Low Frequency Noise Measurements in La 0.7 Sr 0.3 MnO 3 Thin Films on (100) SrTiO 3

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Abstract. We report measurements of the 1/f noise in 75 nm, 100 nm and 200 nm thick $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films deposited onto (100) $SrTiO_3$ substrates by pulsed laser deposition. The samples were patterned using photolithography into bridges with various widths (20 µm to 150 µm) and lengths (50 µm to 300 µm). The voltage noise spectra $S_V(f)$ clearly showed two regions: excess noise depending on the bias current with a 1/f behavior at low frequency and Johnson noise (4kTR where R is the resistance of the device) at higher frequency. In the investigated 10 Hz – 100 kHz frequency range no deviation from the 1/f behavior was noticed neither as a function of the temperature (300 - 400 K) nor of the bias current. We particularly investigated the validity of the semi-empirical Hooge relation in the 300 – 400 K temperature range, which means across the metal-insulator transition. The voltage noise density S_V in LSMO bridges was found to be proportional to the square of the bias voltage V in the whole temperature range, indicating that noise arises from resistance fluctuations. Unexpectedly the normalized Hooge parameter α_H/n was found not to be volume independent, indicating in a first approach that the noise source localization is not homogeneous. Finally a α_H / n value of 8×10^{-31} m^{-3} have been obtained, which is among the lowest level reported in LSMO thin films and promising for the realization of uncooled bolometers.

Keywords: 1/f noise, manganite, thin films
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INTRODUCTION

Among the perovskite manganese oxides $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films have attracted big interests because of their high Curie temperature (360 K), thus enabling room-temperature applications [1]. The LSMO epitaxial thin films can be considered as good candidates for the uncooled microbolometer fabrication for example [2]. The influence of the geometry of the devices on the measured electrical fluctuations in the films has not been investigated in detail so far. In the present study we measured the 1/f noise in bridges patterned in a 75 nm, 100 nm and 200 nm thick LSMO epitaxial thin films deposited onto (100) $SrTiO_3$. First, we will very briefly describe the sample preparation and the noise measurement set-up. Results are given and finally compared to literature.

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EXPERIMENTAL DETAILS

The LSMO thin films were deposited by pulsed laser deposition from a stoichiometric target onto (100) $SrTiO_3$ single crystal substrate. The deposition conditions were optimized for producing single-crystalline films with smooth surface as judged by X-ray diffraction (XRD) and atomic force microscopy (AFM). The XRD study indicated a highly (100) orientation of the LSMO films. A 500 nm thick gold layer was deposited by the RF sputtering technique to make low resistive four-probe connections. Then the LSMO thin films were patterned by UV photolitography and argon ion etching for forming bridges with various widths (20 µm to 150 µm) and lengths (50 µm to 300 µm). The contacts between the sample holder and the patterned film were finally made using aluminium wires by ultrasonic bonding. The electrical resistance (R) was measured in the 300K – 400K temperature range by the four-probe method. The normalized R(T) curves present the same shape for all the different geometries. The resistivity of the film calculated at 300K ranges in the 15-25 µΩ·m.

The four probe noise measurement set-up consists of a current source made of a low noise voltage source and a high output resistance value (more than ten times the resistance of sample under test) and a low noise differential preamplifier that provides a voltage gain of 10000. The spectral density of the amplified output noise signal was finally obtained using an external spectrum analyzer HP 3562A.

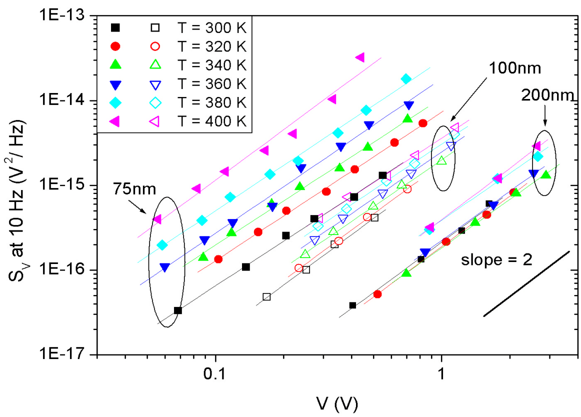

FIGURE 1. Spectral voltage noise density measured at 10 Hz for three LSMO bridges patterned in LSMO films of different thicknesses and geometries (75nm×20µm×300µm; 100nm×150µm×300µm and 200nm×100µm×300µm). For each sample the temperature was increased from 300K to 400K. A line with slope = 2 is shown as a guide for the eye.

