Reactive laser synthesis of hybrid nickel oxide – nitrogen doped graphene-based electrodes for energy storage

Ángel Pérez del Pino*[,1], Andreu Martínez Villarroya[1], Alex Chuquitarqui[1], Constantin Logofatu[2], Dino Tonti[1], Enikö György[1,3]

[1] Instituto de Ciencia de Materiales de Barcelona, Consejo Superior de Investigaciones Científicas (ICMAB-CSIC), Campus UAB, 08193 Bellaterra, Spain.

[2]National Institute for Materials Physics, PO Box MG 7, 77125 Bucharest, Romania

[3] National Institute for Lasers, Plasma and Radiation Physics, PO Box MG 36, 77125 Bucharest, Romania

*Corresponding author (Telephone:+34 935801853; E-mail: aperez@icmab.es)

Supporting material

1. Optical image of samples

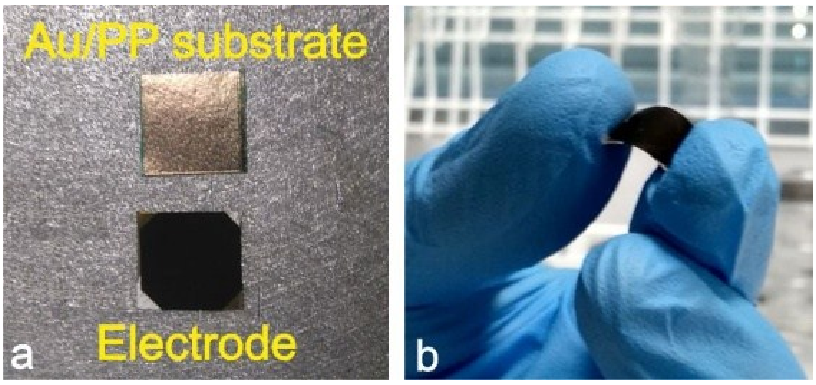


Figure S1. (a) Image of Au/Cr/PP substrate and GO/Au/Cr/PP electrode. (b) The electrodes are highly flexible.

2. SEM images of the GO and GO-NiO samples

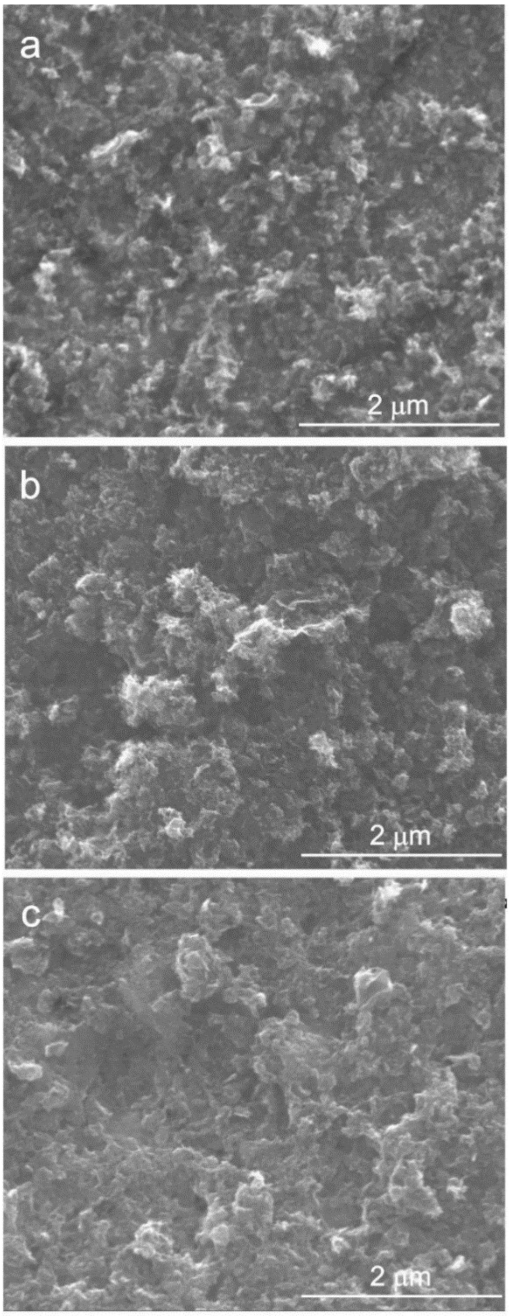


Figure S2. SEM images of (a) GO-NH_3, (b) GO-Melamine and (c) GO-Urea samples.

