Development of Scanning SQUID Microscope for Studying Room Temperature Samples

Yusheng He [a,1], Hongsheng Ding [b], Xiaoming Yan [b], Fenghui Zhang [a], Shiji Han [a], Shiying Dong [a], Duo Jin [a]

[a] *Institute of Physics, Chinese Academy of Sciences, Beijing 100080*

[b] *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, Beijing 100080*

Abstract

Scanning SQUID microscope based on niobium junction dc SQUID has been developed. The SQUID is mounted inside the insulation vacuum of a cryostat, which is separated from room temperate samples by a 65 μm thick sapphire window. The spatial resolution of the microscope is about 100-150 μm and the magnetic field sensitivity is on the order of 3$\sim$60pT/$\sqrt{Hz}$ in magnetically unshielded environment. Various samples are being studied with the microscope.

Key words: Scanning SQUID Microscope; Room temperature samples;Magnetic image

1. Introduction

In recent years, there has been increasing interest in incorporating superconducting quantum interference devices (SQUIDs) into magnetic microscopes. Many kinds of scanning SQUID microscope have been developed for different purpose [1–4]. In this paper we will report the construction of a scanning SQUID microscope for room temperature samples and the primary experimental results.

2. Construction of the Microscope

The microscope is built using a thin film dc SQUID magnetometer with Nb-Al-AlOx-Nb tunnel junctions[4]. The SQUID is mounted horizontally and measures the vertical component of the magnetic field above the sample. To determine the field sensitivity, we measured the equivalent flux noise spectrum of the SQUID in flux-locked mode using HP 35665A signal analyzer. The flux noise ranged from $8\times10^{-5}\Phi_0/\sqrt{Hz}$ (Φ_0=2×10^{-15} Wb) at 1kHz to $2\times10^{-3}\Phi_0/\sqrt{Hz}$ at 1Hz, corresponding to a magnetic field sensitivity of 3$\sim$60pT/$\sqrt{Hz}$ in unshielded environment.

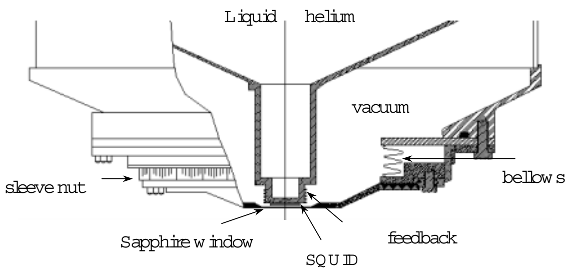

Fig. 1. The scheme of the bottom of the cryostat.

For measuring room temperature samples while keeping the SQUID below 9K, the essential task is to make a unique cryostat, as shown in Fig. 1. The body of the cryostat is made of brass and stainless steel. The SQUID is mounted at the lower end of a cold finger in vacuum jacket, where the cold finger

[1] Corresponding author. Present address: Institute of Physics, Chinese Academy of Sciences, Beijing 100080 E-mail: yshe@cl.cryo.ac.cn.

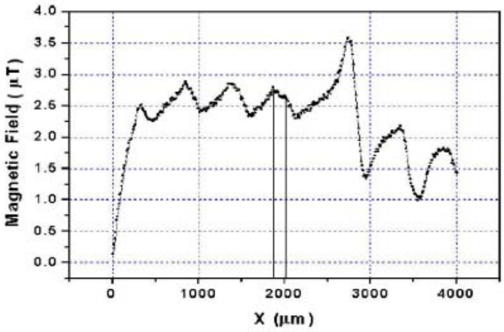

Fig. 2. Field distribution of the patterned thin film sample.

is thermally anchored to the liquid helium container. There is a thin sapphire window (65 μm thick, 7 mm in diameter) just below the SQUID. The position of the window can be adjusted by rotating a sleeve nut and a separation between SQUID and the window on the order of 30μm can be then easily achieved. With an evaporation rate of liquid helium at 0.1 liter/hour, this cryostat can keep working for more than 30 hours.

The sample is mounted on a stepper motor driven x-y stage with an attainable resolution of 0.6 micrometers. Because the stepper motors are about 50 cm away from the SQUID, the magnetic interference from the motors can be neglected.

3. Experimental Results

To demonstrate the spatial resolution of the mocroscope, a thin film sample of some pairs of parallel magnetic lines with different separations was scanned. Two lines with 140μm apart can be distinguished, as indicated by the two vertical lines in Fig. 2.

Images of ferromagnetic ink marked patterns on bank notes, such as US dollar bill, were successfully obtained by the microscope, in which magnetic field

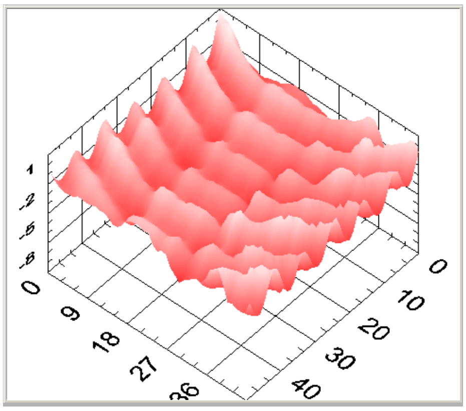

Fig. 3. Magnetic structure on the surface of a floppy disk.

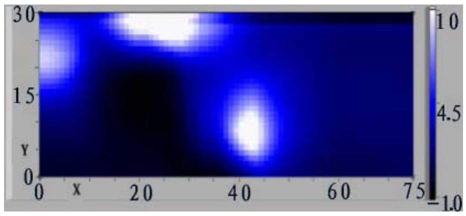

Fig. 4. Image of 3 indents in a stainless steel sample.

ranging from about -0.1μT to +1.3μT.

Magnetic structure of a piece double density 5.25-inch floppy disk is shown in Fig. 3, where the magnetic field varies from -2μT to 0.4μT. Both the tracks and sectors along tangential and radial directions respectively for data storage can be clearly seen.

Local damages, such as scratches and dents, as well as fatigue and mechanical stress can generate remnant magnetization in certain stainless steels. This can be easily detected with a SQUID microscope. The surface of 1-mm-thick stainless steel slab with several artificial dents was examined. Fig. 4 shows 2D-image of the magnetic field distribution on the slab surface in which three dents with white color caused by strikes with various power can be recognized.

4. Conclusion

A scanning low-T_c SQUID microscope for room temperature sample has been constructed. Measurements on various samples showed that the microscope operates very well in a normal laboratory environment without any static and radio-frequency magnetic shielding.

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