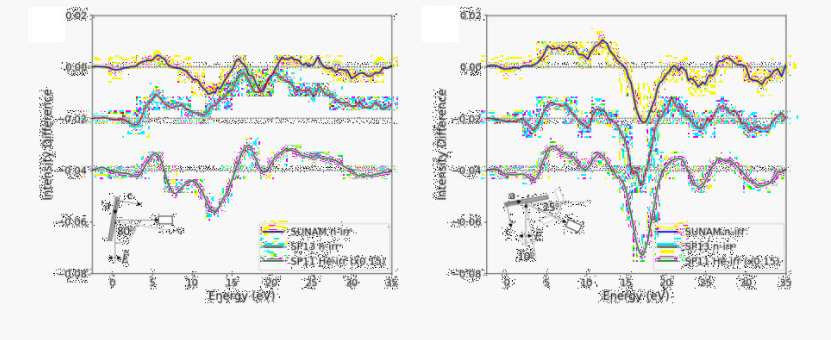

Figure 1: XANES difference spectra for 300 keV He^+ and neutron irradiated coated conductors in two orientations.

The work in Oxford has been supported by EPSRC fellowships (EP/L022907/1 and EP/W011743/1).

[1] K. Adams et al. Superc. Sci. Technol. 36 10LT01 (2023)
[2] R. Nicholls et al. Comms. Mater. 3 52 (2022)
[3] D. Fischer et al. Superc. Sci. Technol. 31 044006 (2018)

***Keywords (Index Terms)*— Irradiation, REBCO, coated conductor, XANES, EXAFS**