Scalable Production of Graphene-Based Wearable E-Textiles

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Supporting Information

Supporting Information 1: Pigment Dyeing

In order to compare the performance of rGO coated fabrics, the same cotton fabric was pigment dyed using a commonly used recipe for pigment dyeing, Table S1. Pigment Black HDT was used to produce a 3% o.w.f. (on the weight of the fabric) colour shade on the cotton fabric. Pigment Black HDT is a carbon-based pigment. Lyoprint PBA, a commonly used binder for pigment dyeing, was used to bind and cross-link the pigment with the fibre. A small amount of fixing agent Lyoprint PFL was used to increase the colour fastness of pigment dyed fabric. Liquor ammonia helped to initiate the cross-linking at higher curing temperature. Similar padding conditions were used for both the rGO coating and pigment dyeing to ensure the same 80% wet pick up on both fabrics.

Table S1. Pigment Dyeing Recipe

Chemicals	***Recipe***
Pigment Black HDT	7.5 g
Lyoprint PBA (Binder)	30 mL
Lyoprint PFL	2 mL
Ammonia	1 mL
Water	212.5 mL

Supporting Information 2: Structure of Vat Dye and $Na_2S_2O_4$

Sodium hydrosulphite ($Na_2S_2O_4$) has been used commonly as a reducing agent for vat dyes in the textile industry.[1] Figure S1 shows the similar chemical structure of vat dyes and graphene oxides with their oxygen functional groups covalently attached to aromatic benzene rings.[2] Therefore, $Na_2S_2O_4$ was used as an efficient reducing agent to reduce GO to rGO.

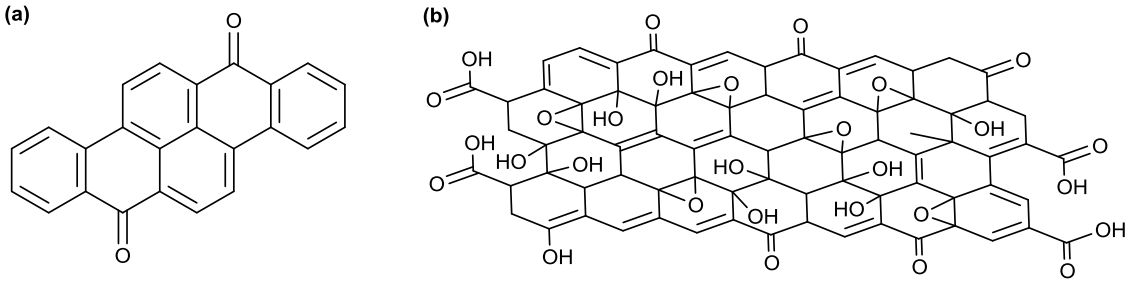
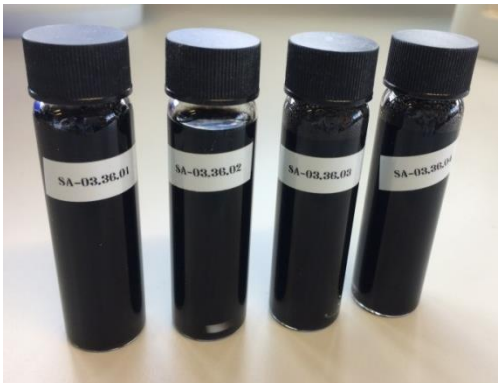


Figure S1. The chemical structure of a) VAT dye from the textile industry (Vat Yellow 4) which is typically reduced by sodium hydrosulphite ($Na_2S_2O_4$) and b) GO prepared by Hummers method

Supporting Information 3: Efficient Reduction of GO with Sodium Hydrosulfite

Figure S2 (a) shows a golden brown dispersion of GO, which turns black immediately after adding $Na_2S_2O_4$, Figure S2 (b).

a) Before adding $Na_2S_2O_4$

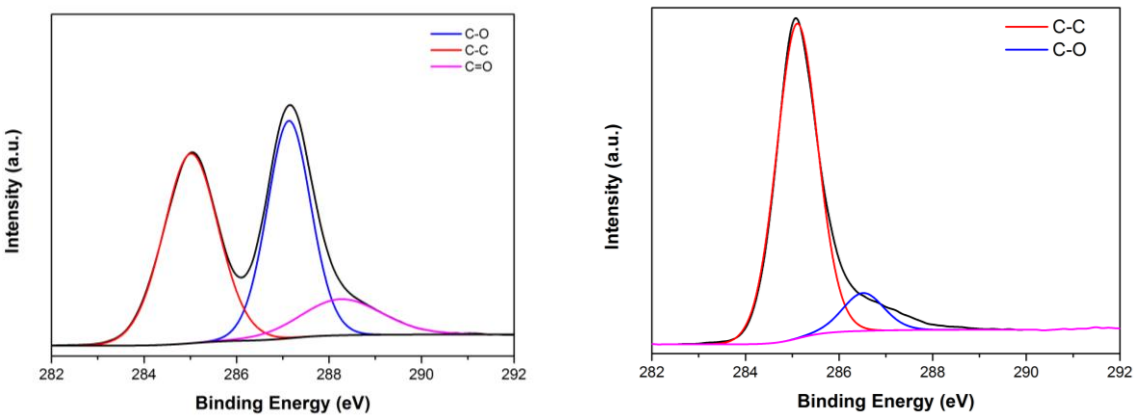


b) Immediately after adding $Na_2S_2O_4$

Figure S2. Image shows a) GO (golden brown) turns b) black rGO dispersion immediately after adding sodium hydrosulfite ($Na_2S_2O_4$)

Supporting Information 4: High Resolution XPS Spectra of GO and rGO

The high resolution C(1s) XPS spectrum of GO and rGO in Figure S3 provides the evidence of the efficient reduction of GO to rGO. Figure S3 a) provides proof of the higher number of oxygen containing functional group present on the surface of GO. The spectrum shows two main peaks can be fitted into three components emerged from C-C/C=C bond in aromatic rings (~284.6 eV), C-O epoxy and alkoxy groups (~286.4 eV) and C=O carbonyl groups (288 eV).[3, 4] After reduction residual oxygen containing groups diminished with a small amount of residual oxygen functional groups left around the binding energy of 288.5 eV, Figure S3b. In general, the C(1s) spectrum of rGO exhibits a similar shape to graphene or natural graphite, which indicates a remarkable restoration of the graphitic structure through chemical reduction.[5]

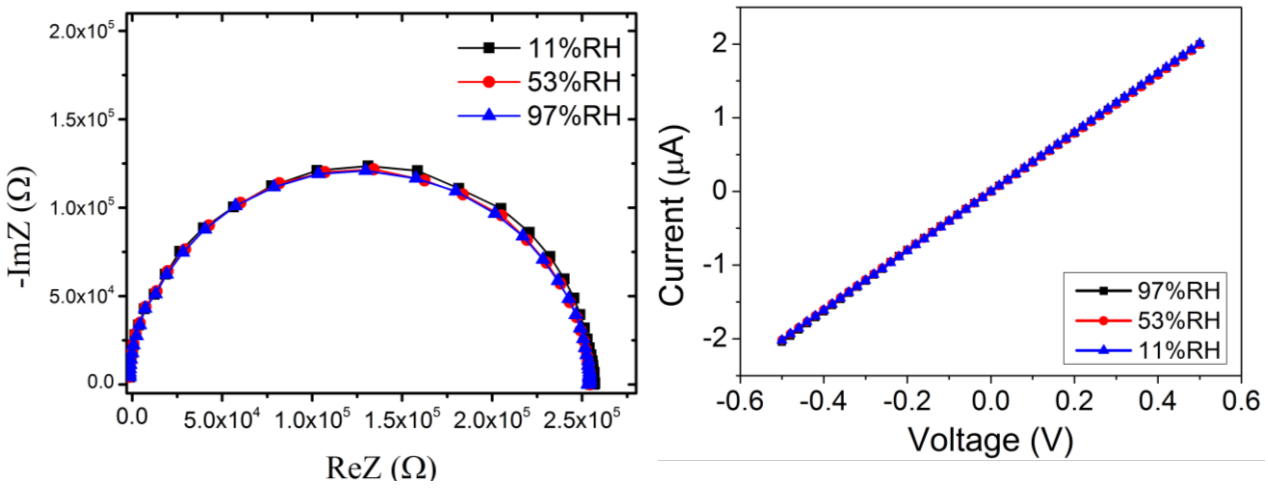


a) GO **b) rGO**

Figure S3. High resolution C (1s) XPS spectrum of GO and rGO

Supporting Information 5: Effect of Humidity on rGO-Coated E-textiles

We used various humidity conditions to observe the effect of humidity on rGO coated e-textiles. The complex impedance spectra (Figure S4a) and I-V curves (Figure S4b) shows humidity had no effect on the impedance and resistance of the rGO coated fabric.



(a) **(b)**

Figure S4. The effect of various humidity % conditions on rGO coated (5 padding pass) cotton fabrics: a) complex impedance spectra (CIS) and b) I-V curves

Supporting Information 6: SEM Images of Untreated, rGO Coated (5 padding pass) and Washed (5 times) rGO Coated Cotton Fabric

SEM micrographs of untreated control cotton fabric showed smooth, featureless cotton fibres, Figure S5. After rGO coating, some inter-fibre bonding and deposition of rGO flakes on the fibres was observed, Figure S6, which was still visible after 5 washing cycles, Figure S7.

