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Residual Resistivity Ratio Measurements

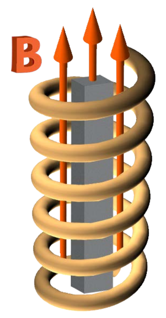
Motivation

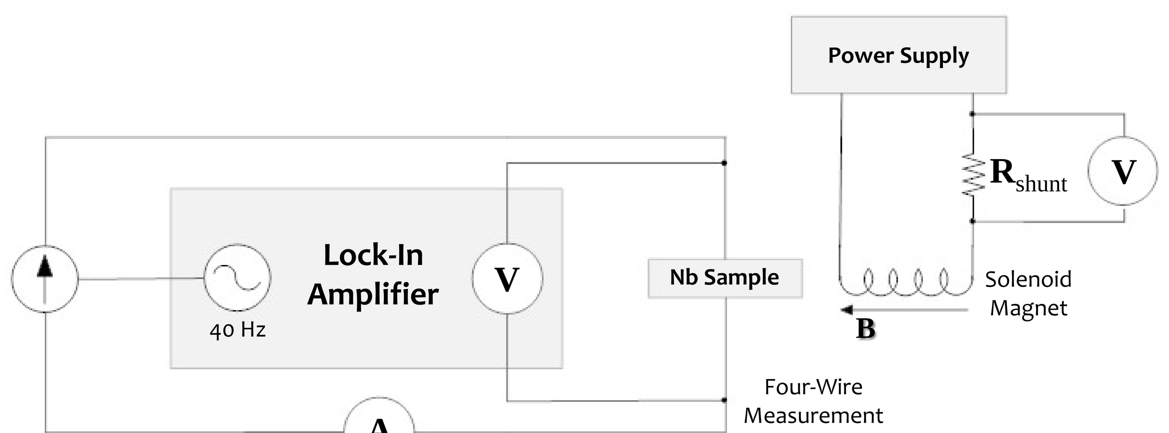
The Residual Resistivity Ratio (RRR) of niobium is an excellent indicator as to how pure a given sample is. This is important because increasing the purity of a niobium cavity increases the maximum accelerating gradient the cavity can withstand before quenching due to thermal instability.

$$RRR = \frac{\text{Resistivity 300 K}}{\text{Residual Resistivity 4 K (Normal State)}}$$

RRR Measurements

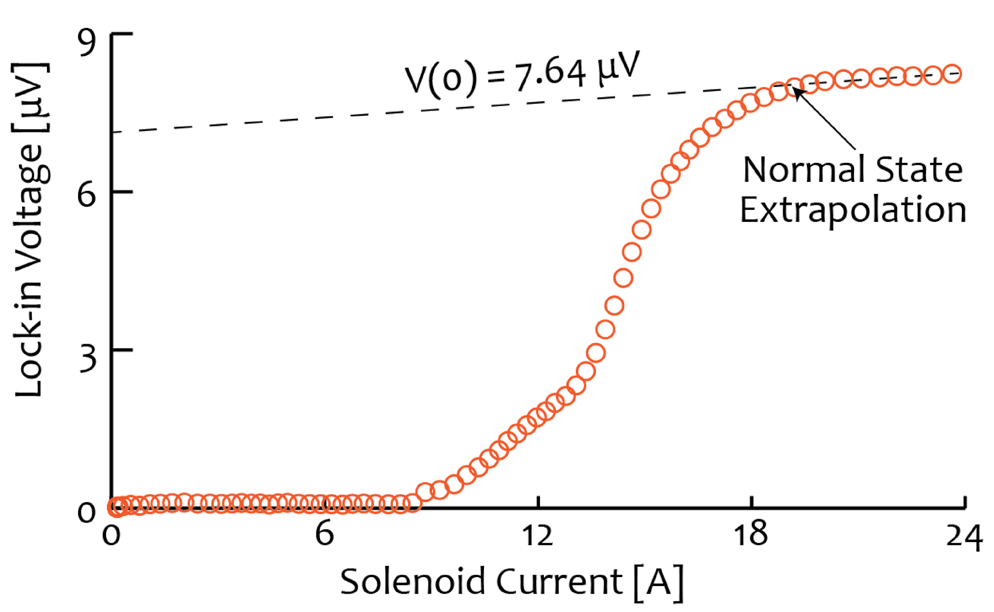
A niobium sample is placed in a solenoid and cooled to 4 Kelvin. In driving a current through the coil, an external magnetic field is produced which serves to bring the sample from the Meissner to normal state.





Circuit Schematic

By extrapolating to zero current, the effects of magnetoresistance are negated and a reading for the low temperature normal state residual resistivity is obtained.



