Chemical deposition of reduced graphene oxide on fabrics

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Abstract

Reduced graphene oxide (RGO) has been deposited on polyester (PES) fabrics to produce conductive textiles [1, 2]. In the first stage, PES is put in contact with the graphene oxide (GO) solution; adsorption of GO sheets takes place on the surface of the fabric. In the second stage GO is reduced to RGO by means of $Na_2S_2O_4$ chemical reduction. Different number of RGO coatings (1-4) was applied to the fabrics and characterized (PES-1G, PES-2G, PES 3G and PES-4G). Fig. 1 shows the SEM micrographs of PES coated with 1 RGO layer, RGO sheets can be distinguished on the surface of the fibers. The conducting textiles obtained have been characterized electrically by means of electrochemical impedance spectroscopy (EIS). The results have shown a decrease of the resistance of more than six orders of magnitude when GO was converted to RGO (from $>10^{11}$ to $2.6 \cdot 10^4$ $\Omega \cdot cm^2$) (single coating) (Fig. 2). This decrease can be correlated to the partial restoration of the sp^2 graphitic structure when GO is reduced to RGO as X-ray photoelectron spectroscopy (XPS) results have shown. With more RGO layers applied, the resistance decrease reached 9 orders of magnitude for 3 layers (23 $\Omega \cdot cm^2$). The phase angle also changed from 90º (insulating behaviour) for PES and PES-GO to 0º for RGO coated samples (conducting behaviour). Electrochemical activity of the coatings was measured by means of cyclic voltammetry (CV) and scanning electrochemical microscopy (SECM). CV of the fabrics has shown that scan rate is a key parameter in the characterization of these materials; only low scan rates allow the proper observation of redox processes. In addition, it is necessary to compensate the ohmic loss of the fabric. Results showed that electroactivity increased with the number of RGO coatings. SECM measurements were performed in the approach mode to test the electroactivity of the fabrics. Two different redox mediators were employed: $Ru(NH_3)_6^{3+/2+}$ and $Fe(CN)_6^{3-/4-}$, obtaining best results with the second one. The explanation for this is that $Fe(CN)_6^{3-/4-}$ is sensitive to the state of carbon surface. On the other hand $Ru(NH_3)_6^{3+/2+}$ represents the simplest case of an outer-sphere electron transfer with no known chemical interactions with the surface. A clear electroactivity change was observed when GO was reduced to RGO; the behaviour passed from negative feedback for PES-GO (insulating material) to positive feedback (conducting material) (Fig. 3). In this case, the values of positive feedback also changed with the number of RGO coatings, from 1.1 for one RGO coating to 1.6-1.7 for 2-4 coatings (Fig. 3). It should be taken into account that SECM is a local technique and the sample is not biased, in this case only the degree of coverage plays a role in the electrochemical activity. With 2-4 coatings the sample is completely coated and no differences of electroactivity can be discerned by SECM (in this case the better contact between the different RGO sheets for more RGO coatings does not play a role since sample is not biased). By means of CV and EIS, these differences could be appreciated since a higher number of coatings allowed a better contact between the different RGO sheets and consequently a better conductivity was observed. The results obtained by means of SECM also showed that the fabrics could also act at open circuit potential as an oxidant or a reductant with equal heterogeneous transfer electron charge transfer kinetics in both cases.

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References

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Figures

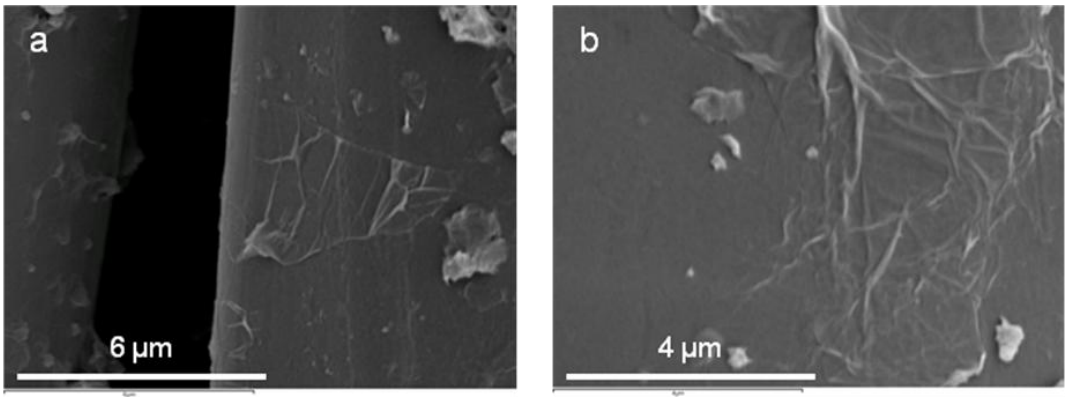

Figure 1. Micrographs of PES-1G samples (polyester coated with one RGO coating).

