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Spin Diffusion in Superconductors through Mesoscopic Ferromagnet/Superconductor Interfaces

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Recently spin-dependent transport properties in various nanostructure systems have attracted much research interest. Information on the spin diffusion in nano-scale superconductors, in addition to the academic interest, is essential in designing spin-dependent nano-devices involving superconductors.

In this study we studied the spin diffusion in superconductors by observing suppression of the superconductivity in mesoscopic Al wires in contact with ferromagnetic Co wires. Several specimens consisting of (50-66 nm thick, 200-270 nm wide) Co wires and overlaid (70-80 nm thick, 270-400 nm wide) Al wires with different interfacial resistances were investigated. For a specimen, a spin-polarized current was applied to the Al wire from the Co wire through the interface and the electrical transport properties of a few mm-long portion of Al wire from the interface were measured by four terminal lock-in technique. The spin diffusion length was estimated by the measuring the finite voltage drop from the portion of the suppressed superconductivity of an Al wire, which extended over a few mm, increased with temperature, and diverged as temperature approached the superconducting transition temperature T_c of Al from below. The spin diffusion in the superconducting state of Al wires seems to be closely related to nonequilibrium relaxation of the quasiparticles into the paired state.

We also studied the effect of spin injection along the c-axis direction of $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals. To that end, we microfabricated mesa structure ($10\times4\times0.1\mu m^3$) on the surface of single crystals. About 80-nm-thick Co contact electrode of lateral dimension $10\times4\times0.08\mu m^3$ and 300-nm-thick Au electrode were then deposited in a four-terminal configuration on the mesa with predeposited 20-nm-thick Au layer. This structure was used to inject either an unpolarized or a spin-polarized current into the mesa of layered CuO_2 double layers. For an ordinary unpolarized-current injection through the Au electrode clear quasiparticle branch splitting from each intrinsic Josephson junction in the mesa was observed. In contrast, spin-polarized current injection through Co electrode caused pair breaking in the CuO_2 double

layers and thus led to the reduction of the superconducting gap and the interlayer Josephson critical current density. The latter effect indicates that the junction of Co/(20 nm thick)Au/Bi-2212 structure was effective for the spin injection into Bi-2212 material. In the presentation resulting spin diffusion characteristics in Bi-2212 single crystals along the c-axis direction will be discussed..