R-VSM and MOKE magnetometers for nanostructures

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Abstract

Two highly sensitive magnetometers: resonance –VSM and MOKE for hysteresis loop measurements of nanostructures are described. They are simple from the electronic point of view as well as from mechanical construction, the cost of designed instruments is very low in relation to commercial devices. The example measurement of minor hysteresis loops of MTJ is discussed.

Keywords: magnetometry, VSM, MOKE, spin electronics
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In this paper we describe two magnetometers: resonance vibrating sample magnetometer (R-VSM) [1] and magnetooptical Kerr effect magnetometer (MOKE) [2] designed for hysteresis loop measurements of monoatomic layers and spintronics nanostructures. For obtaining full information about magnetization reversal process in magnetic multilayers both magnetometers should be used, because both methods are complementary. R-VSM measurements deliver information about averaged magnetization process from the whole volume of the sample, whereas magnetooptical information from MOKE magnetometer is local, limited by light-beam spot and depth with an exponential decay. Both arrangements are characterized by low cost and sophisticated electronics solutions. There are the following main advantages of R-VSM in relation to the Foner's VSM [3]: sample oscillates in parallel to the direction of external magnetic field, therefore it is always in the region of homogeneous field (in the Foner's VSM sample vibrates perpendicularly to the direction of external magnetic field), the configuration of pick-up coils in the form of small Smith coils is more favourable [4] than two pairs of pick-up coils connected adversely as in conventional Foner's VSM, and the oscillations of the sample are more stable due to controlled resonance frequency by amplifier with negative feedback. Block diagram of R-VSM is shown in Fig. 1. The thin film is attached to the end of a glass pipe-rod, which oscillates with mechanical resonance frequency of the rod-sample system (75 Hz). Oscillations are forced by piezoelectric transducer. The capacity bridge sensor (E) supplied by generator (50 kHz) delivers the reference signal proportional to the position of the sample. The measuring head (A) of R-VSM is universal and could work in the Helmholtz coils as well as in an electromagnet. The test measurements of hysteresis loops were performed on the sample prepared by MBE-technique, in the thickness range of 2ML to 4 ML of Fe [1]. The obtained sensitivity is better than 10^{-5} emu.

The arrangement for measurements of MOKE hysteresis loop is shown in Fig. 2. The system is especially recommended for rapid measurements up to 1500 field steps per second. Using Wollason prism and low noise

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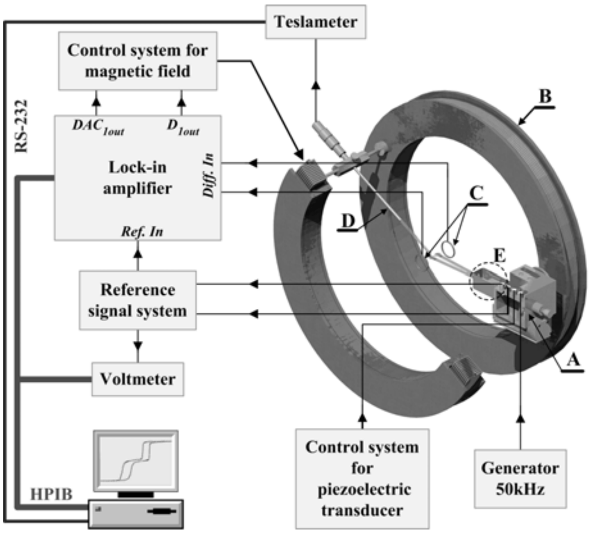

Fig.1. Block diagram of R-VSM; A - head, B – Helmholtz coils, C – pick-up coils, D - Hall probe, E – capacity sensor of sample position.