RESULTS

Every bridge of each sample presented 1/f noise. No telegraph noise was noticed in the whole temperature range. The Hooge's empirical relation usually describes the 1/f noise in homogeneous sample [3]:

$$\frac{S_V}{V^2} = \frac{a_H}{n} \times \frac{1}{W \times f} \qquad (1)$$

where S_V is the voltage spectral density, R is the resistance of the bridge, V is the bias voltage (i.e. the bias current multiplied by the resistance value), α the Hooge's parameter, n the charge carrier density, Ω the sample volume and f the measuring frequency. α_H / n is defined as the normalized Hooge parameter.

In the following we shall verify the validity of the Hooge relation as a function of its main parameters. As expected in the case of resistance fluctuations figure 1 shows that S_V quadratically varies with V and, in addition, that the slope is independent of the temperature in the 300 – 400 K range. Secondly the normalized Hooge parameter α_H / n was calculated using equation (1) for all the measured bridges. It is plotted as a function of the volume of the bridge in figure 2. Closed symbols represent the 100 nm thick film and open symbols the 200 nm thick film. From the Hooge relation one would expect a volume independent value of α_H / n, which is clearly not the case. A more careful analysis shows actually that α_H / n is length independent but not width independent. Figure 3 shows indeed the evolution of α_H / n for different widths as a function of the temperature in the case of the 100 nm and the 200 nm thick LSMO films. We believe that this dependency can arise from the magnetic microstructures of the films. A study of the magnetic domain size as a function of the width of the bridges is therefore in progress. Figure 3 also remarkably shows that no 1/f noise peak was observed at the transition temperature, thus indicating a quite continuous transition contrary to what has been measured in $La_{0.7}Ca_{0.3}MnO_3$ films [4].

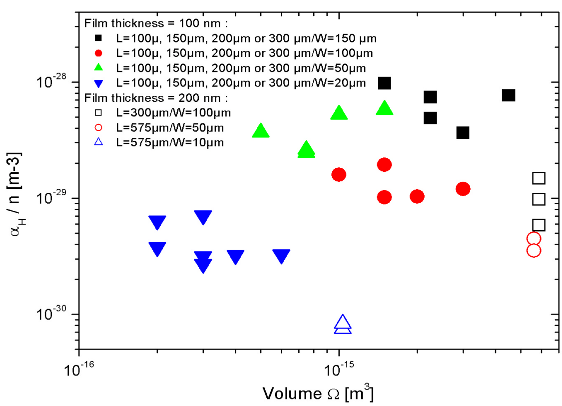

FIGURE 2. Normalized Hooge parameter as a function of the volume Ω of the bridge for the 100 nm thick and the 200 nm thick LSMO films.

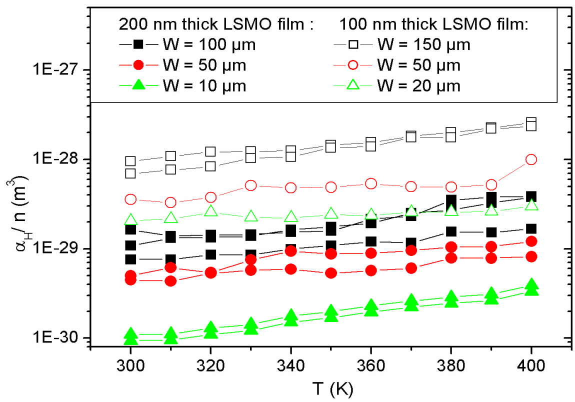

FIGURE 3. Normalized Hooge parameter as a function of the temperature for the 100 nm thick and the 200 nm thick LSMO film.

CONCLUSION

The 1/f noise level measured in the set of three patterned LSMO thin films was very low, even through the metal-insulator transition, which makes this material potential for bolometric and device applications. Our lowest α_H / n value is equal to 8 × 10^{-31} m^{-3} and was measured in the 10 µm bridge of the 200 nm thick LSMO film, which is among the lowest reported value for LSMO [5, 6]. The normalized Hooge parameter has been found to be length independent but not width independent. Magnetic domain imaging by Kerr microscopy as well as further noise measurements are now in progress in order to study the possible correlation between noise and magnetic domain structures.

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