



## Ozone detection based on nanostructured $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ thin films

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Fiorido; Marc Bendahan; Khalifa Aguir

Abstract: The present paper describes the synthesis of gas sensors based on thin films perovskite-type La<sub>0.8</sub>Pb<sub>0.1</sub>Ca<sub>0.1</sub>Fe<sub>0.8</sub>Co<sub>0.2</sub>O<sub>3</sub> over a [SiO]<sub>2</sub>/Si substrate with interdigitated Pt-electrodes using the drop coating method. The perovskite starting nanoparticles have been prepared by the sol-gel method and they have an orthorhombic structure with Pnma space group. The prepared thin film has been tested as a sensitive film for ozone detection and shows a promising response. The detection of low concentration of ozone (equal to 50 ppb) makes the prepared thin film a potential sensor for ozone detection.

## Cover letter

**Pr. Moez BEJAR**

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**22/12/2019**

**Dear Editors of the Journal of Alloys and compounds.**

I am pleased to submit our manuscript entitled:

**“Ozone detection based on nanostructured  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  thin films”**

for consideration for publication in the **Journal of Alloys and compounds**.

It has not been published elsewhere and that it has not been submitted simultaneously for publication elsewhere. In this manuscript, we investigated the response of  **$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$**  compound toward the Ozone oxidizing gas.

Thank you for your consideration,

Yours Sincerely;

**Pr. Moez BEJAR**

## Prime Novelty Statement

The  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sample has been prepared using the drop coating method. The structural and Ozone gas-sensing properties were reported. The gas sensing properties of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  shows that our sensor can detect low concentrations of Ozone-gas and we deduced that our sensor can be used as promising candidates to detect Ozone-gas added to that our captor is able to detect this dangerous gas at different concentration.

# Ozone detection based on nanostructured $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$ thin films

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## ABSTRACT

The present paper describes the synthesis of gas sensors based on thin films perovskite-type  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  over a  $\text{SiO}_2/\text{Si}$  substrate with interdigitated Pt-electrodes using the drop coating method. The perovskite starting nanoparticles have been prepared by the sol-gel method and they have an orthorhombic structure with  $Pnma$  space group. The prepared thin film has been tested as a sensitive film for ozone detection and shows a promising response. The detection of low concentration of ozone (equal to 50 ppb) makes the prepared thin film a potential sensor for ozone detection.

**Keywords:** perovskite, drop-coating, thin films, semiconductor, gas sensor, ozone.

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## I- INTRODUCTION

Recently, the synthesis of advanced materials for many applications has been widely investigated in literature. In particular, the interest for the perovskite materials  $\text{LnMO}_3$  (Ln: lanthanide and M: trivalent cations), destined for innovative technological applications, such as catalysis, magnetocaloric and gas sensing field, have grown steadily [1-4].

The  $\text{LaFeO}_3$  is a potential functional material which is used in many fields such as gas-sensing in the detection of many gases, including  $\text{HCHO}$ ,  $\text{CH}_4\text{O}$  and  $\text{CH}_3\text{COCH}_3$  [5-9]. Also, derivatives of  $\text{LaFeO}_3$  are very used in the detection of dangerous gases. Song et al. have proven that introducing Pb in the A-site to replace Lanthanum (La) increase the response of  $\text{LaFeO}_3$  material [10]. In addition, the introduction of Ca in  $\text{LaFeO}_3$  has caused the increase of sensitivity of  $\text{La}_{1-x}\text{Ca}_x\text{FeO}_3$  to alcohol [11]. In another study, H.

Saoudi et al. [12] have reported that introducing Cobalt (Co) in B-site in  $\text{La}_{0.8}\text{Ca}_{0.1}\text{Pb}_{0.1}\text{Fe}_{1-x}\text{Co}_x\text{O}_3$  perovskite materials will increase the response because the sample with  $x=0.05$  shows the higher sensitivity of  $\text{NH}_3$ -gas compared to  $\text{La}_{0.8}\text{Ca}_{0.1}\text{Pb}_{0.1}\text{FeO}_3$  sample.

The ozone-gas has been emerged in many fields, *e.g.* textile, food, water treatment, pharmaceutical and chemical industries [3]. Consequently, ozone constitutes one part of the summer toxic smog. However, for a concentration above  $120 \text{ ppb}$  in the atmosphere, Ozone could cause serious health problems (*e.g.* burning eyes, lung damage and respiratory irritation) [13, 14]. Moreover, the air quality is classified referring to the Ozone amount in the atmosphere: very good ( $0 - 50 \text{ ppb}$ ), good ( $50 - 100 \text{ ppb}$ ), poor ( $100 - 200 \text{ ppb}$ ) and very poor ( $> 200 \text{ ppb}$ ) [3]. For all the above reasons, the monitoring of the Ozone concentration in our atmosphere is becoming a serious issue.

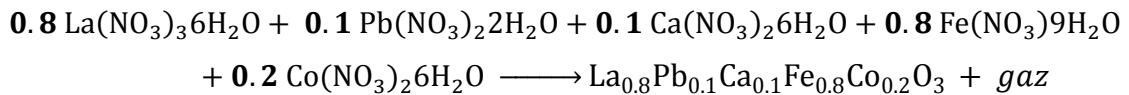
In our previous published work related to this framework, we have demonstrated the high sensing properties of  $\text{La}_{0.885}\text{Pb}_{0.005}\text{Ca}_{0.11}\text{FeO}_{2.95}$  towards the  $\text{NH}_3$ -gas [1].

In line with our interest in the study of gas sensing, we report in the present research the synthesis of a thin film gas sensor based perovskite-type  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  over a  $\text{SiO}_2/\text{Si}$  substrate with interdigitated Pt-electrodes using a drop coating as a new method.

