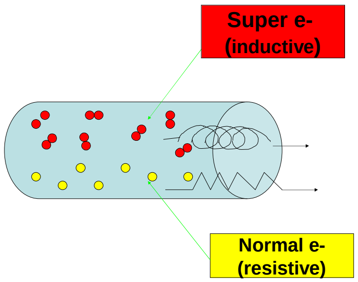
Doping Dependent Microwave Nonlinearity of $Tl_2Ba_2CaCu_2O_{8-x}$ Superconductor

Candace Goodson
Advisor: Professor Remillard

1. The Basics

• Superconductivity occurs when there is an absolute loss of DC electrical resistance at or below T_c, and the interior magnetic field is excluded
•The area of superconductivity that is being studied is best illustrated by the Two-Fluid Model:



Normal e-

Super e- (kinetic inductance)

$$\frac{1}{Z_s} = \frac{1}{R_c} + \frac{i}{\omega L_k}$$

$$Z_s = \frac{\omega L R_c}{\omega L_k + i R_c} = R_s - i X_s$$

$$\lim_{\omega \to 0} Z_s = 0$$

$$\lim_{\omega \to \infty} Z_s = R_s$$

Surface Impedance

Surface Resistance

Surface Reactance

Nonlinear Ohm's Law

$$V = I \cdot (R_s(I) + i X_s(I))$$

Motivation:

- Determine whether annealing will change key characteristics of the TBCCO superconductor
  - Critical Temperature
  - Shape of the Surface Resistance versus Dissipated Power Curve

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Reference for empirical model of hole doping:

R.S. Liu and P.P. Edwards, "Effects of Inherent (Auto) Doping and Oxygen Nonstoichiometry and their Relationship ti the Band Structure of Tl-Based Superconductors," in Thallium-Based High-Temperature Superconductors, A.M. Hermann and J.V. Yakhmi, eds., (Dekker, New York, 1994).

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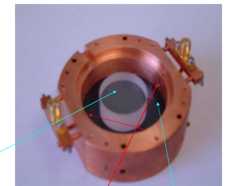
2. Methods of Measurement

Sapphire Dielectric Resonator (SDR)

•Measures the surface resistance as a function of induced microwave currents

•Gives the resonant frequency and the quality factor, Q.



Equation used to find surface resistance

$$\frac{1}{Q} = \frac{R_s}{G} + f_d \tan\delta$$

Surface Resistance — Geometry factor — Quality factor — Characteristic of dielectric — Characteristic of superconductor

Equation when used for round robin

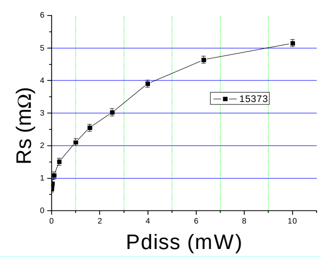
$$AB = \frac{1}{Q_{AB}} = \frac{R_{s,A}}{G_{top}} + \frac{R_{s,B}}{G_{bot}} + f_d \tan(\delta)$$

$$BC = \frac{1}{Q_{BC}} = \frac{R_{s,B}}{G_{top}} + \frac{R_{s,C}}{G_{bot}} + f_d \tan(\delta)$$

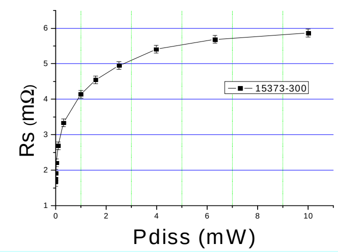
$$AC = \frac{1}{Q_{AC}} = \frac{R_{s,A}}{G_{top}} + \frac{R_{s,C}}{G_{bot}} + f_d \tan(\delta)$$

3. Data

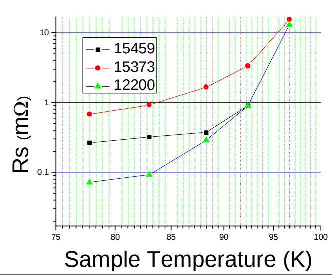
Round Robin of a Pre-N_2 annealed samples of $Tl_2Ba_2CaCu_2O_{8-x}$ at 5.56 GHz at 77.8 K



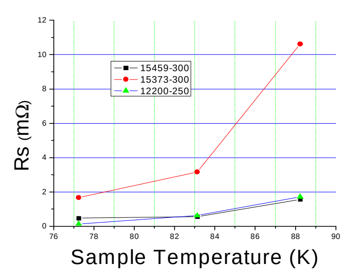
Round Robin of a Post-N_2 annealed samples of $Tl_2Ba_2CaCu_2O_{8-x}$ at 5.56 GHz at 77.8 K



Round Robin Measurements of Three Pre-N_2 annealed samples of $Tl_2Ba_2CaCu_2O_{8-x}$ at 5.56 GHz

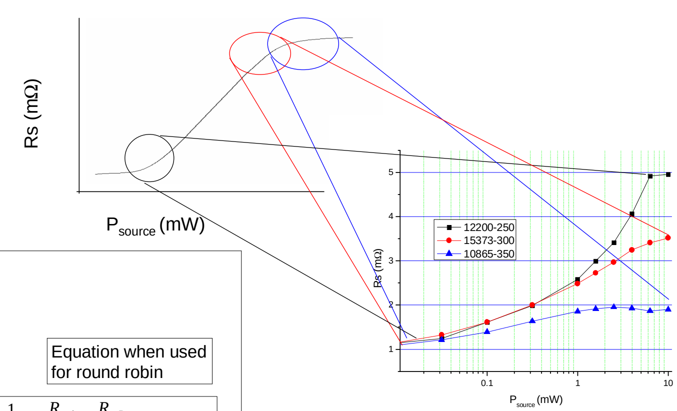


Round Robin Measurements of Three Post N_2-annealed samples of $Tl_2Ba_2CaCu_2O_{8-x}$ at 5.56GHz



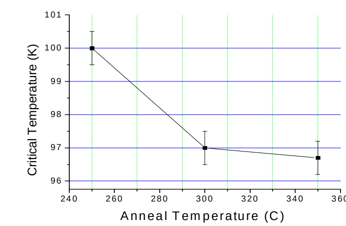
4. Results

Typical Form of R_s(H) with Full Dynamic Range



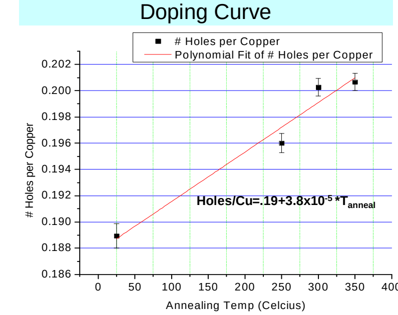
Post-Annealed Samples Shifted to a Higher Nonlinear Regime

As anneal temperature increased (from 250°C-350°C), the critical temperature decreased



The critical temperature serves as a direct measurement of the dopant concentration.

Doping Curve



Therefore: The hole doping of the superconductor can be controlled by N_2 annealing.