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Comment on "A case study on the scaling of 1/f noise: $La_{2/3}Sr_{1/3}MnO_3$ thin films" [J. Appl. Phys. 113, 094901 (2013)]

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The problem of non-standard scaling of the 1/f noise in thin manganite films was revisited in the above paper, suggesting the quantum theory of fundamental flicker noise for the interpretation of the unusual dependence of the normalized Hooge parameter on the sample volume. Experimental evidence has been reported, showing that in these materials such volume dependence is, instead, an artifact of extrinsic noise sources, e.g., contact noise. Moreover, the proposed theoretical model implies a linear temperature dependence of the Hooge parameter, which is against the experimental data reported here. Based on these arguments, it is possible to conclude that the quantum theory of fundamental flicker noise cannot be applied to the case of $La_{2/3}Sr_{1/3}MnO_3$ thin films. © *2014 AIP Publishing LLC*. [http://dx.doi.org/10.1063/1.4868864]

Manganese oxides have demonstrated their potential for electronic applications, such as microbolometers at room temperature. Therefore, the identification of the real electric noise sources and processes is a fundamental requirement for the realization of high-performance devices based on these compounds.

The most common type of low-frequency electric noise is 1/f or flicker noise, which is usually modeled using the Hooge empirical relation as[1]

$$S_V = \frac{\alpha_H}{n}\frac{V^2}{\Omega f}. \tag{1}$$

In Eq. (1), S_V is the voltage-spectral density, V the dc voltage, α_H/n the normalized Hooge parameter (being n the charge carrier density), Ω the sample volume, and f the frequency. This Hooge formula has no general physical explanation, but is used to compare the noise level in different materials of different size. In particular, α_H/n should be independent of the geometry of the investigated samples and of the bias condition.[1] A detailed study of the 1/f noise in manganites has, instead, revealed the dependence of α_H/n on the sample width, but no explanation to this observation was initially proposed.[2] Experiments performed under the same conditions as in Ref. 2 demonstrated, soon after, that the volume dependence of the normalized Hooge parameter in manganite compounds is fictitious and essentially due to the presence of a dominant contact noise contribution.[3] The methodology reported in Ref. 3 allowed to evaluate the intrinsic Hooge's constant $[\alpha_H/n]^{int}$, which is strictly related to the material properties. This simple explanation was able to clarify the anomalous dependence of the noise data reported in Ref. 2, but was critically revisited by K. A. Kazakov in terms of the quantum theory of fundamental flicker noise.[4] According to this latter theory, the intrinsic noise level of homogeneous samples can be written as

$$\frac{\alpha_H}{n} \sim \frac{e^3}{\pi\hbar^2 c^3} g\mu T, \tag{2}$$

where μ is the charge carrier mobility, T the absolute temperature, e the elementary charge, c the speed of light, $\hbar$ the reduced Planck constant, and g a geometrical factor.[4]

By assuming constant electron mobility on temperature, as commonly reported in literature for manganite compounds,[5,6] Eq. (2) predicts a linear dependence on T of α_H/n. In order to better clarify this aspect, an accurate characterization of the 1/f noise amplitude in the temperature range

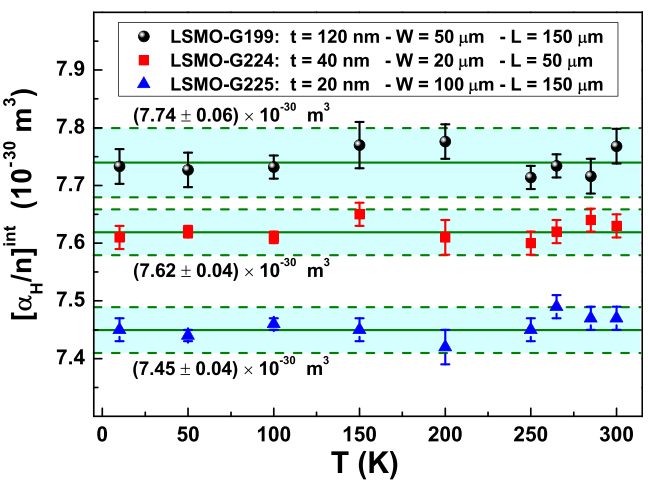

FIG. 1. Temperature dependence of the intrinsic normalized Hooge parameter for different $La_{0.7}Sr_{0.3}MnO_3$ thin films. All the samples have been patterned in order to form well defined inline geometries, having different volumes. The dimensions (t = thickness - W = width - L = length) are reported in the inset. The horizontal solid lines give indication of the mean values, which are shown together with their standard deviations (95.4% confidence interval) in the shaded areas.

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between 10 and 300 K has been performed on the same samples of Refs. 2 and 3. An experimental technique, based on noise measurements taken in a sequence of a four-probe and a two-probe connection, has been used to separate and to subtract spurious noise components from the real spectral trace of the sample. The application of this reduction procedure, whose details are described in Ref. 7, has allowed to determine contact and background noise. Therefore, the intrinsic voltage-spectral density of the measured $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) thin films on $SrTiO_3$ substrates has been obtained and the results of the subsequent noise level analysis are shown in Fig. 1. Here, a clear temperature-independent intrinsic Hooge parameter for different LSMO samples is evident, in contrast with the prediction of quantum 1/f noise as in Eq. (2). It is worth noting that the experimental value of the normalized Hooge parameter is substantially the same in all samples, notwithstanding their different volume and width.

All the discussion made so far and the experimental findings may lead to the conclusion that quantum effects are not responsible for the noise processes in LSMO manganite compounds. Quantum theory of flicker noise could explain unusual electric noise behavior in other systems. However, in manganites there is enough experimental evidence that such theoretical model is not applicable.

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