## II- EXPERIMENTAL DETAILS

### II-1) Preparation of perovskite nano-powder

Nano-powder of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  has been prepared by mixing different nitrates:  $\text{La}(\text{NO}_3)_3 \cdot 6\text{H}_2\text{O}$ ,  $\text{Pb}(\text{NO}_3)_2 \cdot 2\text{H}_2\text{O}$ ,  $\text{Ca}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$ ,  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$  and  $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$  as precursors according to the proportion indicated in the equation below:



Then, the collected powder has been sintered at 300, 600 and 900 °C for 24h for each temperature.

### II-2) Thin film preparation

The perovskite thin-film was deposited over the  $\text{SiO}_2/\text{Si}$  substrate ( $4 \text{ mm} \times 4 \text{ mm}$ ) with interdigitated Pt- electrodes by the drop coating method. Firstly, a slurry of  $20 \text{ mg}$  of

perovskite mixed with 20 ml of 2-propanol has been prepared and ultrasonicated for 10 min at 40 °C to ensure a good homogenization for the mixture. Subsequently, the deposition of the thin film was assured by coating the substrate drop by drop using a micropipette. The process has been combined with heating at 50 °C after each drop to remove the solvent. The thin film properties were optimized at 8 drops which makes a total of 20  $\mu$ l. Finally, after the deposit of 8 drops a heating for one hour at 550 °C will take place(**Fig. 1**).

### **II-3) Ozone sensing measurement:**

To investigate the ozone sensing properties of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  films, the sensors have been introduced in a test chamber allowing the control of the sensor temperature under variable gas concentrations. Dry air has been used as a reference gas. Ozone gas was generated by oxidizing oxygen using a pen-ray UV lamp (Stable Ozone Generator UVP/185 nm). The intensity of the UV radiation was varied by shifting a shutter around the lamp. The different ozone concentrations are obtained in the range of 30–800 ppb with a flow rate of dry air maintained at 0.5 l/min.

The operating temperature of the sensor has been adjusted between 160 °C and 280 °C to determine the best sensor response. In this case, our sensor was exposed to 100 ppm ozone-concentration for 1 min in order to identify the best operating temperature.

The applied dc voltage for sensor measurement is 1V and the current is measured using a computerized sourcemeter type Keithley 4250. The sensor response is defined as  $S = R_a/R_g$ , where  $R_a$  and  $R_g$  are the resistance under air and the resistance when the sensor is exposed to ozone-gas, respectively.

## **III- RESULTS AND DISCUSSION**

### **III-1) Scaling analysis**

The Rietveld refinement of the X-ray diffractogram of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  nanopowder (**Fig. 2**) has revealed that our sample crystallizes in the orthorhombic structure with the  $Pnma$  space group. The lattice refined parameters  $a, b$  and  $c$  are 5.5493, 7.8489 and 5.5394 Å, respectively. The  $(hkl)$  Miller indices corresponding to the main reflexion planes of our sensor are (1 0 1), (0 0 2), (2 2 0), (0 4 0), (1 0 3), (3 2 1), (2 4 2) and (3 2 3). Moreover, the analysis using “X0 Pert High Score Plus” program has shown the presence of  $\text{Fe}_3\text{O}_4$  as secondary phase.

The crystallite size ( $D_{W-H}$ ) of the powder has been evaluated using the Williamson-Hall method [15] ( $\beta \cos(\theta) = f(4\sin(\theta))$ ) (Fig. 3). The sensor has shown a nanometric crystallite size equal to 43.870 nm.

$$\beta \cos(\theta) = k\lambda/D_{WH} + 4\varepsilon \sin(\theta) \quad (\text{Eq. 2})$$

Where  $\beta$  is the width at half height,  $\varepsilon$  is the coefficient due to structural defects,  $k$  represents the grain form factor ( $k = 0.9$ ),  $\lambda$  is the radiation wavelength ( $\lambda = 1.5406 \text{ \AA}$ ) and  $\theta$  is the angle corresponding to each peak.

### III-2) Ozone sensing properties:

Fig. 4 shows the variation of the electrical resistance as a function of time under dry air with a temperature increasing from 25 to 180 °C. The results show that the resistance decreases with increasing the temperature, which proves the semiconductor behavior of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor [16].

In order to determine the operating temperature of our compound, the sensor responses in presence of 100 ppb of ozone have been carried out at different temperatures between 160°C and 280°C. Fig. 5 shows the resistance variation versus time at 170, 190, 260 and 280 °C during ozone exposing time of 1 min.

The results show that the sample displays reversibility and the curves present good stability of the baseline. Furthermore, the sample resistance has declined upon exposure to an oxidizing gas [17], indicating the *p*-type semiconductor behavior of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor [18]. In fact, with an oxidizing gas, such as Ozone, the conductivity increases due to the enhancement of the holes of concentration.

Table.1 summaries the ozone ( $\text{O}_3$ )-responses values of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor. The maximum of the sensitivity ( $R_a/R_g$ ) has been reached at 170 °C when our sensor was exposed to 100 ppb for 1min, 170 °C is considered as the operating temperature ( $T_{Op}$ ) of the sensor.

The sensor performances have also been evaluated with different ozone concentrations and the results are presented in Fig. 6(a). The results exhibit the sensing ability of the thin-film in all the studied ozone concentrations. In the same way, Fig. 6(b) shows that the response intensities increase together with the ozone concentration and reach a maximum of 3.6 for the concentration of 400 ppb. The recorded values are depicted in Table 2. These values are better compared with those reported earlier [19-22].

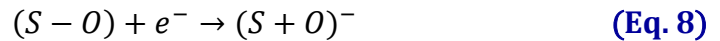


The response time ( $\tau_{resp}$ ) is another important parameter to evaluate the sensor, which is the time required to reach 90 % of the electrical resistance when the sensor is exposed to Ozone gas [1]. The response time values ( $\tau_{resp}$ ), recorded and gathered in Table 3, have revealed that  $\tau_{resp}$  decreases when increasing the concentration at the operating temperature of 170 °C. The same trend was observed previously by Masami Mori and *al.* [3]. In contrast,  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor has low response time values compared to other perovskite materials, such as  $\text{SmFeO}_3$  [3].

The  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  response, signal and response time are influenced by the quantity and quality of oxygen adsorbed on the surface of our sensor [23]. On the surface, atmospheric oxygen can be adsorbed very easily and atoms or molecules become chemisorbed ions  $\text{O}^-$  or  $\text{O}_2^-$ . When the temperature increases the state of oxygen on the surface undergoes the following reactions (from Eq. 3 to Eq. 6) and this phenomenon is demonstrated theoretically by using the  $\text{SnO}_2$  model [24]. In fact, our thin film presents an increase in hole concentration because when oxygen species are adsorbed in  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  the sensor surface will capture electrons from our sensor which is a *p*-type semiconductor and consequently a depletion region of electrons is thus formed [25]. Added to that, at the operating temperature ( $T_{op}$ ) we have a maximum of oxygen adsorbed on the surface of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor [1].



The chemical reactions process between free adsorption site S and the triatomic gases, as Ozone ( $\text{O}_3$ ), are [26]:



#### IV- CONCLUSION

In this research paper, the  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor has been successfully prepared by the drop coating method and tested as an ozone sensor. The prepared thin-film showed sensitivity to *ppb*-levels of ozone gas. The resistance study as a function of

time at different working temperatures depicted the good sensitivity of our sensor especially at the operating temperature of  $170\text{ }^{\circ}\text{C}$ . In addition, our sensor can be used in the distinction of the air quality for the ozone and sub-ppm levels detection becomes possible.

Our study shows the possibility of the use of our sensor in the field of the detection of ozone-gas. Another necessary part of our work is the study of the selectivity of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor.

