Patterning and Etching Electron-Doped Cuprate Films

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Abstract:
Scaling analysis of voltage vs. current isotherms is a favorite tool to study the normal-superconducting phase transition in cuprate superconductors. This measurement has never been performed on the electron-doped cuprate superconductor Pr$_{2-x}$Ce$_x$CuO$_4$, despite unusual behaviors which may alter this phase transition and yield interesting results (behaviors such as the extended doping range of the antiferromagnetic phase and the quantum critical point). We photolithographically pattern and etch via ion mill our superconducting cuprate samples at the Cornell NanoScale Science and Technology Facility (CNF) and conduct voltage vs. current measurements at Ithaca College.

Summary of Research:
The experimentally accessible critical regime of the high-temperature superconductors, coupled with the prediction of a possible new phase transition in a field, generated great interest in the normal-superconducting phase transition [1,2]. Since then, the scaling analysis of voltage vs. current curves has often been used to determine the existence of and the critical parameters for the phase transitions in a magnetic field and in zero field. Yet nearly two decades later, the results from transport experiments have yielded little consensus in the literature regarding the exponents for either phase transition from transport data.

While data should obey scaling if a phase transition exists, work by my colleagues and myself has shown that conventional scaling may be too flexible to uniquely determine the critical parameters of a phase transition [3], and we proposed an experimental criterion to remove the ambiguity in the scaling analysis. Our recent work on the zero-field transition in hole-doped cuprates [4-6] has clarified the experimental and intrinsic difficulties in measuring this transition and yielded consistent results in ac and dc measurements in films and crystals.

We will now use the knowledge of the scaling analysis that we have gained and apply it to a novel material. We will measure the critical dynamics of Pr$_{2-x}$Ce$_x$CuO$_{4-y}$ (PCCO) using dc voltage vs. current measurements as a function of doping and field. This electron-doped superconductor has displayed an array of interesting behaviors, such as d-to-s-wave pairing, a transition to an insulating state, and a quantum critical point. Any and all of these phenomena may have consequences for the normal-superconducting phase transition, and these experiments may yield new and interesting results.

We pattern our PCCO films into four-probe patterns at the CNF. Typical bridge dimensions are 40 µm by 8 µm, where 2 µm is the smallest dimension of our pattern, used for attaching the voltage leads to the current bridge. Figure 1 shows a microscope picture of the voltage leads after patterning. After patterning, we use an ion mill to etch our samples. We have shown that we can etch the film safely without degrading the sample. Once patterned and etched, we take the films to Ithaca College for contact evaporation.
Finally, we have begun to expand our research into measurements of the critical current in the hole-doped cuprate \( \text{YBa}_2\text{Cu}_3\text{O}_7 \) (YBCO). The critical current should also obey a scaling relation close to the transition temperature. We pattern and etch these films at the CNF in these patterns, we use a long meander line to increase the voltage sensitivity. Figure 2 shows a patterned sample for the critical current measurement.

All measurements are conducted at the low temperature laboratory in the Physics Department at Ithaca College.

References: