Experimental demonstration of a persistent current

Generation of a spin-polarized persistent current in a non-magnet is investigated by introducing a non-uniform magnetic field from an epitaxial FePt nanopillar with perpendicular magnetic anisotropy. Such a spin-polarized persistent current has been theoretically proposed almost 20 years ago [1] but it has not been experimentally demonstrated to date. A device with such a current is expected to open up new research horizons as a spin source for quantum computation.

The quantum phases of charged particles in mesoscopic structures have been investigated intensively. Their interference and oscillatory behaviors have been induced by application of an external field [2]. Electrons traveling along semiconductor or normal metal rings threaded by a magnetic flux acquire a quantum dynamical phase that produces interference phenomena such as the Aharonov-Bohm (AB) [3], Aharonov-Casher [4] and Altshuler-Aronov-Spivak (AAS) effects [5]. In addition, An electron acquires an additional phase element known as the geometrical or Berry phase when the spin of the electron rotates during its orbital motion along the ring-shaped path.

Two sets of devices for the demonstration of a spin-polarized persistent current were fabricated using a new method. An epitaxial ferromagnetic FePt film was grown on a MgO(001) substrate by ultrahigh vacuum sputtering, followed by patterning into a nanopillar with the diameter of 120, 180, 220 and 270 nm in design by a combination of electron-beam lithography and Ar-ion milling. A polycrystalline non-magnetic Ag film was then grown and patterned into a nanoring with the inner diameter of 200, 260, 300 and 350 nm and the width of 100 nm in design in a similar manner. One set has 10 FePt nanopillars in a series with two electrical contacts on each end, allowing to measure the summation of spin-polarized persistent current generated by the 10 nanopillars [see Figs. 1(a) and (b)]. Another set has 1 nanopillar as we fabricated earlier [see Figs. 1(c) and (d)] as a reference.

These devices were measured using a four-terminal method, typically showing between 160 and 260 Ω. We then measured the devices at the Toshiba Cambridge Research Laboratory and found that the resistance is increased by almost 50%.

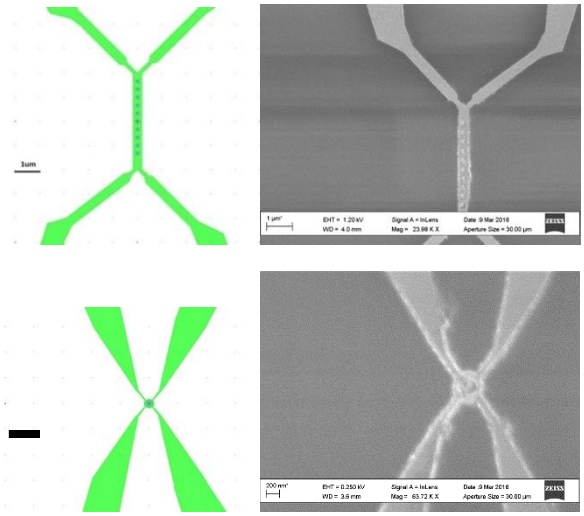

Fig.1 (a) Schematic diagram of 10 FePt nanopillar device with (b) the corresponding scanning electron micrograph (SEM). (c) Schematic diagram of 1 FePt nanopillar device with (d) the corresponding SEM.

In summary, we successfully fabricated and characterized a new quantum device consisting of a ferromagnetic FePt nanopillar enclosed by a nonmagnetic nanoring. We found the devices were very fragile against static charge. We plan to continue to fabricate these devices with a thicker and more robust electrodes to experimentally detect the spin-polarized persistent current.

References

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