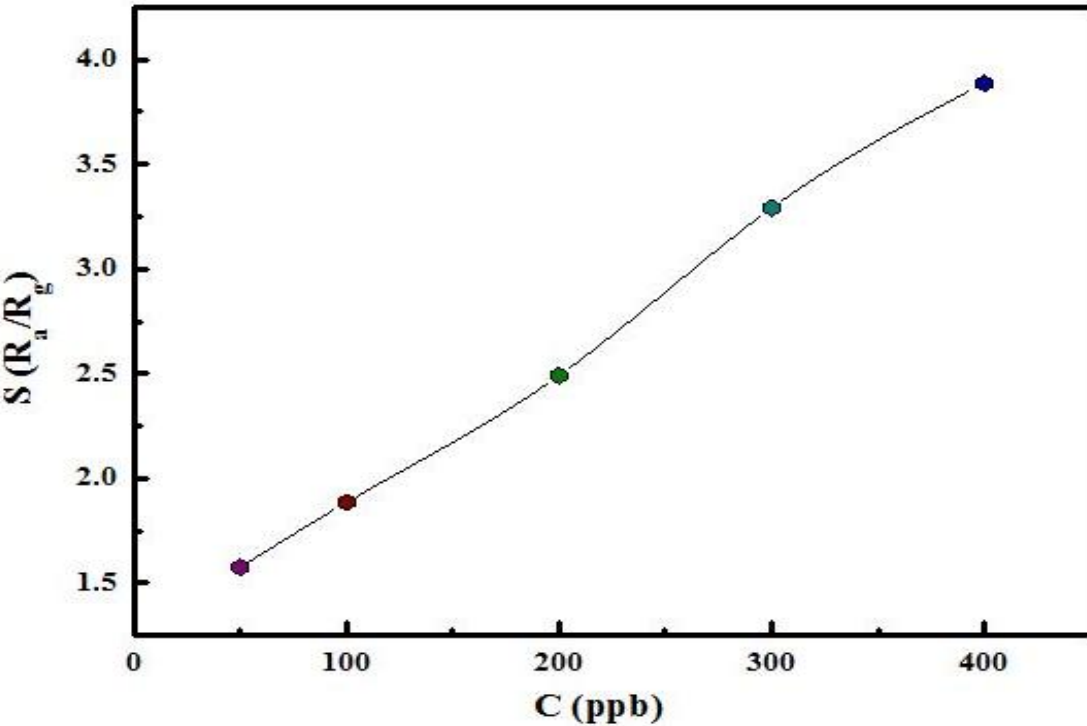
## REFERENCES

- [1] S. Smiy, A. Omri, R. Moussi, A. Ben Ali, S. Hcini , B.F O. Costa , E.K. Hlil, E. Dhahri, Influence of Non-magnetic  $Ti^{4+}$  Ion Doping at Mn Site on Structural, Magnetic, and Magnetocaloric Properties of  $La_{0.5}Pr_{0.2}Sr_{0.3}Mn_{1-x}Ti_xO_3$  Manganites ( $x = 0.0$  and  $0.1$ ), J . Supercond Nov Magn, 2 (2018) 4825.
- [2] S. Smiy, H. Saoudi, A. Benali, M. Bejar, E. Dhahri, T. Fiorido, K. Aguir, New perovskite compound  $La_{0.885}Pb_{0.005}Ca_{0.11}FeO_{2.95}$  for gas sensing application, Chemical Physics Letters, 735 (2019) 136765.
- [3] M. Mori, J. Fujita, Y. Itagaki, Y. Sadaoka, Ozone detection in air using  $SmFeO_3$  gas sensor for air quality classification, J. Ceramic Society of Japan, 119 (2011) 926.
- [4] A. Benali, S. Azizi, M. Bejar, E. Dhahri, M.F.P. Graça, Structural, electrical and ethanol sensing properties of double-doping  $LaFeO_3$  perovskite oxides, Ceramics International, 40 (2014) 14367–14373.
- [5] X. Liu, H. Ji, Y. Gu, M. Xu, Preparation and acetone sensitive characteristics of nano- $LaFeO_3$  semiconductor thin films by polymerization complex method, Materials Science and Engineering B, 133 (2006) 98-101.
- [6] Y.M. Zhang, J. Zhang, J.L. Chen, et al. Improvement of response to formaldehyde at  $Ag - LaFeO_3$  based gas sensors through incorporation of SWCNTs, Sensors and Actuators B, 195 (2014) 509–514.
- [7] J. Qin, Z.D. Cui, X.J. Yang, et al, Synthesis of three-dimensionally ordered macroporous  $LaFeO_3$  with enhanced methanol gas sensing properties, Sensors and Actuators B, 209 (2015) 706–713.
- [8] Y.P. Chen, H.W. Qin, X.F. Wang, et al, Acetone sensing properties and mechanism of nano- $LaFeO_3$  thick-films, Sensors and Actuators B, 235 (2016) 56–66.
- [9] L. Ma, S.Y. Ma, Z. Qiang, X.L. Xu, Q. Chen, H.M. Yang, H. Chen, Q. Ge, Q.Z. Zeng, B.Q. Wang, Preparation of Co-doped  $LaMO_3$  nanofibers with enhanced acetic acid sensing properties, Materials letters, 200 (2017) 47–50.
- [10] P. Song, H. Qin, L. Zhang, K. An, Z. Lin, J. Hu, M. Jiang, The structure, electrical and ethanol-sensing properties of  $La_{1-x}Pb_xFeO_3$  perovskite ceramics with  $x \leq 0.3$ , Sensors and Actuators B, 104 (2005) 312–316.
- [11] L. Kong, Y. Shen, Gas-sensing property and mechanism of  $La_{1-x}Ca_xFeO_3$  ceramics, Sensors and Actuators B, 30 (1996) 217–221.

- [12] H. Saoudi, A. Benali, M. Bejar, E. Dhahri, T. Fiorido, K. Aguir, R. Hayn, Structural and  $NH_3$  gas-sensing properties of  $La_{0.8}Ca_{0.1}Pb_{0.1}Fe_{1-x}Co_xO_3$  ( $0.00 \leq x \leq 0.2$ ) perovskite compounds, *J. Alloys. Compds*, 731(2018) 655-661.
- [13] K. Fan, H. Qin, L. Wang, L. Ju, J. Hu.  $CO_2$  gas sensors based on  $La_{1-x}Sr_xFeO_3$  nanocrystalline powders, *Sensors and Actuators B*, 177 (2013) 265-269.
- [14] Z.C. Xu, M.F. Liu, C.C. Chen, X.N. Ying, Change disproportionation in  $La_{1-x}Ca_xFeO_3$  ( $x = 0.4$  and  $0.5$ ) investigated by mechanical spectroscopy, *J. Applied Physics*, 115 (2014) 123516.
- [15] A.G.K. Williamson, W.H. Hall, X-ray line broadening from fcc aluminum and Wolfram. *Acta Metall.* 22 (1953)1.
- [16] A. Van der Ziel, *Solid State Physical Electronics*, second ed, 1976.
- [17] R. Boulmani, M. Bendahan, C. Lambert-Mauriat, M. Gillet, K. Aguir, Correlation between rf-sputtering parameters and  $WO_3$  sensor response towards ozone, *Sensors and Actuators B*, 125 (2007) 622–627.
- [18] G. Martinelli, M. C. Carotta, M. Ferroni, Y. Sadaoka, E. Traversa , Screen-printed perovskite-type thick films as gas sensors for environmental monitoring, *Sensors and Actuators B*, 55 (1999) 99–110.
- [19] S. Vallejos, V. Khatko, J. Calderer, I. Gracia, C. Cané, E. Llobet, X. Correig, Micro-machined  $WO_3$ -based sensors selective to oxidizing gases, *Sensors and Actuators, B* 132 (2008) 209.
- [20] W. Qu, W. Wlodarski, A thin-film sensing element for ozone, humidity and temperature, *Sensors and Actuators B*, 64 (2000) 42.
- [21] V.R. Mastelaro, S.C. Zilio, L.F.D. Silva, P.I. Pelissari, M.I.B. Bernardi, J. Guerin, K. Aguir, Ozone gas sensor based on nanocrystalline  $SrTi_{1-x}Fe_xO_3$  thin films, *Sensors and Actuators B*, 181 (2013) 919.
- [22] M. Mori, Y. Itagaki, Y. Sadaoka, Effect of VOC on ozone detection using semiconducting sensor with  $SmFe_{1-x}Co_xO_3$  perovskite-type oxides, *Sensors and Actuators B*, 163 (2012) 44.
- [23] X. Liu, B. Cheng, J. Hu, H. Qin, M. Jiang, Semiconducting gas sensor for ethanol based on  $LaMg_xFe_{1-x}O_3$  nanocrystals , *Sensors and Actuators B*, 129 (2008) 53.

- [24] U. Pulkkinen, T.T. Rantala, T.S. Rantala, V. Lantto, *J. Mol. Catal. A: Chem*, 166 (2001) 15.
- [25] S. Xu, Y. Yang, C. Jiang, J. Gao, L. Jing, P. Shen, L. Li, K. Shi, Enhanced  $NH_3$  gas sensing performance based on electro spun alkaline-earth metals composited  $SnO_2$  nanofibers, *J. Alloys. Compds*, 618 (2015) 240–247.
- [26] J. Guerin, M. Bendahan, K. Aguir, A dynamic response model for the  $WO_3$ -based ozone sensors, *Sensors and Actuators B*, 128 (2008) 462.

Graphical abstract



## Research Highlights

- $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sample crystallizes in the orthorhombic structure with Pnma space group.
- Our compound presents a nano-metric size.
- $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  shows a *p*-type semiconductor behavior.
- $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor can detect the Ozone-gas even with low concentration equal to 50 ppb.
- $T=170^\circ\text{C}$  is the operating temperature of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor.

**Table 1:** The relationship between response ( $S = R_a/R_g$ ) and temperature ( $T$ ) of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  based sensors to Ozone gas.

$T$ (°C)	$S$	$T$ (°C)	$S$
160	1.282	230	1.146
170	1.286	240	1.129
180	1.139	250	1.131
190	1.206	260	1.118
200	1.187	270	1.106
210	1.152	280	1.132
220	1.186		

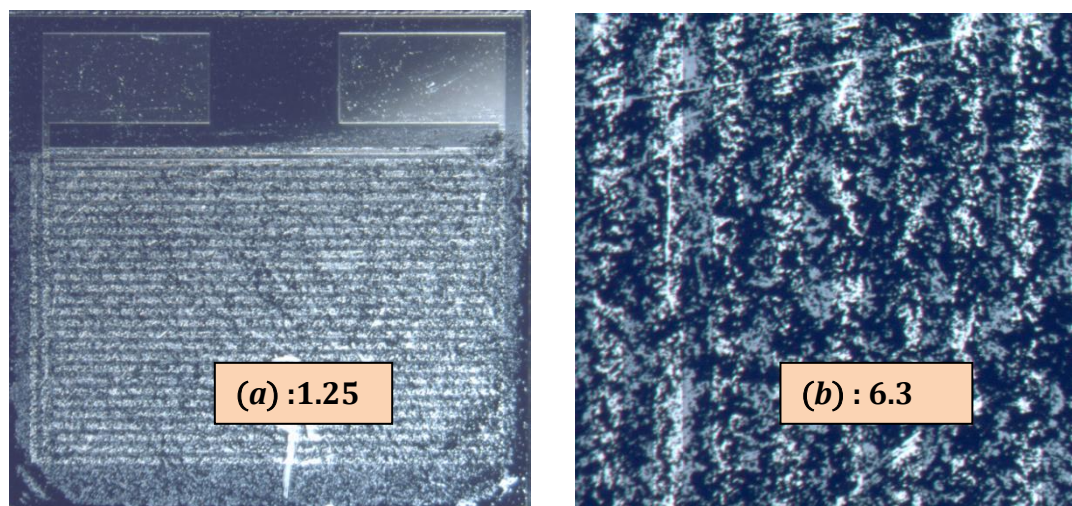


**Table 2:** Response values ( $S = R_a/R_g$ ) of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor (our study) compared to others materials considered for Ozone sensing application.

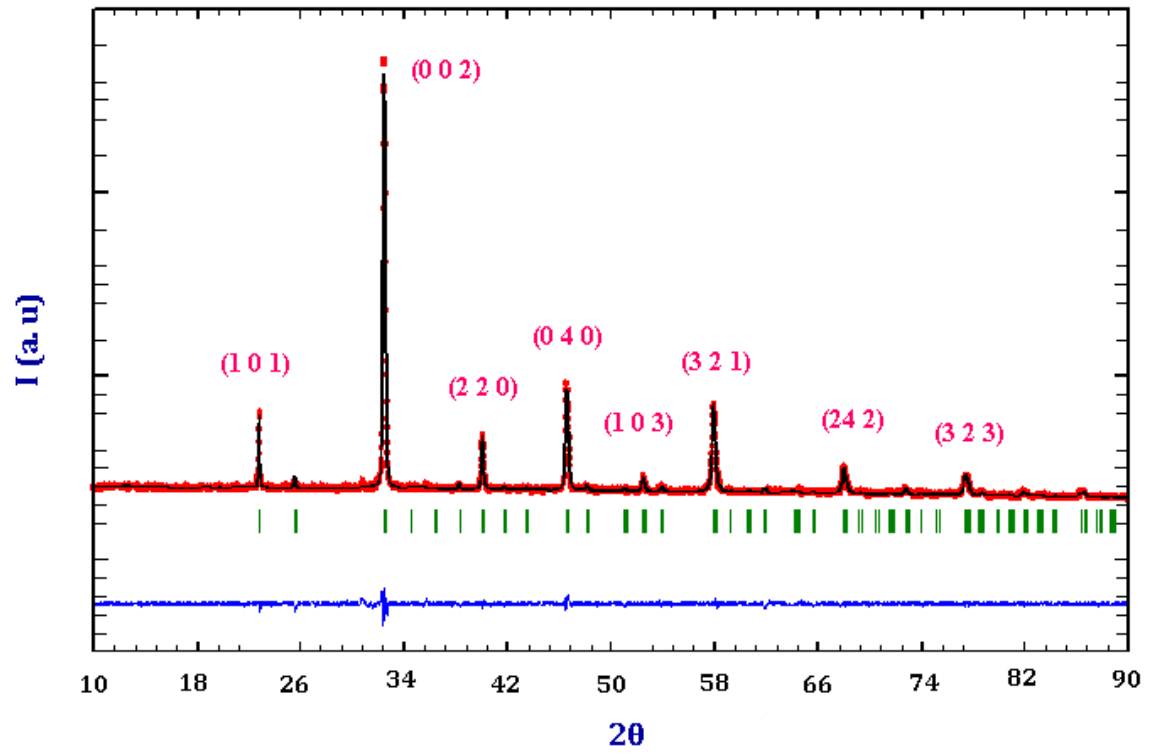
<i>Sensors</i>	<b>T</b> (°C)	<b>C</b> (ppb)	<b>S</b>	<b>References</b>
$\text{WO}_3$ (EG : 50 $\mu\text{m}$ )	250	200	1.7	[19]
$\text{WO}_3$ (EG : 50 $\mu\text{m}$ )	250	400	2.3	[19]
$\text{WO}_3$ (EG : 50 $\mu\text{m}$ )	250	800	2.8	[19]
$\text{WO}_3$	300	50	1.25	[20]
$\text{WO}_3$	300	100	1.42	[20]
$\text{WO}_3$	300	150	1.78	[20]
$\text{WO}_3$	300	175	2.25	[20]
$\text{SrTi}_{0.925}\text{Fe}_{0.075}\text{O}_3$	250	75	3	[21]
$\text{SmFe}_{0.8}\text{Co}_{0.2}\text{O}_3$	200	400	3	[22]
$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$	170	50	1.6	Our study
$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$	170	100	1.9	Our study
$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$	170	200	2.5	Our study
$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$	170	300	3.3	Our study
$\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$	170	400	3.9	Our study

**Table 3:** Response times ( $\tau_{resp}$ ) of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor at different concentrations (C) at the operating temperature of 170 °C compared to the  $\text{SmFeO}_3$  sensor.

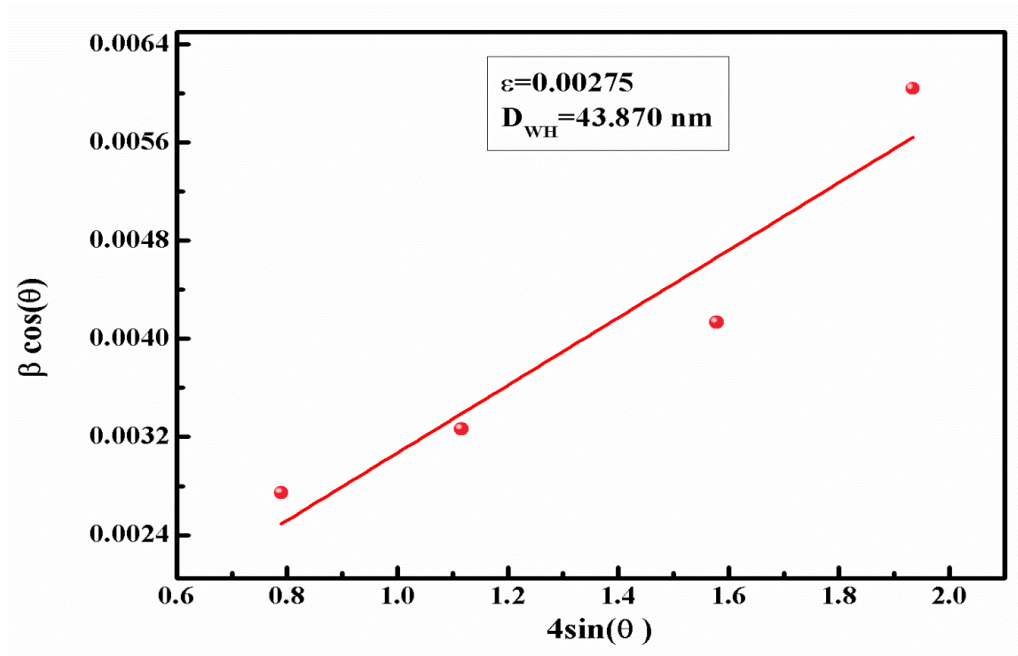
<i>Sensors</i>	<b>T (°C)</b>	<b>C (ppb)</b>	<b><math>\tau_{resp}</math> (min)</b>	<b>References</b>
<b><i><math>\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3</math></i></b>	<b>170</b>	<b>50</b>	<b>3.5</b>	<b>Our study</b>
<b><i><math>\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3</math></i></b>	<b>170</b>	<b>100</b>	<b>3.0</b>	<b>Our study</b>
<b><i><math>\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3</math></i></b>	<b>170</b>	<b>200</b>	<b>2.5</b>	<b>Our study</b>
<b><i><math>\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3</math></i></b>	<b>170</b>	<b>300</b>	<b>2.2</b>	<b>Our study</b>
<b><i><math>\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3</math></i></b>	<b>170</b>	<b>400</b>	<b>2.1</b>	<b>Our study</b>
<b><i><math>\text{SmFeO}_3</math></i></b>	<b>200</b>	<b>50</b>	<b>8.4</b>	<b>[3]</b>
<b><i><math>\text{SmFeO}_3</math></i></b>	<b>200</b>	<b>300</b>	<b>5.2</b>	<b>[3]</b>
<b><i><math>\text{SmFeO}_3</math></i></b>	<b>200</b>	<b>500</b>	<b>4.0</b>	<b>[3]</b>
<b><i><math>\text{SmFeO}_3</math></i></b>	<b>200</b>	<b>3000</b>	<b>1.2</b>	<b>[3]</b>



