S/F/S Josephson junctions with a strongly ferromagnetic Ni barrier

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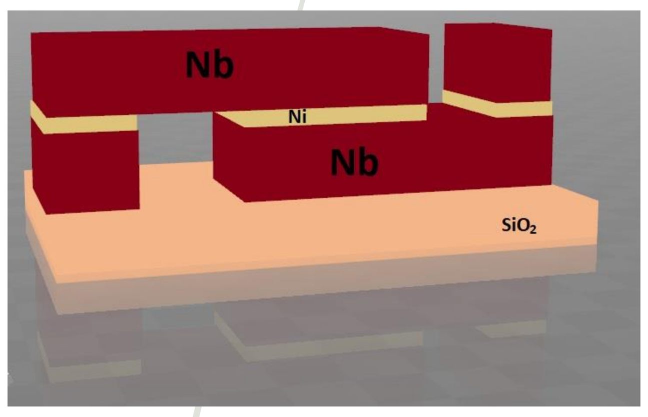
Here we study experimentally SFS junctions with a pure strong ferromagnet Ni between Nb layers. The aim is to investigate if the strong F-barrier is suitable for preparation of SFS junction with significant Josephson coupling. We fabricate and study nano-scale Nb/Ni/Nb junctions with sizes down to 120 nm and with different thickness of Ni-barrier (2-20 nm). Also was analysed magnetization and other characteristics of Josepson spin valves with different geometries and sizes in S/F1/N/F2/S junctions (thickness F1≠F2 and N(Cu)).

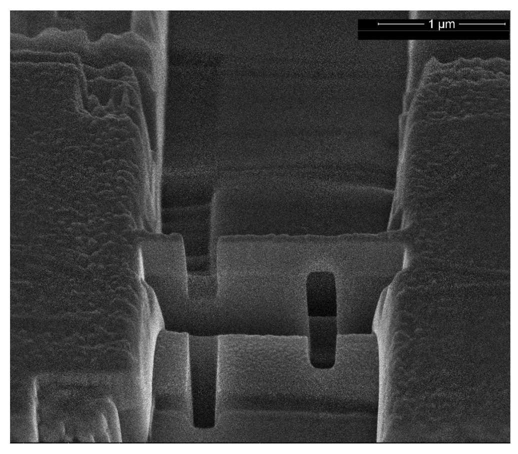
Sample preparation



a) Schematic 3D model of the junction

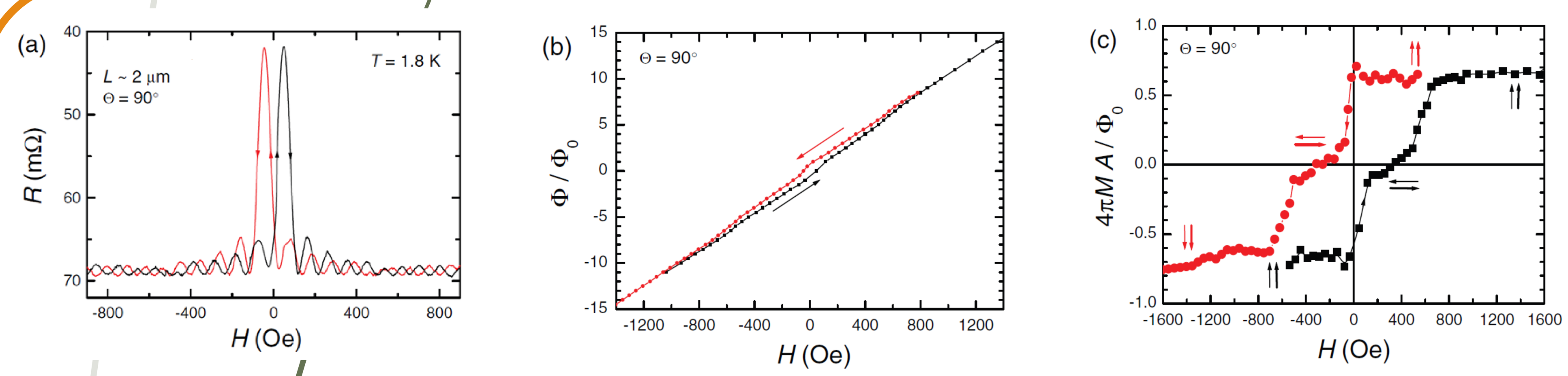
The layers were deposited by physical sputtering in three steps:
- deposit Nb (200 nm)
- magnetic spacer
- deposit (Nb 200 nm)

The variation in barrier thickness was achieved by angle-deposition. The contacts and leads were defined with photolithography and reactive ion etching ($CF_4 + O_2$). The junctions were fabricated by angled FIB cuts with sub-micron geometers.

