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Spin-polarized current effects in disordered $\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$ half-metal thin films

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Abstract. We have investigated by means of noise spectroscopy the transport properties of half-metal $\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$ (LBMO) thin films deposited on MgO substrates. A reduced metal-insulator transition temperature and a peculiar noise behavior is observed in the films grown on MgO substrates, when compared with similar films grown on SrTiO_3 substrates. In particular, a large increase of noise is observed below the metal-insulator transition temperature, associated to a current induced reduction of the excess noise level. This finding is explained in terms of the spin torque effect between regions with depressed Curie temperatures among the ferromagnetic metallic domains. The proposed theoretical model, taking into account the half-metal character of manganites, describes well the experimental data.

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1. Introduction

Presently, one of the major research fields in solid-state physics, and in particular within the area of strongly correlated electron systems, is represented by the study of manganese oxides [1, 2]. These materials exhibit a large variety of physical phenomena (Metal-Insulator transition, Colossal Magneto-Resistance, Half-Metallicity, etc.) and are ideal systems where to investigate basic condensed matter physics and possible new applications as magnetic field sensors, magnetic reading heads and magnetic memories.

Among the mixed valence oxides, the most investigated manganite series is of general formula $\text{La}_{1-x}\text{A}_x\text{MnO}_3$, with divalent alkali-earth ion $\text{A}=\text{Sr}, \text{Ca}$ and Ba . Compounds with strontium ($x \sim 0.3$) exhibit a high Curie temperature of about 360 K , which induces expectations for the realization of magnetic devices operating at room temperature. Recently, Hayashi *et al* [3] and Kanai *et al* [4] have reported an enhancement of the metal-insulator transition temperature in LBMO thin films, improving their potential for room temperature applications. Investigations of the noise properties of these compounds have been initially aimed at the evaluation of the intrinsic noise level, to compare their potential performances to those of already existing devices [5]. Moreover, noise measurements have been recently used as an effective tool to provide insight into the fundamental transport mechanisms in many different materials [6]. In the case of manganite compounds, for example, noise measurements have outlined different behaviors related to different strain states [7], strong similarities between the magnetoresistance and magnetonoise $1/f$ dependence [8] and peculiar phenomena related to the presence of intrinsic phase separation [9]. The so-called "fluctuation spectroscopy" has been proved to be a very informative method for studying the kinetic processes in condensed matter which can give important hints about fundamental physical phenomena, and unrevealing possible strategies to lower the intrinsic noise response, a mandatory requirement for the realization of high-performance devices based on manganites.

In order to better understand the mechanisms influencing the electrical conduction in half-metal mixed valence oxides, we have performed spectral density measurements on $\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$ thin films deposited on (100) SrTiO_3 (STO) and (100) MgO substrates. LBMO films are expected to experience a negligible strain effect when grown on STO. However, when grown on MgO , because of a very large in-plane lattice mismatch, LBMO experiences a strong strain that quickly relaxes after few unit cells by the inclusion of point defects, structural dislocations, etc. The electrical and noise properties of films deposited on MgO are quite different from those of otherwise identical LBMO samples grown on STO substrates. An anomalous current induced reduction of the noise level, is found in the MgO case when compared with the standard behavior observed in the STO case. A spin torque model, taking into account the half-metal character of manganites and applied between regions with depressed Curie temperatures among the ferromagnetic metallic domains, excellently describes the experimental data.

2. Sample preparation and dc electrical transport properties

All the analyzed LBMO samples have been deposited on (100) STO and (100) MgO substrates by pulsed laser deposition (PLD) technique using a KrF excimer pulsed laser source ($\lambda = 248 \text{ nm}$). Films have been fabricated from a stoichiometric target and using an energy density per laser shot of about 3 J/cm^2 . The depositions have been performed for 20 minutes with a laser repetition rate of 3 Hz , in an $O_2 + 5\%O_3$ atmosphere with a pressure of 1 Pa and with the substrate temperature at $670 \text{ }^\circ\text{C}$, resulting in films with a thickness of about 20 nm . Such a value is expected to be well above the "dead layer" threshold. Even though its physical origin is not completely understood, in many manganite systems a depressed conducting layer (i.e., dead layer) has been observed between film and substrate at the interface. This region (usually $2\text{-}3 \text{ nm}$ thick) is characterized by resistivity values of several orders of magnitude higher than the metallic manganite film. As a consequence, its contribution to conduction properties of thick LBMO films (such as in our case) can be neglected. Details on growth procedure are described elsewhere [10, 11].

X-ray diffraction (XRD) characterizations at $\text{Cu K}\alpha$ wavelength have been performed in the Bragg-Brentano configuration to study the structural properties of all the deposited samples. The whole set of the asymmetric XRD measurements are in agreement with a good in-plane matching and epitaxy between the STO substrate and the LBMO film, here after called "epitaxial LBMO" [10]. On the other hand, for the films on MgO, the XRD measurements show a relaxation of the substrate induced strain which takes place in the very first layers at the film/substrate interface, with the films growing epitaxial [11]. Rocking curve analysis have been also carried out. The results obtained by the comparison of the two spectra (for the STO and MgO substrates) reveal a mosaic spread of crystalline domains for the films on MgO, here after called "disordered LBMO". All other sources of structural disorder, such as domains size, granularity, and morphology, seem to be masked by this very large mosaicity [11].

