Supporting Information for New Journal of Chemistry

Hydrogen-gas sensors based on graphene functionalized palladium nanoparticles: the impedance response as a valuable sensor evaluation

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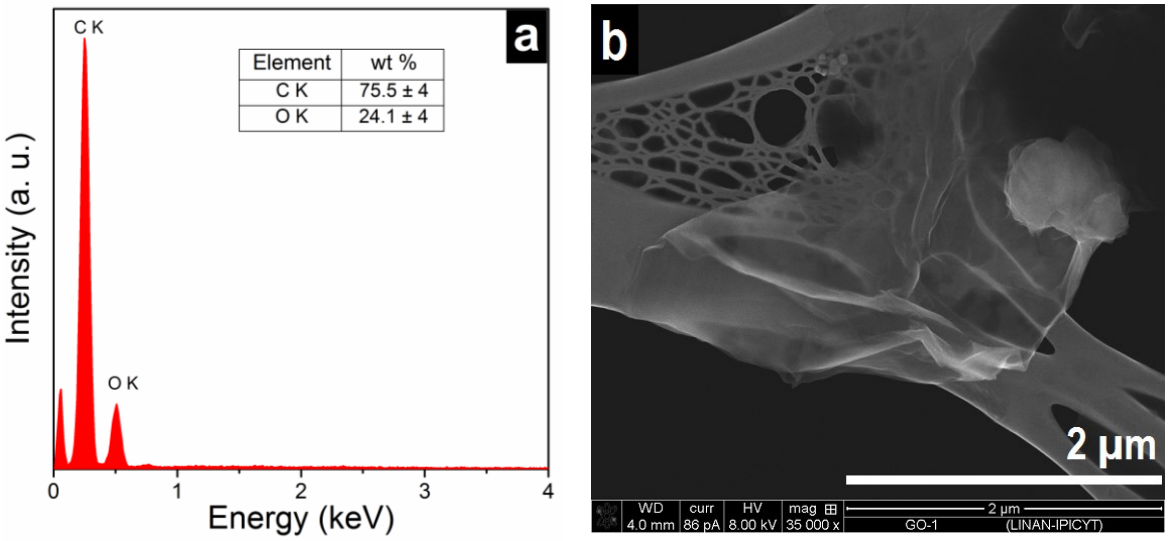


Fig. S1 (a) EDX spectra of dried graphene oxide synthetized by modified Hummers method and (b) the corresponding SEM image.