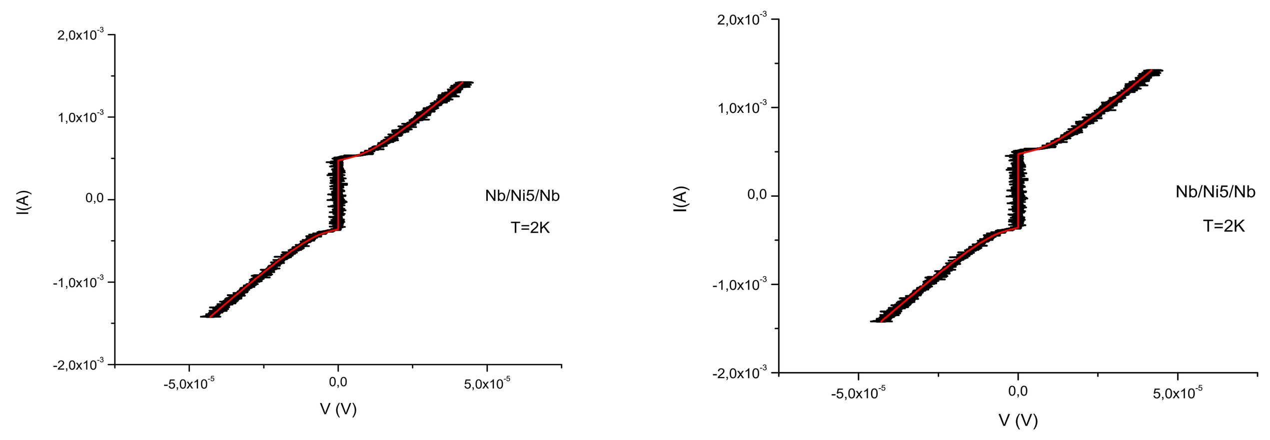


b) Tilted SEM image of a represented junction

RESULTS

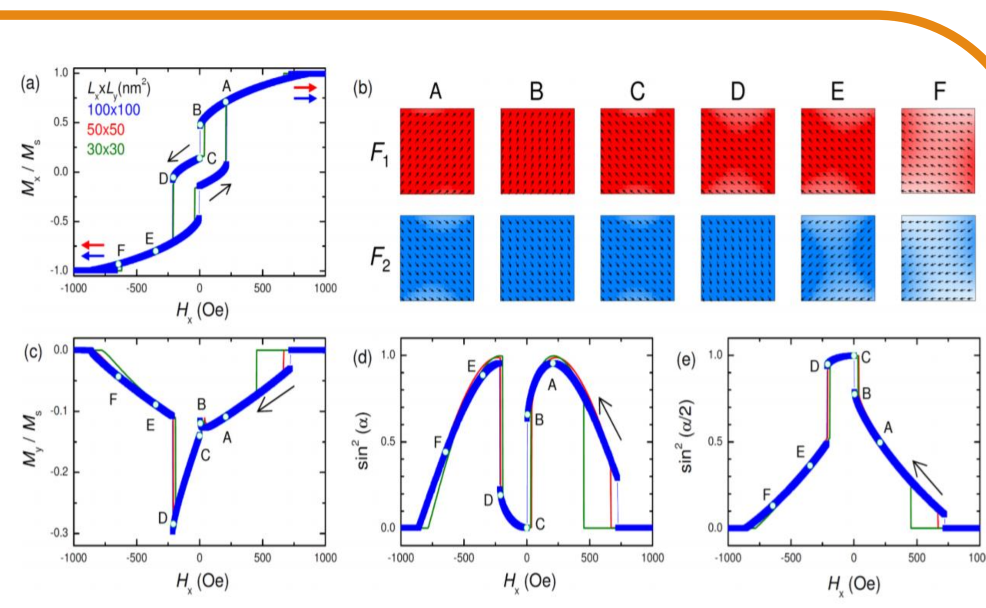


a) Fraunhofer modulation of R(H) at Θ = 90◦ for upward (black) and downward (red line) field sweeps. b) Magnetic field dependencies of the flux in the junction. Each point represents integer or half-integer Φ_0, corresponding to maxima or minima in R(H) from panel (a) c) Magnetization curves at Θ = 90◦ , obtained from the data in panel (b). The intermediate step with M ∼0 corresponds to the antiparallel state of the spin valve.