Calculating Magnetic Flux Penetration in Type II Superconductors

Motivation

In a type II superconductor, the Bean-Livingston barrier prevents the penetration of flux vortices parallel to a cavity surface from entering the cavity. However, this barrier disappears when the surface magnetic field exceeds the Superheating field, $H_{sh.}$ By making an analogy with electrostatics, the method of images may be applied to calculate the interaction energy between a flux vortex and cavity wall. These techniques are explored in [1] and used to calculate the vortex entrance field in the presence of a grain boundary, of which we have analyzed with respect to using Nb_3Sn as a superconducting surface.

Electrostatic Analogy

At distances r << λ, the local magnetic field of a single flux quantum as derived from the London Equation takes the form of a Poisson equation, with the effective source term being the vortex core. This problem is analogous to electrostatics when h possesses translational symmetry along the z-axis. [2]

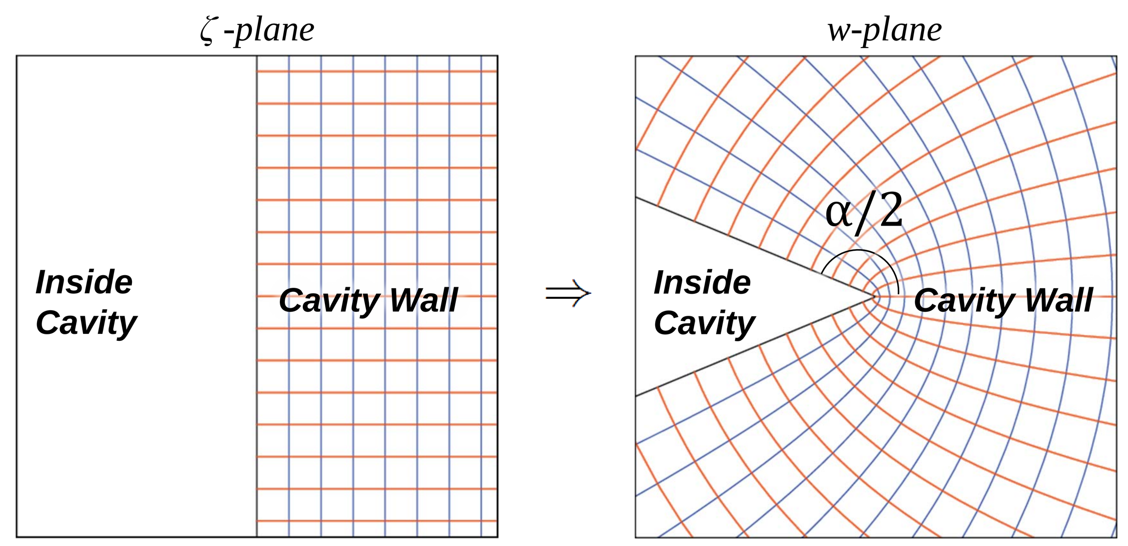
	Electrostatics	Vortices
Potential	V	λh
Charge	q	$\frac{\phi_0}{4\pi\lambda}$
Current Density	$\vec{j}$	$-\lambda^2 \operatorname{curl} \vec{h}$

Using Conformal Transformations

The local field (h) of a flux vortex satisfies Laplace's equation and is therefore conservative.

$$h_z = \frac{\phi_0}{2\pi\lambda^2} \ln\left(\frac{\lambda}{r}\right), \qquad (r \ll \lambda)$$

This allows the field to undergo a conformal transformation from one plane geometry to another, whereby the transformed field h remains harmonic.



Modeling a surface defect using the transformation $w = \zeta^{\alpha/\pi}$

Method of Images

By treating the cavity surface as a grounded infinite conducting plane, the method of images gives the magnetic field distribution due to a vortex at x_0 as

$$h(\zeta) = \frac{\phi_0}{2\pi\lambda^2} \ln\left|\frac{\zeta + x_0}{\zeta - x_0}\right|, \qquad (\zeta = x + \imath y)$$

Published Results

The attraction forces were found to be

$$\zeta\text{-plane} \qquad f_\zeta = -\frac{\phi_0}{4\pi\lambda}^2 \frac{1}{x_0}$$

$$w\text{-plane} \qquad f_w = -\frac{\phi_0}{4\pi\lambda}^2 \frac{\pi}{\alpha u_0}$$

A grain boundary may be modeled by the case α→2π, of which the transformed attractive force is a factor of 2 smaller than the attractive force for a flat surface. The entrance field is ultimately found to be

$$H_e \simeq H_c \left(\frac{\xi}{\lambda}\right)^{1-\pi/\alpha}$$

Conclusions

With respect to the grain boundary modeling of the conformal transformation, the smaller coherence length of Nb_3Sn appears to make the metal much more susceptible to surface defects as a superconductor than for that of Nb.