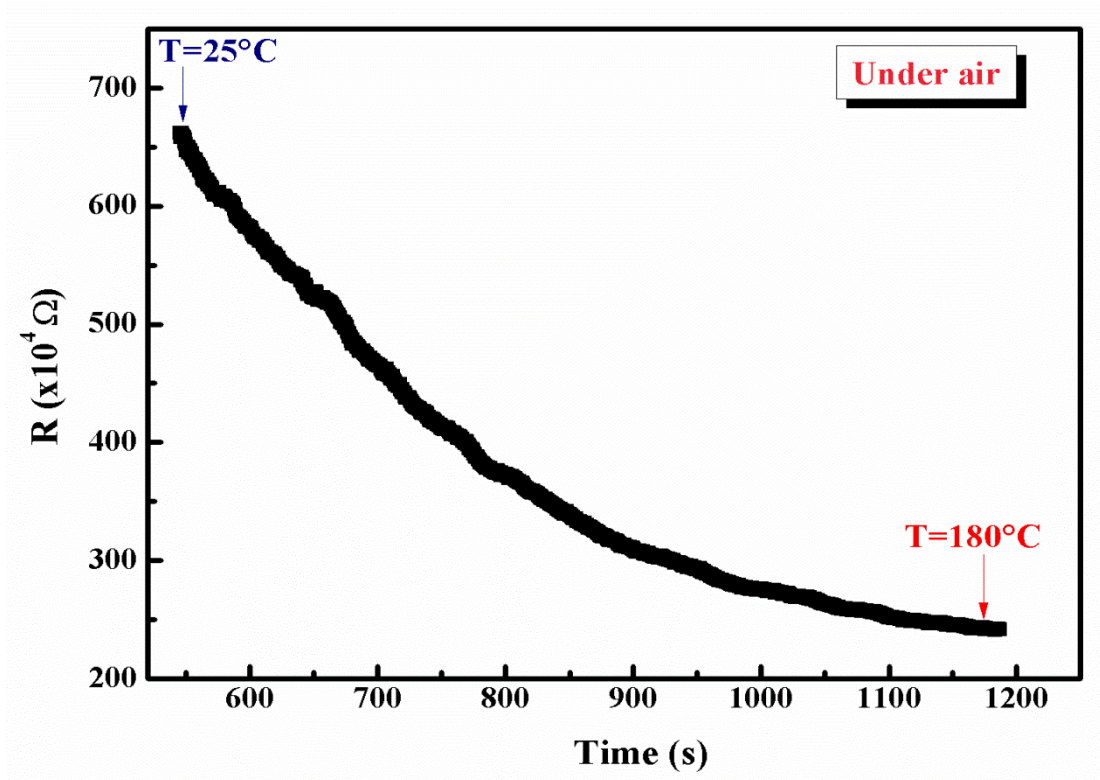
**Figure 1:** (a) Optical sensor view after drop coating of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor and (b) the zoom of the figure.



**Figure 2:** Observed (red), calculated (black solid line), their difference patterns (blue) and the Bragg positions (green) of  $La_{0.8}Pb_{0.1}Ca_{0.1}Fe_{0.8}Co_{0.2}O_3$  sensor and the secondary phase which is attributed to the  $Fe_3O_4$  impurity.