*Current-voltage characteristics: **a)** of Nb/Ni 5nm/Nb at 2K temperature*
***b)** Nb/Ni 5nm/Nb at 7K temperature*

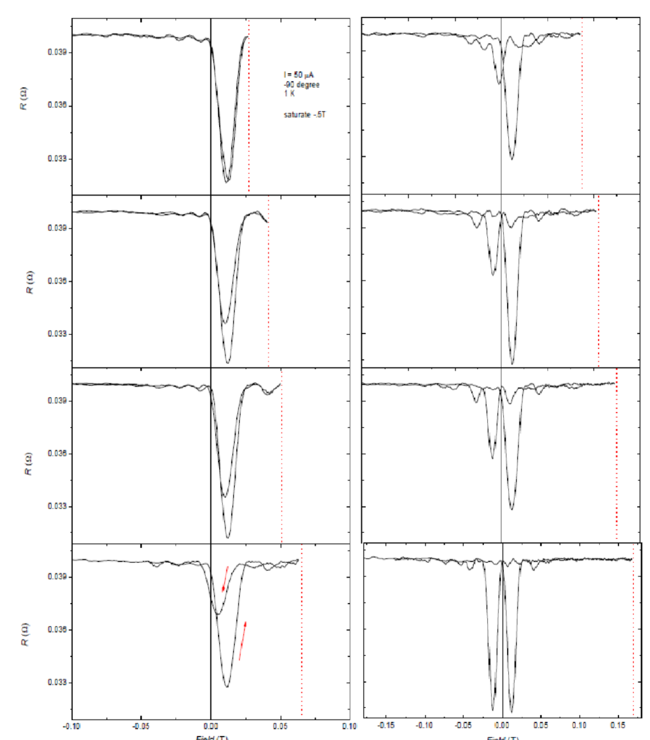
Characteristics of a monodomain "scissor" switching of square-shape spin valves Ni(5nm)/Cu(10nm)/Ni(7.5nm) of different sizes.



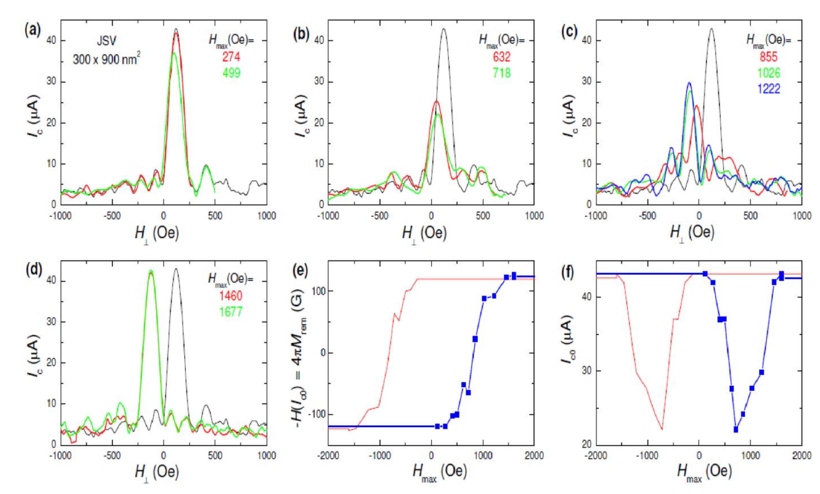
***a)** Calculated magnetization loop Mx (Hx). Note pronounced intermediate step CD, which manifests the magnetostatically stable antiparallel state of the spin valve.*

