An eco-friendly approach for inkjet printed graphene-based chemiresistive sensors

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The sensing capabilities of the graphene have been largely explored in the recent years due to its outstanding properties [1]: extremely high sensitivity to external environment, excellent surface-volume ratio, as well as the absence of bulk phenomena which affect the response signal.

One of the most promising graphene fabrication techniques, in terms of sensor device performances, is the Liquid Phase Exfoliation (LPE) [2]. In our previous works, the potential to effectively exfoliate natural graphite by means of a low environmental impact process, i.e. using a solvent mixture of water and isopropanol (IPA), has been demonstrated [3].

In the present work, as step further in the direction of green approach, we employ the so-developed liquid phase exfoliated graphene suspension as ink to fabricate chemi-resistive gas sensors on glossy paper by inkjet printing (IJP) (Fig.1). The main aim of the current research is to manufacture sensing devices through a sustainable process by using eco-friendly solvents and recyclable substrates.

With respect to the conventional solution-processable methods, the main IJP capability is related to small ink volumes deposition that entails a more controlled drying process. This specific potentiality of the IJP has been exploited in order to investigate the performances of this green device prototype upon NO_2 and NH_3 exposure in environmental conditions.

Graphene has been prepared according to the LPE process reported in ref. [3]. Graphite flakes (Sigma-Aldrich product code 332461) have been dispersed into a mixture of IPA and ultrapure water (at 1 mg/ml) and sonicated in an ultrasonic bath. Afterwards, the dispersion has been centrifuged in order to remove unexfoliated graphite crystallites.

A Raman analysis has been carried out by means of Renishaw InVia Reflex spectrometer (514 nm excitation source, backscattering configuration) on samples drop casted onto SiO_2(250 nm)/Si substrate. The spectrum, shown in Fig. 2, displays all the three characteristic bands of a graphitic material (D at 1320 cm^{-1}, G at 1575 cm^{-1} and 2D at 2650 cm^{-1}). As reported by Ferrari et al [4], the shape of the 2D band is correlated to the number of graphene layers, so confirming the effectiveness of the graphite exfoliation.

The graphene suspension has then been inkjet printed onto paper support including e-beam evaporated interdigitated Cr/Au (30 nm/120 nm) electrodes.

The devices have been characterized by exposure to 240 ppb of NO_2 and 250 ppm of NH_3, by detecting the conductance variation $\Delta G/G_0$. Under NO_2 exposure $\Delta G/G_0$ has been estimated equal to 13,7% , whereas in NH_3 the response is limited at 2,1% (Fig. 3). These results confirm the specificity of pristine graphene towards NO_2 [5]. Additionally, this prototype exhibits a good degree of repeatability in the sensing behavior.

To sum up, the present study opens new perspectives towards the graphene functionalization to detect different analytes.

References

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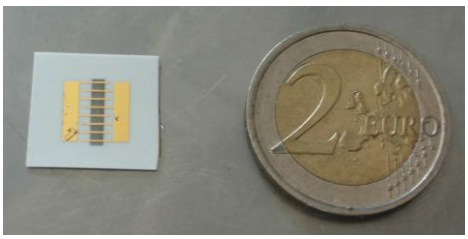

Figure 1: A picture of the IJ printed device on glossy paper..

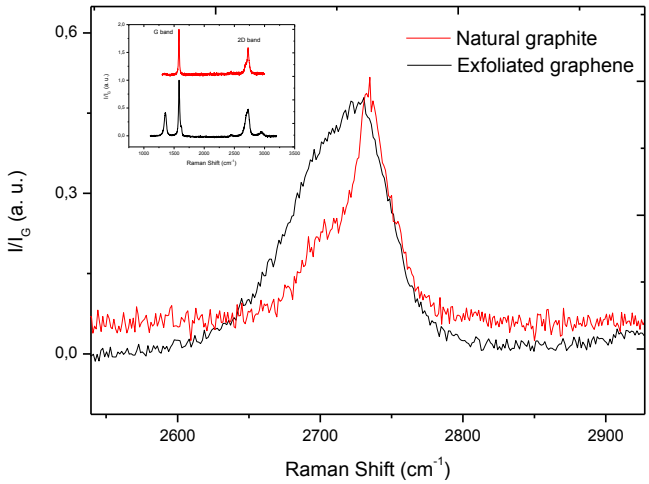

Figure 2: The 2D band of Raman spectra of the graphite and LPE graphene, When the material is exfoliated into less than five layers, the 2D band shape is significantly different from that of graphite. In the inset are reported the whole spectra for both materials.

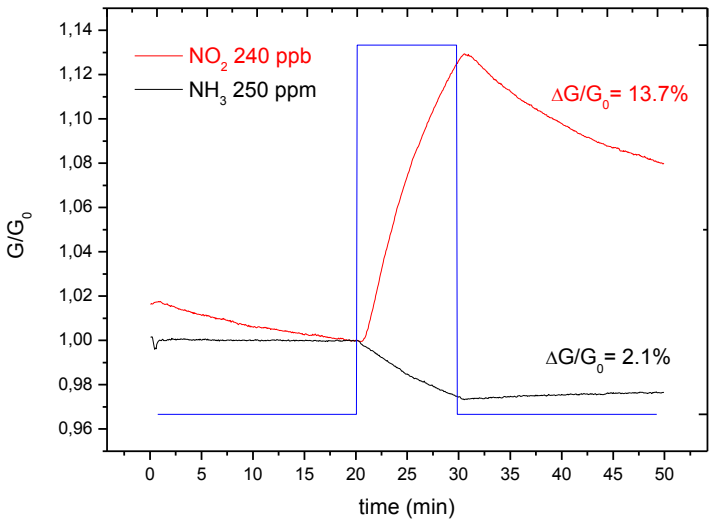

Figure 3: The dynamic responses towards NO_2 and NH_3, which display the specificity of the IJP device towards NO_2.