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Abstract

Functionalization of Indium Tin Oxide with Noble Metals Nanoparticles in Hydrogen Sensing †

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Abstract: This work presents a simple method of synthesis of hydrogen-sensitive composites, starting from commercial materials, namely ITO, Rh, Pd and Pt nanoparticles. These composites, prepared by mechanical mixture and tested vs. 0.5% H2 showed promising results at temperatures below 250 °C, in line with those obtained in the literature on similar materials, prepared with more energy- and time-consuming methods.

Keywords: hydrogen sensing; metal oxides; metal catalysts

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1. Introduction

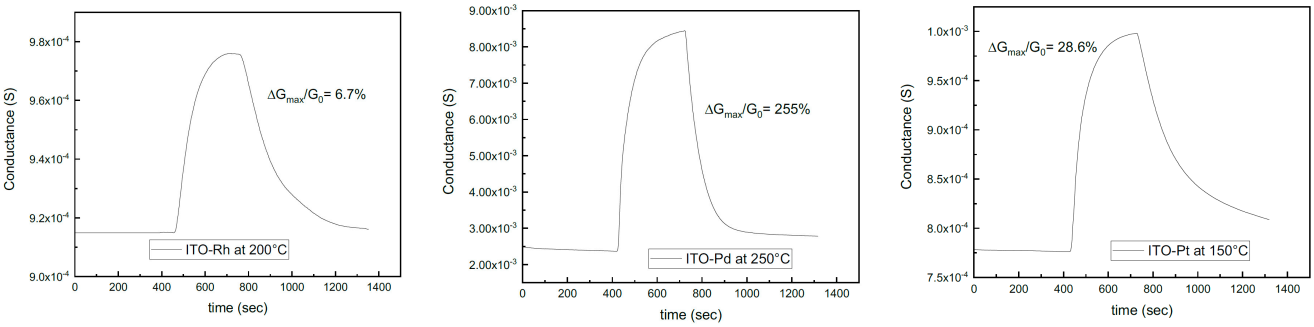
Hydrogen has been identified as an attractive alternative to fossil fuels to reduce greenhouse gas emissions; for this reason, there are large investments being made in a hydrogen economy all over the world [1]. However, H2 is an odorless, colorless, flammable and explosive gas in concentrations in air of 4%, hence the need to effectively monitor and manage its storage, transport and distribution, and the importance of H2 sensors for fast leak detection [2]. Traditional H2 gas sensors based on metal oxide (MOX) usually requires the functionalization with metals catalysts to ease the interaction with H2 and improve the MOX sensors' performance [3]. Several papers on H2 detection present various metal/MOX composites, mostly in the form of thin films, made with techniques that are generally costly in terms of both time and energy consumption [4–6]. Herein, we present hydrogen-sensitive nanocomposites, consisting of commercial materials, Indium Tin Oxide (ITO) nanoparticles (NPs) functionalized with Rh, Pd and Pt NPs, synthesized through a simple mechanical mixture in liquid phase. The chemo-resistors based on these composites were tested vs. 0.5% H2 diluted in synthetic air at different operating temperatures in the range 50–250 °C, with results that are in line with those reported in the literature on similar materials.

2. Materials and Methods

The ITO NPs were purchased from Merk Life Science S.r.l. (Milano, Italy). Colloidal dispersion of Pt, Pd and Rh NPs, (0.05 mg/mL), were bought from Metrohm DropSens (Llanera, Spain). Graphene dispersion (GNP) was obtained by liquid phase exfoliation of graphite in H2O/IPA according to reference [7]. Per each preparation, ITO (0.005 g) was dissolved in 2 mL of purified water (MilliQ system), added with 1 mL of colloidal dispersion of the metal NPs and 1.2 mL of GNP were added and bath-sonicated for 1 h. The addition of the GNP to the composite was aimed to adjust the conductivity of the sensing films to the operating range of the measurement equipment. Sensing devices were fabricated by drop-casting the dispersions onto Al2O3 substrate with gold IDEs (finger contact width 250 µm; gap between fingers 860 µm). Films were first dried for 1 h at 180 °C on hot plate and then annealed in air at 270 °C for 1 h.

3. Discussion

Figure 1 shows the responses of each device operated at the temperature that optimizes its performance in terms of signal variation, response and recovery times. As expected, each material has an intensity of response that depended on the different coupling of the metal catalyst to the ITO. The performances of the devices in terms of operating temperature were in line with those reported in the literature [8]. The mechanisms that rule the interaction with the gas are still being investigated, and will be discussed by evaluating the work functions of the individual materials, the binding energies of the H2, and the electronic and chemical sensitivity of the metal/MOX junctions.



(**a**) (**b**) (**c**)

Figure 1. Dynamic response of the prepared nanocomposite (**a**) ITO-Rh n; (**b**) ITO-Pd; (**c**) ITO-Pt. Devices were biased at 1 V. Sensing tests towards 0.5% of H2 were performed in synthetic air with RH 50%.

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