行政院國家科學委員會專題研究計畫　期中進度報告

極低溫下電子相位相干時間之量測(1/2)

計畫類別：個別型計畫
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執行期間：94年08月01日至95年07月31日
執行單位：國立交通大學物理研究所

計畫主持人：林志忠

計畫參與人員：Christophe Le Touze，黃旭明、葉勝玄、韓顏吉、陳劭其、江品頁、　洪舜治

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行政院國家科學委員會補助專題研究計畫 □ 成 果 報 告 ■期中進度報告

極低溫下電子相位相干時間之量測(1/2)
Electron Dephasing Time at Ultra-low Temperatures(1/2)

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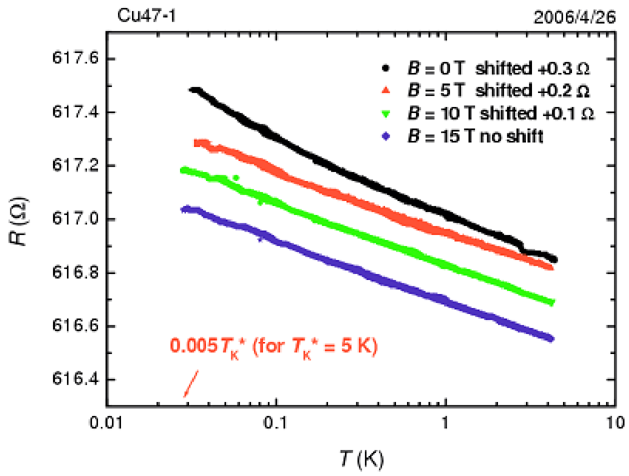
Electron Dephasing Time at Ultra-Low Temperatures

In the past year, we have been working on very low temperature measurements of the resistances and magnetoresistances of thin and thick $Cu_{93}Ge_4Au_3$ films down to 20 mK. The goal of this project is to study the electron dephasing (decoherence) time near zero temperature. In particular, we are interested in the very fundamental issue of whether the electron dephasing time in a mesoscopic metal should be "saturated" to a finite value or "divergent" to infinity as the temperature approaches absolute zero. A finite electron decoherence time at zero temperature would signify the failure of the Fermi-liquid picture in mesoscopic systems at very low temperatures. It would also imply the failure of the scaling theory of Anderson localization. Moreover, a finite decoherence time would greatly hinder the capacity and realization of quantum computation.

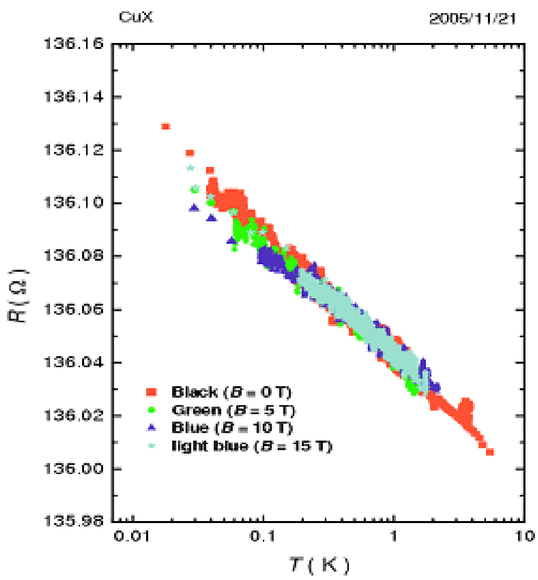
Our metal films were fabricated by DC sputtering deposition method. The level of disorder of the films was controlled by adjusting the deposition rate. The electrical-transport measurements down to 300 mK were performed at the Low-Temperature and Mesoscopic Physics Laboratory of Prof. Juhn-Jong Lin at NCTU. For ultra-low temperatures down to 20 mK, the electrical-transport measurements were carried out at the Low Temperature Physics Laboratory of Dr. Kimitoshi Kono at RIKEN, Japan.—This experiment is an international collaboration.

In our case, the electron dephasing time is extracted from the quantum interference effect of weak localization. The weak-localization induced magnetoresistance is fairly small (which is a quantum correction to the classical Boltzmann transport), and thus high-sensitivity detection is required. In particular, at very low temperatures, electron heating must be avoided. We have solved these problems and successfully achieved ultra-low temperature measurements on our films.

The figure below shows an example of the resistance of a 150-´ thick film measured down to 30 mK in zero field and in a magnetic field of 5, 10, and 15 T, respectively. Notice that the resistances have been vertically shifted for clarity. Assuming a characteristic Kondo temperature of $T_K \approx 5$ K for this film, our lowest measuring temperature corresponds to $0.005T_K$! Such a low temperature range allows us to investigate the Kondo problem and spin-flip scattering in detail. Whether spin-flip scattering contributes to the measured dephasing time is one of the controversies of the "saturation problem."



The figure below shows the resistance of a 6410-´ thick film measured down to 20 mK. The resistance is logarithmic in temperature all the way down to our lowest measurement temperature, suggesting that there is no electron heating. The resistance is insensitive a high magnetic fields, implying that electron scattering with dynamical defects (e.g., electron—two-level-system (TLS) scattering) could be important in this case. This issue requires further study.



The figure below shows a plot of the electron dephasing times for a series of thin films with various sheet resistances. Notice that the dephasing time for each film has been vertically shifted for clarity. This figure illustrates that the measured electron dephasing time is very weakly dependent on temperature. Around 6 K, there is a “plateau” (i.e., temperature independent electron dephasing time). Below about 4 K, there is an upturn in the dephasing time in strongly disordered films. The upturn reveals a systematic dependence on the level of disorder of the film. We believe that the weak temperature behavior of the dephasing time around 6 K is not due to magnetic spin-spin scattering. Instead, it is conjectured that electron—TLS interactions might be important in our samples, which governs both the temperature behavior of the resistance and the electron dephasing time.

In short, in the first year of this two-year project, we have successfully carried out electrical-transport experiments down to very low temperatures. Our results for the electron dephasing times are to shed light on the "saturation problem." Whether the electron dephasing time should saturate as the temperature approaches absolute zero is a fundamental issue in the condensed matter physics in general and is related to the possible realization of quantum computation in particular. In the coming year, we shall continue on more challenging measurements. Our preliminary results have recently been reported as a 40-minute **invited talk** at the *International Workshop on Quantum Coherence, Noise and Decoherence in Nanostructures*, held at Dresden, Germany, on May 22-26, 2006.