A Hydrated Superconductor

Karmela Padavic, Bikash Padhi, Akshat Puri

A brief discussion of

Superconductivity in 2D CoO$_2$ Layers

Kazunori Takada, Hiroya Sakurai, Eiji Takayama-Muromachi, Fujio Izumi, Ruben A. Dilanian & Takayoshi Sasaki

Presentation Outline

• Background: phenomenology and history
• Unconventional SCs
• Superconductivity in CuO$_2$ layers
• Critical assessment of the presented work
• Citation analysis and consequent studies
• Summary and conclusions
Discovery of Superconductivity

- Discovered in 1911 by Heike Kamerlingh Onnes.
- Perfect conductivity of Hg below 4.19 K.
- Perfect conductor below a critical temperature ($T_c$):

http://spectrum.ieee.org/tech-talk/semiconductors/materials/superconductivity-celebrates-100-years
http://www.writework.com/essay/superconductivity
Zero Electrical Resistance in Superconducting Phase

- Resistance drops to 0 at $T_c$

![Graph showing the transition from resistance to zero at $T_c$]
Several Properties Reveal the SC Phase Transition

- Transitions in electronic heat capacity, resistivity.

![Diagram showing transitions in electronic heat capacity and resistivity.](http://upload.wikimedia.org/wikipedia/commons/0/08/Cvandrhovst.png)
Superconductors exhibit a Meissner Effect

- The spontaneous expulsion of a magnetic field which occurs during transition to superconductivity.

http://en.wikipedia.org/wiki/Meissner_effect
http://www.nature.com/nmat/journal/v11/n8/fig_tab/nmat3333_F1.html

Fig. from [2]
SC response to magnetic field: Type I and II

- Response to external magnetic field differs: Type I (single critical field, above which all superconductivity is lost); or Type II (two critical fields, between which there is partial penetration of the magnetic field and creation of vortices)

http://physics.aalto.fi/groups/nanospin/facilities/pulsed-laser-deposition/critical/
SC Mechanism described by BCS Theory

- BCS Theory (1957): Superconducting current is a superfluid of pairs of electrons interacting through an exchange of phonons (Cooper pairs).

Achieving higher $T_c$

- Unconventional, non-BCS superconductivity discovered in the 1980s, LaBaCuO with $T_c = 35$ K (1986)

http://dpmc.unige.ch/gr_gaps/index.html
Superconductivity in CuO$_2$ layers: Motivation

- Discovery of high-$T_c$ superconducting copper oxides (which have a similar layered 2D structure) has prompted a search for the same behavior in other layered metal oxides with 3d transition metals like Co and Ni.

- d-wave SCs: Antiferromagnetic spin fluctuation in a doped system causes pairing, with wave functions having a $d_{x^2-y^2}$ symmetry.
Superconductivity in CoO$_2$ layers: Growth and Structure

• Na$_x$CoO$_2$yH$_2$O sample obtained through chemical oxidation process from Na$_{0.7}$CoO$_2$
• Intercalation of water molecules occurs in addition to the deintercalation of Na$^+$ ions

Determining the Structure: XRD/Rietveld analysis

Susceptibility Measurements

- In a measurement under external magnetic field $H=20$ Oe a steep decrease of susceptibility was observed at about 5K both in zero-field cooling and field cooling processes.

- Magnetization measurement indicates this material is a Type II superconductor with a lower critical field of 100 Oe.

Resistivity Measurements

- A sharp decrease of resistivity was observed at around 4K
- Discrepancy in $T_c$ compared to the susceptibility measurement due to variation in water content of each sample
- Experimentally challenging measurement due to the nature of the specimen

Citation Analysis

- This study of $\text{Na}_x\text{CoO}_2\text{yH}_2\text{O}$ was cited more than 1100 times.
- The same material was studied in depth by both theoretical and experimental works.
Subsequent Model for SC in NaCoO$_2$

- Resonating Valence bond Theory developed by P. W. Anderson and G. Baskaran.

![Diagram](image)

Fig. from [6]
Superconductivity in CoO$_2$ layers: Critical Assessment

- H$_2$O is the most probable candidate for the new molecule that enters the structure.
- Possible trace amount of impurities.
- It was impossible to prepare a tightly sintered ceramic specimen for the resistivity measurement.
- Resistivity $T_c$ is lower than $T_c$ from magnetic measurements. Possibly due to varying water content.
- Nothing mentioned about the triangular lattice with magnetically frustrated geometry in contrast to the square lattice of the CuO$_2$ plane.
Thank You