# NANOSCALE SPIN-FILTERS BASED ON MAGNETIC $CoPt_3$-Au HETERODIMERS

*Giuseppe Maruccio*, Pasquale Marzo*, Roman Krahne*, Angela Fiore*, Teresa Pellegrino*, Vincenzo Piazza§, Fabio Beltram§, Roberto Cingolani*, Ross Rinaldi**
**National Nanotechnology Lab of CNR-INFM, Via per Arnesano, Lecce, Italy*
*§ Scuola Normale Superiore di Pisa, Piazza dei Cavalieri 7, Pisa, Italy*
giuseppe.maruccio@unile.it

Modern electronics has to face fundamental and technological limitations approaching the nanoscale [1]. In this respect, an interesting strategy to enhance the computational capabilities is to exploit novel phenomena and degrees of freedom and the intrinsic "binary" nature of the electron spin makes spintronic devices [2, 3] the ultimate candidate for ultra-dense data storage since they are expected to be smaller, more versatile, more robust and less power consuming than conventional charge-based electronic devices in addition to the important advantage of nonvolatility. Nevertheless, nearly all nanoelectronic applications neglect the spin, while so far spintronics mainly focused on bulk and typically involved ferromagnetic layers or diluted magnetic semiconductors. Here we proceed a "step forward" and miniaturize spin devices at the nanoscale, building them from elementary functional units.

More in detail, we realized tunnel junctions with magnetic nanoparticles as bridge, specifically heterodimers consisting of two inorganic $CoPt_3$ and Au domains joined together through a small interfacial area [4]. To fabricate the nanodevices, we employed a method we recently demonstrated for the simultaneous fabrication (without the need of expensive e-beam systems) of large arrays of nanojunctions working at room temperature [5]. The electrode gap is defined by optical lithography and a selective wet-etching of a AlGaAs/GaAs quantum well structure and controlled with nanometer precision by the thickness of the quantum well and of the deposited metal layer. A selective oxidation of the Al rich barrier reduces the bulk leakage current by six orders of magnitude and extends the applicability of the produced devices to room temperature functionality.

To interconnect the NPs, we functionalized the electrodes by hexane-1,6-dithiols and then immobilized the nanoparticles by incubation of the substrate in a diluted NP solution. After each deposition step, the devices were rinsed with the respective solvent. This procedure led to an immobilization and a stable attachment of nanoparticles. By diluting the colloidal solution (from $10^{-6}$M to $10^{-11}$M), we were able to control the number of NPs in the gap until to have single/few nanoparticles participating in the electrical transport. SEM images (not shown) confirm the immobilization of few nanoparticles. **Figure 1c** shows typical I-V and dI/dV spectra at 1.6 K of $CoPt_3$-Au heterodimers interconnected in the mesa nanojunctions. A number of steps are visible in the characteristics and different evenly spaced dI/dV peaks are observed with typical separation between adjacent peaks around 100 mV, a value close to that expected for NPs of similar dimensions.

The evolution of the differential conductance curves with the magnetic field is shown in **Figure 2a**, where a two dimensional map of the differential conductance as a function of the bias and the magnetic field is reported. We did not observe a clear Zeeman spin splitting nor a significant shift of the peaks when the magnetic field is increased from 0 T to 12 T. However, we observed a clear spin-filter effect [6]. In fact, we observed an increase of the magnetoresistance (MR) of the nanojunction as a function of the magnetic field (**Figure 2b)** as a consequence of the spin-dependent scattering of the not spin-polarized electrical carriers from the normal electrodes with those of the magnetic nanoparticles that have a preferential direction of the spin. Recently a similar spin-filter effect was reported by Liao et al. in nanodevices based on single magnetite ($Fe_3O_4$) nanowires [6]. We observed positive MR with a maximum value

around 10-12% at 0.4 T and 1.7 K (as a reference Liao et al. reported positive MR with a maximum value around 15% at 8 T and 120 K, decreasing at lower fields and higher temperatures). The lower dimentionality of our heterodimers, resulting in SET processes, adds further advantage to our system and allows to investigate the interplay between single electron tunneling and spin dependent tunneling. As a consequence, our approach opens the way to fabricate spintronic nanodevices, where the spin degree of freedom is employed to store, transfer and read information.

**References:**


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**Figures:**

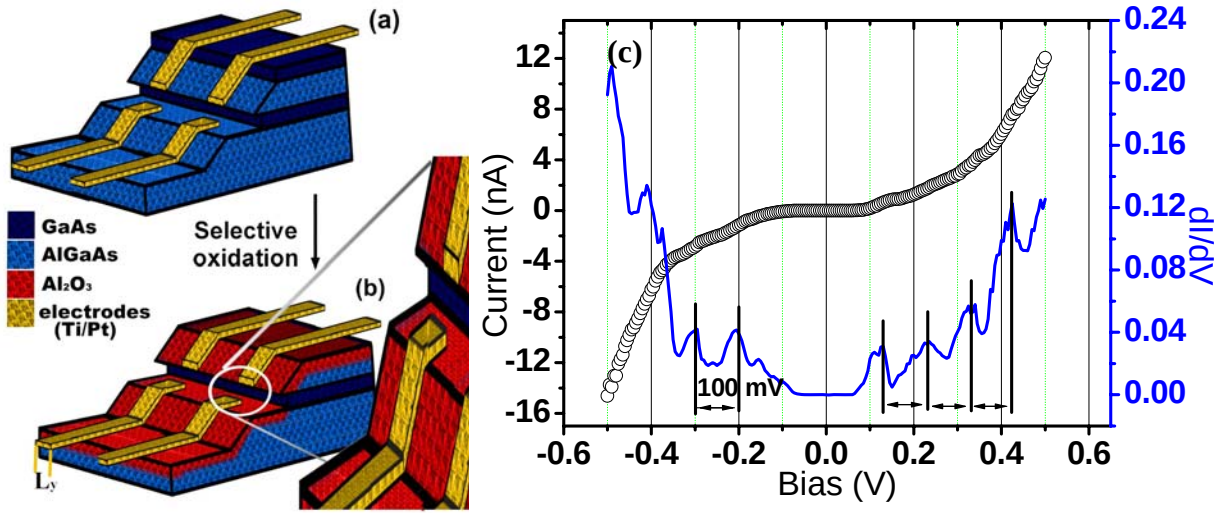


**Figure 1.** Schematics of the **(a)** unoxidized and **(b)** oxidized mesa nanojunctions used to fabricate the spin filter nanodevices. **(c)** Typical I-V characteristics and differential conductance spectra acquired at 1.6 K in devices consisting of mesa tunnel junctions bridged by $CoPt_3$-Au heterodimers.

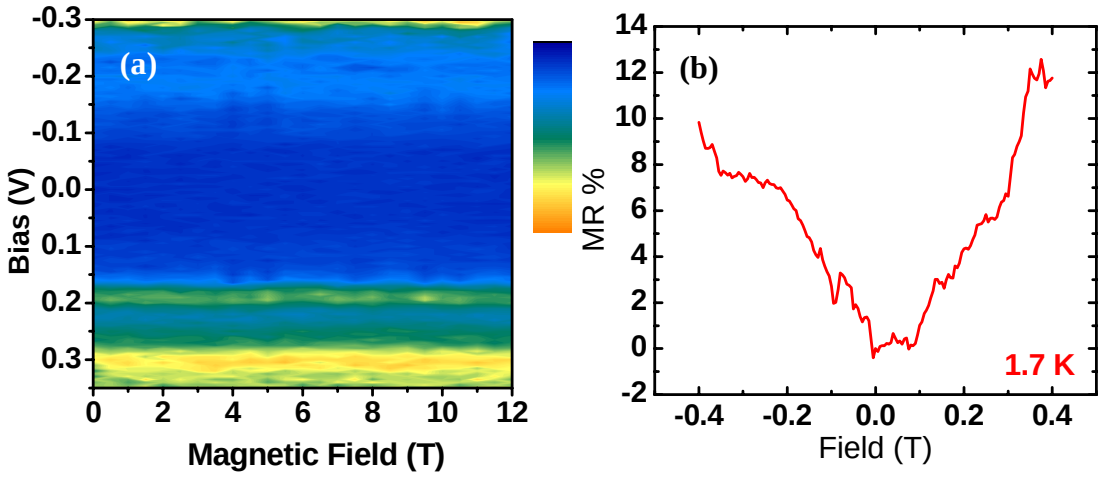


**Figure 2 (a)** Two dimensional plot showing the evolution of the differential conductance with the magnetic field. (b) Spin filter effect (magnetoresistance as a function of the magnetic field at 1.7 K) in nanodevices based on $CoPt_3$-Au heterodimers.