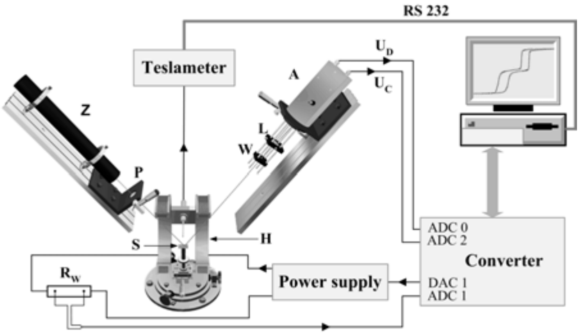

Fig. 2. Schematic layout of MOKE system; Z - laser, P – polarizer, W - Wollaston prism, L – lens, A – differential amplifier, H – Helmholtz coils.

differential amplifier [5], very high angle resolution of Kerr rotation (10^{-3} min) was obtained. The calibration of the Kerr rotation angle was performed on the Fe-wedge sample in the thickness range of 1ML to 50 ML of Fe [2].

The demonstrative measurements of the minor loop of MTJ with the structure of Ta(5)/Cu(10)/Ta(5)/NiFe(2)/ Cu(5)/IrMn(10)/CoFe(2.5)/Al-O/CoFe(2.5)/**NiFe(t)**/Ta(5), where **t** = 10, 30, 60 and 100 nm are shown in Fig. 3. The minor loop is always shifted in the direction indicating a ferromagnetic coupling between pinned (CoFe) and free (CoFe+NiFe) layers. The decrease of shifting field (H_s) and coercivity (H_{cf}) of the free layer with increasing NiFe thickness is observed (Fig. 4a). The interlayer coupling energy J = $1.04 \cdot 10^{-5}$ J/m^2 was obtained from the fit $H_s = J/t_f M_f$. The small hysteresis loop of underlayer permalloy (NiFe(2)) is measured only in R-VSM (Fig. 3a) and not in MOKE (Fig. 3b) due to light absorption. H_s is the same for measurements by R-VSM and MOKE and independent of the method and the frequency of the sweeping field (Fig. 4a). Due to domain wall damped motion H_c values are about 30 % higher for measurement by MOKE magnetometer with 1Hz sweep field (5 ms per step). The minor loop is very well reproduced by one domain model calculations (Fig. 4b).

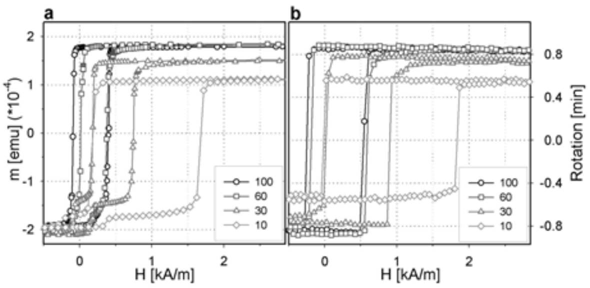

Fig. 3. Minor hysteresis loops of MTJ; change of field step every 5 s – R-VSM (a) and 5 ms – MOKE (b).

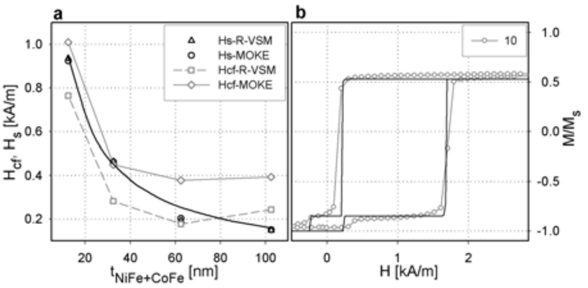

Fig. 4. a) Free layer thickness dependence of H_s and H_{cf} measured by R-VSM and MOKE; the solid line fitted for J=$1.04 \cdot 10^{-5}$ J/m^2 b) calculated (solid line) and measured by R-VSM (circles) minor loops of free layer.

In conclusion, the designed magnetometers are highly sensitive and due to simple operation method are recommended for hysteresis loop measurements of monoatomic layers and spintronics nanostructures. They are simple from the electronic point of view as well as from mechanical construction, the cost of designed instruments is very low in relation to commercial devices.

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