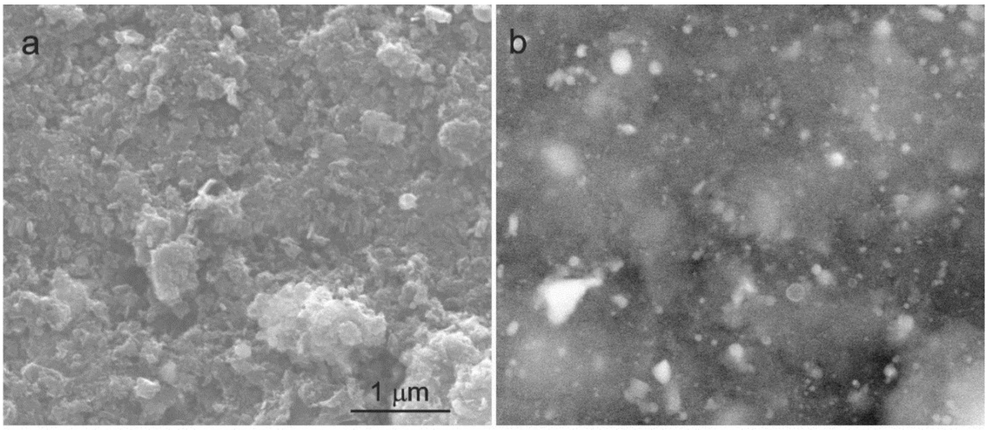
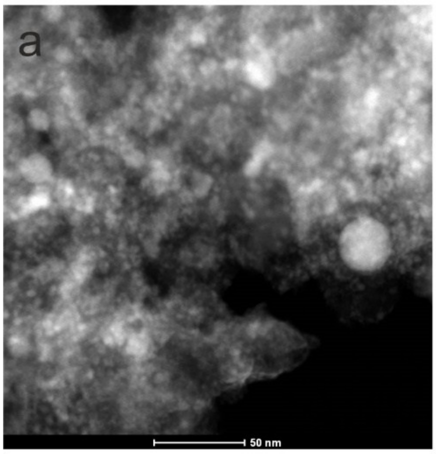


Figure S3. SEM images of GO-NiO-Melamine film. (a) Secondary and (b) corresponding backscattered electron images. The bright elements in (b) are attributed to Ni-rich regions (Ni has higher atomic number than C).

3. Typical TEM analyses of GO / NiO samples



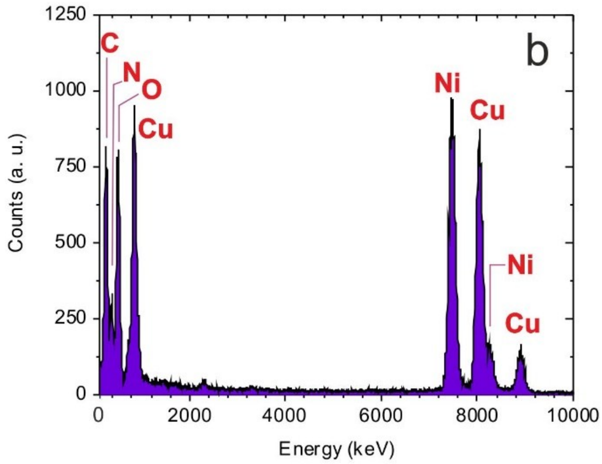


Figure S4. (a) HAADF-STEM image of GO-NiO-Melamine sample. (b) Typical EDAX spectrum of GO-NiO-Urea sample. The energy peaks are associated to their corresponding chemical elements.