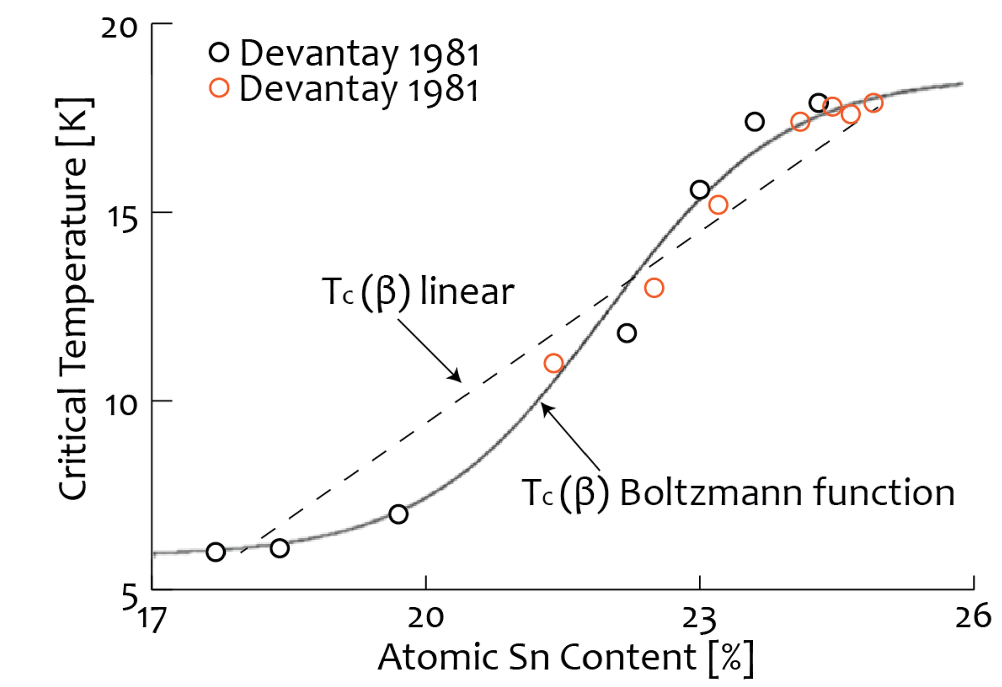
References

1. A. Buzdin, M. Daumens. Electromagnetic pinning of vortices on different types of defects. Physica C 294 (1998) 257-269
2. A Buzdin, D. Feinberg. Electromagnetic pinning of vortices by non-superconducting defects and their influence on screening. Physica C 256 (1996) 303-311.

Critical Temperature Measurement System

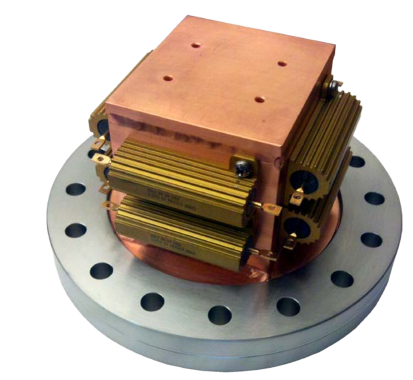
Motivation

The Critical Temperature (T_c) of a Nb_3Sn sample is strongly dependent on the chemical composition of the metal. Construction has begun on a Critical Temperature measurement system so that the composition of a given sample may be measured.



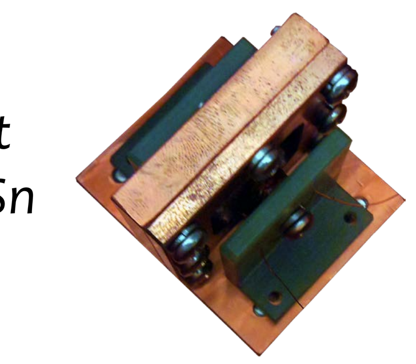
System Construction

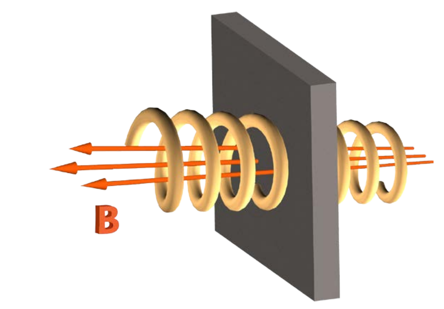
The upper structure of the T_c measurement system, with radiation shielding attached.



The copper housing unit with resistor heating elements.

The sub-assembly that holds the sample Nb_3Sn and inductor coils.





Conceptual view of Nb_3Sn between inductor coils.

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