Three channel non-force magnetic SQUID microscope

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Abstract

The development of scanning magnetic microscope (SMM) without appreciable applied forces or magnetic excitations on specimens are presented. The magnetic microscope is intended to measure weak magnetic field distributions near the object surface at micron and sub-micron scales. Specifically, the SMM consists of three measurement units with respective output channels.

Key words: SQUID scanning magnetic microscope; ferromagnetic flux concentrator; spatial resolution

1. Introduction

Three types of magnetic microscopes (MM) are known till now: magnetic force microscope; magnetic SQUID microscope; magnetic Hall microscope. The peculiarity of any MM is special type of magnetic detector that are moved above a testing object (TO) surface. In the present article the description of a principle of operation and design of new three channel MM including improved SQUID measuring channels and a not cooled channel, constructed on the basis of a special fluxgate magnetometer is done. This MM allows to study both "warm" and cooled up to temperature of liquid nitrogen (77K) objects. Principal distinctive features of new MM are application of the ferromagnetic concentrator of a magnetic flux between SQUID and TO [1] and also in a fluxgate and usage of an special fluxgate having enough high sensitivity to a magnetic field of dipole sources and also high spatial resolution. Usage of the ferromagnetic needle as the concentrator allows to improve MM resolution, allows to use more sensitive SQUIDs, "to approach" effectively the SQUID detector to TO. New MM allows measurement of a vertical component of a TO magnetic flux.

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2. The description of a three channel MM design

The general view of MM channels and its basic units is given in figure 1. Channels situated in the middle and in the right are used for a TO study at $T = 300K$ and channel situated in the left is used for a TO testing at $T = 77K$. First two channels are combined by the moved two-axis table of the electromechanical scanner. The table with TO can be set under a central fluxgate channel or under a right SQUID channel. During TO research at $T = 300K$ a fluxgate channel is used first, that allows previously to examine area of 10x10 mm with spatial resolution up to 10 microns and with sensitivity up to 10^{-9} Tesla. After finding of the most interesting area TO can be moved under a right SQUID channel, which allows to examine a square having the size of 100x100 micron with the spatial resolution of 0,1-1 micron at sensitivity up to 10^{-12} Tesla. The SQUID is manufactured from a high temperature superconductor $YBa_2Cu_2O_{7-\delta}$ and has an operation

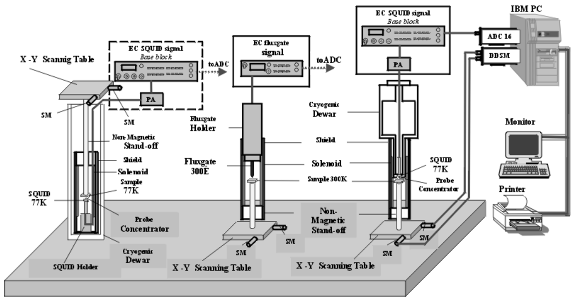

Fig. 1. Scheme of Magnetic Microscope. EC-Electronic Convertor, PA-Preamplifier, ADC 16-Analog Digital Convertor 16-bit Resolution, DDSM - Drive Device Stepper Motors, SM-Stepper.

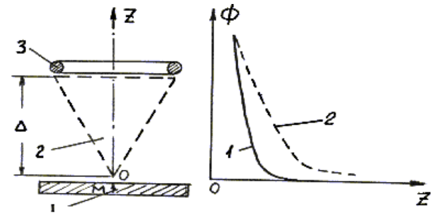

Fig. 2. a)The scheme of the magnetic flux detector (3) for measurement of dipole source field with magnetic moment M(1).The dashed lines shows the position and shape of the ferromagnetic concentrator (2). b) Dependence of the magnetic flux (Φ) through detector on its distance (Z) to a magnetic dipole (M) without the concentrator (1) and with the concentrator (2).

temperature close to 77K. The left-hand channel has as the detector also HTSC SQUID with the ferromagnetic concentrator. The channel parameters on sensitivity and spatial resolution coincide with parameters of right-hand SQUID channel. The TO holder is entered into the nitrogen cryostat of this channel from above it. The 2D-scanner are situated in the top part of the cryostat. The MM now are testing. The high spatial resolution of designed MM is provided first of all by application between the magnetic field detector and TO of the ferromagnetic needles as a magnetic concentrator . The detector and concentrator locations relatively TO is shown in figure 2a. Dependencies of the magnetic flux through the detector (for example, contour of an interferometer) on the distance to TO in a case without the concentrator and with the concentrator is shown in figure 2b. The gap Δ in case SQUID application as the detector corresponds to the wall thickness of the cryostat in which SQUID is arranged. This wall separate SQUID from "warm" TO having magnetic moment M. For provision of high channel parameters of the fluxgate channel the special design of the fluxgate sensor was applied (see figure 3). The fluxgate sensor looks like a closed ferromagnetic circuit with two pointed parts (curving radius for them is no more than 10 microns). One of these parts is detecting part of the fluxgate. It is approached to the TO surface up to 10 microns. The coils 1 and 2 serve for magnetization of the circuit with frequency f and coil 3 serves for registration of output voltage on frequency 2f. The area between a sensor tip and coil 3 serves as concentrator of a magnetic flux produced by TO. The developed design of non-force MM can be improved in future for spatial resolution enhance, since there is a capability to combine the principles scanning tunnel MM [2] and our scanning magnetic microscope. In this case concentrator of a magnetic microscope can be moved above a TO surface on a distance of 10-20 Å, measuring a geometrical relief of a TO surface and its magnetic relief in a atomic-molecular level.

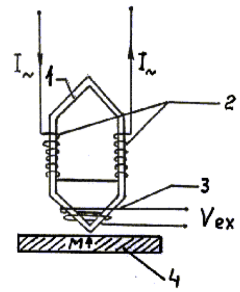

Fig. 3. Scheme of the fluxgate detector. 1- ferromagnetic circuit, 2-exitation coil, 3-coil for produce of the output voltage (Vex), 4-testing object.

Acknowledgements

The ILTPE authors wish to express their gratitude to STCU Foundation for support (Project N2266).

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