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Measurement and Analysis on Local Magnetization Properties of RE-123 Coated Conductor with DC Transport Current and External Magnetic Field

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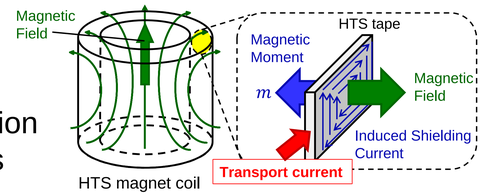
1. Introduction

Magnetization by screening current due to tape shape has been recognized as a critical problem for magnet applications comprising coated conductors (CCs) from the viewpoint of field homogeneity and temporal stability.

Understanding and modeling of the magnetization in CCs are crucial for the quantitative estimation and the compensation of its influence on the magnets



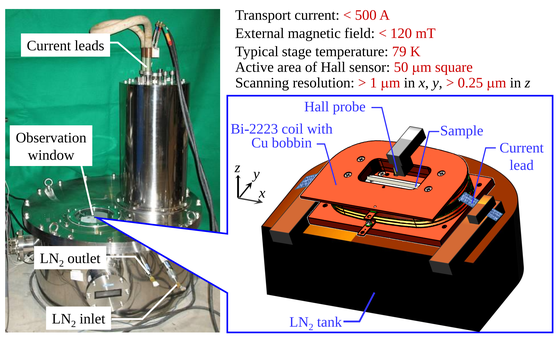
Conventional studies:
> MPMS, pickup coil, etc.: without spatial resolution
> Scanning Hall-probe microscopy (SHPM): with spatial resolution without simultaneous applications of transport current and external magnetic field

This study:

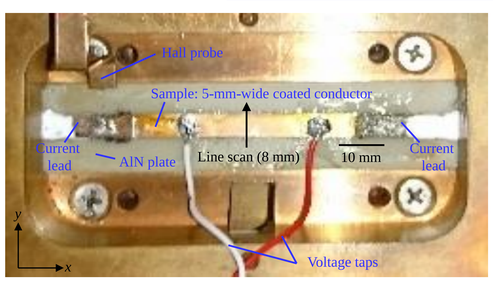
Spatially Resolved Measurement and Analysis on Magnetization Properties in a RE-123 CC with Simultaneous Applications of Transport Current and Magnetic Field

2. Methods

Scanning Hall-probe Microscopy (SHPM)



Transport current: < 500 A
External magnetic field: < 120 mT
Typical stage temperature: 79 K
Active area of Hall sensor: 50 μm square
Scanning resolution: > 1 μm in *x*, *y*, > 0.25 μm in *z*



Finite Element Method (FEM)

A commercial software PHOTO-Series EDDY with considering the following equations into 2.2-μm-thick layer in a 5-mm-wide GdBCO CC

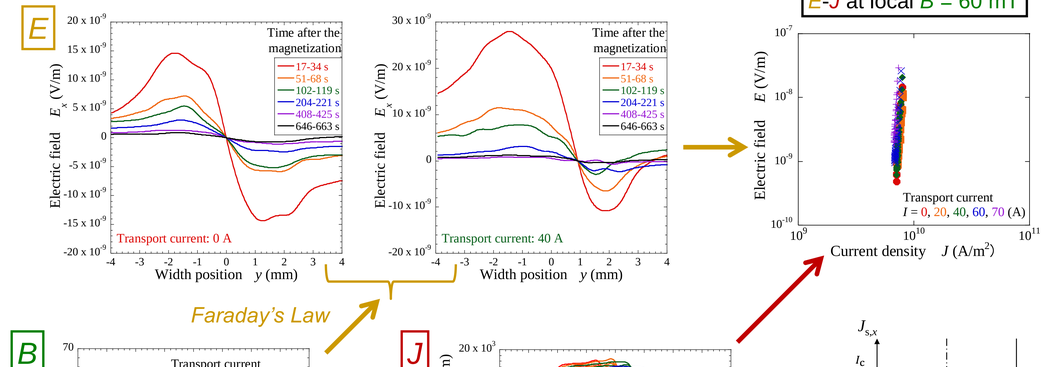
$$J = J_c\left(\frac{E}{E_c}\right)^{1/n} \qquad J_c = J_{c0}\left(\frac{B}{B_0}\right)^{\gamma}$$

