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Feature Article: SQUID Application - STM-SQUID Microscope

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Magnetic microscopy is one of the SQUID application research themes. A session of the SQUID microscope took place at the International Superconductive Electronics Conference (ISEC) 2013, held in Boston. We reported on an STM-SQUID microscope, receiving high acclaim due to its uniqueness and high resolution.

The SQUID microscope presented here has two significant attributes; ① a probe with high permeability and uniquely sharpened sub-micron tip (Figure 1), along with a capability that can transfer the captured local magnetic fields on the sample surface to the SQUID, and ② the application of a DC voltage to the probe that allows a controlled and constant flow of tunnel current when the probe gets close to the sample surface. This behaves as a scanning tunneling microscope (STM), able to maintain a nano-scale distance between the sample surface and the tip of probe. In addition, it is simultaneously able to observe both the roughness and magnetic field of the sample surface.

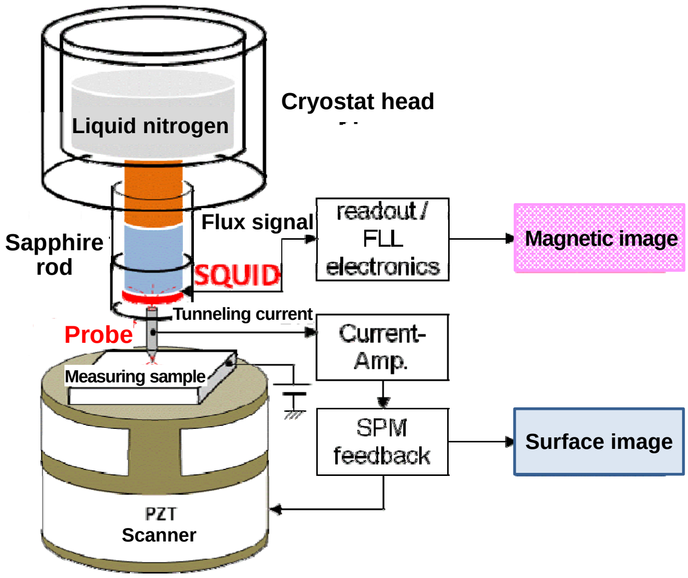

Fig.1 Conceptual diagram of STM-SQUID microscope

Figure 2 shows an arrangement of the SQUID, the needle and the sample of the STM-SQUID microscope A SQUID is attached to a sapphire rod, which is cooled to liquid nitrogen temperatures by placing it at the bottom of a liquid nitrogen vessel. One side of the probe needle is located near the SQUID which is in vacuum and its sharpened tip is located in outside of vacuum and close to the sample at room temperature.

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The sample is attached on a 3D XYZ piezo-scanner. The XY scanner scans the surface of the sample and its surface morphology and magnetic field can be observed by Z scanner.

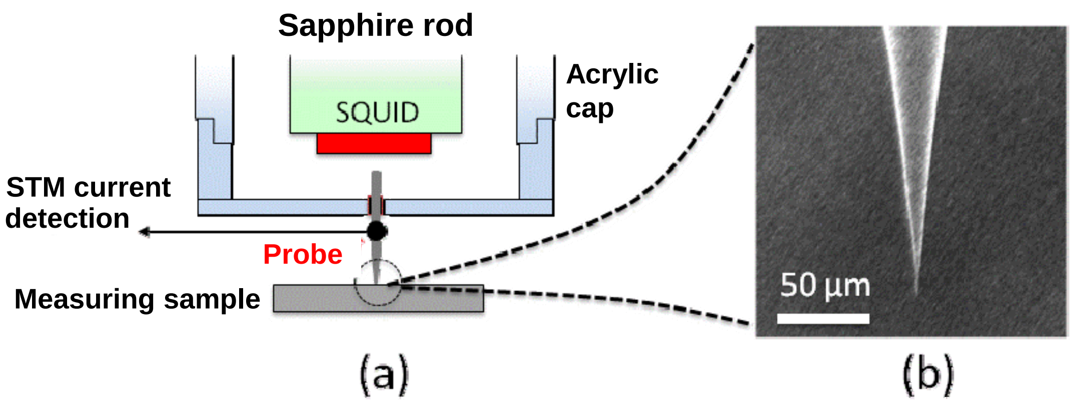

Fig. 2 Probe positioned for magnetic measurements and the SEM image of the probe tip

Figure 3 shows example images of the magnetic domains of Ni thin films (1μm film thickness), together with its STM image of the surface roughness, both of which were simultaneously observed. The surface is almost flat although a nano-scale roughness exists. The magnetic image clearly shows the magnetic domains of Ni thin films.

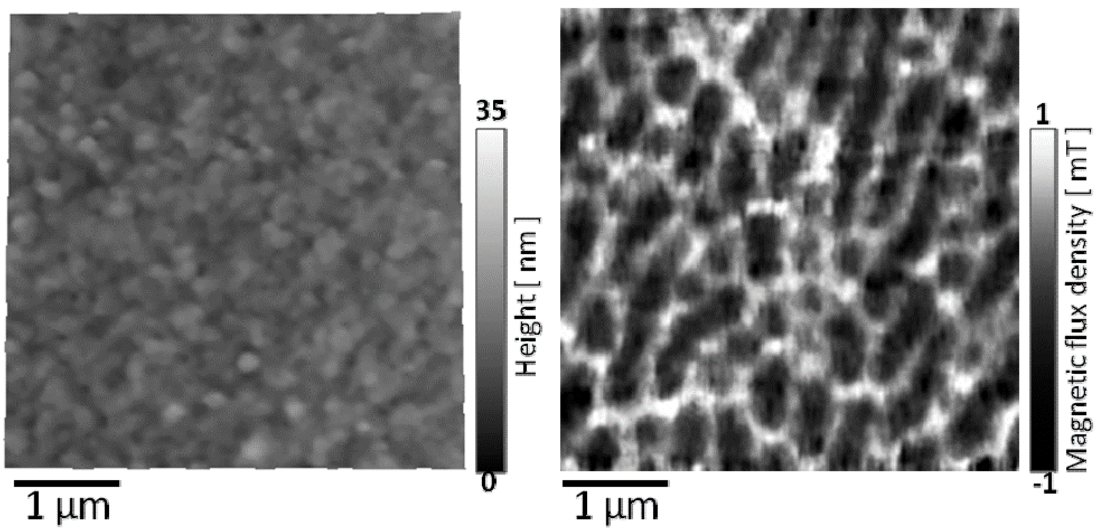

Fig. 3 STM image (left) and magnetic field distribution image (right) of the Ni thin film surface

There is a problem measuring insulating materials since the STM requires a tunnel current to flow between the probe and the sample, and thus the technique is limited to only conductive samples. In its place, an AFM-SQUID microscope is currently undergoing development and will progressively permit observations of insulating magnetic materials.

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Active R&D related to SQUID microscopes are currently being undertaken in Europe and the USA. The unique method of probe by Osaka University group in Japan can realize higher resolutions and simultaneously observe the surface morphologies of samples at ambient temperature. It therefore demonstrates its superior characteristics.

The SQUID microscopes have a promising future as research tools for the observation of magnetic materials exhibiting a variety of microstructures.

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