Scanning probe microscopy stage for low temperature and high magnetic field imaging

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A compact scanning probe microscope for low temperatures and high magnetic fields is constructed in SCANSET. The scanning microscope is equipped with two nanoscale probes, a Hall probe and a single electron transistor, in combination with high magnetic fields and extremely low temperatures: this makes it possible to investigate a variety of phenomena in condensed matter physics, related for instance to the quantum Hall effect, heavy fermions, superconductors or topological insulators.

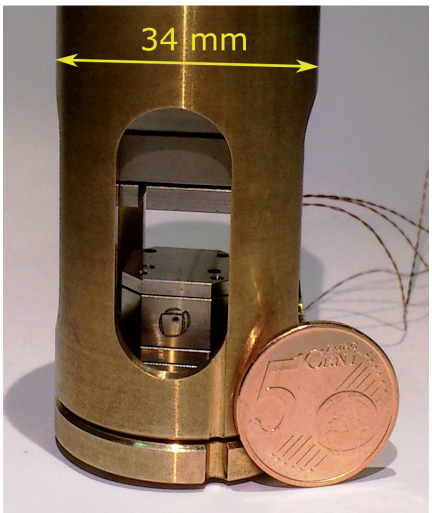

Fig.1: the compact scanning probe microscope.

We constructed an extremely compact scanning probe microscope (3.4 cm in diameter, Fig.1) with a rather large scan range (30x30 µm2) at low temperature. Due to this compact design the complete scan stage fits in the cold bore of an 18T superconducting magnet and is mounted on an Oxford dilution refrigerator (50 mK). We developped two different nanoscale scanning probes for the microscope in order to open a large spectrum of applications in the frame of LANEF.

First, we engineered micro-Hall probes at Néel (Fig. 2) which enables the microscope to map magnetic induction at the sample surface. Typical applications are the visualization of magnetic domains and the characterization of novel superconductors and superconductor/ferromagnet hybrid structures [1].

Second, a nanoscale scanning single electron transistor (SET), which is a very sensitive charge detector, was fabricated at Néel(Fig. 2). With the nanoscale SET on a tip we first mapped a well known charge distribution produced by electrostatic gates on a Si/SiO surface (Fig. 3b). Fig. 3a shows the SET current variations induced by these three gates measured in a distance of 200 nm. These measurements demonstrate a spatial resolution of the order of 200 nm and a very high electric field sensitivity.

The SET microscope is now used to probe locally the compressibility of electronic states in encapsulated graphene. Moreover we will investigate new compound superconductors, e.g. $PdTe_2$, with low critical temperatures (T_c<1.5 K) with the Hall probe option of the microscope.

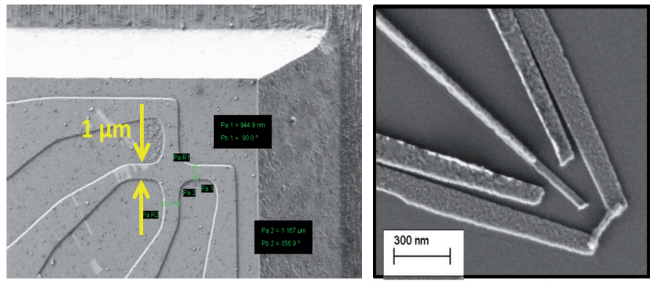

Fig 2: Micrometer sized Hall probe (left) and nanoscale single electron transistor (right) engineered close to a sharp edge of a substrate.

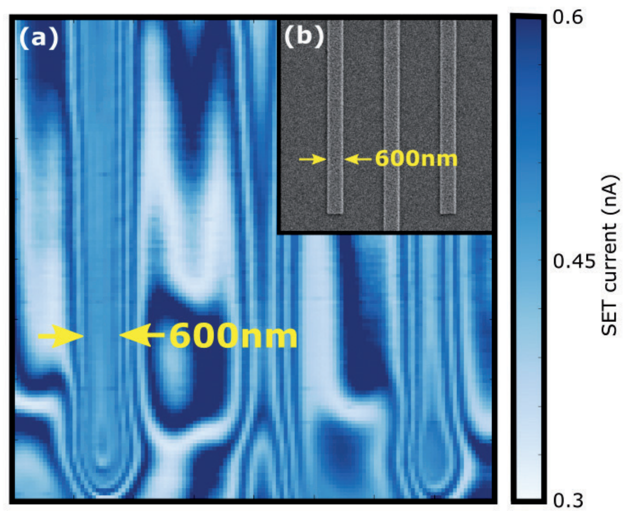

Fig. 3: (a) Map of the current through the SET measured in a distance of about 200 nm above three electrostatic gates (b).

OUTCOMES

[1] Quantitative magneto-optical investigation of superconductor/ferromagnet hybrid structures, Rev. Sci. Instrum 89, 023705 (2018).

Oral presentations: Roman Kramer at Vortex IX and X, Rhodes, Greece, 2015 and 2017.
Jorge Nacenta at C'Nano, Lyon, France, 2017

Poster presentation: Jorge Nacenta at Bienal de la Real Sociedad Española de Física, Santiago de Compostela, Spain, 2017

Collaboration: Prof. Alejandro Silhanek, Université de Liège, Liège, Belgium.

Leverage:

PhD: Jorge Nacenta (2015-2018) funded by Fondation Nanoscience.

3 year IUA chair for Roman Kramer.