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Simulation of Flux Linkage Between the Pick up Coil of a Squid Magnetometer and an Axial Two Dimensional Manganese Stearate Sample

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Abstract: The possibility of magnetic order in a sample depends on its spatial dimensionality and order parameter components. Mermin and Wagner proved that no magnetic order, ferromagnetic or antiferromagnetic, exists in an isotropic Heisenberg, Ising or XY 2 dimensional (2d) magnet. However, Onsager and some other scientists proved that under certain conditions of temperature in Ising model and anisotropy, transition to order is possible in 2d' magnetic material. SQUID is the most modern and sensitive of all non-destructive evaluation instruments of all magnetic detectors. A 2d Mangense Stearate ($MnSt_2$) sample was fabricated, mounted and moved along the axis of a SQUID magnetometer. Magnetic flux simulation for the design of an ideal axial sample and holder configuration expected of such sample is hereby considered.

Key words: Magnetic flux, coil, $MnSt_2$, magnetometer, SQUID, simulation

INTRODUCTION

A pick up coil or gradiometer design used in coupling flux of a magnetic sample to a measuring system is based on certain essential characteristics, such as the physical size and location of the sample, sensitivity, impedance matching and optimisation of signal to noise performance between the gradiometer and the input coil to the measuring system such as SQUID. Wikswo (2007) also showed that a second order differential gradiometer is insensitive to distant background magnetic effects, uniform field and uniform field gradients.

SQUID (an acronym for superconducting Quantum Interference Device) characteristics and applications are well discussed by Greenberg (1998). The SQUID is usually biased to produce a periodic response related to the magnetic flux enclosed by the superconducting ring, with a periodicity of $\varnothing_0 = 2.07 \times 10^{-5}$ Wb. In the flux nulling method, the SQUID, system's response to the input flux is detected, amplified and fedback through the tank circuit to cancel out any externally applied changes in the flux coupled into it. The total flux in the SQUID is thereby kept constant. It is also by this means that these changes are measured in terms of the SQUID output $\varnothing_0$. The efficiency of the feedback loop depends on its slew rate. The maximum slew rate for the rf. SQUID is of the order of $10^6\ \varnothing_0\ \text{sec}^{-1}$. if the slew rate is expected like when a spurious magnetic effect arises from background materials, the device breaks lock and gives out a disproportional output.

Manganese atom is normally paramagnetic, but the order of the 2d $MnSt_2$ thin film is model dependent. The film will reveal its true order when properly magnetized and placed in an ambient of appropriate temperature that is also compatible with its size and structure.

Pomerantz and Segmneller (1980) used magnetic resonance method to study such magnetism and concluded that it was weakly paramagnetic. Several methods have been used to study properties of two dimensional magnetism (Leonard and Johnson, 1998; Fresand and Zummerman, 1998). However, SQUID has not been used for this purpose. A SQUID magnetometer to monitor the magnetic flux of a magnetized 2d $MnSt_2$ thin film was designed and constructed. However, the objective in this study is to consider the flux simulation expected of the magnetized sample and its substrate, as it traversed the axis of a second order pick up coil of the measuring system.

MATERIALS AND METHODS

A 200 layer 2d $MnSt_2$ thin film was deposited on both sides of an aluminised microscope glass coverslip by the Langmuir Blodgett (LB) technique (Asalou, 1983). The substrate together with the monolayer film was supported by a perspex holder, which had two major features. Mechanical protection of the fragile sample was provided by a thin copper rod. Details of the main parts of the Perspex holder system and sample, together with the associated net susceptibility (χ_{eff}), are shown in Fig. 1. The SQUID magnetometer complete system consisted of, a

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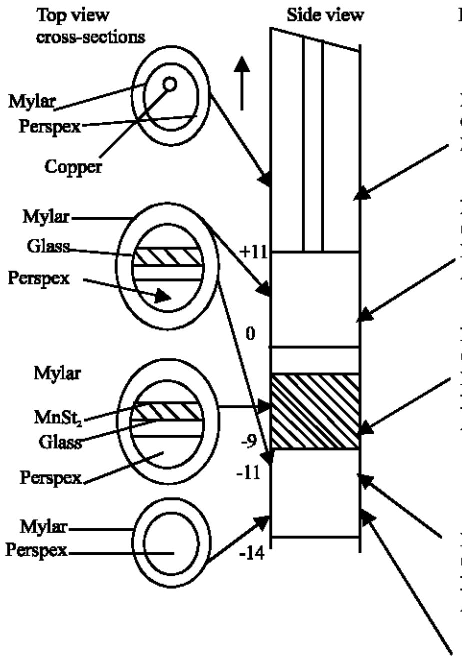

Material	χ@ 4.2 k unit of (10^{-6} S.I)	Fractional area	Effective
Perspex	-165.9	1	
Copper	+213.6	0.00156	-147.62
Mylar	+746.7	0.025	
Perspex	-165.9	0.33	
Glass	+213.6	0.0143	
Mylar	+746.7	0.025	
Aluminium	+24.4	7×10^{-5}	-36.25
Perspex	-165.9	0.33	
Glass	+213.6	0.0143	
Mn St_2	+3.24	1	-32.84
Mylar	+746.7	0.025	
Aluminium	+24.4	7×10^{-5}	
Perspex	-165.9	0.33	
Glass	+213.6	0.0143	-36.25
Mylar	+746.7	0.025	
Aluminium	+24.4	7×10^{-5}	
Perspex	-165.9	1	
Mylar	+746.7	0.025	-146.32

Fig. 1: Magnetic susceptibility strucure of support rod and sample region. For $MnSt_2$ $\chi = \chi_{eff}$

He^4 cryostat shielded by an Outer Vacuum Compartment (OVC) and a Nitrogen (N_2) jacket. Inside it, was a He^3 insert unit, which consisted essentially of three main sections; the sample access port, the Sorption Vacuum Compartment (SVC) and the Inner Vacuum Compartment (IVC). During operation the He^3 insert with the 2T superconducting magnet fixed symmetrically to the IVC tail, was mounted inside the cryostat where cooling took place. The sample could be introduced into the system through the sample access port at any stage of the operation. The 1.2 K pot and He^3 pot were situated inside the IVC, with the 1.2 K pot mounted such that the pumping line joining the SVC and He^3 pot passed through it. By this means, the SVC would pump the liquid He^4 in the 1.2 K pot, till its temperature dropped to 1.2 K and subsequent condensation of He^3 into its pot accompanied with a fall in temperature till it reached 0.3 K, its limit, would take place. The cryogenic magnetometer sensor of the hybrid SQUID used for the system, screened with lead and its niobium case, was mounted in He^4 bath and joined rigidly to its electronically operated rf head, mounted on top of the cryostat. The sensor was kept well away from the superconducting magnet at the IVC tail. The sample siphon top loading system, with the perspex holder and sample fixed to its end, was thermally anchored to both the He^3 moveable platform and the 1.2 K pot. Flux from the magnetized sample was then coupled by the second order pick up coil, also mounted inside the IVC tail, to the SQUID sensor. Details of the operation of the cryostat, together with its design and construction are described by Asaolu (Asalou, 1983). The cryostat was cooled initially with liquid N_2 and He^4 before cooling the sample finally to 0.3 kK.

Theory: From the reciprocity theorem, Zijlstra (1961) stated that the flux Ø linked with the pick up coil from a sample of length L, magnetization M, volume V is given by:

$$Ø = \mu_0 MVh(Z_1) \qquad (1)$$

where, h (Z_1) is the field produced at the sample position Z_1 by a current of 1.0A in the pick up coil, μ_0 is the permeability of free space and $Z_1 = L+Z+Y$, as in Fig. 2, which is a simplified form of Fig. 1, for the purpose of easy simulation. In the figure, the sample and its substrate are divided into three broad sections with susceptibilities, χ_1, χ_2, χ_3 with $\chi_1 = \chi_3 = 10^{-6}$ S.I Unit and $\chi_2 = 2 \times 10^{-6}$ S.I. Unit. If m_1 represents the magnetic moment per unit length of section one with susceptibility χ_1, then

$$m_1 = (\text{Volume of unit length})^* M$$

Following some manipulations, the change $Ø_c$ in flux signal as the sample and substrate move into the pick up coil from Z_0-Z can be shown to be:

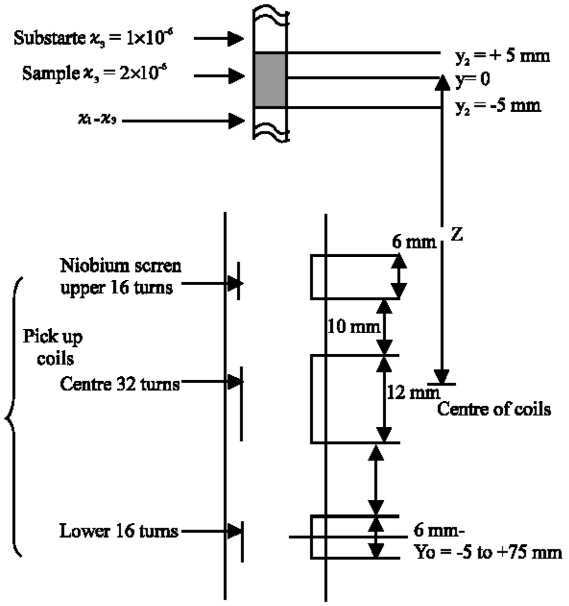

Fig. 2: Sunstrate and pick up coil arrangement

$$\phi_z - \phi_{zo} = \underline{\mu_0}(\Sigma\{0 - m_1\}[Fn.\{Z + L + y_0\} - Fn.\{Z_0 + L + Y_1\} + \{m_1 - m_2\} [Fn.\{Z + L + Y_1\} - Fn\{Z_0 + L + Y_1\} + \{m_2 - m_3\} [Fn.\{Z + L + Y_2\} - [Fn\{Z_0 + L + Y_2\} \quad (2)$$

Where, $Fn, (Z_1) = \frac{Z_1}{[Z_1^2 + a^2]^{1/2}}$

a = average radius of the current loop and Z_0= the initial position from which the sample was inserted into the coil (i.e., $0>Z>Z_0$). A Basic Computer programme to calculate $\varnothing_c$, taking various positions of loop coil into consideration was then drawn up.

RESULTS AND DISCUSSION

The result obtained as the sample carrier together with the $MmSt_2$.film sample is carried through the pick up coil is as sketched in Fig. 3. Z represents the distance of the center of glass substrate from the middle of the central coil and the perpex bottom end is 14 mm, below the center. With Z = 49.0 mm the top end of the upper rod at a distance of 13.0 mm away, which increases to a maximum at Z = 8.0 mm. when the rod end is just leaving the lower end of the coil. This end is now detected by the top end of the middle coil which is wound in opposition. Hence the output flux signal starts to decrease. The edge of the paramagnetic substrate is also at this stage moving through the upper coil and thereby aiding the flux decrease.

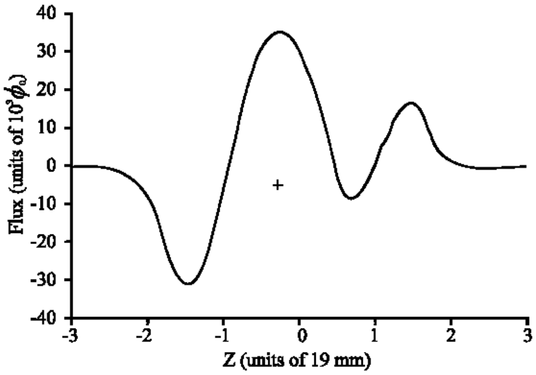

Fig. 3: Flux simulation for carrier/sample/subtrate as shown in Fig. 2

With Z = 5.8 mm above the top of the middle coil and the rod end 2.2 mm below the center of the coil a minimum signal is attained. Hence it the middle coil detecting the paramagnetic substrate which causes the signal to begin to increase as Z goes to zero.

At Z = 0, the end of the rod has just reached the top of the lower coil. the decrease in signal for small negative Z values is due to the movement of the sample region out of the middle coil. the shape and magnitude of the signal are also influenced by the diamagnetic end of the rod entering the lower coil to produce an increasing signal. The signal goes through zero and reaches a minimum due to the sample being sensed by the lower coil. At Z= -16 mm the rod end is -14 mm away and hence well clear of the coil system. Hence signal at lager negative Z values is thus due entirely to the sample moving through the lower coil and this is paramagnetic.

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