Even though a detail structural investigation of these two classes of LBMO thin films was previously reported [10, 11], a qualitative description of the basic differences in the structural properties of these two systems is here provided. In the case of LBMO films grown on STO (panel a figure 1), because the "epitaxy" relation between film and substrate, all the LBMO unit cells are perfectly aligned among each other (STO substrate is not expected to induce a strain effect). As a consequence, the overall alignment of the out-of-plane axes is extremely good and narrow rocking curves are measured. Conversely, even though the LBMO films grown on MgO (panel b figure 1) show a general alignment among all the unit cells (still there is c-axis orientation and the in-plane four-fold symmetry is measured), it is inappropriate to refer at an epitaxy relation between film and substrate (the latter is in-plane rotated of about 45° with respect to the substrate in-plane crystallographic axes). In this case, because of fast structural relaxation, it is most likely the formation of structural defects, dislocations, etc. at the boundary with the MgO substrate and among the single LBMO unit

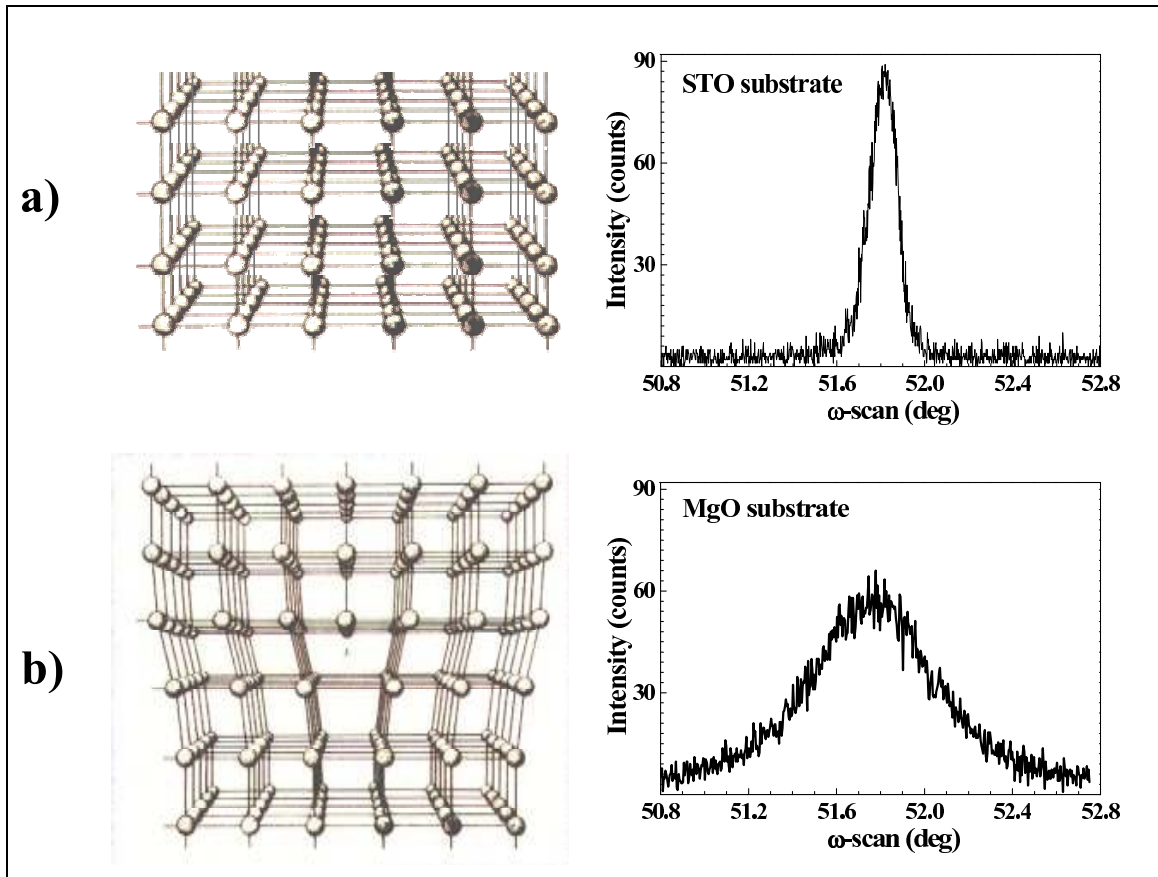


Figure 1. (Colour on-line) Sketch of the overall atomic alignment in LBMO films grown on STO (panel a) and MgO (panel b) substrates, respectively. Aside the two sketches, the measured rocking curves are reported.

cells. In other words, the semicoherent growth-mode of LBMO at MgO interface has to accommodate the mentioned structural imperfections, which are absent in the coherently-grown LBMO films on STO substrates. Such an accommodation might locally (on atomic/nanometric scale) occur through the stretching of some LBMO unit cells (as reported in figure 1), and/or through the insertion of point defects, and/or by the rotation of some neighbor LBMO unit cells, and so on. Nevertheless, all these imperfections are not enough to destroy the c-axis and in-plane oriented growth, and LBMO films grown on both the STO and MgO substrates show equal in-plane lattice parameters and the four-fold symmetry. The only observable effect is the wider rocking curves measured in the case of MgO substrates (see figure 1), visible due to the very high accuracy of the measurement technique. The overall alignment of all the LBMO unit cells is expected to be better in films grown on STO, where a coherent defect-free growth takes place. The LBMO regions of the films grown on MgO substrates, in which all these defects and dislocations occur, are characterized by worse structural, magnetic and conducting properties, compared with the optimal LBMO regions.

Standard four-probe technique with in line geometry has been used to investigate

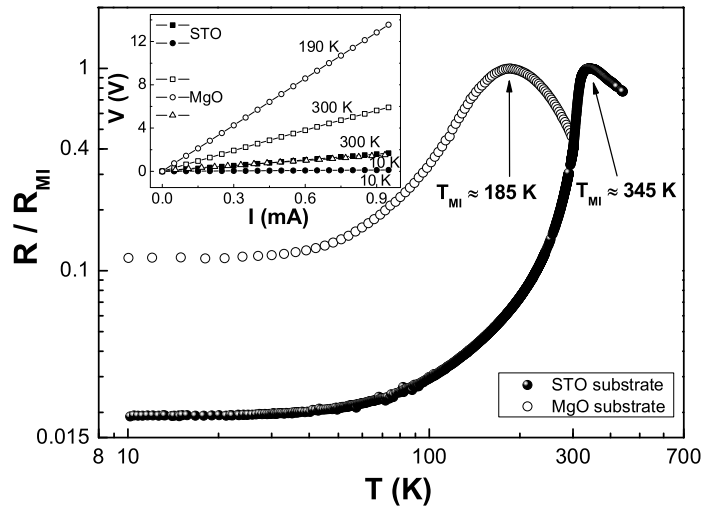


Figure 2. Temperature dependence of the normalized resistance R/R_{MI} for two investigated LBMO samples deposited on STO (full circles) and MgO (open circles) substrates. $R_{MI} = 7460 \Omega$ for STO and 14820Ω for MgO substrate, and is referred to the metal-insulator transition temperature T_{MI} (345 K for STO and 185 K for MgO substrate). In the inset I - V curves recorded at several temperatures for the same samples are shown.

the dc electrical transport properties of the samples. In order to prevent any surface damage, no photolithographic processes have been performed and the connections between the external circuitry and the thin films were made using ultrasonic aluminum wires bonding. All the measurements have been carried in a closed-cycle refrigerator, stabilizing the temperature with a GaAlAs thermometer and a resistance heater controlled in a closed feedback loop to better than 0.1 K. The sample temperature was measured by a Cernox resistor thermometer, in contact with the sample holder.

R - T and I - V curves have been taken in current-pulsed mode, measuring the voltage drop with a digital multimeter. Figure 2 shows the temperature dependencies of the normalized resistance R/R_{MI} for two $\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$ thin films deposited on STO and on MgO substrates. R_{MI} is defined as the highest resistance value, corresponding to the metal-insulator transition temperature T_{MI} . The most striking feature in figure 2 is the significant difference between the values of T_{MI} , despite the very similar deposition and post-annealing processes. For STO substrate, T_{MI} has the same value found in bulk material ($T_{MI} \approx 345 \text{ K}$); instead for MgO substrate, $T_{MI} \approx 185 \text{ K}$ is sizeably lower than the Curie temperature T_C [10]. The other strong difference in the R vs T curves in figure 2 is the different resistance reduction at low temperature. The LBMO film grown on MgO substrate shows a reduction of two orders of magnitude in the resistance, whereas the film grown on STO substrate shows three orders of magnitude reduction. Despite of the differences in the resistivity behavior, linear I - V curves have been found in all the temperature range analyzed (10 – 300 K) for both the LBMO systems. The measurements have been performed fixing the sample temperature and

using current pulses of 2 *ms*. The inset in figure 2 shows *I-V* characteristics at different temperatures. An Ohmic behavior is clearly evident for the two LBMO samples at all the measured temperatures. In overall the dc electrical transport measurements performed on the two different LBMO systems show a metal-like behavior, with a suppression of T_{MI} and a less pronounced decrease of resistance at low temperatures for the disordered LBMO.

3. Noise spectral density measurements

We have investigated the physical mechanism behind the transport properties in LBMO films grown on different substrates, by analysis of voltage noise spectra at various bias currents and temperatures. All the noise measurements were made using the same four contacts configuration as of the dc measurements. The samples have been biased by a dc current source, while the voltage fluctuations have been amplified by a low noise preamplifier and subsequently analyzed by a signal analyzer. The spectra have been acquired in the $1 \div 100000$ *Hz* frequency range and the instrumental background noise was 1.4×10^{-17} V^2/Hz .

In the STO case, the measured voltage spectral traces S_V are always characterized by only two components. The first component, which is dominant at frequencies below 1 *kHz*, has a typical $1/f$ dependence [12, 13]. The second noise component, which appears at higher frequencies, is frequency independent and can be associated to two distinct mechanisms [12]: I) Johnson noise, with a spectral density S_V^{JN} proportional to the temperature and to the sample resistance; II) shot noise, with a spectral density S_V^{SN} proportional to the dc bias current. In figure 3 the resistance spectral noise density S_R , defined as S_V/I^2 , of the LBMO sample on STO substrate is shown at the two

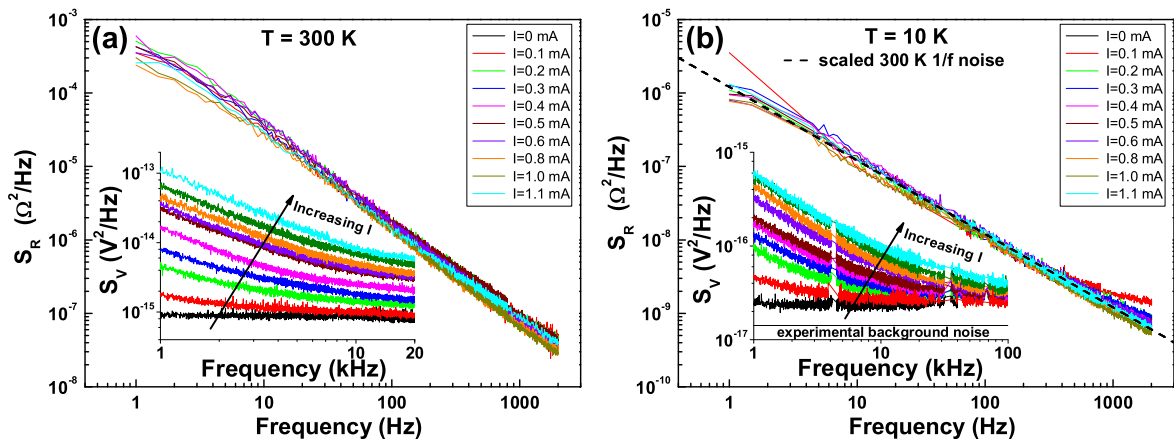


Figure 3. (Colour on-line) Spectral traces S_R of epitaxial LBMO for different current levels and at $T = 300$ K (a) and $T = 10$ K (b). In (b) the $1/f$ noise level, S_R , at $T = 300$ K, scaled with the ratio of resistances R_{10K}^2/R_{300K}^2 , is shown as a dashed line. In the insets, the high frequency components of the voltage spectral density are shown for various dc current values.

temperatures 300 and 10 K, for various bias current values. A systematic analysis of dc bias current dependence of the voltage spectral density shows that, both at $T = 300$ K and at $T = 10$ K, the $1/f$ voltage noise spectral density scales with the squared dc bias current, while the white noise spectral density scales linearly with the dc bias current (see the insets of figure 3). A fit, not reported here, of the dc current scaling of the white noise levels is consistent with the predominance of the shot noise model with the addition of a small, frequency independent, background noise. At lower frequencies, the fact that the voltage spectral density scales with $1/f$ and with the squared dc bias current confirms the hypothesis that the $1/f$ noise is originated by resistance fluctuations. Moreover, the renormalized noise level S_R/R^2 is the same at the two analyzed temperatures, as shown by the dashed line in figure 3(b). This gives a strong indication that the dynamic processes responsible of fluctuations are standard in the case of epitaxial LBMO, that is $S_V = (H * R^2 * I^2) / f$, where H is proportional to the Hooge parameter [12, 13]. A similar behavior has been found in metals and half-metals, in a large number of experiments and several other models.

In the case of disordered LBMO films on MgO, the analysis of the voltage spectral

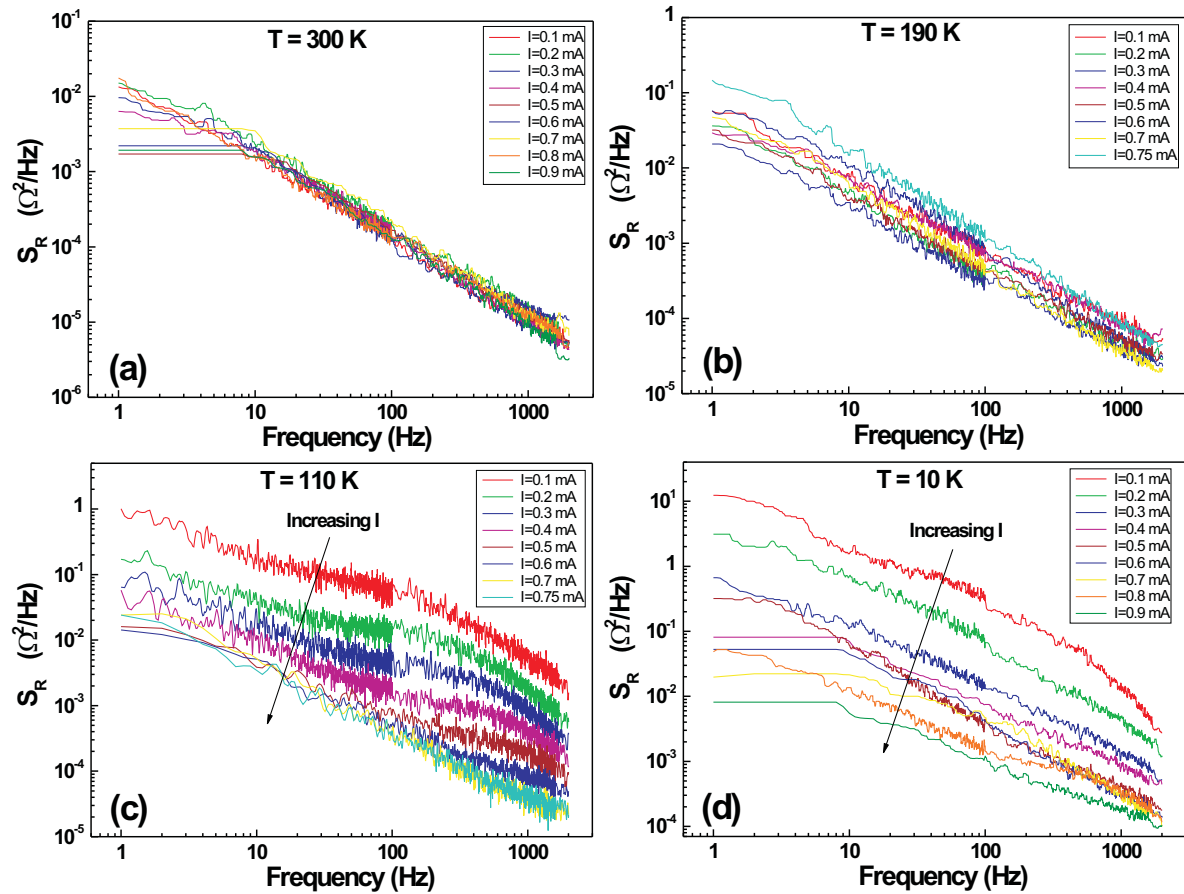


Figure 4. (Colour on-line) Spectral traces S_R of disordered LBMO for different dc bias currents and temperatures.

density shows distinct behaviors in the temperature range of 10 – 300 K. As shown in figure 4, S_R has different current dependence at various temperatures. In particular, for $T > T_{MI}$ the noise level does not appreciably vary with the bias current [figure 4(a)]. On the contrary, at $T \leq T_{MI}$ the resistance spectral density starts to significantly decrease with increasing bias current [figure 4(b), 4(c) and 4(d)]. This peculiar behavior is present even if the dc electrical transport properties are Ohmic. This is different from the case of $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ ultrathin films, reported in [14], where an unusual current dependence of voltage noise is a consequence of a negative current-resistance effect. At $T = 190$ K, corresponding to T_{MI} of the disordered LBMO, the S_R spectral traces show a clear 1/f dependence and some change in amplitude as a function of the bias current but without a clear trend. At lower temperatures the noise spectra show peculiar features. The frequency dependence is no longer strictly of 1/f type, even allowing some freedom of the frequency exponent value [12]. An analysis of the spectral traces at 110 and 10 K shows that, at low frequencies, the noise spectral density could be well described by the sum of a 1/f and a Lorentzian component, as

$$S_R^{EXP}(f) = \frac{K}{f^\alpha} + \frac{B\tau}{1 + (2\pi f\tau)^2}, \quad (1)$$

where K and α (close to 1) are the 1/f noise amplitude and frequency slope, respectively, τ and $A \equiv B\tau$ are the relaxation time and the amplitude of the Lorentzian component. The best fit values of the three parameters K , τ and A exhibit a clear dependence on the dc bias current, as shown in figure 5.

The evidence of a Lorentzian term in the spectral traces gives a strong indication of the presence of random telegraph noise generated by the random switching between two different resistance values in the investigated samples. If $E(1)$ and $E(2)$ are the energy values of the two states responsible for the random transitions and $\Delta E = E(1) - E(2)$ is their difference, the total rate of transitions back and forth in the system, the inverse relaxation time (τ^{-1}), is given by [12]

$$\tau^{-1} = \nu_1 \exp(\Delta E/k_B T) + \nu_2 \exp(-\Delta E/k_B T), \quad (2)$$

where ν_1 and ν_2 are two coefficients defined in terms of the corresponding attempt frequencies to surmount the energy barriers. Here we consider the simple case of a system with the same number of electrons and degeneracy in the two states.

Following the general model of random telegraph noise reported in [12], the amplitude of the Lorentzian component in equation (1) can be computed in terms of the energy difference ΔE as

$$A \sim \nu_1 \nu_2 [\nu_1 \exp(\Delta E/k_B T) + \nu_2 \exp(-\Delta E/k_B T)]^{-3}. \quad (3)$$

Assuming, as will be discussed below, that ΔE decreases linearly with the dc bias current from an initial value ΔE_0 , that is

$$\frac{\Delta E}{k_B T} = \frac{\Delta E_0 - \lambda I}{k_B T}, \quad (4)$$

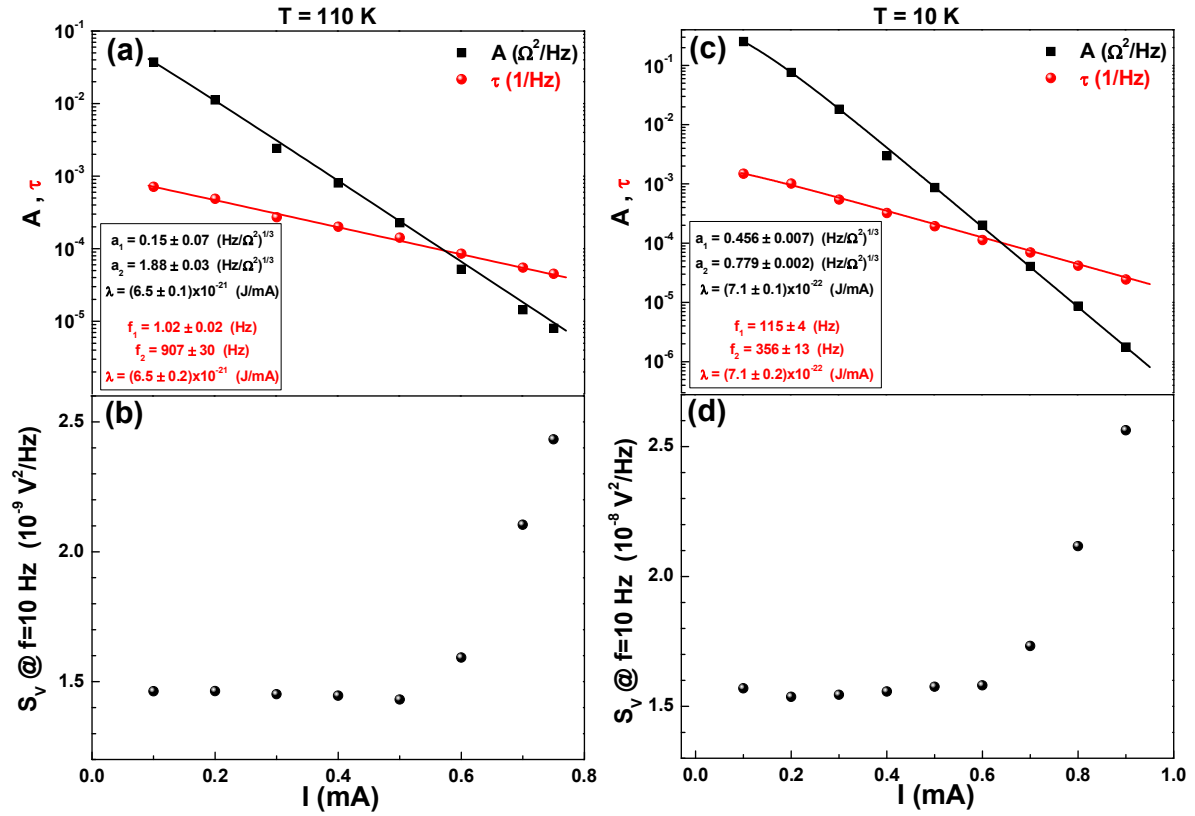


Figure 5. (Colour on-line) Current dependencies of the amplitude A and the relaxation time τ of the Lorentzian spectral component observed at 110 K (a) and at 10 K (c), for the same disordered LBMO sample as in figure 4. The 1/f voltage noise, computed at 10 Hz, is shown in (b) and (d) for the same temperatures.

we obtain a good fit of the experimental current dependence observed in figure 5(a) and 5(c) with equations (2) and (3) rewritten as

$$\tau = [f_1 \exp(-\lambda I/k_B T) + f_2 \exp(\lambda I/k_B T)]^{-1} \quad (5)$$

$$A = [a_1 \exp(-\lambda I/k_B T) + a_2 \exp(\lambda I/k_B T)]^{-3}, \quad (6)$$

where f_i and a_i can be simply expressed in terms of ν_i and ΔE_0 . The values of the fitting parameters are reported in the figure insets.

Regarding the 1/f noise component, the graphs of figure 5(b) and 5(d) clearly show the presence of a temperature dependent threshold bias current. Below this threshold (≈ 0.5 mA at 110 K and ≈ 0.6 mA at 10 K) the 1/f voltage noise is independent on the bias current. Above the threshold, where the Lorentzian contribution is negligible, the 1/f noise shows a standard scaling with the squared dc bias current, as at temperatures above T_{MI} . Correspondingly, as the bias current is increased from 0 to 1 mA the value of the fitting parameter α , the exponent of the 1/f noise, is found to smoothly increase from 0.8 to 1. We note here that values of α from 0.8 to 1.2 are commonly found in systems exhibiting "1/f" noise [12]. However, in our case we have that $\alpha \rightarrow 1$ when the noise spectra tend to the standard resistance fluctuation behavior.

