Supporting Information for

Hybrid thin films of graphene nanowhiskers and amorphous carbon as transparent conductors

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Experimental methods, TEM image (Fig. S1), XPS (Fig. S2) and Raman (Fig. S3) spectra.

Methods

The hybrid FGW films were prepared by a floating CVD technique with pyridine as the sole carbon source and polished polycrystalline copper as the substrate. First, the Cu foil (20~100 μm thick) was heated to 900 °C in an Ar flow (100 mL/min) and annealed for 30 min at this temperature. Then pyridine was pumped in with a feeding speed of 10 μL/min in an Ar flow (300 mL/min) for 10 min. Cu foil was cooled down to room temperature at a fast cooling rate of 10~20 °C/s. Carbon atoms decomposed from pyridine were out-diffused onto the surface of the Cu substrate to form the carbon layers.

The samples were characterized using scanning electron microscopy (SEM, LEO1530, 10 kV), transmission electron microscopy (TEM, JEOL2010, 200 kV), Raman spectroscopy (Renishaw, RM2000, He-Ne laser excitation line at 633 nm), X-ray photoelectron spectroscopy (XPS, PHI Quantera SXM, AlKα), vertical scanning white-light interfering profilometer (Phase shift microXAM-3D) and Auger electron spectroscopy (AES, PHI-700). To measure its transmittance and sheet resistance, the FGW film was transferred to a highly polished quartz substrate. Optical transmission spectra were taken by Perkin Elmer precisely Lambda 950 UV/vis/NIR optical spectrometer. The sheet resistance is calculated using the equation: $R_s=(\pi/\ln2)[(R_x+R_y)/2]f$, where f is a factor that is a function of R_y/R_x (L. J. Van der Pauw. *Philips Tech. Rev.* 1958, 20, 220).

n-Si (100) wafers (doping density: 1.5~3×10^{15} cm^{-3}) with a 300 nm SiO_2 layer were patterned by photolithography and wet-etching of oxide (by HF solution) to make square windows of 0.1 cm^2 where n-Si was exposed. The front and back contacts were made using sputtered Au on the SiO_2 and Ti/Au on the back side of the n-Si. The hybrid FGW film was then transferred to the top of the patterned wafer and dried to make a conformal coating with the Au layer and the underlying n-Si, serving as the transparent upper electrode and the anti-reflection layer. Forward bias is defined as positive voltage applied to the FGW film. The devices were tested with a solar simulator (Thermo Oriel 91192-1000) under AM 1.5 condition. The current-voltage data were recorded using a Keithley 2635 SourceMeter.

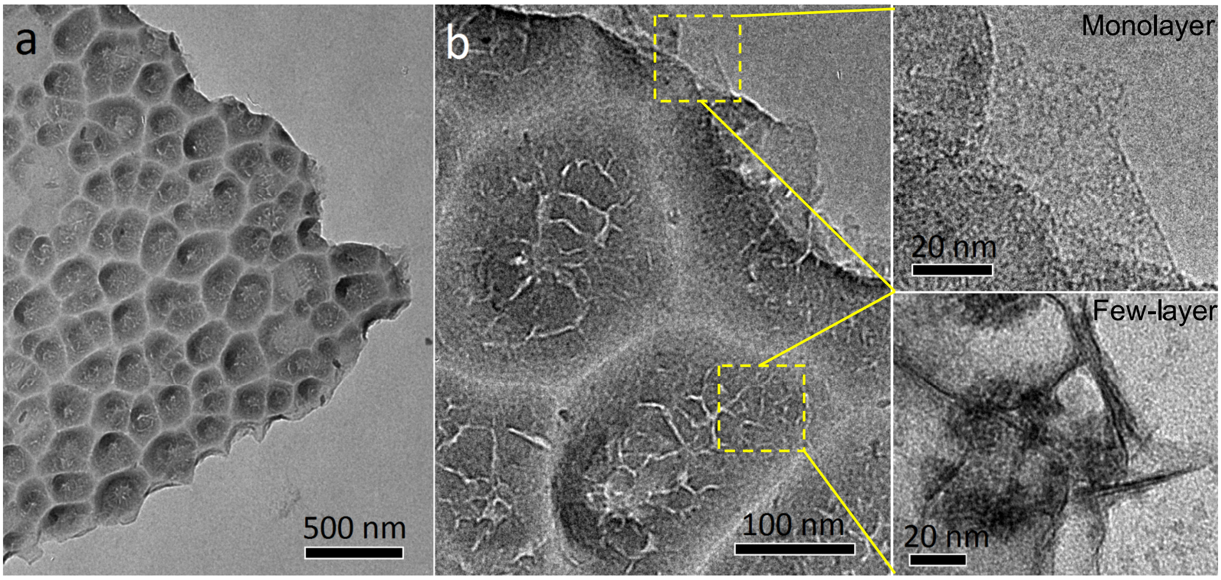

Fig. S1 TEM images of the FGW film. (a) Low resolution; (b) High resolution.

