Spin Injection in F/N(S)/F Structures

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New electron transport effects, arising from the ability to create and manipulate non-equilibrium spins in metals, semiconductors and superconductors, is the subject of intense current research due to their recent applications in data storage as well their potential for spin-based logic and quantum computation. Much is still unknown about non-equilibrium spins in various materials. Here we report on our studies of spin injection and detection in Ferromagnet/Normal(Superconductor)/Ferromagnet nanodevices. We discuss spin relaxation in the normal versus the superconducting state as well as gap suppression by spin imbalance.

A multi-terminal device allowing an in-situ measurement of the spin injection efficiency (spin polarization in the injection point) and the spin diffusion length is shown in Fig.1. A non-local measurement configuration (Co voltage probes 2-3 outside the Co-Al current path 4-5) is used to detect the non-equilibrium spin accumulation in Al. Thus measured injection efficiency for our Co/Al-O/Al junctions and the spin diffusion length in Al are ~10% and ~1µm at 4 K, respectively [1]. In the superconducting state of the Al center electrode, a significant enhancement of the spin signal is observed at quasi-particle energies above the gap energy – a signature of slowed spin relaxation as compared to the normal state.

An interesting extension of the structure described above is obtained by reducing the volume of the N/S center electrode. This increases the effective spin accumulation, which is inversely proportional to the volume of the island, and leads to higher magnetoresistance (MR). For nano-sized islands, charging effects become important and the resulting device is a spin-polarized single electron transistor. A large change in the conductance of the device between the parallel and antiparallel states (MR~1, i.e. nearly an on/off switch) is expected when the amount of accumulated spin on the island is sufficient to suppress the superconducting gap. A change of only a few spins can drive the island normal/superconducting. Large MR is observed [2].


Fig.1. SEM micrograph and non-local spin diffusion signal in an F/N(S)/F device.