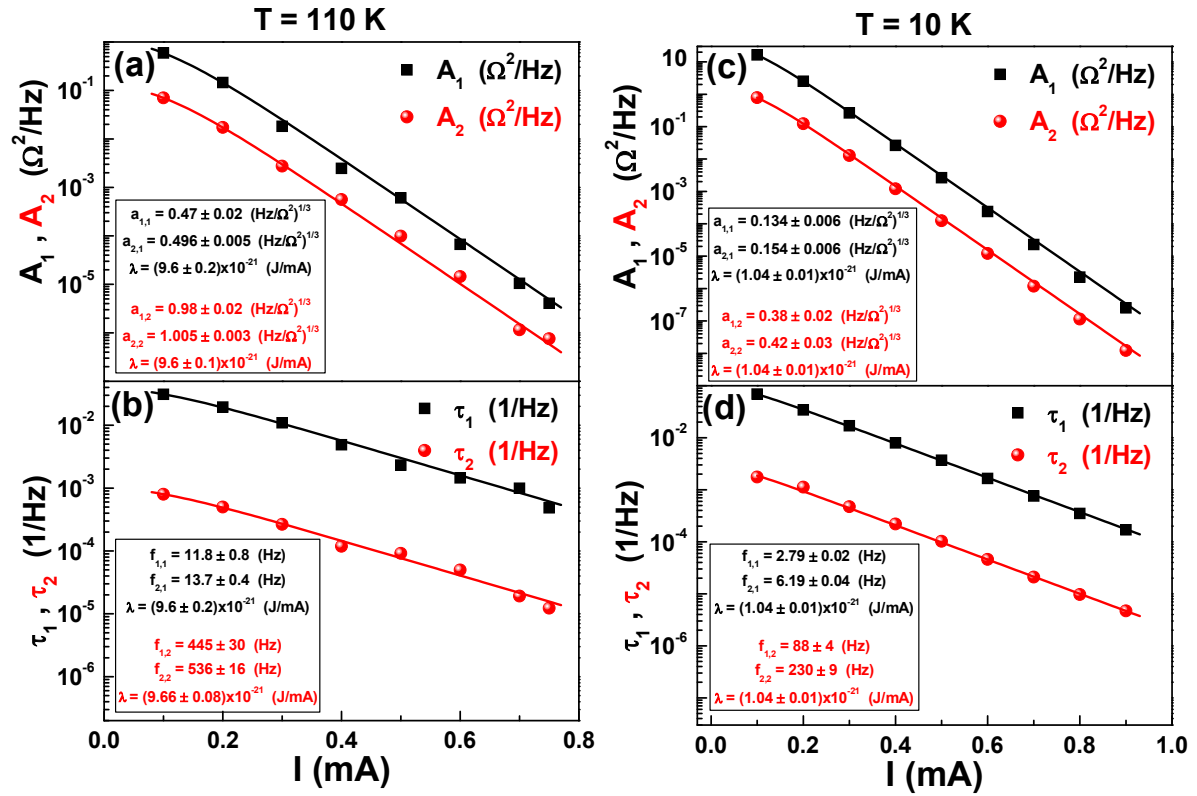


Figure 6. (Colour on-line) Current dependencies of the amplitudes A and the relaxation times τ of the two Lorentzian spectral components observed at 110 K [(a),(b)] and at 10 K [(c),(d)], for the same disordered LBMO sample as in figure 4. The curves are the fit of the data according to equations (5) and (6), while in the insets are reported the values of the fitting parameters. The second index in each parameter refers to the Lorentzian component.

In order to further investigate the noise properties of the disordered LBMO, we have also performed a fitting of the measured spectra with a model of noise including two Lorentzian sources added to a $1/f$ type. In this case

$$S_R^{EXP}(f) = \frac{K}{f^\alpha} + \frac{B_1 \tau_1}{1 + (2\pi f \tau_1)^2} + \frac{B_2 \tau_2}{1 + (2\pi f \tau_2)^2}, \quad (7)$$

and, as before, we define $A_i \equiv B_i \tau_i$ with $i = 1, 2$.

By performing the same fitting procedure as for the single Lorentzian case, we find the results shown in figure 6. This time, however, we have that the $1/f$ voltage noise component is strictly quadratic in the bias current. Indeed we observe that in this case for all noise spectra considered, $\alpha = 1$ and $K = 0.028 \text{ } \Omega^2/\text{Hz}$ at $T = 110 \text{ K}$ and $K = 0.090 \text{ } \Omega^2/\text{Hz}$ at $T = 10 \text{ K}$. Moreover, the characteristic times and amplitudes of the two Lorentzians are very well described by the same expressions (5) and (6).

At this stage, and considering the available quality of the experimental spectra, we cannot indicate which model, (1) or (7), better describes the data. In both cases, however, it is clear that in order to explain the experimental spectra, additional

Lorentzian noise contributions have to be considered and that again in both cases, the hypothesis of a linear dependence of the energy level difference ΔE on the bias current allows a very good reproduction of the experimental results.

In summary, we can state that for disordered LBMO, the noise properties are quite different from those of epitaxial LBMO, and in particular: I) above the T_{MI} of the sample the voltage noise spectrum is substantially of 1/f type and scales with the squared dc bias current, consistently with the hypothesis of being originated by resistance fluctuations, as in the epitaxial case; II) below the T_{MI} an excess noise is observed, composed by 1/f and additional Lorentzian type spectrum; III) depending on the number of Lorentzian sources considered, the 1/f noise shows a regular (two Lorentzians) or irregular (one Lorentzian) bias current dependence; IV) the additional Lorentzian noise appears as caused by a source randomly switching between different resistance values, which is modulated in amplitude and relaxation time by the dc current; V) the type of current modulation is consistent with the hypothesis of a linear dependence on the dc current of the energy difference of the two resistance states.

4. Discussion

Several theoretical interpretations, involving also a non-magnetic origin of the measured electric noise in the disordered LBMO samples, can be considered: I) fluctuation-induced tunneling; II) two-level tunneling; III) percolative resistive paths; IV) Joule heating; V) temperature fluctuations; VI) spin torque effect.

I) Fluctuation-induced tunneling in disordered granular samples would result into an increasing resistance at low temperatures, nonlinear I - V curves and a quadratic current dependence of the white noise voltage component, as predicted by Sheng [15] and reported in polycrystalline double perovskitic thin films (see Savo *et al* in [6]). Our experimental results, in particular the decreasing resistance at low temperatures and linear I - V curves, bring us to exclude this theoretical interpretation as a possible noise source.

II) Two-level tunneling has been proposed as a possible explanation of an unusual dependence of resistance and voltage noise on current in $\text{La}_{1-x}\text{Sr}_x\text{MnO}_3$ ultrathin films [14]. However, this model predicts a number of features such as: nonlinear I - V curves, a specific temperature and current dependence of the characteristic frequency of the Lorentzian component, and a linear increase of the 1/f amplitude with temperature, that are not observed in our disordered LBMO thin films.

III, IV) Both percolating resistive paths and Joule heating predict normalized spectral traces which increase with the resistance following a power law [12]. This would imply that in the ferromagnetic metallic region the noise level increases as temperature or, equivalently in the case of Joule heating, the current is varied. However, the measurements performed on the disordered LBMO samples show an opposite trend as clearly reported in figure 3(c) and 3(d). This experimental evidence seems to also exclude these mechanisms as the origin of noise.

