Axial strain effects of superconducting properties in detwinned RE123 coated conductors.


High Field Laboratory for Superconducting Materials (HFLSM), Institute for Materials Research (IMR), Tohoku University

*present address: Kyusu University
RE123 coated conductors

Schematic grain structure

Polycrystalline metallic tape

IBAD textured buffer layer

Buffer layer

YBCO

Pole figure

YBCO (103)

(103) \(\phi\)-scan

Int. (arb unit.)

0 90 180 270 360

\(\phi\) (deg)

Longitudinal direction

a-domain

b-domain

a-axis

b-axis

a-axis

b-axis
The strain effect of REBCO tapes is complicated because of the coexistence of $a$- and $b$-axis domains and the large anisotropy of the strain effect in the $ab$-plane.
De-twinning process (Strain Annealing)

YBCO

\[ a = 0.382 \text{ nm} \]
\[ b = 0.389 \text{ nm} \]
\[ c = 1.168 \text{ nm} \]

\( b \)-axis is about 1.8 % longer than \( a \)-axis

\[ T, P (\text{N}) \]

Annealing condition (In air)

\[ T = 300^\circ\text{C} \]

Furnace cooling

\[ 200^\circ\text{C} \]

SS curve at high temperature

Temperature fall

Strain released at 200\(^\circ\text{C}\)

\[ T = 300^\circ\text{C} \]

Young's modulus 211 GPa

Coexistence of $a$- and $b$-axis domains

Align of in-plane crystal axis (detwin)

Anneal under strain

Transmission XRD (Mo $K\alpha$)

Suzuki et al., IEEE TAS, 25 (2015) 8400704
After tensile strain anneal with 1%, the cracks along $a$-axis appeared.

We checked the internal strain under external strain.

$J_c (77K, \text{sf}, 0\%)$
- $2.6 \text{ MA/cm}^2$ for as-received
- $0.79 \text{ MA/cm}^2$ for $a$-axis ($\parallel$ cracks)
- $0.013 \text{ MA/cm}^2$ for $b$-axis ($\perp$ cracks)

Slope $\approx 0.57$
Strain dependence measurements of $T_c$ and $J_c$ (4-point bending)

Acknowledgment: The strain dependency was measured using the Dr. Nishijima’s 4 point bending apparatus.
Effect of axial tensile strain on $T_c$

(a) Strain along $a$-axis

(b) Strain along $b$-axis

S. Awaji et al., Scientific Reports 5 (2015) 11156
External strain dependence of $T_c$

(a) Strain along $a$-axis

(b) Strain along $b$-axis

Lattice parameter under the strain

Optimum value?

Macmanus-Driscoll, J. L. & Wimbush, IEEE TAS. 21, 2495 (2011)

S. Awaji et al., Scientific Reports 5 (2015) 11156
Critical current

\[ J_c (77K, sf, 0\%) = 2.6 \text{ MA/cm}^2 \text{ for as-received} \]
\[ = 0.79 \text{ MA/cm}^2 \text{ for } a\text{-axis} \]
\[ = 0.013 \text{ MA/cm}^2 \text{ for } b\text{-axis} \]

As-received: dome-like
\( a\text{-axis: dome-like but shift a peak position} \)
\( b\text{-axis: almost linear} \)
The strain sensitivities of $J_c$ are larger in higher fields.
Strain annealing under compressive strain

Intensity (arb. unit)

2θ (deg.)

Longitudinal

(020) (200)

as-received
0.25% compression
0.5% compression

20.5 21 21.5 22
$J_c$ properties

**As-received**

![Graph showing $J_c$ properties for As-received material with different temperatures and magnetic fields.](image)

**0.5% Compression**

![Graph showing $J_c$ properties for 0.5% Compression material with different temperatures and magnetic fields.](image)
We succeeded in de-twinning of REBCO coated conductors by strain annealing, although cracks formed. Using de-twinned REBCO sample, external strain dependences of $T_c$ and $J_c$ were investigated.

✓ Critical temperature
  • The strain dependencies for the a and b axes obey a power-law but exhibit opposite slopes.
  • The optimum conditions of the CuO$_2$ plane in RE123 are a square with a lattice constant of 0.385 nm to attain a high critical temperature.

✓ Critical current
  • The strain dependencies of $J_c$ seem to be similar to those of $T_c$.
  • Magnetic field increases the strain sensitivity along both a- and b- axes, although those are opposite each other.

✓ The annealing under compressive strain is a promising way for de-twinning without cracking.