4. Mean distance between defects and density of defects in GO-deposited materials calculated through Raman measurements.

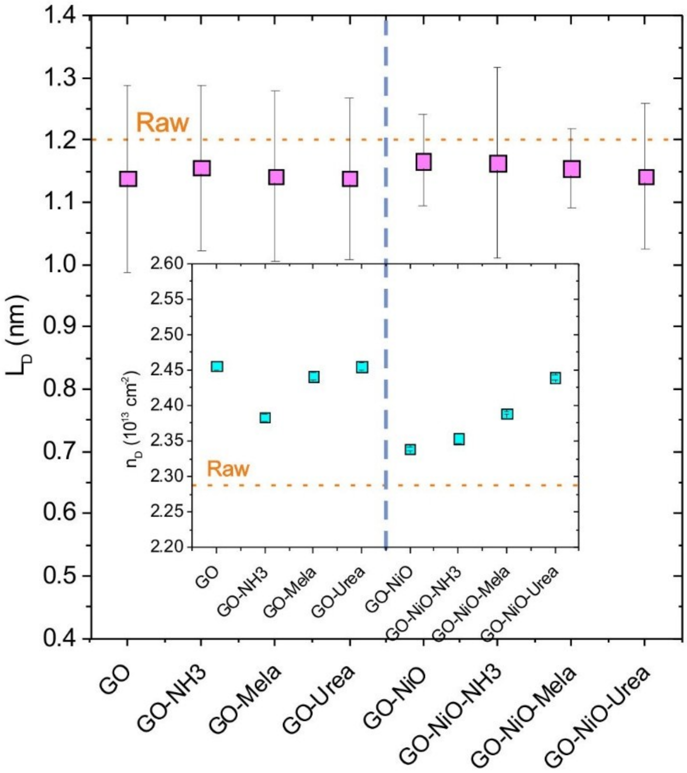


Figure S5. Mean distance between defects (L_D) in GO-deposited materials. Inset: corresponding density of defects (n_D).

5. Calculation of C, O, N concentrations in GO structure in presence of NiO

Due to the presence of NiO nanostructures in the deposited GO-NiO samples, the atomic concentrations of C, O, N measured through XPS in rGO material should be recalculated.

Being the total atomic quantities of C, O, N and Ni respectively named as qC, qO, qN and qNi, and considering NiO material as stoichiometric,

$$qNi = qO_{NiO} \quad (1)$$

$$qO = qO_{NiO} + qO_{rGO} \rightarrow qO_{rGO} = qO - qO_{NiO} = qO - qNi \quad (2)$$

Therefore, the atomic concentration recorded by XPS is

$$[C]_{XPS} = \frac{qC}{qC + qN + qO + qNi} \equiv \frac{qC}{qCNO + qNi} \quad (3)$$

$$[O]_{XPS} = \frac{qO}{qCNO + qNi} \quad (4)$$

$$[Ni]_{XPS} = \frac{qNi}{qCNO + qNi} \quad (5),$$

where qCNO = qC+qN+qO.

By using (2) and (3), the real atomic concentration in rGO, considering all the measured carbon and nitrogen atoms present in the rGO structure, would be

$$[C]_{rGO} = \frac{qC}{qC + qN + qO_{rGO}} = \frac{qC}{qCNO - qNi} \quad (6)$$

$$[O]_{rGO} = \frac{qO_{rGO}}{qC + qN + qO_{rGO}} = \frac{qO - qNi}{qCNO - qNi} = \frac{[O]_{XPS} - [Ni]_{XPS}}{1 - 2[Ni]_{XPS}} \quad (7)$$

$$\frac{[C]_{rGO}}{[C]_{XPS}} = \frac{qCNO + qNi}{qCNO - qNi} = \frac{1}{1 - 2[Ni]_{XPS}} = \frac{[N]_{rGO}}{[N]_{XPS}} \quad (8)$$

Therefore, with equations (7) and (8) it is possible to calculate $[C,N,O]_{rGO}$ from the atomic concentrations measured by wide scan XPS.

