A systematic study of the impact of geometry on the low frequency noise in patterned La0.7Sr0.3MnO3 thin films at 300 K

Sheng Wu, Bruno Guillet, Laurence Méchin, Jean-Marc Routoure

A systematic study of the impact of geometry on the low frequency noise in patterned $La_{0.7}Sr_{0.3}MnO_3$ thin films at 300 K

S. Wu*, B. Guillet†, L. Méchin† and J.M. Routoure(*)†

*GREYC, CNRS UMR 6072, ENSICAEN, University of Caen Basse Normandie 6, Bd du maréchal Juin 14050 Caen Cedex. France. *routoure@greyc.ensicaen.fr Phone (+33)231452722 / Fax (+33)231452698

†GREYC, CNRS UMR 6072, ENSICAEN, University of Caen Basse Normandie 6, Bd du maréchal Juin 14050 Caen Cedex. France. *routoure@greyc.ensicaen.fr / Phone (+33)231452722 / Fax (+33)231452698

Abstract. We report systematic measurements of low frequency noise performed at room temperature in $La_{0.7}Sr_{0.3}MnO_3$ ($LSMO$) thin films (thickness =150 nm) patterned with different lengths (50 μm to 300 μm) and widths (20 μm to 400 μm). Noise measurements were performed using two probe configuration, four probe configuration and even six probe configuration. Different 1/f noise contributions were observed for the film, for the current contacts and also for the voltage contacts. For the smallest devices, the noise spectral density of the film contribution does not follow the classical quadratic dependence with the DC voltage. The current contact contribution is due to current crowding at the metal/LSMO interface as already reported. The voltage contact contribution could be attributed to DC current circulation into the voltage contacts.

Keywords: 1/f noise, manganite, thin films
PACS: 73.50 T, 75.47 Lx

INTRODUCTION

Manganite thin films are promising for next generation devices and sensors[1]. In the $La_{0.7}Sr_{0.3}MnO_3$(LSMO) case, it has been demonstrated that high sensitivity bolometers can be realized [2, 3]. High performance room temperature spintronic devices, magnetoresistances as well as strain gauge could also be obtained due to the low value of the low frequency (LF) noise[4]. A systematic study of the impact of length, width and thickness and appropriated geometries on the low frequency (LF) noise level is therefore necessary for future sensor developments [5].

Systematic measurements of LF noise at room temperature in patterned $La_{0.7}Sr_{0.3}MnO_3$ ($LSMO$) thin films of thickness 150 nm, various lengths L (50 μm, 100 μm, 150 μm, 200 μm and 300 μm) and two widths W (20 μm and 100 μm) have been performed. The spatial homogeneity of the film was checked by resistivity measurements; magnetic characterizations versus temperature have revealed a Curie temperature close to 350 K and the temperature of maximal resistance was found to be about 390 K. These values are very close to the bulk ones proving the good crystallinity of the thin films. The noise measurements have been performed directly on prober using a Karlsuss PM5 with two, four or six probes.

EXPERIMENTAL CONDITIONS

Devices geometry

Deposition process as wall as the patterning technique of the devices can be found in [5]. An optical photography of one device is given in the figure (1). It consists of bridges with different lengths and widths with two current pads IP and IM and various voltage pads (V1 to V4 on one side of the bridge and V1' to V4' on the other side) which allows various device lengths. The metallic pads are realized using gold. The bridge lengths between V1 -V2, V2 - V3 and V3 -V4 are $100\mu m$, $50\mu m$ and $150\mu m$ respectively.

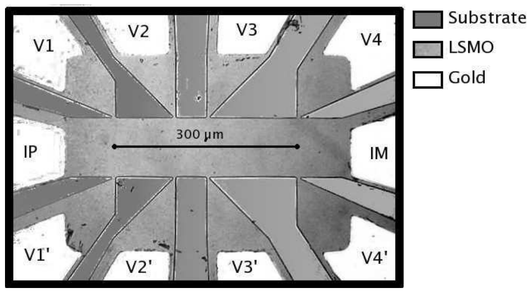


FIGURE 1. Optical photography of one 100 μm width bridge with the two current probes IP and IM and 2 x 4 voltage probes (V1...V4, V1'...V4') on each side of the bridge. The bridge lengths between V1 -V2, V2 - V3 and V3 -V4 are $100\mu m$, $50\mu m$ and $150\mu m$ respectively.

Two probe, four probe and six probe configurations

The experimental set-up mainly consists in one low noise high output impedance DC current source previously described in [6] and up to two identical voltage amplifiers. It is assumed here that the DC current source is ideal: its output impedance is infinite and its noise contribution is negligible. We also suppose that the noise contribution of the voltage amplifier is negligible and that the input impedance of the amplifier is very high so that no DC current flows in its inputs. The device is connected at the output of the DC current source and the DC voltage and the fluctuations are measured using the voltage amplifiers. A spectrum analyzer (HP3562A or HP89410A) is connected at the output of the amplifiers. It calculates the noise spectral density or the cross spectral density in the case of the six probe configuration.

