# Evaluation of Solution-Processed Reduced Graphene Oxide Films as Transparent Conductors: Supporting Information

*Héctor A. Becerril,[†] Jie Mao,[‡] Zunfeng Liu,[‡] Randall M. Stoltenberg,[†] Zhenan Bao,[†]* Yongsheng Chen[‡]**

[†]Department of Chemical Engineering, Stanford University, 381 North-South Mall, Stanford, CA 94305, USA.

[‡] Key Laboratory for Functional Polymer Materials and Center for Nanoscale Science & Technology, Institute of Polymer Chemistry, College of Chemistry, Nankai University, Wenjin Rd 94, Tianjin 300071, China.

## Size and Thickness Distributions of GO Nanosheets

Our GO powder contains individually dispersed, heavily oxidized graphene sheets as can be appreciated from the following figure.

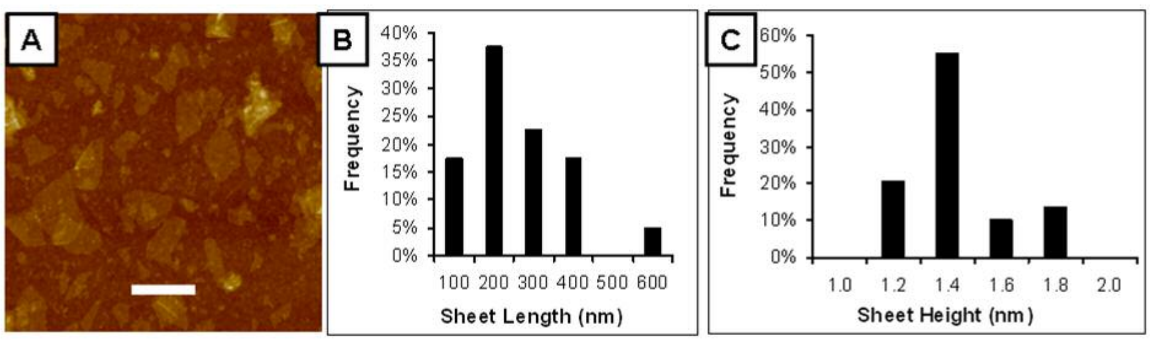


**Fig. S1. (A)** Tapping mode AFM height image of isolated GO sheets, white bar is 500 micrometers. Histograms of the lateral dimensions **(B)** and average sheet height **(C)** for isolated GO nanostructures. Average sheet length was ~ 364 nm with 33% relative standard deviation (rsd); average height was 1.4 nm with a 12% rsd.

## AFM Thickness Measurements of GO Films

We measured thickness of our GO films using a profilometer (Dektak 150, Veeco Metrology Inc.) and AFM (AFM, Multimode Nanoscope IIIa with Extender electronics, Veeco Metrology Inc., Santa Barbara, CA) for thinner films. In both cases we carefully scratched through the GO film using a soft metal tool to avoid damaging the underlying substrate. We then scanned the instrument tip across the edge of the film at several different places in the case of the profilometer, or collected an image of the edge in the case of the AFM. **Fig. S2** shows tapping mode AFM height images of film edges.