6. Deconvolution of XPS peaks. Integrated areas.

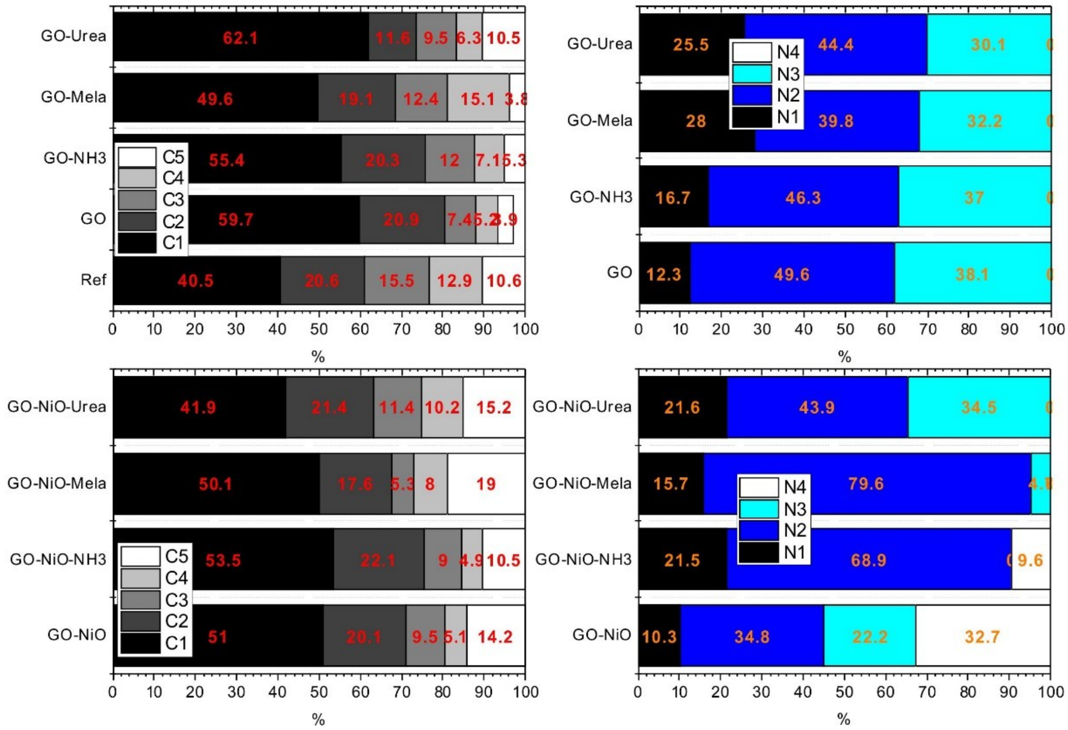


Figure S6. Integrated area of XPS C1s and N1s deconvoluted components.

7. Electrochemical characterization of electrodes.

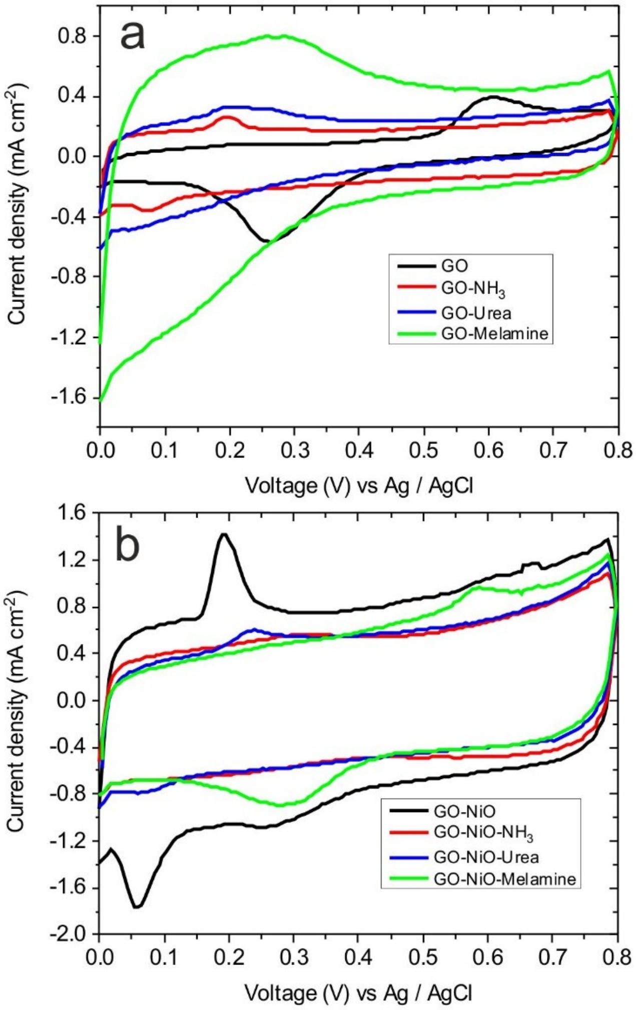


Figure S7. Cyclic voltammetry plots at a 150 mV s^{-1} scan rate of samples deposited (a) without and (b) with NiO NPs.

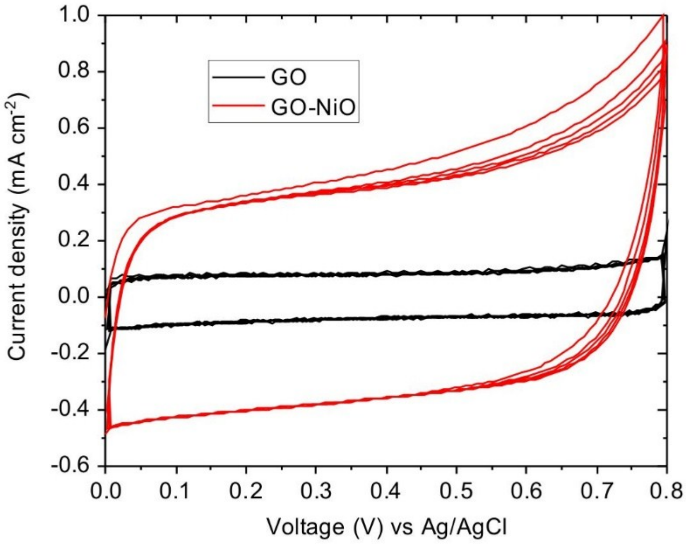


Figure S8. Additional voltammetry cycles measured at 150 mV s^{-1} scan rate of samples GO and GO-NiO.