ABSTRACT

The Josephson effect refers to the coupling between two superconducting layers separated by a non-superconducting material, where supercurrent across the device is dictated by the phase difference between the two electrodes as $I = I_C \sin\phi$. I_C is the maximum possible critical current across the device and ϕ is the phase difference across the electrodes. The magnetic field sensitivity of the Josephson junctions (JJs) is embodied in ϕ, which is the phase difference between the two electrodes. Furthermore, when two of these devices are embedded into the parallel arms of a superconducting ring, a Superconducting Quantum Interference Device (SQUID) is obtained which is an extremely sensitive flux-to-voltage converter, useful in the areas of field sensing and quantum computation. In this thesis, we have conducted a few mutually independent experiments to show the applicability of the phase-sensitive Josephson devices (JJs and SQUIDs) to the area of spintronics.

In the first experiment, we integrated a (Pt/Cu) Rashba interface as a barrier into a planar Josephson junction. In the supercurrent carrying state of the Nb-(Pt/Cu)-Nb junction a finite quasiparticle current at the Pt/Cu interface generates a non-equilibrium spin density via the Rashba-Edelstein effect. We find that the magnetic moment of the Rashba-Edelstein spin density can introduce a phase into the Josephson junction which alters the magnetic field response of the junction. Therefore, with a suitable magnetic field history a Josephson junction can be biased with an arbitrary phase, without using any magnetic material. In a separate experiment, we have used Focused Ion beam lithography to optimize a vertical Josephson junction structure Nb-(CuMn)-Nb, suitable for the studies of the interaction between the Josephson effect and spin glass correlations. Even in the very dilute limits, Mn strongly suppresses superconductivity at the Nb-CuMn interface. We show that having a buffer layer of Au between Nb and CuMn overcomes this detrimental effect and allows for the fabrication of working Josephson junctions with much thicker CuMn, suitable for studies of RKKY interactions in the superconducting state of the junction. In another experiment, we studied the local magnetic response of a film of single molecule magnetic Mn12-acetate by growing the film on a Niobium nano-SQUID with 50 nm loop size. We were able to detect signatures of magnetization tunnelling in the SMM molecules close to the SQUID loop.