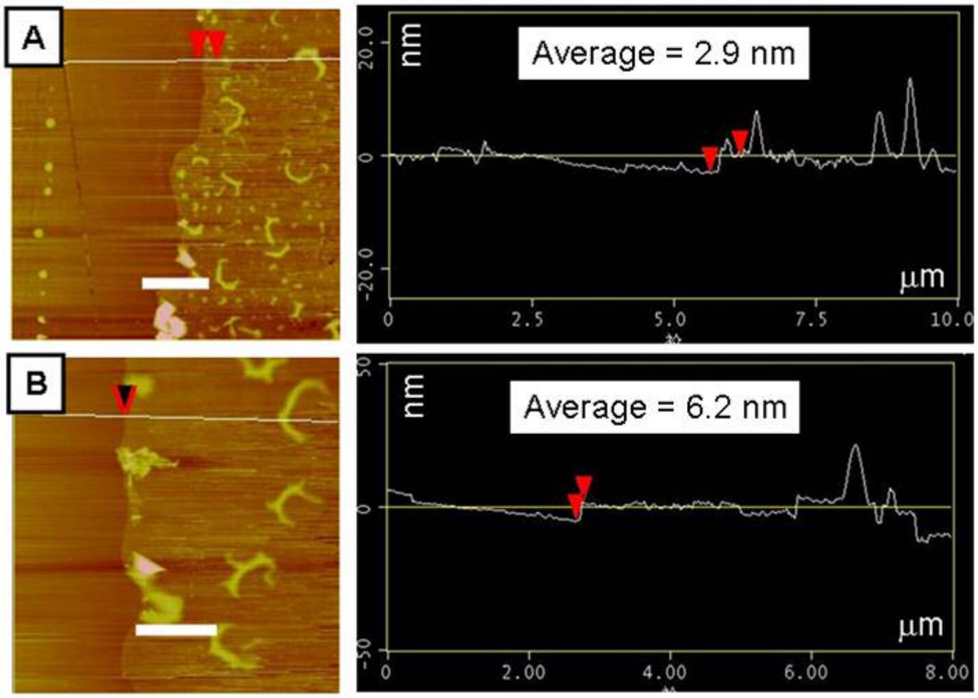


**Figure S2**. AFM tapping mode images of GO film edges and corresponding section analysis.

## Solution Concentration of GO vs. Film Thickness

The thickness of spin-coated GO can be tuned through adjusting GO concentration in solution or by performing multiple coating steps. The first method is most reproducible and allows fabrication of films with thickness up to ~ 25 nm (**Fig. S3**) and is likely limited by the solubility of GO.

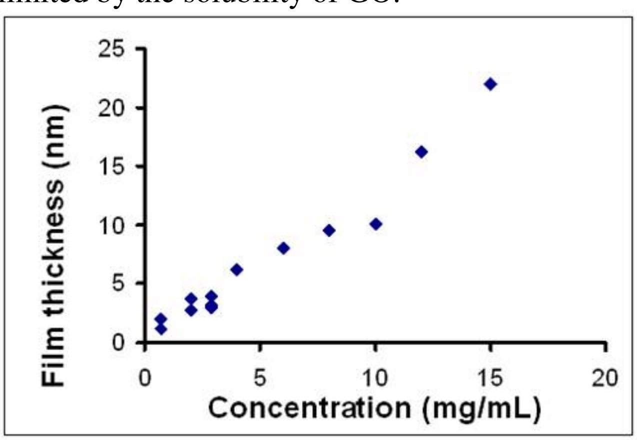


**Fig. S3**. Relationship between GO concentration in solution and film thickness for single-step, spin-coated samples.

Repeated spin-coating of GO solutions onto the same substrate can lead to deposition of increasingly thick films. This method is useful because it allows fabrication of films with thickness not limited by GO solubility. However, this method has a large variability in the film thickness obtained. This observation is likely a consequence of water partially removing a fraction of the already deposited layers, and so it is preferable use nearly saturated GO solutions when the repeated spin-coating method is used.

## Sample Fabrication and Characterization Parameters

**Table S1** displays GO concentration, spin-coating cycles, reduction methods, film thickness, film transparency to 550 nm light, sheet resistance and film conductivity for all the samples depicted in **Fig. 3** and Fig. **6**. Samples sorted by reduction method and conductivity.

