

*Supplementary Information for Publication*

## **Gas-phase rapid reduction of graphene oxide through photoionization of gold nanoparticles**

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*Detailed process:* GO nanoflakes were obtained by the oxidation of spark produced graphite particles (Fig. S1, which acted as precursors) with 40 mL of H<sub>2</sub>SO<sub>4</sub> and 1.8 g of KMnO<sub>4</sub>. The residence time of the graphite particles in a flow reactor was 3.8 min to form GO. The formed GO was rinsed and then injected with ethanol into the reservoir of a collision atomizer. Another spark discharge was used to produce Au nanoparticles, and the particle-laden flow was employed as the operating gas for atomizing the GO solution. The Au particles passed over the atomizer orifice, where they mixed with atomized GO droplets to form Au/GO hybrid droplets. The droplets then passed through a 180 nm (or 250, 360 nm) wavelength UV irradiated tubular chamber with an intensity of 0.14 J m<sup>-2</sup> sec<sup>-1</sup> to process photoionization and simultaneous ethanol extraction of the droplets.

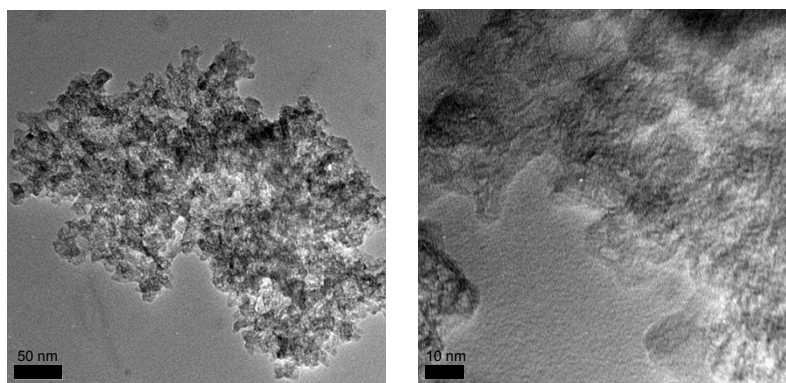


Fig. S1. High- and low-magnification TEM images of graphite nanoparticles.

*Tandem DMA analysis:* The tandem DMA system consisted of two nano DMAs (NDMA, 3085, TSI, US), NDMA 1 and 2, and a condensation particle counter (CPC, 3776, TSI, US). NDMA 1 and 2 were placed before and after a UV chamber, respectively, which contained a UV lamp (UVP, US) with a wavelength of 180 nm (or 250, 360 nm). NDMA 1 was operated as an electrostatic particle classifying system, which was operated at a chosen fixed voltage provided by a direct current power supply (205B, Bertan, US) to extract the particles of equivalent electrical mobility. The particles exiting NDMA 1 (all with equivalent electrical mobility) passed through a serial system consisting of an aerosol charge neutralizer (4810, HCT, Korea) and a cylindrical electrostatic precipitator to form uncharged monodisperse particles (with a

diameter of 20 nm), and finally the particles were then fed into the UV chamber with an intensity of  $0.14 \text{ J m}^{-2} \text{ sec}^{-1}$ . To prevent charge neutralization of the photoionized particles by coexisting negative ions, an ion trap was employed to collect the negative ions from the UV chamber. The particles from the trap were finally scanned by NDMA 2 to measure the charge distribution corresponding to the initially selected mobility diameter.

*Raman spectroscopy:* The structural changes occurring during the reduction were also reflected in the Raman spectra (T64000, HORIBA Jobin Yvon, Japan) (Fig. S2). The spectra shows an increase in the ratio between the *D* and *G* bands ( $I_D/I_G$ ), indicating an increased number of defects or edge areas from GO to rGO. According to a report by Stankovich et al.,<sup>S1</sup> the increase in the  $I_D/I_G$  ratio from 0.86 to 1.14 is because the new graphitic domains created during the reduction of GO to rGO are smaller in size (*i.e.* smaller in-plane  $sp^2$  domains are formed) than the size of the GO before reduction. Therefore, the decreased average size of the rGO makes the  $I_D/I_G$  ratio increase.

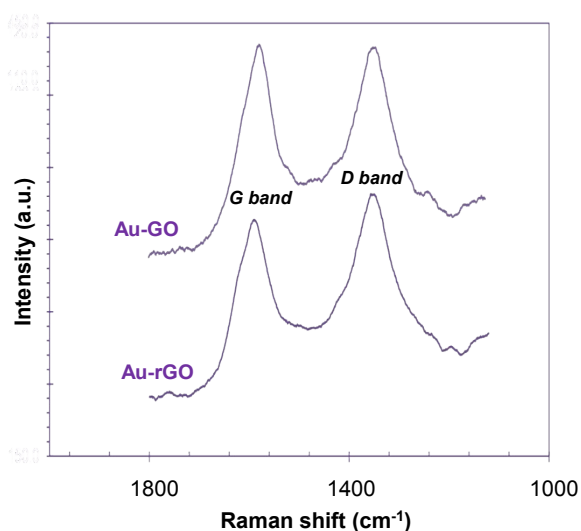


Fig. S2. Raman spectra of the Au-GO and Au-rGO nanoflakes.

*XPS Analysis:* XPS (K-Alpha, Thermo Scientific, US) was used to characterize the reduction state of GO nanoflakes (Fig. S3).

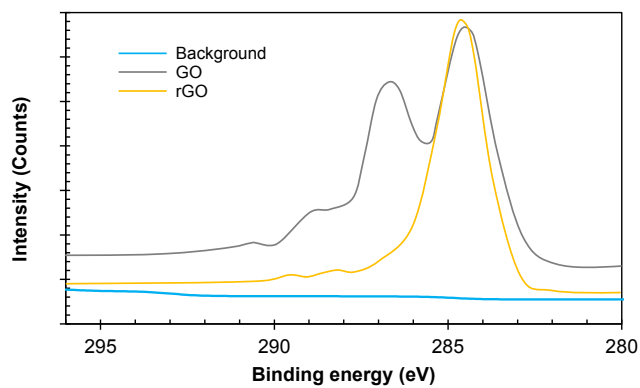


Fig. S3. C1s XPS spectra of the GO and rGO nanoflakes.

S1) S. Stankovich, D. A. Kikin, R. D. Piner, K. A. Kohlhaas, A. Kleinhammes, Y. Jia, Y. Wu, S. T. Nguyen and R. S. Ruoff, R. S. *Carbon* 2007, **45**, 1558.