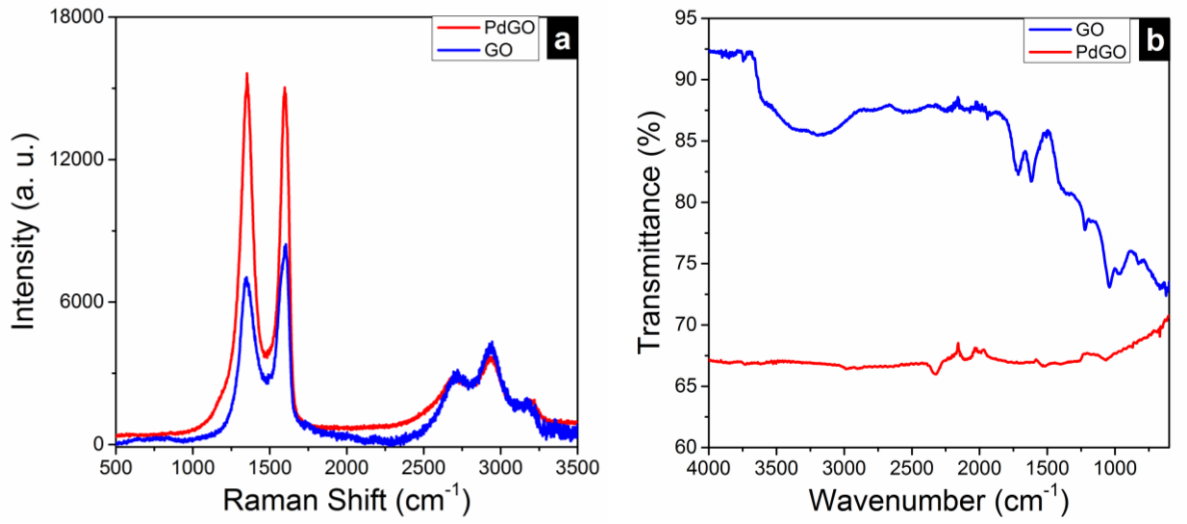
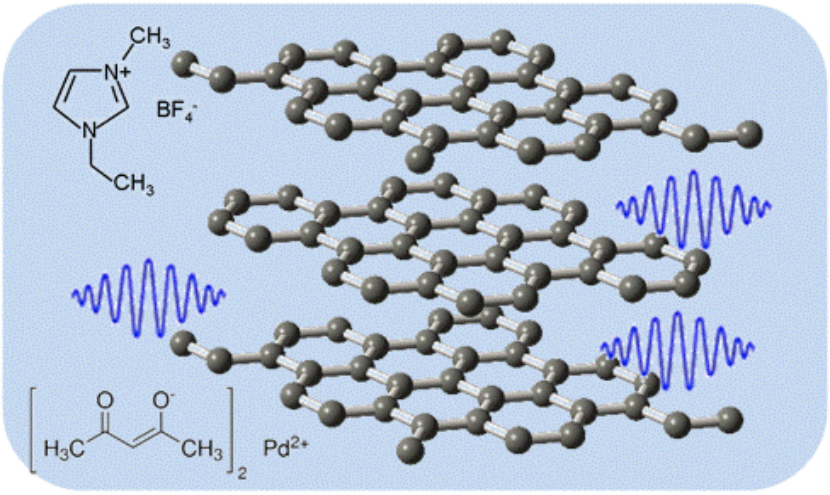
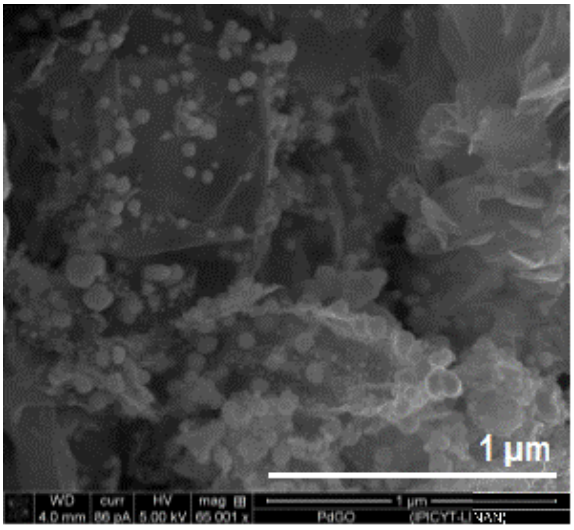


Fig. S2. (a) Raman spectra of dried PdGO compared with GO. (b) FTIR spectra of dried PdGO, compared with GO, which indicates removal of functional groups.





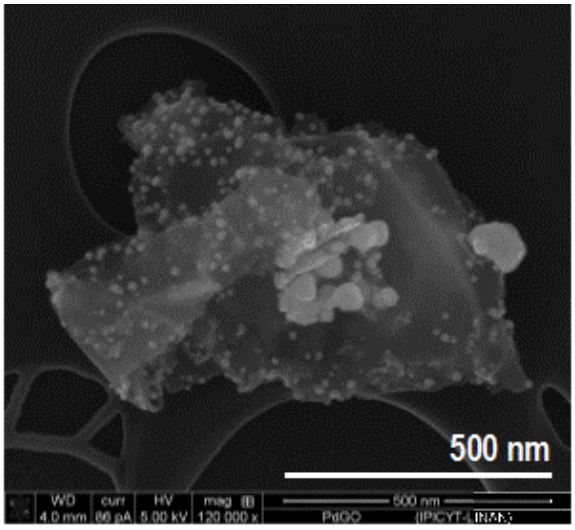


Fig. S3 Schematic representation of hydrothermal-microwave exfoliation method to produce PdGO sample.

Table S1. Mixture conditions of the used gas and equivalent hydrogen concentrations in ppm and vol. %.

