Experimental demonstration of a persistent current

A new method to generate a spin-polarised persistent current in a non-magnetic nanoring has been theoretically proposed almost 20 years ago [1]. This method utilises a Berry phase induced in the ring due to a non-uniform magnetic field application onto the system. In this work, we have been developing a nanofabrication process to demonstrate such a persistent current at low temperature.

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: 200-350 nm) with an FePt nanopillar (diameter: 120-270 nm) inside by a combination of electron-beam lithography and Ar-ion milling. The Cu nanoring is 150 nm wide and 20 nm thick.

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 (device A). Four contacts are fabricated near the nanoring for measurement of the induced current.

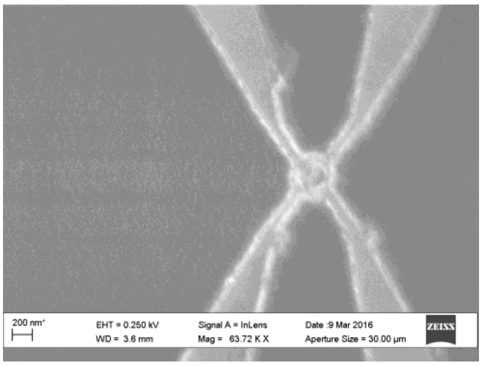

Fig. 1 Fabricated quantum device A, consisting of an FePt nanopillars surrounded by a Cu nanoring.

We have also fabricated a new device with 10 nanopillars in line surrounded by a Cu electrode as shown in Fig. 2 (device B). This is similar to the semiconductor device showing a quantum geometrical effect [3] and is anticipated to increase the signal-to-noise ratio for our measurements..

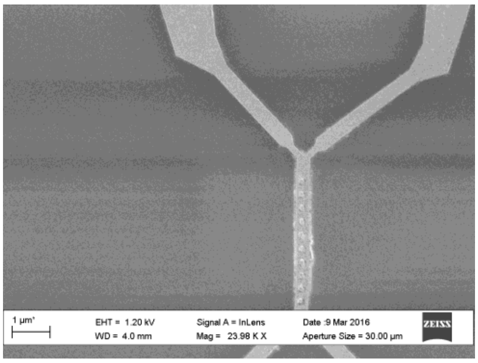

Fig. 2 Fabricated quantum device B, consisting of 10 FePt nanopillars in a line surrounded by a Cu electrode.

We plan to perform the low-temperature measurements at the Toshiba Cambridge Laboratory this summer. An improved device is expected to demonstrate a spin-polarised persistent current, which is absolutely different from the conventional spin-current generation methods. Our devices are also expected to reveal fundamental physics of the spin transport in a geometrically-confined structure.

References

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