V) In the case of temperature fluctuations, as reported by Voss and Clarke [16], the noise level S_N is proportional to the quantity $(T\beta)^2$, where the coefficient β is experimentally evaluated as dR/RdT . For the disordered LBMO the two measured quantities, S_N and $(T\beta)^2$, are completely different.

VI) A model, in our opinion the most appropriate one, that could be able to give a physical explanation of the experimental results takes into account the half-metal character of manganites and is based on the spin torque effect. A strong evidence of the magnetic origin of noise in disordered LBMO is the significative change of the noise current dependence only below T_{MI} , where the effects due to a spin torque mechanism are enhanced by the presence of many ferromagnetic small clusters. This experimental finding leads us to exclude self-induced magnetic field effects which should be higher near T_C , significantly larger than T_{MI} , where the spin polarization of the carriers starts to occur.

Structural and electrical transport properties characterizations [11], carried out on disordered LBMO, reveal physical features quite different from those of epitaxial LBMO, which are comparable with the bulk system. All the experimental structural results suggest a growth mechanism of the LBMO films on MgO which lead to a more disordered system formed by bulklike domains separated by a large number of punctual defects and/or structural dislocations. The regions associated to these defects and dislocations, typically few *nm* wide, are characterized by depleted conducting and magnetic properties and can be viewed as paramagnetic or ferromagnetic metallic domains having depressed Curie temperatures. This hypothesis is also consistent with the magnetic properties measured on the same films [11].

In agreement with this scenario, the experimental noise results can be associated to the presence of domains with Curie temperatures lower than the bulk value. At low temperatures, these domains can have different equilibrium configurations with respect to the orientation of the magnetization of adjacent domains, depending on the sign of the exchange interaction, which in turn depends on height of the energy barrier between the domains [17]. The size of these domains is typically nanometric, as the case reported in literature for a current-driven magnetization due to a spin-transfer torque mechanism [18, 19]. Moreover, the high resistivity values measured on the disordered LBMO samples [11], comparable with the ones found by Pallecchi *et al* for their nanoconstrictions [20], gives a strong indication of a torque effect on the magnetic domains due to a spin polarized current. As a matter of fact, under the effect of thermal fluctuations, the nanometric domains can randomly flip their magnetic equilibrium orientation, thus generating a random change of the electrical resistance of the multi domain structure [20], described by the Lorentzian noise source which produce, together with a "non-standard" 1/f noise component below a threshold current, the spectral traces shown in figure 4(c) and 4(d).

The peculiar exponential decrease of the amplitude and characteristic time of the Lorentzian component and the unusual current dependence of the 1/f noise vs the dc current can be associated to the half-metal character of manganites. From the spin

torque model, it is predicted that a spin polarized current flowing between domains with different Curie temperatures exerts a torque on the local magnetic domains [20, 21], due to local exchange interactions between polarized charge carriers and magnetic moments, decreasing the height of the energy barrier felt by the carriers across the adjacent domains. This, according to [17], implies that the energy reduction is linear in current and, as a consequence, the switching probability becomes different in each state and the overall spectral noise properties are modified following equation (4). The excellent agreement with the measured experimental data, shown in figures 5 and 6, gives a strong indication of the plausibility of the outlined scenario in describing the current reduction of the measured noise, at low temperatures, in disordered LBMO thin films. This peculiar noise behavior is no longer observed at temperatures $T > T_{MI}$. Above the metal-insulator transition no flip of magnetic domains is expected since the spin torque effect is less important due to the reduced connectivity of the ferromagnetic domains, along with the reduced spin-polarization of the current and the reduced magnetic susceptibility of the smaller regions with depressed T_C . In this situation a standard behavior associated to the ferromagnetic domains with higher Curie temperatures prevails, the noise level approaches that of epitaxial LBMO and no anomalous bias current dependence of the noise is observed. The linear dc current voltage characteristics, shown in the inset of figure 2, are not unexpected if multiple magnetic domains and current paths are present, due to the unpatterned nature of the investigated samples. In this case both signs of the current may be active in rotating the domains and a symmetric effect and linear I - V curves are expected on average and have been already observed in similar half-metal systems [20].

At the lowest investigated temperature ($T = 10$ K), the same qualitative behavior of the noise spectra is observed, figure 4(d), with an overall enhancement of the $1/f$ noise level, suggesting that additional noise sources are active in the low temperature limit. As a matter of fact, in our physical system as the temperature is lowered more and more domains become magnetically active and can contribute to the resistance fluctuations through the random flipping of their magnetic orientation. This gives a consistent explanation of the observed noise increase.

5. Summary

Noise measurements have been performed on epitaxial and disordered $\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$ (LBMO) thin films. Different conduction mechanisms have been pointed out in the two systems. A standard noise behavior, due to resistance fluctuations in bulklike domains, has been observed for epitaxial films at all temperatures and for disordered films above the metal-insulator transition temperature. Larger and unusual current dependent $1/f$ noise, together with random telegraph noise have been found for LBMO on MgO thin films, below the metal-insulator transition, and interpreted by considering a spin torque effect acting on zones with reduced magnetic properties. Within this model the bias current, due to the half-metal character of manganites, has a magnetic ordering effect

that reduces the generated electrical noise. Measurements performed with an external magnetic field could be very helpful to better understand the dynamic behaviors of the charge carriers in this class of compounds. Further investigations would be useful to clarify these aspects and are presently under development.

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