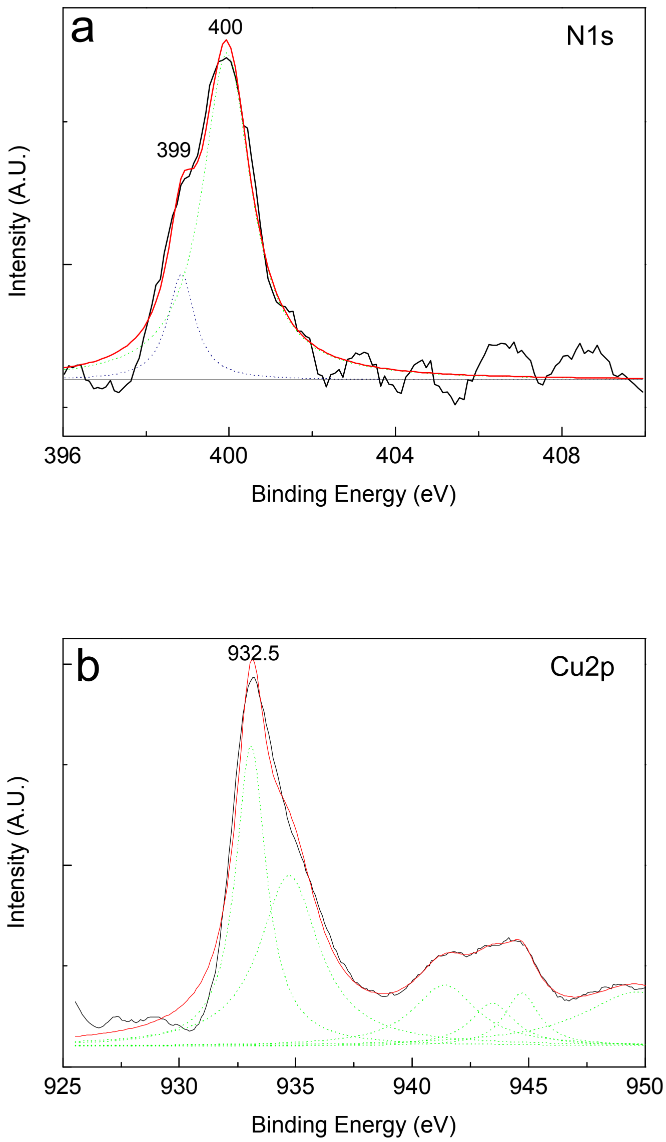

Fig. S2 XPS spectra of as-grown FGW film. (a) N1s; (b) Cu2p.

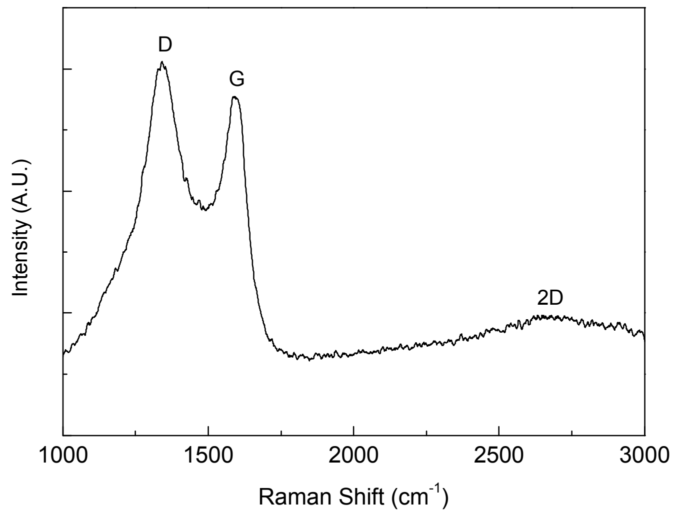

Fig. S3 Raman spectrum of the FGW film.