Highlights

Superconducting and correlated low dimensional materials and devices for quantum electronics and spintronic - 2019

Independent Geometrical Control of Spin and Charge Resistances in Curved Spintronics

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Spintronic devices operating with pure spin currents represent a new paradigm in nanoelectronics, with a higher energy efficiency and lower dissipation as compared to charge currents. This technology, however, will be viable only if the amount of spin current diffusing in a nanochannel can be tuned on demand while guaranteeing electrical compatibility with other device elements, to which it should be integrated in high-density three-dimensional architectures. Here, by using a combination of experimental investigations and theoretical analysis, we demonstrate that pure spin currents can effectively propagate in metallic nanochannels with a three-dimensional curved geometry. Our strategy relies on the possibility to grow metallic nanochannels with a geometrically driven strongly inhomogeneous nanometer-scale thickness, t. The size-dependent resistivity, ρ, of the metallic channels yields a different local behavior for the sheet resistance ρ/t and the spin relaxation length $\lambda \propto 1/\rho$. As a result, an appropriate engineering of the nanochannel thickness allows for designed nanochannels, where one can achieve independent tuning of the spin resistance without affecting the total charge resistance, and vice versa. This capability allows for the design of an element with simultaneous matching of spin resistance to a spin-based circuit, e.g., for efficient spin injection, and matching of charge resistance to a charge-based circuit, e.g., for efficient power transfer.

As a proof of concept, we demonstrate the modulation of spin currents and of charge currents in lateral nonlocal spin valves with ultrathin metallic channels directly grown on curved templates [Fig.1], which were created in the form of trenches in a silicon dioxide substrate by using used focused ion beam etching. Increasing the height of the trenches led to channels with increasing curvature, allowing us to systematically explore the effect of the channel geometry.

The obtained control of spin and charge resistances is fundamental to spintronics, as it enables practical magnetoresistance in two terminal devices and the concatenability and reduced feedback in spin logic architectures. These results laid the foundation for the design of efficient pure spin current-based electronics, which can be integrated in complex three-dimensional architectures.

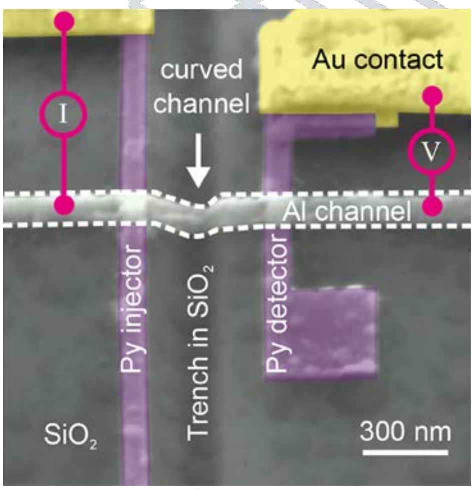

Fig. 1: Scanning electron microscope image of a spin valve device with a curved Al channel across a trench. The electrical connections for nonlocal spin valve measurements are also depicted.