Comparison of $J_C$ in GdBaCuO Tape Using Dc Magnetisation and Harmonic Ac Susceptibility Measurements

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Abstract

Dc magnetisation is a technique regularly used to perform non-destructive measurements of the critical current density ($J_C$) in superconducting materials.

- Measurements of $J_C$ using Dc magnetisation are highly sensitive to inhomogeneity in the applied Dc field [1]. If the field inhomogeneity is comparable to the self-field of the superconductor, $J_C$ will appear to drop to zero.

- We have compared Dc magnetisation measurements of $J_C$ to harmonic Ac susceptibility measurements of $J_C$ for a rectangular GdBaCuO tape.

$J_C$ from Ac Susceptibility of Superconducting Tapes

The real and imaginary susceptibility constants were calculated from the harmonic measurements. The penetration parameter $\gamma$ and $J_C$ were then obtained using the analytic expressions [3]:

$$\chi'(\gamma) = \frac{2\chi_0}{\pi} \int_0^\pi \left( 1 - \cos \theta \right) \frac{\cos \theta}{2} d\theta$$

$$\chi''(\gamma) = \frac{2\chi_0}{\pi} \int_0^\pi \left( 1 - \cos \theta \right) \left[ \frac{\cos \theta}{2} \right] - S(\gamma) \sin \theta d\theta$$

Where $\chi_0$ is the susceptibility at zero applied field, including demagnetisation factors, and $\gamma$ is the penetration parameter.

$$\gamma = \frac{3\pi \chi_0 H_{ac}}{(3w - w^2) J_C}, \quad S(\gamma) = \frac{1}{2\gamma} \left[ \arccos \left( \frac{1}{\cosh \gamma} \right) + \tanh \gamma \right]$$

The index $n$ from Ac Susceptibility Data

- Faraday’s law gives the electric field in the superconductor during Ac susceptibility measurements:

$$\int E \cdot dl = - \int \frac{\partial B}{\partial t} \cdot dA$$

<table>
<thead>
<tr>
<th>$B_{DC}$ (T)</th>
<th>1.0T</th>
<th>3.0T</th>
<th>5.0T</th>
<th>6.0T</th>
<th>7.0T</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>6.5</td>
<td>4.5</td>
<td>2.1</td>
<td>1.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- Measured values of $J_C$ at different frequencies of the excitation field provide the index of transition, $n$.

- Dc magnetisation measurements were performed with a sweep rate of 0.02T/s. This is comparable to Ac measurements at 77 Hz.

Conclusions

- There is a large discrepancy between $J_C$ obtained via Ac susceptibility and Dc magnetisation measurements.

- An analysis of the harmonic Ac susceptibility has been used to determine $J_C$ for a GdBaCuO tape.

- There is a large discrepancy between Ac and Dc measurements at high temperatures and applied fields.

- The error in $J_C$ in Dc magnetisation measurements increases as the Dc field inhomogeneity becomes comparable to the self-field.

References


The data are available at [http://dx.doi.org/10.15128/r1m613mx56q](http://dx.doi.org/10.15128/r1m613mx56q) and associated materials are on the Durham Research Online Website at [http://durham.ac.uk/duro](http://durham.ac.uk/duro).