100 sccm = 100mL/min		Hydrogen concentration	
V_a = air volume	V_g = hydrogen volume	Volume (%)	ppm
95 mL/min	5 mL/min	5%	50000
97 mL/min	3 mL/min	3%	30000
99 mL/min	1 mL/min	1%	10000
99.5 mL/min	0.5 ml/min	0.5%	5000
99.9 mL/min	0.1 mL/min	0.1%	1000
99.99 mL/min	0.01 mL/min	0.01 %	100

Hydrogen concentrations were determinate by the next equation:

$$\frac{V_g}{V_a + V_g} = \frac{V_g}{V_T}$$

where $V_g = gas\ volume$, $V_a = air\ volume$, and $V_T = total\ volume$

The setup contains gas cylinders and regulators, flow controller, test chamber and analyzer system. The gas flow rate was controlled by the flow controller valve and mass flow controller (Aalborg) and the flow rate was checked flow rate with a universal gas flowmeter (Agilent Technologies ADM1000). A check valve was set up at the outlet line to maintain the outflow of the gases near atmospheric pressure, where the exhaust gas was bubbled in water.

Hydrogen concentration was controlled by its amount in the mixture with synthetic air. Compressed air (UN 1002) and hydrogen gas (Chromatographic grade, UN 1049, 99.998% MIN.) were purchased from INFRA México. All tests were performed under the following atmospheric conditions: temperature: 24° ± 2°C, pressure: 1.0 ± 0.05 bar, gas flow rate: 100 ± 2% sccm and relative humidity: 50% ± 10%.

Fig. S4 Detection with longer time for of six different H_2 concentrations with the PdGO sensor at room temperature.

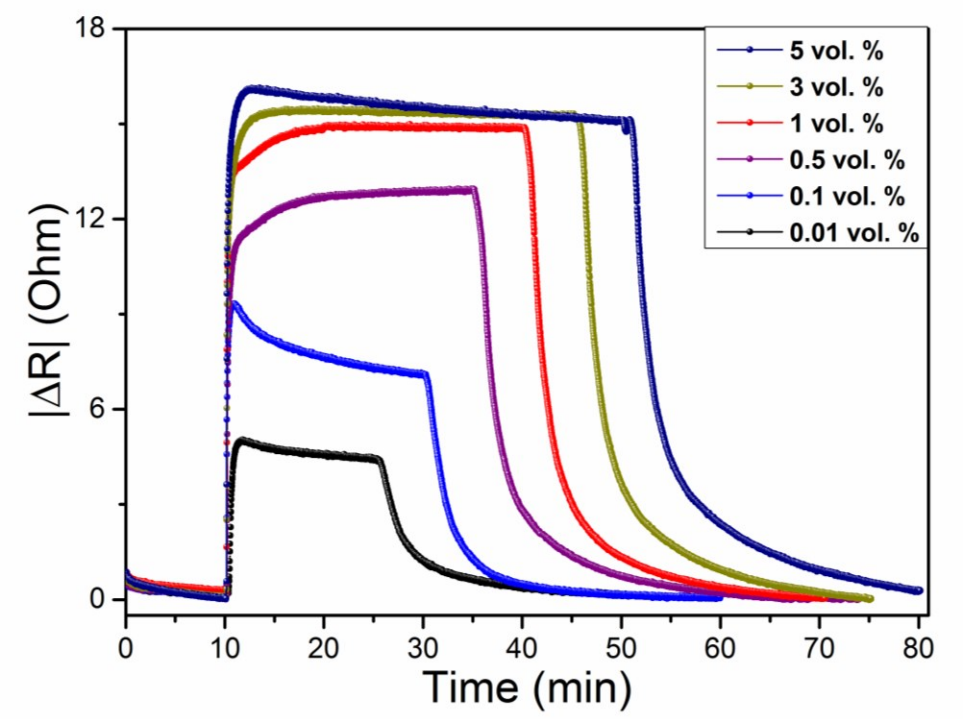


Fig. S5. Raw data tests of hydrogen detection from 0.1to 5 vol. % in air for six cycles.

