The Biaxial Strain Dependence of the Critical Current Density of a (RE)BCO Coated Conductor at 77 K

Jack R. Greenwood¹, Elizabeth Surrey² & Damian P. Hampshire¹

1. Superconductivity Group, Centre for Materials Physics, Department of Physics, Durham University DH1 3LE, UK.
2. Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, Oxfordshire OX14 3DB, UK.

Introduction

We have recently designed and commissioned a 2D sample holder known as a ‘Crossboard’ [1], which has been used to apply biaxial stresses in-plane to a (RE)BCO SuperPower SCS4050 APC tape [2] and measure the effect on the critical current density (Jc). Data are presented for magnetic fields up to 0.7 T at 77 K. We also present a theoretical model that is used to describe the experimental data taken using the Crossboard. We show that the in-field, biaxial strain dependence of the tape’s critical current density Jc(B,εxx,εyy) is governed by the Jc’s of the A- and B-domains in the (RE)BCO layer, which have their crystallographic a- or b-axes (respectively) aligned along the tape length, with twin boundaries lying along the [110] direction. The experimental results and the parameterisation show that the tape has roughly equal populations of A- and B-domains (f = 0.49) and that the strain sensitivity of the critical temperature along the a-axis is 1.8 K%/1 and along the b-axis is -1.3 K%/1, in both domains. Applications that are subjected to multiaxial loads during their manufacturing process and operation that can be described using the formalism given in this work, include CORC® and Roebel cables [3,4].

The Biaxial Strain Model for Jc (BSJ)

• The (RE)BCO layer is treated as a 1D chain of A- and B-domains that have their a- and b-axes aligned along the length of the tape. The Jc of the whole tape (Jc) has contributions from the Jc’s of the A- and B-domains (JcA and JcB, respectively) [5]

Jc = Jc[B(εxx,εyy)] = fJc[A(εxx)] + (1 - f)Jc[B(εyy)]

(1)

where f and 1-f are the fractions of A- and B-domains and N is the tape’s quality index.

• The Jc of domain type i is calculated using the engineering scaling law [5]:

Jc = A[B(εxx,εyy)]h -n(1 - (1/3) y)2

(2)

where i = A or B and A, p and q are fitting constants, n is fixed at 2.5, B(εxx) and Tc are the upper critical magnetic field and critical current density of the domain respectively and h is the reduced field B/Bc2.

• The Tc’s of the A- and B-domains are taken to be linear functions of εxx and εyy:

Tc[A(εxx)] = Tc[0(0)](1 + αεxx)Tc[A(εyy)] = Tc[0(0)](1 + αεyy)

(3a)

Tc[B(εxx,εyy)] = Tc[0(0)](1 + βεxx)Tc[B(εyy)] = Tc[0(0)](1 + βεyy)

(3b)

where Tc[0(0)] is the critical temperature of an A- or B-domain at zero net strain and εxx and εyy are pre-strains along x and y respectively, caused by the tape’s manufacturing process and cooldown. βεxx and βεyy are the strain sensitivities of Tc of a (RE)BCO single crystal along its a- and b-axes respectively [6].

• The Bc2’s of the A- and B-domains are related to their respective Tc’s using a power law. [5,7]

Experimental Results & Their Parameterisation

• The data were fitted with εxx = εyy = 0.

• Jc(B,εxx,εyy) is parabolic with respect to ε strain near εxx = 0% for the ‘applied σxx’ and ‘applied σyy’ with compressive σyy’ data and is linear for the ‘εxx = εyy’ data.

• The (RE)BCO layer has f = 0.49, so the populations of A- and B-domains are roughly equal.

• 1.8 K%/1 along the a-axis and -1.3 K%/1 along the b-axis, in both domains.

Conclusions

We have:

1) Measured Jc(T,θ,εxx,εyy) using the Crossboard in fields up to 0.7 T at 77 K.

2) Developed a theoretical model to describe the in-plane biaxial strain dependence of Jc of a (RE)BCO tape.

The experimental data and the theoretical model show that:

1) Jc(εxx,εyy) has a parabolic behaviour near εxx = 0 when we apply an a-stress to the tape, whether we add a constant y-stress or not.

2) Jc(εxx,εyy) has a linear behaviour near εxx = 0 when we fix εyy = εxx.

3) The fractions of A- and B-domains are approximately equal.

4) Jc is 1.8 K%/1 along the a-axis.

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