**Table S1**. Complete characterization data for samples plotted in **Fig. 3** and **Fig. 6**.

| Sample | Red. Method[a] | Conc. (mg/mL) | # of Spinning-Steps | Thickness (nm) | %T (550nm) | Sheet Resistance (ohms/sq) | Conductivity (S/cm) |
|---|---|---|---|---|---|---|---|
| | A | 2.9 | 1 | 3 | 93 | 3.8E+05 | 8.2E+00 |
| H2 | A | 2.9 | 1 | 3 | 93 | 2.6E+05 | 1.2E+01 |
| H3 | A | 2 | 1 | 3 | 92 | 1.7E+05 | 2.1E+01 |
| H4 | A | 6 | 1 | 8 | 69 | 3.5E+04 | 3.5E+01 |
| H5 | A | 4 | 1 | 6 | 78 | 3.1E+04 | 5.2E+01 |
| H6 | A | 8 | 1 | 10 | 64 | 1.2E+04 | 8.9E+01 |
| H7 | A | 10 | 1 | 10 | 54 | 9.9E+03 | 1.0E+02 |
| H8 | A | 2.9 | >1 | 8 | 63 | 1.2E+04 | 1.1E+02 |
| H9 | A | 7 | >1 | 27 | 32 | 2.6E+03 | 1.4E+02 |
| H10 | A | 7 | >1 | 31 | 29 | 2.0E+03 | 1.6E+02 |
| H11 | A | 15 | 1 | 20 | 40 | 2.8E+03 | 1.8E+02 |
| G1 | B | 0.7 | 1 | 1 | 98 | 8.7E+05 | 1.0E+01 |
| G2 | B | 2 | 1 | 4 | 95 | 3.5E+04 | 7.7E+01 |
| G3 | B | 12 | >1 | 20 | 78 | 3.0E+03 | 1.6E+02 |
| G4 | B | 0.7 | >1 | 8 | 92 | 7.4E+03 | 1.7E+02 |
| G5 | B | 12 | 1 | 16 | 82 | 3.5E+03 | 1.8E+02 |
| G6 | B | 0.7 | >1 | 6 | 84 | 4.4E+03 | 3.6E+02 |
| G7 | B | 15 | 1 | 22 | 76 | 1.1E+03 | 4.1E+02 |
| G8 | B | 15 | >1 | 30 | 67 | 7.3E+02 | 4.5E+02 |
| G9 | B | 15 | >1 | 77 | 18 | 2.5E+02 | 5.2E+02 |
| G10 | B | 15 | >1 | 67 | 29 | 2.7E+02 | 5.5E+02 |
| G11 | B | 0.7 | >1 | 7 | 85 | 2.3E+03 | 6.0E+02 |
| G12 | B | 15 | >1 | 68 | 28 | 2.0E+02 | 7.4E+02 |
| G13 | B | 15 | >1 | 66 | 30 | 2.0E+02 | 7.7E+02 |
| G14 | B | 15 | >1 | 51 | 45 | 2.0E+02 | 9.6E+02 |
| G15 | B | 15 | >1 | 94 | 0 | 1.0E+02 | 1.0E+03 |
| G16 | B | 15 | >1 | 42 | 55 | 2.1E+02 | 1.1E+03 |
| G17 | B | 7 | >1 | 41 | 20 | 1.6E+02 | 1.5E+03 |
| G18 | B | 15 | >1 | 92 | 2 | 5.7E+01 | 1.9E+03 |
| G19 | B | 15 | >1 | 94 | 0 | 5.2E+01 | 2.0E+03 |
| G20 | B | 0.7 | >1 | 100 | 0 | 4.2E+01 | 2.4E+03 |
| V1 | C | 2.9 | >1 | 5 | 92 | 1.4E+08 | 1.4E-02 |
| V2 | C | 2.9 | 1 | 3 | 94 | 2.2E+08 | 1.5E-02 |
| V3 | C | 7 | >1 | 55 | 29 | 7.4E+04 | 2.4E+00 |
| U1 | D | 2.9 | >1 | 9 | 96 | 3.0E+11 | 3.9E-06 |

* Reduction methods: **A** Hydrazine vapor + annealing at 400 °C under argon flow. **B** Vacuum graphitization at 1100 °C. **C** Hydrazine vapor. **D**. Non-reduced.