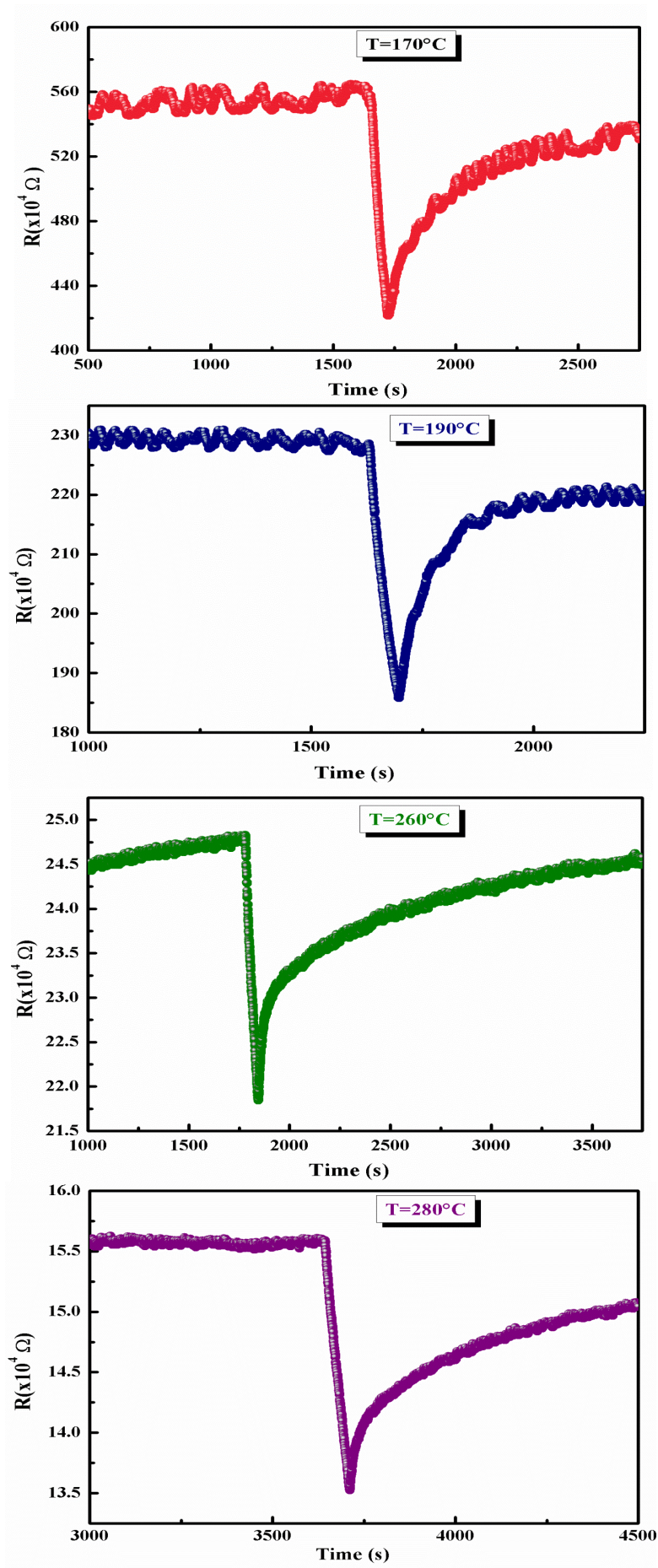


**Figure 3:** The Williamson–Hall analysis plots of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor.

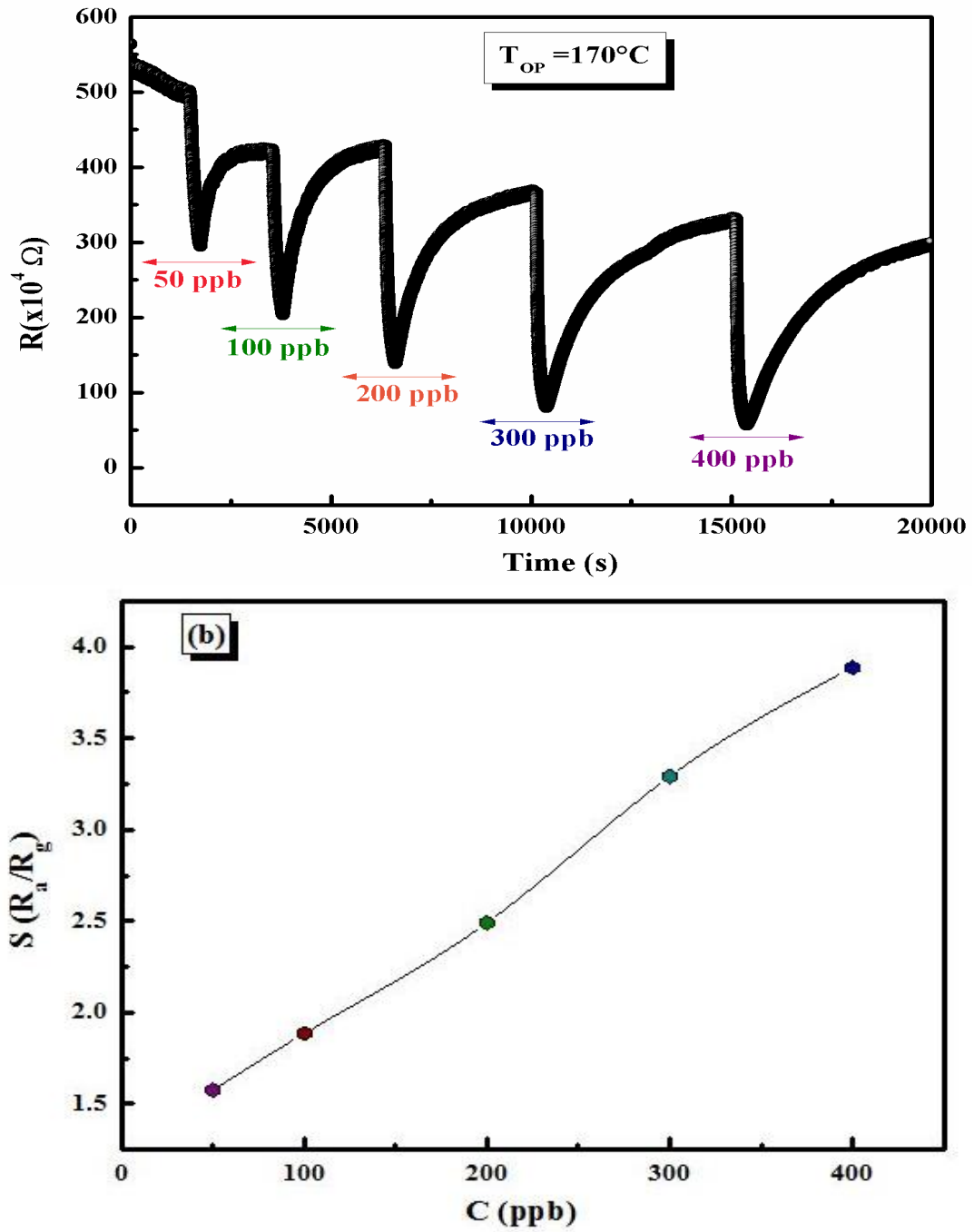


**Figure 4:** Resistance vs. time of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor.





**Figures 5:** Ozone gas response of  $\text{La}_{0.8}\text{Pb}_{0.1}\text{Ca}_{0.1}\text{Fe}_{0.8}\text{Co}_{0.2}\text{O}_3$  sensor as a function of time at several temperatures (170, 190, 260 and 280 °C).



**Figures 6:**  $La_{0.8}Pb_{0.1}Ca_{0.1}Fe_{0.8}Co_{0.2}O_3$  sensor response ( $S$ ) to (a) oxidizing gas ( $O_3$ ) and (b) sensor responses depending on the  $O_3$  concentration.



**Declaration of interests**

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: