Characterization of uncooled ultra low-NEP LSMO bolometers at 3.39 μm and in the MWIR and LWIR bands

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***Abstract*— $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) uncooled suspended bolometers have been characterized at 3.39 µm (He-Ne laser) and with a blackbody source at different temperatures. These bolometers could achieve ultra low NEP values below 1 pW·Hz$^{-1/2}$ with few microwatts power consumption at 300 K.**

I. INTRODUCTION

Manganite $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) is a material with interesting physical properties for the manufacturing of bolometers once it shows a strong variation of electrical resistivity as a function of temperature close to 300 K [1]. It also has a very low noise level compared to other resistive materials such as semiconductors and other oxide-based materials [2-4]. This makes possible the fabrication of sensitive sensors working at room temperature with a very low level of noise for targeted applications such as bolometers, thermal sensors or gas sensors.

We successfully fabricated LSMO/$SrTiO_3$ suspended bridges using silicon micromachining techniques to form single line structures or square areas constituted of parallel lines (of width 2 or 4 µm) [5,6]. In this paper, we will focus on the results of a 4 µm wide and 100 µm long LSMO/$SrTiO_3$ suspended bridge fabricated with the process described in [6].

II. RESULTS

Electro-thermal characterizations of different devices with different geometries have been performed from 260 K to 340 K. We used a blackbody source and different wavelength windows (Al_2O_3, NaCl, (7.3-16 µm) longpass filter) to estimate if the bolometers could measure different wavelength radiations. In order to control the incident power and accurately measure the beam radius at the bolometer for narrow band analysis, a He-Ne laser 3.39 µm was used (Fig. 1).

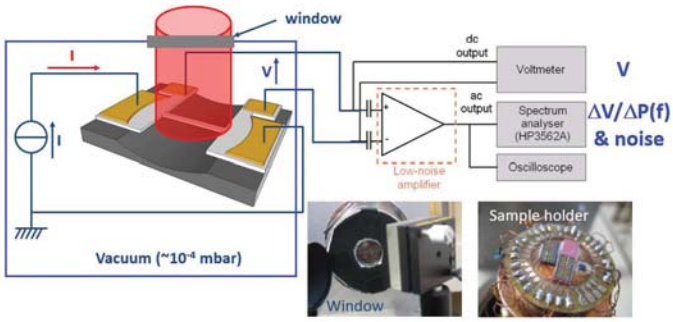

Fig. 1. Optical measurement setup.

I-V curves have been measured between 260 K to 340 K in order to get R(T) curves for different bias current and the thermal conductance. For example at 7 µA (Fig. 2), the maximum value of dR/dT was found to be around 1700 Ω.K^{-1} at 300 K and the maximum TCR was of 3.7x10^{-2} K^{-1}, similar to literature [1]. An electro-thermal analysis performed with COMSOL simulation software confirms the sensor model.

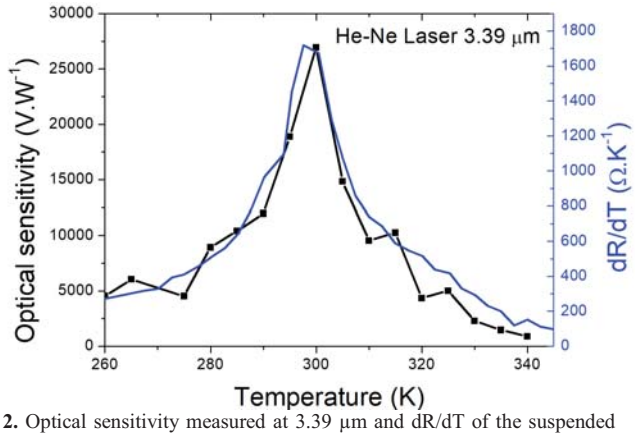

Fig. 2. Optical sensitivity measured at 3.39 µm and dR/dT of the suspended bridge versus temperature at 7 µA.

Optical sensitivity and derivative of the bolometer resistance versus temperature (dR/dT) have been compared showing the bolometric behaviour of the detector (Fig. 2). Very low thermal conductance (around 10^{-7} W·K^{-1}), an absorption coefficient of around 30 % and cut-off frequencies of around 200 Hz have been measured.

Low frequency noise measurements have also been performed at different bias currents and temperatures. Typically, the noise power spectral density consists of a low frequency noise and a white noise. The latter increases slightly with temperature since the Johnson noise is proportional to the electrical resistance value and the temperature whereas the readout noise is almost constant. For high bias current, the bolometer properties become strongly non homogeneous in volume. The excess noise behaviour change and the phonon noise increases slightly. Finally, a noise analysis shows that the phonon noise could be dominant over the other noise sources (Johnson noise, 1/f noise, instrumental noise) if the operating conditions give the highest responsivities (few µA).

The Noise Equivalent Power (NEP) expresses the minimum detectable power per square root bandwidth of a given detector at a modulation frequency. It is the ratio between the noise power spectral density S_V ($V^2.Hz^{-1}$) and the sensivity. It is desirable to have a NEP as low as possible, since a low NEP

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value corresponds to a lower noise floor and therefore a more sensitive detector.

The total NEP of a bolometer is determined by different noise sources such as the photon noise, the phonon noise, the Johnson noise, the excess noise and the readout noise. The photon noise due to the background radiation received by the bolometer is not considered at room temperature since it is negligible.

In these conditions, it is possible to get phonons noise limited bolometers even at low current bias. Noise Equivalent Power (NEP) around 1 $pW \cdot Hz^{-1/2}$ could be obtained at 300 K and 5 µA indeed (Fig. 3). A such low power consumption could be interesting for many sensor applications. Using appropriate bolometer size, it is possible to get lower NEP values.

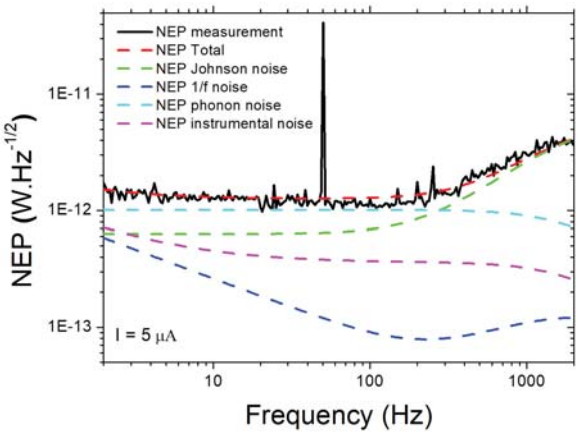

Fig. 3. Measured and calculated NEP (dashed lines) at 300 K of the suspended bridge at 5 µA.

In conclusion, we demonstrated the fabrication of uncooled LSMO bolometers with very low thermal conductance thus leading to state-of-the-art performance (phonon noise limited bolometer at 300 K, time constant in the 0.7–1 ms range, specific detectivity D* of $2 \cdot 10^9$ $cm \cdot Hz^{-1} \cdot W^{-1}$ close to the background-limited infrared photodetector limit). Our technology is also promising for the realization of many other MEMS (MicroElectro-Mechanical-Systems) devices based on LSMO working in the MWIR/LWIR bands for wireless or IoT applications such as the ethanol gas and methanol gas detections for example.

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