For all the configurations, the DC current source is connected between IP and IM probes. The mathematical derivation is not described here but it can be shown that :

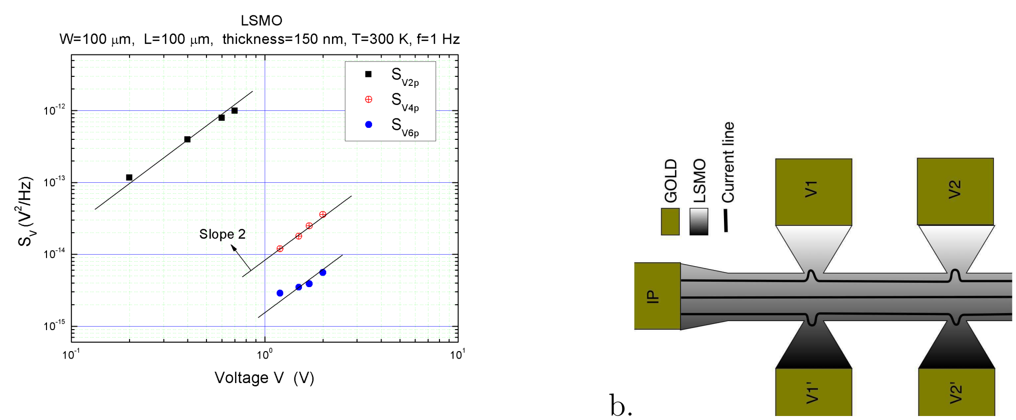
- in the two probe configuration, one voltage amplifier is connected to the IP and IM probes. *The noise contribution of the film and the current contact can be estimated.*

- In the four probe configuration, one voltage amplifier is connected to the voltage probes. *The noise contribution of the film and of the voltage contact can be estimated.*
- In the six probe configuration, two voltage amplifiers are connected on each side of the bridge. With a spectrum analyzer that calculates the cross spectral density, all the uncorrelated noise sources disappear and *only the contribution of the film can be estimated.*

The LF noise spectral densities or cross spectral densities of the devices were measured for different DC current across the film in the two probe (S_{V2p}), four probe (S_{V4p}) and six probe configurations(S_{V6p}).

RESULTS AND ANALYSIS

Only the results obtained for the device with $L = 100\ \mu m$ and $W = 100\ \mu m$ will be shown and discussed. The same behavior has been measured for the other lengths and widths. In figure (2a) are plotted S_{V2p}, S_{V4p} and S_{V6p} for $f = 1\ Hz$ versus the current in the device. It clearly shows that the three contributions for the film, the current contact and the voltage contact have to be taken into account.



a. b.

FIGURE 2. a. Spectral density measured in the bridge with $L = 100\ \mu m$ and $W = 100\ \mu m$ in the two probe (S_{V2p}), the four probe (S_{V2p}) and the six probe configuration (S_{V6p}). b. Sketch showing the left part of the device with the IP pad and the two first voltage pads and the path of the current lines. The current lines close to the edge of the bridge penetrate more or less deeper in the LSMO part of the voltage contact depending on the shape of the voltage contact and the width of the bridge.

For the contact contribution the current contact noise level has a very high value as already reported [7, 8]. It is found that the noise spectral density follows a quadratic current dependency. It has been attributed to current crowding at the edge of the gold/LSMO interface.

The film contribution does not follow a quadratic DC current dependency. This may be attributed to lorentzian contributions in the spectra. Whatever the slope is, the bridge contribution is 2 times smaller than the voltage contact one. It shows another time that published normalized values of α/n (with α the Hooge constant and n the concentration) may have been overestimated.

The last point concerns the fact that a LF noise contribution is found for the voltage contacts. In a first analysis, it is assumed that no DC current flows into the voltage contact since the input impedance of the voltage amplifier is very high: no 1/f noise should be found in the voltage contact. As shown in the figure (2b), the current line penetrates more or less deeper in the voltage contact depending on the shape of the LSMO part of the voltage contact. This point has been verified using numerical simulation of the current flow in the device. This current circulation in the voltage contacts creates voltage contact noise contributions. These noise contributions disappear when the devices are characterized in the six probe configuration because the noise contributions that appear on each side of the bridge are not correlated.

CONCLUSION

The impact of the geometry of patterned LSMO thin film with different lengths and widths on the LF noise has been reported. It has been shown that three contributions exist for the film, the current contact and the voltage contact. The last one has been attributed to current flowing more or less deeper in the LSMO part of the voltage contact. This study shows that in order to obtain the correct value of the film noise, six probe configuration has to be used. Moreover, in the frame of sensor development, the shape of the voltage contact has to be designed carefully in order to limit as much as possible the LF noise contribution of the voltage contact.

REFERENCES

1. (2008), URL `http://www.itrs.net`.
2. F. Yang, L. Méchin, J.-M. Routoure, B. Guillet, and R. Chakalov, *J. Appl. Phys.* **99** (2006).
3. M. Bibes, and A. Barthelemy, *IEEE Transactions on Electron Devices* **54**, 1003 (2007).
4. L. Méchin, F. Yang, J.-M. Routoure, B. Guillet, S. Flament, and D. Robbes, *Applied Physics Letters* **87** (2005).
5. L. Méchin, J. Routoure, S. Mercone, F. Yang, S. Flament, and R. Chakalov, *Journal of Applied Physics* **103**, 083709–083709 (2008).
6. J.-M. Routoure, D. Fadil, S. Flament, and L. Méchin, “A low-noise high output impedance DC current source,” in *Proceedings of the 19th International conference on Noise and fluctuations, ICNF 2007*, edited by M. Tacano, Y. Yamamoto, and M. Nakao, AIP, 2007, vol. 922, pp. 419–424.
7. C. Barone, A. Galdi, S. Pagano, O. Quaranta, L. Méchin, J.-M. Routoure, and P. Perna, *Review of Scientific Instruments* **78**, 093905 (2007).
8. C. Barone, S. Pagano, L. Méchin, J. Routoure, P. Orgiani, and L. Maritato, *Review of Scientific Instruments* **79**, 053908 (2008).