Procedure

1. Apply external magnetic field of 60 mT in –*z* direction
2. Apply transport current in +*x* direction:
   I = 0, 20, 40, 60, or 70 A
3. Take magnetic field distribution along the width at every 17 s: $B_z(y,t)$

3. Results and Discussion

Experimental Results by SHPM

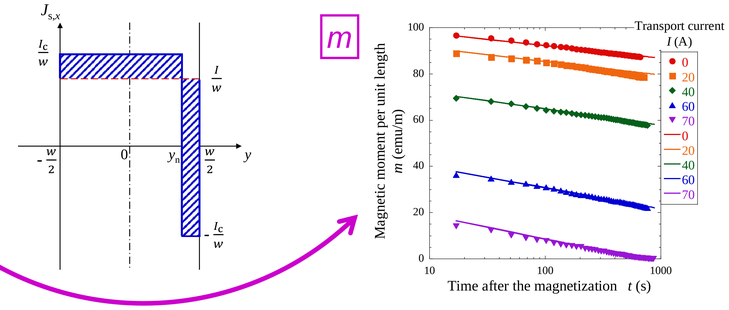


Magnetic field distribution along the width was successfully measured including its time variation for different transport currents.

The corresponding distributions of sheet current density and electric field were visualized.

If the local relationship of them was plot for a certain local magnetic field, e.g., 60 mT here, it was shown that the *J*-*E* relationship lined on the same curve independent of the transport current

The results were apparently complicated but they just follows the local *J*-*E* relationship from higher *E* to lower *E* as time passed.



$$m = \int_{-\frac{w}{2}}^{y_n}\left(|J_{s,x}(y)| - \frac{I}{w}\right)(y_n - y)dy + \int_{y_n}^{\frac{w}{2}}\left(|J_{s,x}(y)| + \frac{I}{w}\right)(y - y_n)dy$$

Plotted by the symbols as experimental results

$$m(I,t) = \frac{wI_c(t)}{4}\left(1 - \left(\frac{I}{I_c(t)}\right)^2\right) = m(0,t)\left(1 - \left(\frac{wI}{4m(0,t)}\right)^2\right)$$

Drawn by the lines as theoretical results

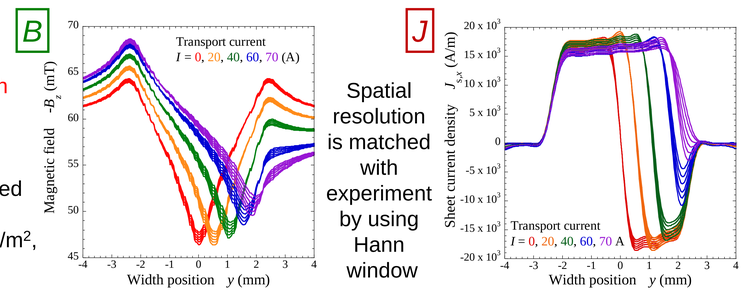
Magnetic moment was estimated from the sheet current density distribution. including its time variation for different transport currents.

The magnitude and the relaxation rate changed with the transport current.

Considering the time variation of critical current influenced by that of electric field criterion, the time variation of the magnetic moment was successfully expressed for different transport currents.

Numerical Results by FEM

The results agree very well with those of the experiment including the dependence on transport current and time by using the parameters determined carefully from the experiment:: $E_c = 10^{-9}$ V/m, $J_{c0} = 7.1 \times 10^9$ A/m², $n = 30$, $B_0 = 60$ mT, $\gamma = -0.32$, $w = 4.72$ mm.



Spatial resolution is matched with experiment by using Hann window

4. Conclusion

Magnetization properties in a RE-123 CC were characterized by a spatially-resolved measurement based on SHPM. Magnetization current distribution was visualized under the condition with simultaneous applications of transport current and external magnetic field including time variation.

The influence of the transport current on the magnetization and its relaxation was clarified and modeled successfully. Furthermore, the experimental results were reconstructed very well by a numerical analysis based on FEM taking account of the findings obtained by the experiment.

We believe that these achievements will significantly contribute to the quantitative estimation and the compensation of the magnetization problem in the magnets comprising RE-123 CCs.

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