***(b)** Configuration of magnetization of the two ferromagnetic layers F1,2 at points A–F along the magnetization curve. A monodomain scissor like rotation of magnetization can be seen. **(c)** Perpendicular to the field magnetization My (Hx) for a downward field sweep. **(d), (e)** Show average values of sin2 of the angle and half the angle between local magnetizations in the two F layers. They represent relative amplitudes of the triplet (d) and the long-range singlet (e) supercurrents, respectively. Note appearance of the characteristic dissimilar double maxima of the triplet current (d) on both sides of the antiparallel state CD.*

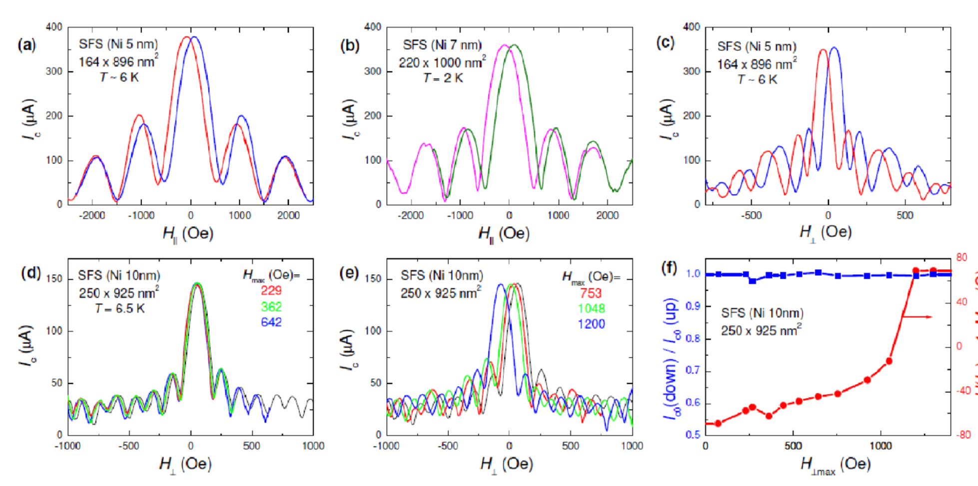
First order reversal curve (FORC)



Resistance of the junction vs magnetic field for upward and downward field sweeps at T=1K for S/F1/N/F2/S junction. (H|| long side)

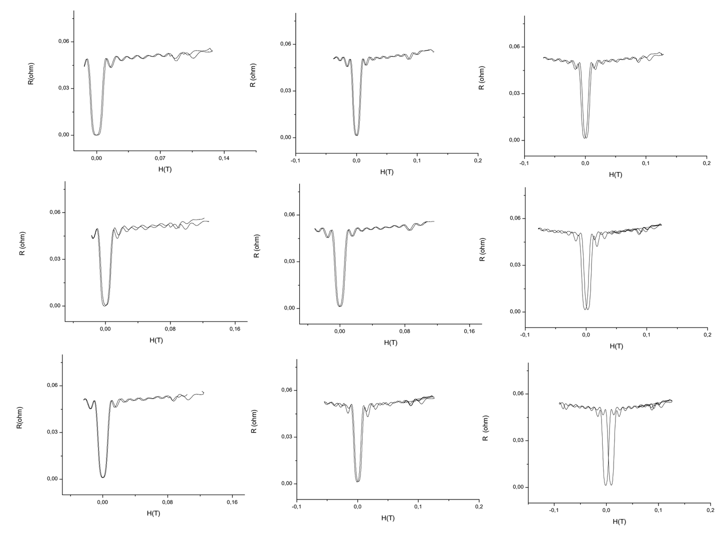


Characteristics of Ni(5nm)/Cu(10nm)/Ni(7.5nm) samples



Characteristics of SFS junction with different Ni thickness

Josephson psevdo spin-valve



Resistance of the junction vs magnetic field for upward and downward field sweeps at T=6.4K for a junction with Ni thickness of 10 nm.

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