Proceedings

Magnetic Sensors Based on AMR Effect in LSMO Thin Films †

Olivier Rousseau, Stéphane Flament, Bruno Guillet, Marc Lam Chok Sing and Laurence Méchin *

Normandie Univ, UNICAEN, ENSICAEN, CNRS, GREYC, 14000 Caen, France;
olivier.rousseau@ensicaen.fr (O.S.); stephane.flament@ensicaen.fr (S.F.); bruno.guillet@unicaen.fr (B.G.); marc.lam@ensicaen.fr (M.L.C.S.)
* Correspondence: laurence.mechin@ensicaen.fr; Tel.: +33-231452689
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Abstract: In this paper, the potentialities of the manganese oxide compound $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) for the realization of sensitive room temperature magnetoresistive sensors are discussed. LSMO films deposited on various types of substrates having different magnetic anisotropies were patterned to form rectangular stripes of width 100 µm and length 300 µm. It is shown that, apart from the well-known colossal magnetoresistance contribution, the anisotropic magnetoresistance effects can be used to exhibit competitive performance at room temperature benefiting from the very low noise of LSMO thin films.

Keywords: magnetoresistance sensor; low frequency noise; manganites

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1. Introduction

The bypass of a damaged section of the spinal cord can be accomplished by detecting the neuronal signals before their reinjection into undamaged neurons. Among the various possible detections, magnetic detection has the advantage of being non-invasive unlike electrodes that measures the action potential of nerve impulses. In order to carry out the detection of the magnetic field of the neurons, which should be of the order of few nT or even below, the sensor must have excellent sensitivity at ambient temperature as well as being insensitive to external disturbances.

One major problem with low-field magnetic sensors is their low frequency noise, also named 1/f noise [1]. Thanks to the low 1/f noise the rare earth manganese oxides, such as $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), may then find important applications in magnetoresistive sensors [2]. In addition, LSMO exhibits a Curie temperature of about 350 K, which allows room temperature applications.

In this paper, we will present our advances towards the optimization of LSMO-based low-noise magneto-resistive sensors. We measured the anisotropic magnetoresistance (AMR) and the low frequency noise in patterned LSMO thin films. Some growth parameters such as the nature of the substrate, and the direction of the patterned stripes with respect to the easy magnetization axis, were modified in order to optimize the magnetic detectivity of the realized devices.

2. Sample Preparation

LSMO thin films were grown by pulsed laser deposition from a stoichiometric target onto $SrTiO_3$ (STO) single crystal substrates of different orientations, namely (001), (110), and vicinal 10°. The laser radiation energy density, the target-to-substrate distance, the oxygen pressure and the substrate temperature were 220 mJ, 50 mm, 0.35 mTorr and 720 °C, respectively. These parameter values were found optimal for producing single-crystalline films with smooth surface as judged by x-ray diffraction and atomic force microscopy. Curie temperature of the LSMO thin films were measured to be close to 340 K, typical for good quality films of this composition.

After LSMO deposition, a 200 nm thick gold layer was ion beam deposited on the films in order to make low resistive connections. The LSMO thin films were patterned by UV photolithography and argon ion etching to form lines. As shown in Figure 1, the mask enables the study of stripes of width W = 100 µm and length L = 300 µm. In each studied LSMO layers 4 stripes were patterned in different directions with respect to the magnetic anisotropy directions of the films, either parallel, perpendicular, at 45° or at −45°.

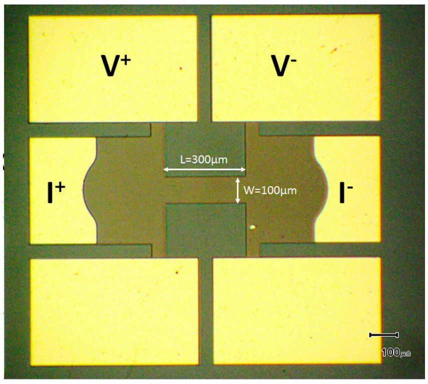

Figure 1. Optical microscope photograph of a 100 µm wide 300 µm long rectangular stripe patterned in LSMO thin films.

3. Magnetoresistance and Low Frequency Noise Measurements

The magnetoresistance and low frequency noise measurements were performed by using a prober equipped with 4 probes. The DC bias current I was applied by using a home-made low noise current source with high output impedance. The sample was connected to the current source using I+ and I− contact pads. The DC voltage was measured by using an instrumentation amplifier connected to V+ and V−. The voltage noise spectral density spectra were recorded using a spectrum analyser (HP3562). The in-plane magnetic field H is provided by a circular coil fixed to a parallelepiped core to concentrate magnetic field lines. Magnetic field was applied either parallel or perpendicular to the easy axis.

Different magnetic anisotropies could be induced in the LSMO films depending on the substrate type, as previously shown in [4]. The magnetoresistance versus magnetic field in the case of a stripe patterned in a 50 nm thick LSMO film deposited on STO (001) and aligned at 45° with respect to the easy axis direction is shown in Figure 2. Two kinds of effect can be distinguished: (i) a Colossal MagnetoResistance effect (CMR) for magnetic field values greater than ±1 mT and (ii) a low field magnetoresistance effect for magnetic field values in the −1 mT to +1 mT range. The first one leads to a small sensitivity with no interesting sensor applications. The second one is related to anisotropic magnetoresistance effects and shows promising values around zero field of about 1 $k\Omega \cdot T^{-1}$.

The noise spectral density was measured at different bias currents in the same stripe as shown in Figure 2. We could clearly observe two types of noise in all our samples: Johnson (or thermal) noise, and 1/f (or flicker) noise. The first one depends neither on the bias current nor on the frequency. It is due to spontaneous fluctuations induced by thermal excitations and it is related to the electrical resistance R of the sample (the voltage noise spectral density is given by the Nyquist formula $4k_BTR$, where k_B is the Boltzmann constant and T the temperature). The second one is a frequency dependent component in 1/f, which gives the name of “1/f”. Remarkably, for a bias current up to 220 µA no increase of the 1/f noise is observed, thus confirming the very low noise of LSMO thin films. The corresponding magnetic detectivity at room temperature is equal to 25 $nT \cdot Hz^{-1/2}$ at 1 kHz.

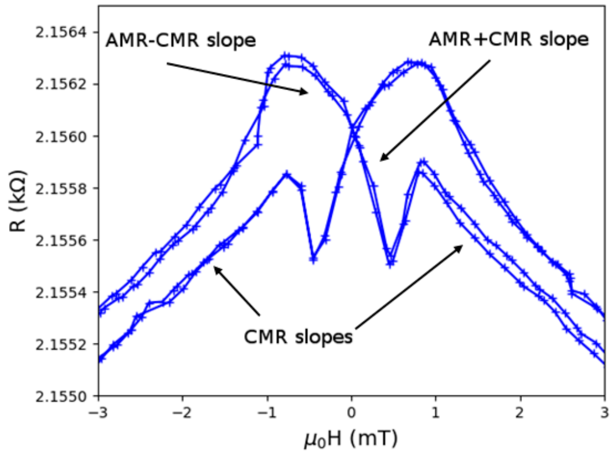

Figure 2. Electrical resistance of a 100 μm wide 300 μm long stripe patterned in a 50 nm thick LSMO film deposited on STO (001) and aligned at 45° with respect to the easy axis direction as a function of applied magnetic field at room temperature.

4. Conclusions

The low field magnetoresistance has been measured in different stripes patterned in LSMO thin films deposited on different substrates. Around zero field promising values of AMR could be measured. These preliminary results open the route towards optimization of the AMR in LSMO thin films by optimizing thickness, anisotropy fields, bias current and geometries in order to lower the measured magnetic detectivity at values of $nT \cdot Hz^{-1/2}$, or below.

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Conflicts of Interest: The authors declare no conflict of interest.

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