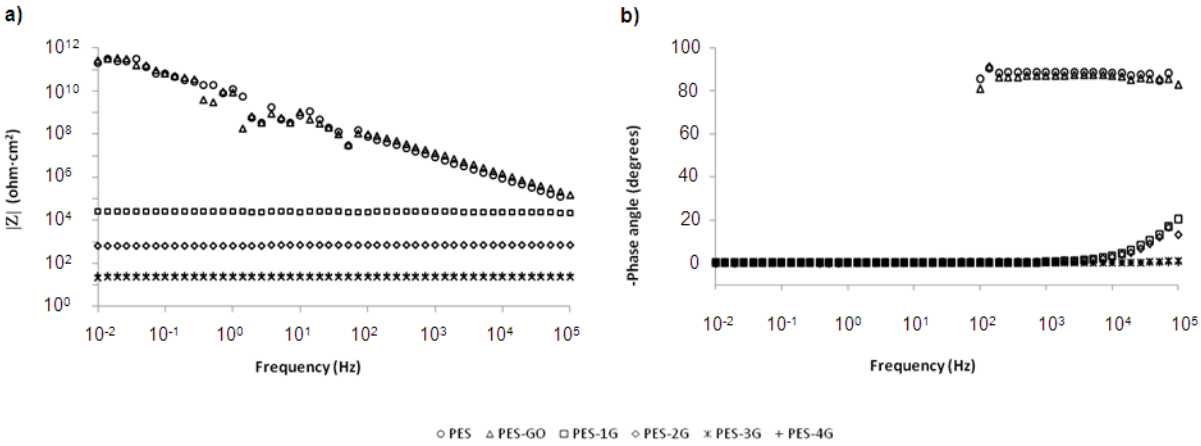

Figure 2. Bode plots for PES, PES-GO, PES-1G, PES-2G, PES-3G and PES-4G samples. Sample located between two copper electrodes. Frequency range from 10^5 Hz to 10^{-2} Hz.

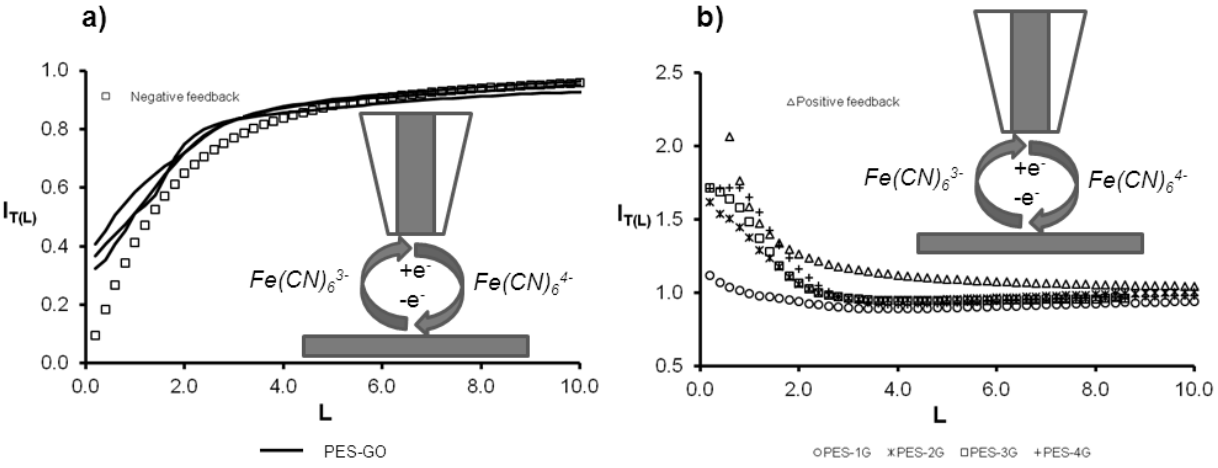

Figure 3. Approaching curves for: a) PES-GO (—) and theoretical negative feedback model (□). b) PES-1G, PES-2G, PES-3G and PES-4G samples. Theoretical positive feedback model is also presented for comparison (Δ). Obtained with a 100 µm diameter Pt tip in 0.01 M $Fe(CN)_6^{3-}$ and 0.1 M KCl. The tip potential was 0 mV (vs Ag/AgCl) and the approach rate was 10 µm·s^{-1}.