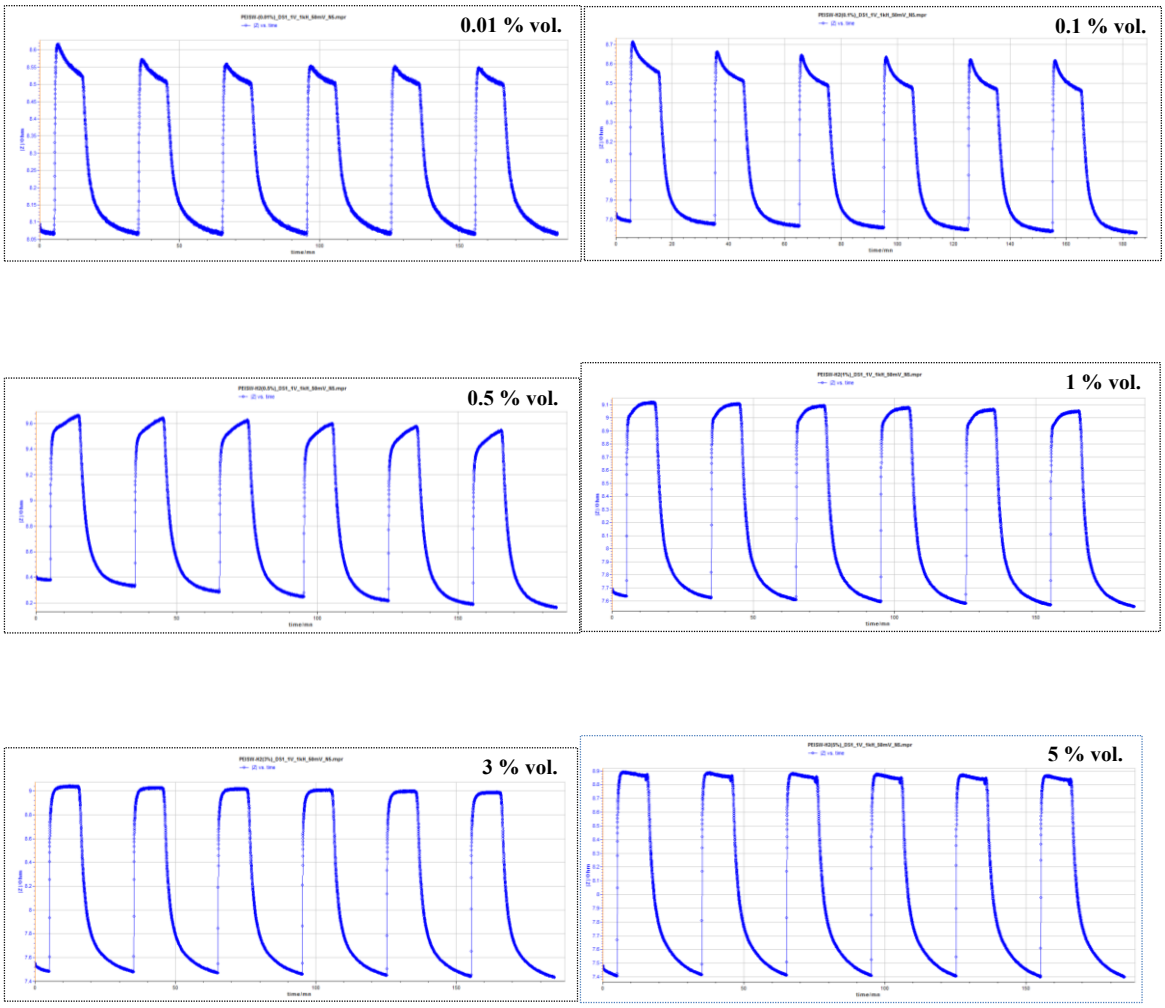


Figure S6. Reproducibility with another sensor fabricate with the same procedure for six different H_2 concentrations.

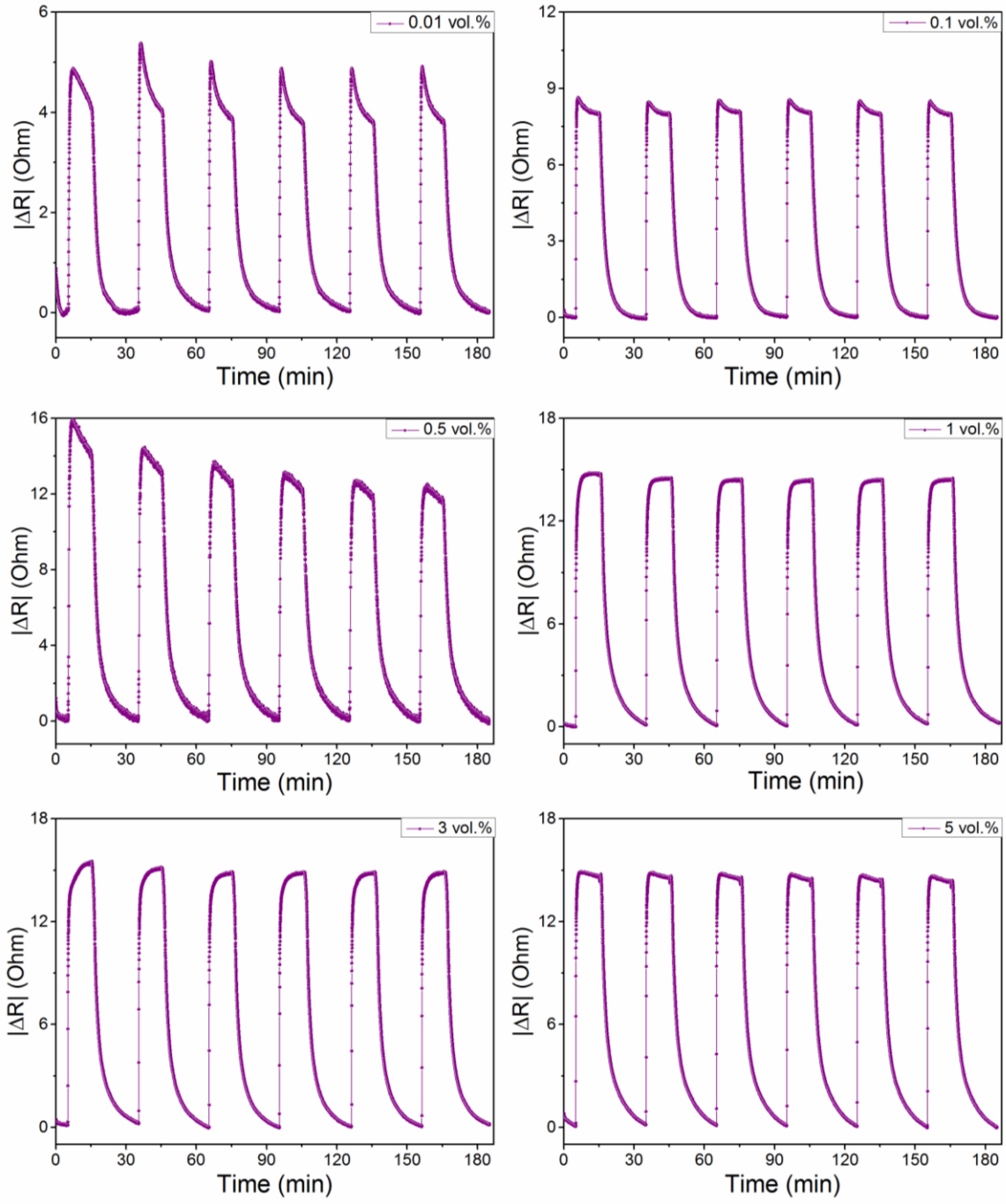


Table S2: Results of reproducibility by comparison two sensor with the corresponding sensitivity values.

H_2-concentration		Sensibility (%)	
Volume (%)	ppm	Device sensor 1	Device sensor 2
0.01 %	100	4.4 ± 0.2	4.1 ± 0.7
0.1%	1000	7.7 ± 0.4	8.0 ± 2.0
0.5%	5000	12.8 ± 0.7	13.4 ± 2.0
1%	10000	14.7 ± 0.8	14.6 ± 0.5
3%	30000	15.5 ± 0.9	14.7 ± 0.4
5%	50000	15.9 ± 0.6	14.7 ± 0.5