

Supporting Information

Electrospun Composite Nanofiber Yarns Containing Oriented Graphene Nanoribbons

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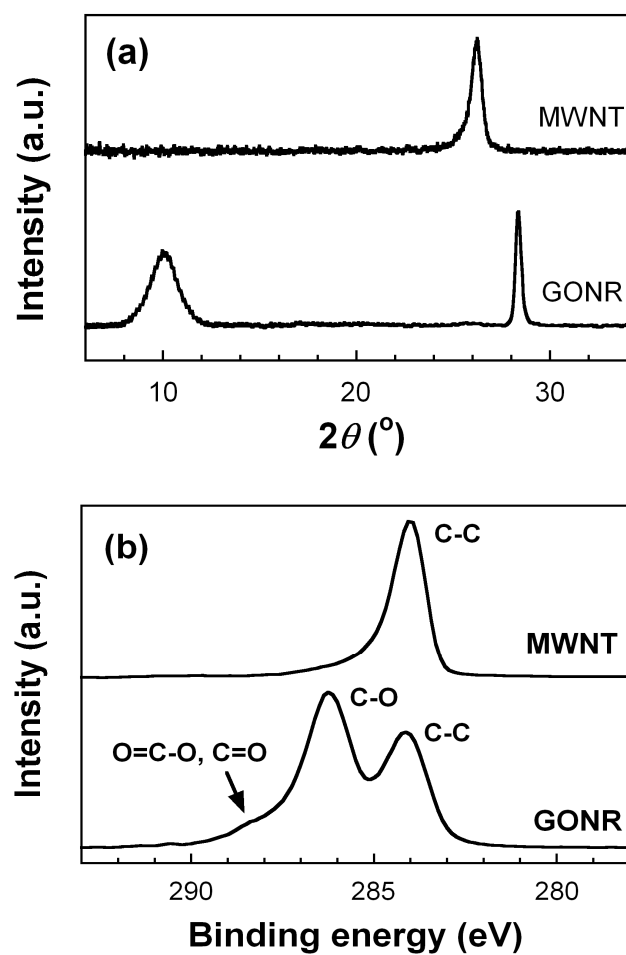


Figure S1. (a) XRD patterns and (b) XPS C1s spectra of the starting MWNTs and the prepared GONRs.

Figure S2 shows the Raman spectra and the mapping images of the spectra at 1580 cm^{-1} (G-band) for the single MWNT and the monolayer GONR. The Raman spectrum of the MWNT shows a high-intensity G-band and 2D-band (2700 cm^{-1}). On the other hand, the spectrum of the single layer GONR shows a G-band and D-band (1360 cm^{-1}). The latter is due to the residual edge and the disorder in the GONR. In addition, the 2D-band peak is broader than those observed in the graphene prepared by the CVD process.^{S1}

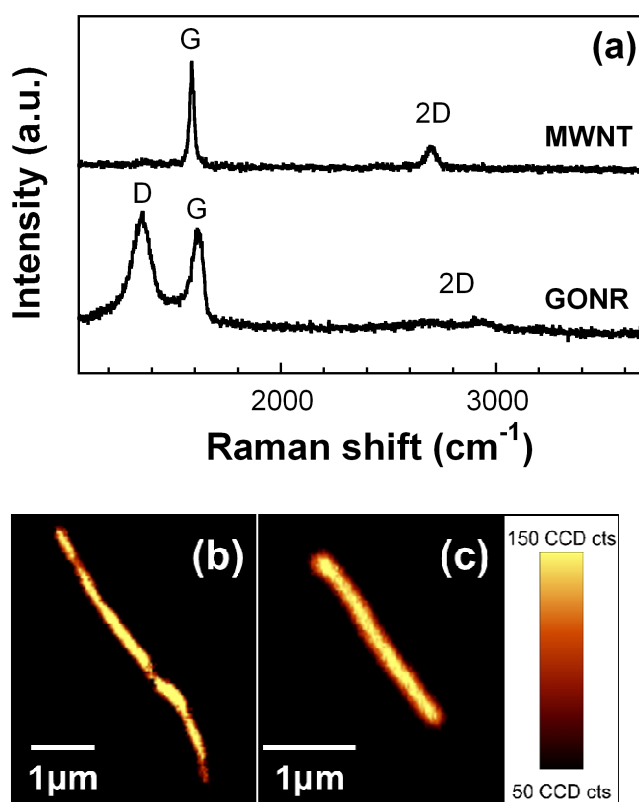


Figure S2 (a) Raman spectra of the starting MWNT and the prepared GONR. Mapping images of G-band for (b) the starting MWNT and (c) the prepared GONR. The samples are the same as those in Figure 1.

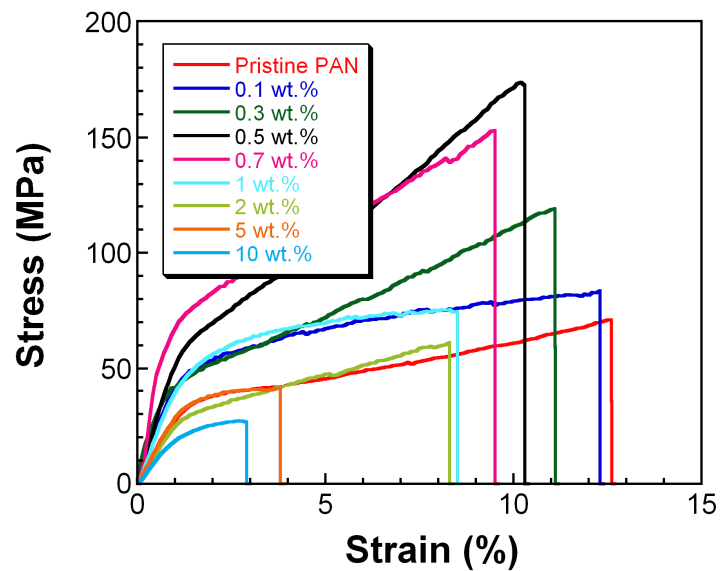


Figure S3. Typical specific stress-strain curves for the as-spun GONR/PAN composite nanofiber yarns. The weight fractions of the GONR are 0, 0.1, 0.3, 0.5, 0.7, 1, 2, 5 and 10 wt%. These curves are as-recorded, and the gauge length was 20 mm for all the samples.

Figure S4 shows that FT-IR spectra of the as-spun PAN, stabilized PAN, and stabilized GONR/PAN composite nanofiber yarns (GONR/PAN = 0.5/99.5 wt/wt). After the stabilization, the peaks at 1595 cm^{-1} ($\text{C}=\text{N}$ band) and 1375 cm^{-1} ($=\text{CH}-$ band) were clearly observed. On the other hand, the intensity of the peak at 2240 cm^{-1} ($\text{C}\equiv\text{N}$ band) was lower. These results demonstrated that the stabilization easily occurred and aromatic structures (*i.e.*, “ladder-structure”) were formed in the PAN and GONR/PAN nanofibers.

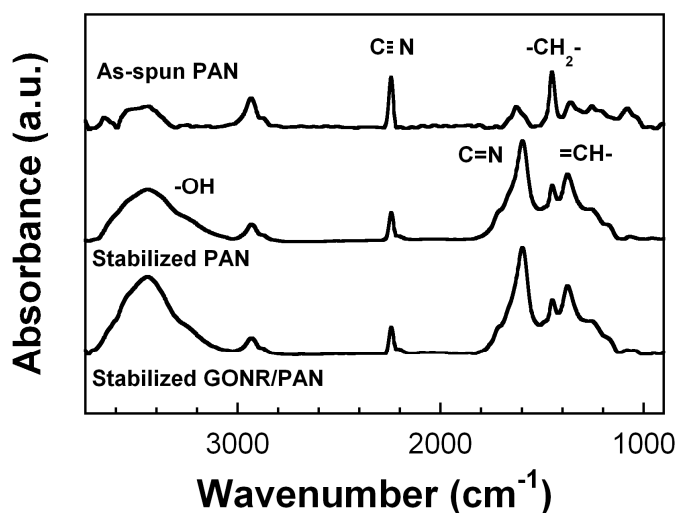


Figure S4. FT-IR spectra of the as-spun PAN, stabilized PAN and stabilized GONR/PAN composite nanofiber yarns (GONR weight fraction is 0.5wt%).