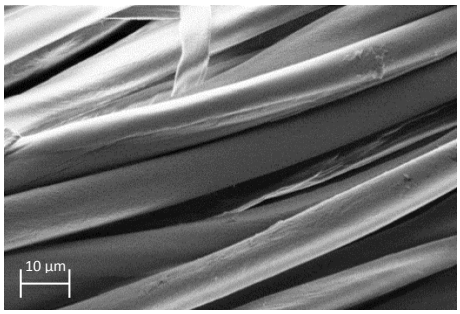


Figure S5. SEM micrograph of untreated control cotton fabrics (X1000)

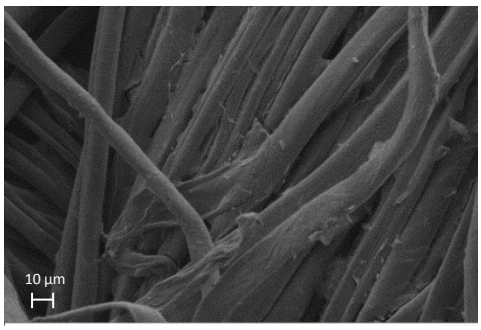


Figure S6. SEM micrograph of rGO coated cotton fabrics (5 padding pass) (X500)

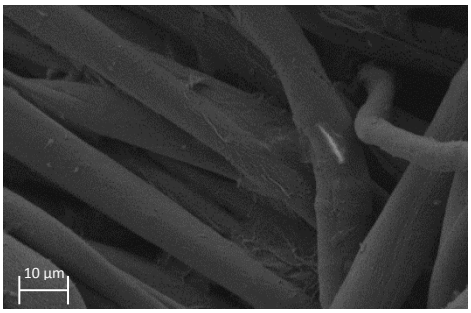


Figure S7. SEM micrograph of washed (5 cycles) rGO coated (5 padding pass) cotton fabric (X1000)

Supporting Information 7: Bending and Compression

Figure S8 shows the cord lengths used to measure the change of resistance during bending and compression. The cord length is defined as the distance between the tensile tester grips for the sensor material under investigation.

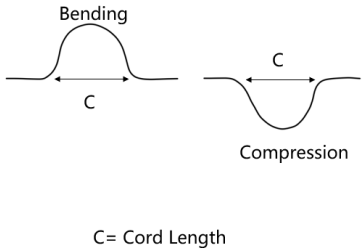


Figure S8. The cord lengths during bending (concave down) and compression (concave upward) of rGO coated textiles in a tensile tester machine

Figure S9 and Figure S10 shows the change in the resistance due to the bending and compression both in forward and reverse direction. Repeatable results were obtained in both forward and reverse directions which demonstrated the suitability of rGO coated e-textiles to be used as human activity monitoring sensors.

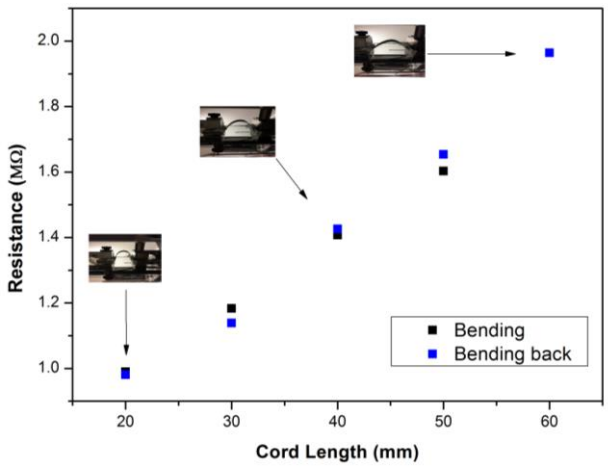


Figure S9. The variation in resistance of the bending sensor in forward (bending) and reverse (bending back) direction

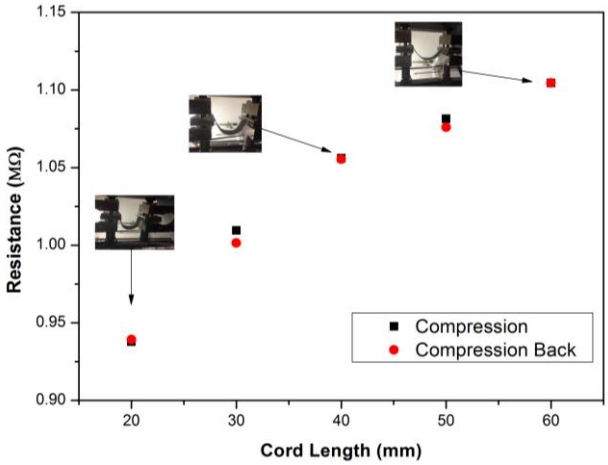


Figure S10. The variation in resistance of the compression sensor in forward (compression) and reverse (compression back) direction

Supporting Information 8: Fabric Appearance

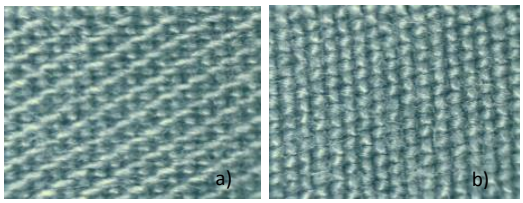


Figure S11. Face (a) and back (b) side of rGO coated fabrics showing different surface structure

References

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