Experimental Observation of a persistent current

We intend to demonstrate an alternative method of generating a spin-polarized persistent current in a non-magnet by introducing a non-uniform magnetic field from an epitaxial FePt nanopillar with perpendicular magnetic anisotropy. Even though such a spin-polarized persistent current was proposed theoretically almost 20 years ago [1], there has been no experimental demonstration to date. This device 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 were 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) and Altshuler-Aronov-Spivak (AAS) effects. In addition, when the spin of the electron rotates during its orbital motion along the ring-shaped path, the electron acquires an additional phase element known as the geometrical or Berry phase.

A new nanofabrication method has been developed to produce a quantum device on a MgO(001) substrate consisting of a non-magnetic nanoring (inner diameter: 200, 260, 300 and 350 nm in design) with an FePt nanopillar (diameter: 120, 180, 220 and 270 nm in design) inside by a combination of electron-beam lithography and Ar-ion milling. The nanoring is 150 nm wide and contains a 20-nm-thick Ag or Cu layer without any Cr adhesion layers onto the MgO substrate by an improved deposition technique. This allows us to avoid any spin-polarized electron flow in the Cr layer.

As shown in Fig. 1, the center nanopillar is designed to provide a nonuniform magnetic field in the nanoring in its remanent state after perpendicular saturation. Such a nonuniform field is theoretically expected to induce a persistent spin current in the nanoring [1]. Four contacts were fabricated near the nanoring for measurement of the induced current. In our improved design, with and without 10 nm off-set was introduced for the nanopillar to control the nonuniformity of the fields.

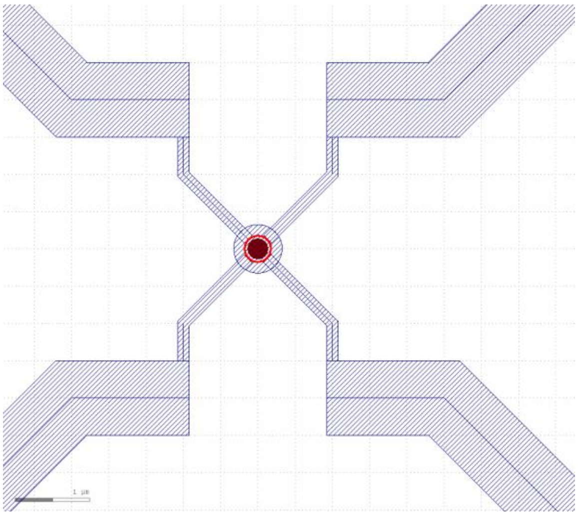

Fig. 1 Design of the quantum device fabricated in this project. The red dot represents the FePt nanopillar and the purple ring and wires represent the Ag and Cu nanowires.

In summary, we have successfully designed a new quantum device consisting of a ferromagnetic FePt nanopillar enclosed by a nonmagnetic nanoring. We have been measuring these devices using a dilution refrigerator at Osaka University.

References

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[2] Y. Imry, *Introduction to Mesoscopic Physics* (Oxford Univ. Press, Oxford, 1997).

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Full Name (Division Name or Affiliation)
E-mail: atsufumi.hirohata@york.ac.uk
http://www-users.york.ac.uk/~ah566/