Room Temperature Relative Humidity Sensing using Polypyrrole Conductive Thin-films

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The main purpose of this work consists of the fabrication of polypyrrole (PPy) conductive thin-films by means of the chemical in-situ polymerization technique using two different oxidants and the study of the sensing properties of these coatings to relative humidity (RH) variations.

Humidity is a commonly measured parameter for an extensive range of applications, such as product quality in industrial processes, air conditioning for human comfort or food production and conservation. Hence, the requirements of humidity sensors may vary from one application to another originating a wide scope of sensing materials and mechanisms [1-2]. PPy has been largely reported in literature as an excellent candidate for the fabrication of both gas and humidity sensors due to the high conductivity, small hysteresis and good linearity when compared with other polymers as well as environmental stability, quick response and room temperature operation compared with some inorganic materials [3]. However, as far as we know, a comparison between the sensing properties of PPy thin-films fabricated by means of the chemical in-situ polymerization technique and using different oxidants has not been reported yet.

Here, interdigitated electrodes with a separation of 10 μm have been used as substrates. The electrodes have been fabricated onto alumina from sputtered platinum thin film using photolithography and ion etching (see Fig. 1). PPy coatings with an approximate thickness of 500nm have been fabricated by means of the in-situ polymerization technique using ammonium peroxydisulphate (APS) and $PdCl_2$ as oxidants as it is described in [4]. A homogeneous coverage of the substrate is obtained after the fabrication of the coatings as it can be observed in Fig. 1 (bottom right). The morphology of the coatings was studied by means of the scanning electron microscope (SEM). The SEM image of Fig. 2a shows a homogeneous coverage of the substrate for the films fabricated using APS as well as the formation of PPY aggregates. Meanwhile, the SEM image of Fig. 2b reveals a porous structure with voids between the PPy aggregates with the PPy coatings fabricated using $PdCl_2$ as the oxidant. Moreover, conductivity measurements shown that the resistance of the films fabricated using $PdCl_2$ doubled that of the films fabricated using APS.
In order to test the sensitivity of the devices they were subjected to RH variations from 20% to 60% at ~23ºC. Resistance measurements performed with both, PPy coatings fabricated using APS and $PdCl_2$ are shown in Fig. 3. The devices show a resistance variation in the range 20-60% RH of 94 Ω and 91 Ω for the films fabricated using APS and $PdCl_2$ respectively. Although the resistance variation of both devices is in the same order of magnitude the relative variation of the resistance compared with the resistance value is of approximately 6.6% and 2.6% for the APS and $PdCl_2$ based coatings respectively. The response times of both devices was in the order of 1-2 min but the device fabricated using APS shows a quicker stabilization time than the one fabricated using $PdCl_2$. Additionally, the devices show high repeatability after several cycles with a small resistance drift which could be attributed to the cross-sensitivity with the temperature. Further experiments are needed in order to establish the optimal properties of the films as well as the cross-sensitivity with different chemical compounds.

To sum up, PPy coatings have been fabricated onto interdigitated electrodes using different oxidants. The sensitive of these coatings to RH variations at room temperature has been measured and compared.

References

[1] Z. Chen, C. Lu, Sensors Letters, **3(4)** (2005) 274-295
[2] C. Y. Lee, G. B. Lee, Sensors Letters, **3** (2005) 1–14
[3] W. Geng, N. Li, X. Li, R. Wang, J. Tu, T. Zhang, Sensors and Actuators B, **125** (2007) 114-119
[4] M. Ferenets, A. Harlin, Thin Solid Films, **515** (2007) 5324-5328

Figures

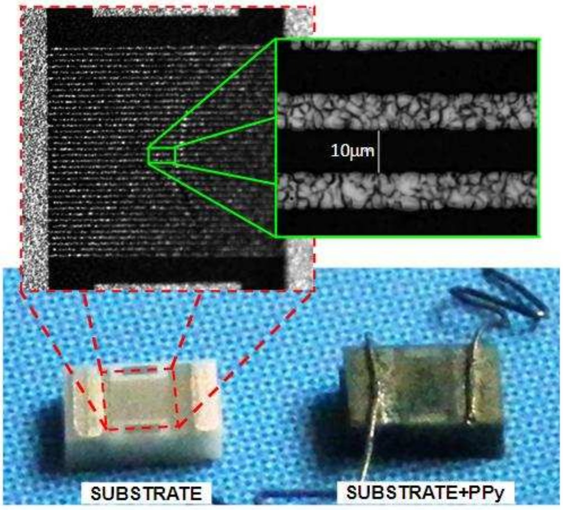

Fig1. Bottom: Interdigitated electrodes substrate (left) and substrate coated with PPy (right). Top: Detail of the interdigitated electrodes.

