W-5

A sensitive magnetometer for analysis of the magnetic properties of materials at the pulsed fields up to 10 T

KRISS G.A. Kapustin*, Y.B. Kim, H.T. Kim, S.H. Cho

*Permanent address: RRC Kurchatov Institute, Moscow, Russia

1. Introduction

High coercivity of new rare-earth magnets prevents their investigations by VSM with conventional electromagnets. In this case an attractive way to achieve higher magnetic field is an application of pulse methods for field generation. This paper describes a pulsed magnetometer with an improved sensitivity of 5×10^{-4} emu at the fields up to 10 T. This magnetometer is designed for investigation of magnetic materials, especially thin magnetic films, at room temperature.

2. Magnetometer construction

Sensitive element of the magnetometer (Fig.1) is a modification of the three-axis-compensated one, which allows us to achieve highest sensitivity of pulsed measurements [1,2]. It consists of three pairs of the coils. Each of the pairs is used for the independent compensation of pickups induced by the three components of pulsed magnetic field. Both coils (2,3) of the main pair have a bore of 4 mm and contain 830 turns of 0.03 mm copper wire. Special care was paid to decrease unbalance of the main coils with a temperature variation. For this purpose the frames of the main coils are produced by vacuum pressing from a composite material, which contains 50% vol. of 10μ crystalline powder of Al_2O_3 (99.98% purity) and 50% of epoxy. Two additional pairs of 1-turn coils (not shown on the fig.1) are used for fine compensation of pickups induced by a transverse component of pulse field. The described above design of the sensitive element allows us to achieve a reproducible compensation level of 10^6 for the longitudinal field component and 10^4 for the transverse components without temperature stabilization of sensitive element.

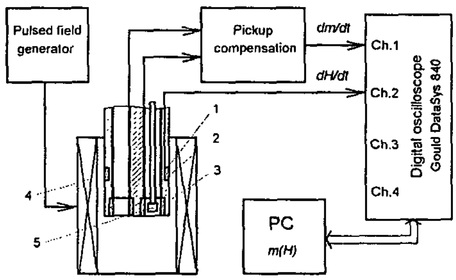

Fig.1. Schematic diagram of magnetometer

Moment of the sample (5) is calculated by a numerical integration of stored data after a subtraction of residual unbalance signal at the sample absence. Magnetic field is achieved by a numerical integration of the signal from the 5-turn coil (1) with thoroughly measured area. Accuracy of the field measurements is about 1 %.

For the magnetic field generation a capacitor bank is used with the full energy up to 18 kJ. The bank is discharged to a water-cooled solenoid (4) with a 25 mm bore, producing a damped oscillating magnetic field with the maximum amplitude up to 10 T.

Magnetometer sensitivity is calibrated (with 1% accuracy) by the known value of the saturation magnetization of pure (99.98%) Ni. At the field amplitude of 10 T the sensitivity reaches 5×10^{-4} emu. This value is comparable with sensitivities of other pulsed magnetometers at the same field amplitude: 10^{-4} emu [3], 5×10^{-4} emu [4], 10^{-4} emu [1,2]. This magnetometer has also an improved sensitivity to volume magnetization: up to 10^{-2} G for the sample volume of 60 mm^3. So high sensitivity at fields ≥10 T was available previously for vibration-type magnetometers [5] only.

3. Hard magnetic application results

As examples of the magnetometer application we show magnetization loops for two hard magnetic materials. Fig.2 represents hysteresis loops for the bulk sample of anisotropic NdFeB material, produced from MQPA-powder by a *Current-Applied Pressure-Assisted* (CAPA) process [6]. In Fig. 3 the hysteresis loop is shown for magnetic NdFeB thin film of 900 nm thickness

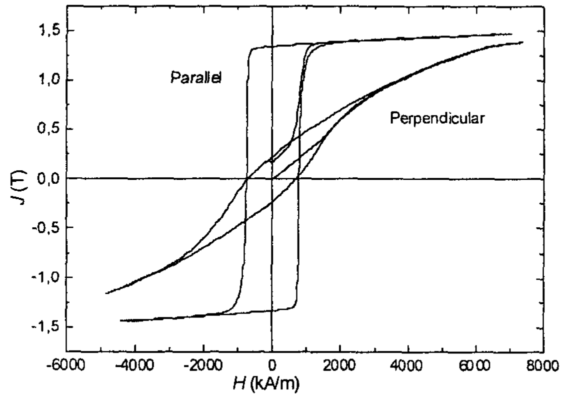

Fig.2. Hysteresis loops for anisotropic magnet

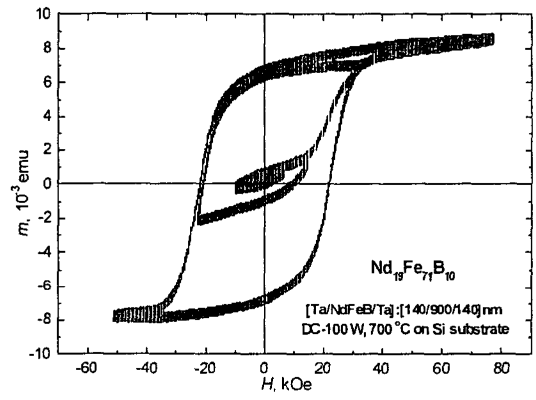

Fig.3. Hysteresis loop for NdFeB thin film

between two 140 nm Ta layers deposited by the DC magnetron sputtering method on the Si substrate. Here vertical thickness of line represents magnetization uncertainty caused by the irreversible part of the magnetometer compensation.

4. Acknowledgements

One of the authors (G.A. Kapustin) acknowledges the support by the Scientists and Engineering Exchange Program of KISTEP.

5. References

[1] G.A. Kapustin, Rev. Sci. Instrum. **70**, 82(1999).
[2] G.A. Kapustin, Instruments and Experimental Techniques, **43**, 263(2000).
[3] K. Yamada and M. Okabe, Physica B, **155**, 389(1989).
[4] A.S. Lagutin, J. Vanacken, N. Harrison, and F. Herlach, Rev. Sci. Instrum. **66**, 4267(1995).
[5] J.C. Picoche, M. Guillot, and A. Marchand, Physica B, **155**, 407(1989).
[6] H.T. Kim, Y.B. Kim, and H.C. Kim, J. Magn. Magn. Mater. **224(2)**, 173(2001).