The biaxial strain dependence of J_c in HTS REBCO tapes at 77 K up to 0.7 T

Daniel Scobbie*, Charles W. A. Gurnham, Mark J. Raine and Damian P. Hampshire
Superconductivity Group, Department of Physics, Durham University, DH1 3LE, UK
*daniel.scobbie@durham.ac.uk

Introduction

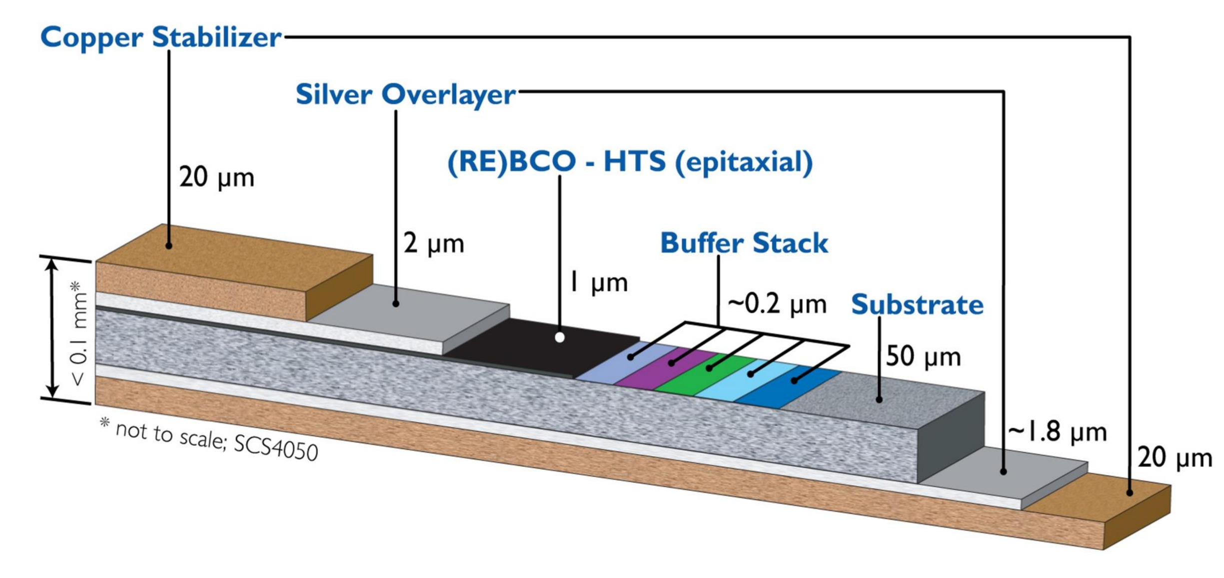

Fig. 1: The structure of the SuperPower HTS tape. The superconducting REBCO layer is shown in black [1].

- This work aims to study the biaxial strain dependence of the critical current density J_c of SuperPower APC REBCO tape at 77 K in applied fields up to 0.7 T.
- The strong Lorentz forces and differential thermal contraction experienced in a fusion magnet system will induce 2D strain. Hence understanding the behaviour of the critical parameters of REBCO under strain is essential.
- Higher magnetic fields will enable more compact fusion devices so it is desirable to use HTS tapes in future magnetically confined fusion devices.

Apparatus and Methods

- The HTS sample is soldered to the springboard made from copper-beryllium alloy (CuBe) using lead-tin solder.
- Strain can be applied to the springboard in both *x*- and *y*-directions. ε_x can be changed in situ at cryogenic temperatures. ε_y must be applied before cooling and is then fixed. Strain is measured using a 2D strain gauge.
- *Jc* is measured using standard 4 terminal transport measurements and defined by an electric field criterion of *E* = 100 µVm^{-1}.
- We can measure *Jc* versus field strength *B*, field angle θ and biaxial strain, ε_x, ε_y at 77 K (and 4.2 K).

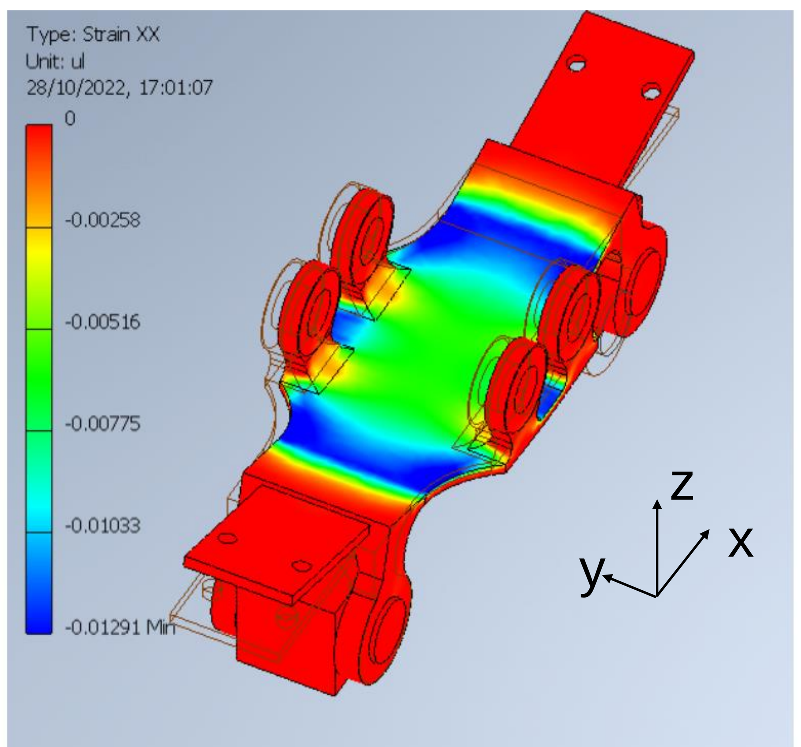

Fig. 2: A finite element analysis showing the *x*-strain profile on the 2D strain board with applied strains of ε_x = -0.5 % and ε_y = 0 %.

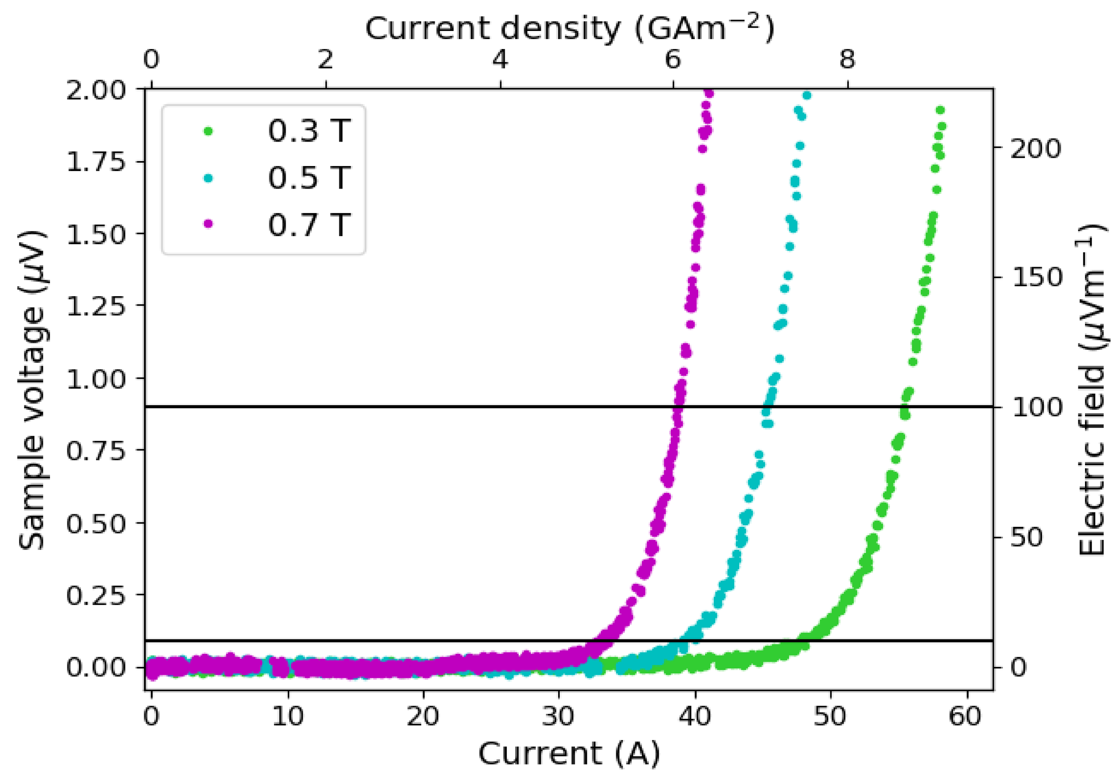

Fig. 3: *V-I* traces for Sample 3 at 0.3 T, 0.5 T and 0.7 T at zero strain. The solid black lines show the upper and lower transition criteria of E = 100 µVm^{-1} and E = 10 µVm^{-1}.

Initial Results

Field-angle measurements – Samples 1 & 2

- *Jc* was measured as a function of angle (-15° ≤ θ ≤ 195°) at 0.3T, 0.5 T and 0.7 T for Sample 2 (Fig. 4).
- Data from Sample 1 are also shown. This sample was degraded due to excessive heating, but the data show agreement with Sample 2 when scaled by 1.13.

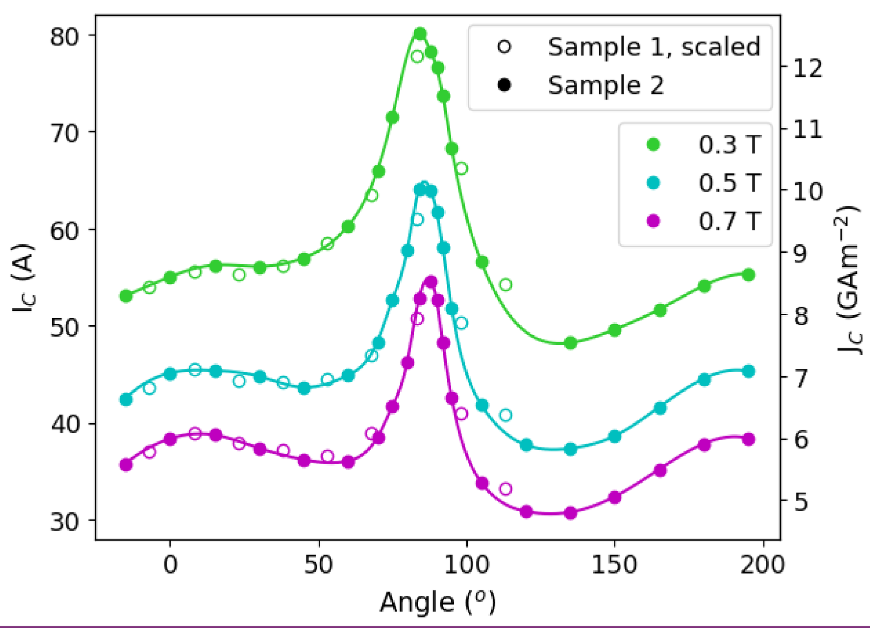

Fig. 4: I_c versus magnetic field and angle. Sample 1 data (open symbols) are scaled by a factor of 1.13 to compensate for sample degradation. They then agree with data for Sample 2 (closed symbols).

Uniaxial strain measurements – Sample 3

- *Jc* was measured as a function of strain applied in the x direction (-0.4% ≤ ε_x ≤ +0.3%).
- During an initial strain cycle (cycle 1), *Jc* was measured at 0.3T, 0.5 T and 0.7 T. During 4 subsequent strain cycles, it was only measured at 0.5 T.
- All cycles display reversibility and the expected inverse parabolic behaviour.
- The offsets in *Jc* between different measurement days is approximately that expected from changes in nitrogen temperature due to variations atmospheric pressure .
- The offsets in *Jc* may also be attributed to thermal cycling of the sample to room temperature.
- An angular variation of ~ 2.7° is be sufficient to explain the observed offsets in *Jc*.

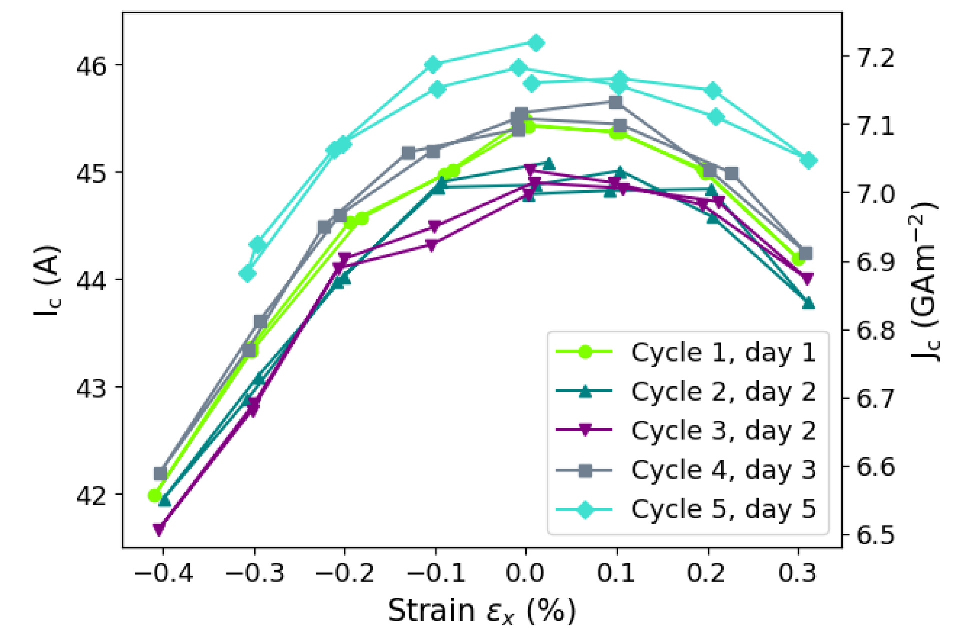

Fig. 5: I_c versus strain at 0.5 T, for 5 uniaxial strain cycles. A data point at -0.4% strain in cycle 5 was removed due to an electrical short affecting the measurement.

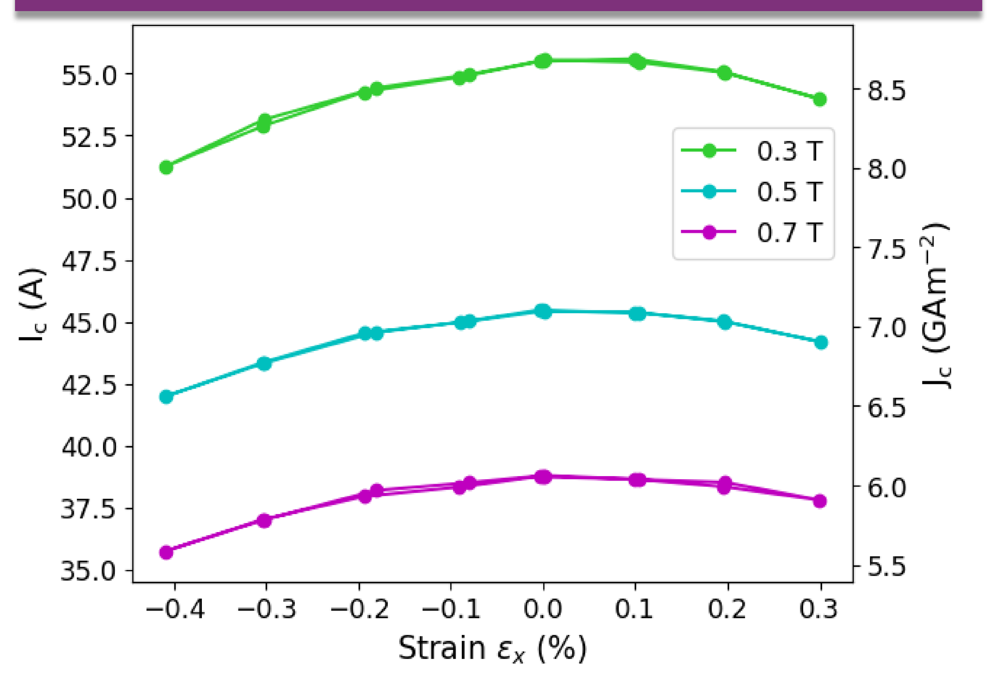

Fig. 6: I_c versus strain at 0.3 T, 0.5 T and 0.7 T during the first uniaxial strain cycle.

Conclusions & Future Work

1. *Jc* measurements versus field, field-angle and uniaxial strain have been completed using a biaxial strain apparatus.
2. In future: the probe angle will be set more precisely using a Hall sensor; the nitrogen temperature will be monitored to correct for it's impact on *Jc*; biaxial applied strains will be measured; the design of the strain board will be further optimised to improve the strain profile.

References

[1] Image from Super Power Inc., url: http://www.superpower-inc.com/content/2g-hts-wire
[2] Wimbush, Stuart; Strickland, Nick; Pantoja, Andres (2017). Critical current characterisation of SuperPower Advanced Pinning 2G HTS superconducting wire. Dataset. https://doi.org/10.6084/m9.figshare.4256624.v3
[3] Jack R. Greenwood, Elizabeth Surrey and Damian P. Hampshire, Biaxial Strain Measurements of J_C on a (RE)BCO Coated Conductor, IEEE Trans Appl Super 28 (4) 8400705 (2018)

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