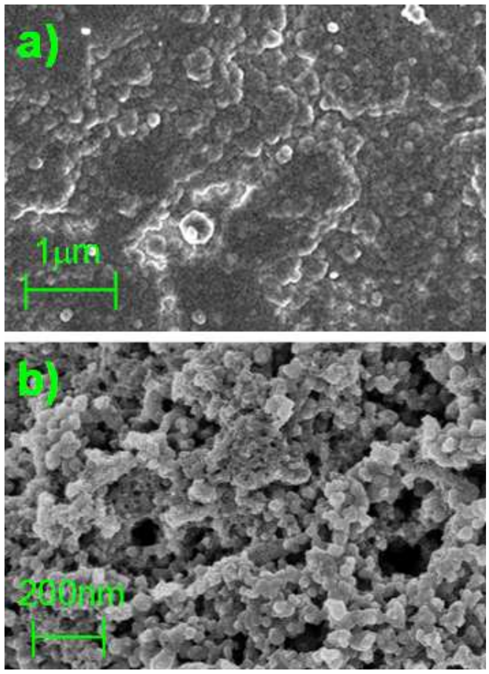

Fig2: SEM images of the PPy coatings fabricated with APS (a) and $PdCl_2$ (b).

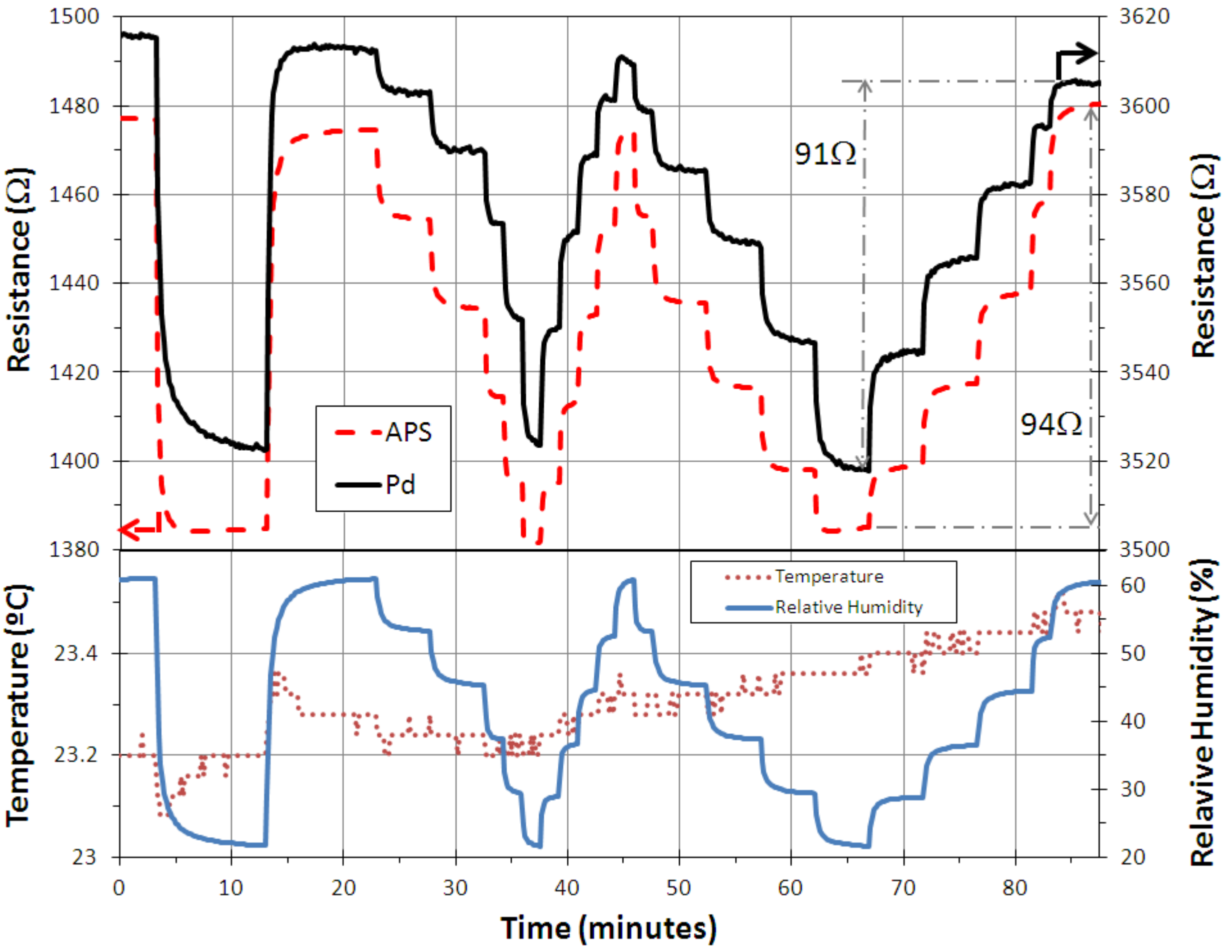

Fig3: Dynamical response of the PPy coatings fabricated using APS (discontinuous red line) and $PdCl_2$ (black line) to relative humidity variations from 20% to 60%.