Figure S5 shows the thermogravimetric curves for the stabilized PAN and GONR/PAN composite nanofiber yarns. For the stabilized PAN nanofiber yarn, the temperature of the 10 % weight loss was 310 °C, and the remaining weight at 800 °C was around 40 % of the initial weight. For the stabilized GONR/PAN composite yarn, on the other hand, the temperature of the 10% weight loss was around 310 °C, and the remaining weight at 800 °C increased with an increase in the GONR fraction. This serves as a confirmation of the preservation of the GONRs in the stabilized fiber.

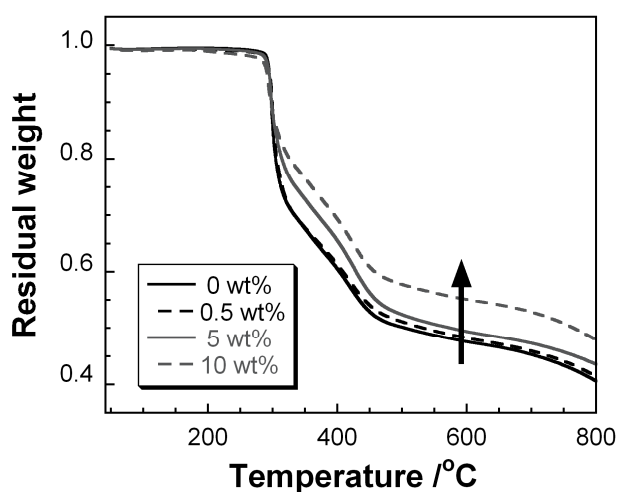


Figure S5. Thermogravimetric curves for the stabilized GONR/PAN composite fiber yarns. The weight fractions of the GONR are 0, 0.5, 5 and 10 wt%.

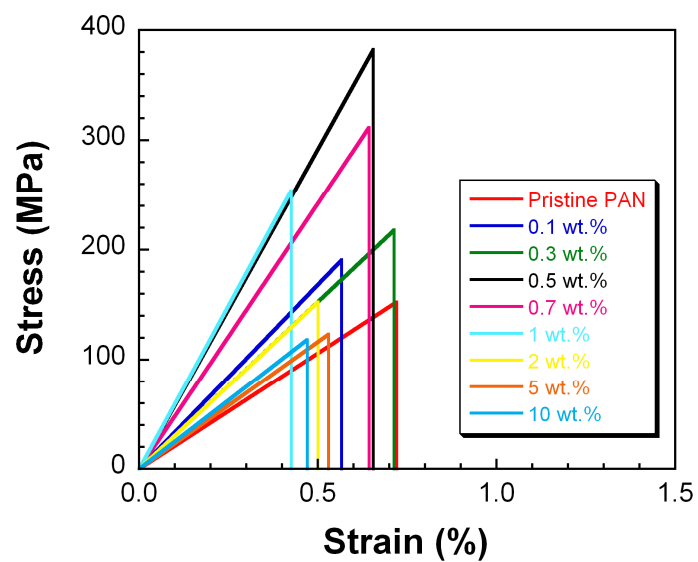


Figure S6. Typical specific stress-strain curves for the GNR/carbon composite nanofiber yarns. The weight fractions of the GONR are 0, 0.1, 0.5, 0.7, 1, 2, 5, and 10 wt%. These curves are as-recorded, and the gauge length was 20 mm for all the samples.

To measure the electrical conductivity of the monolayer GNR, the electronic devices with a monolayer GNR were fabricated on a Si substrate and then annealed in a nitrogen atmosphere at 800 °C for 5 hours. The schematic and SEM images are shown in Figure S7a. The channel length was 1 μm . The electric field effect in the GNR at room temperature was tested using a probe station under atmospheric pressure. The I - V data were collected by an analyzer. Figure S7b shows the $I_{\text{sd}}-V_{\text{sd}}$ curves recorded at different gate voltages for the same electronic device. The conductivity of the annealed GNR (GNR) at a zero gate bias was 53.6 Scm^{-1} , which compares to the reported conductivity for the monolayer GNRs ($\sim 35 \text{ S/cm}$).^{S2}

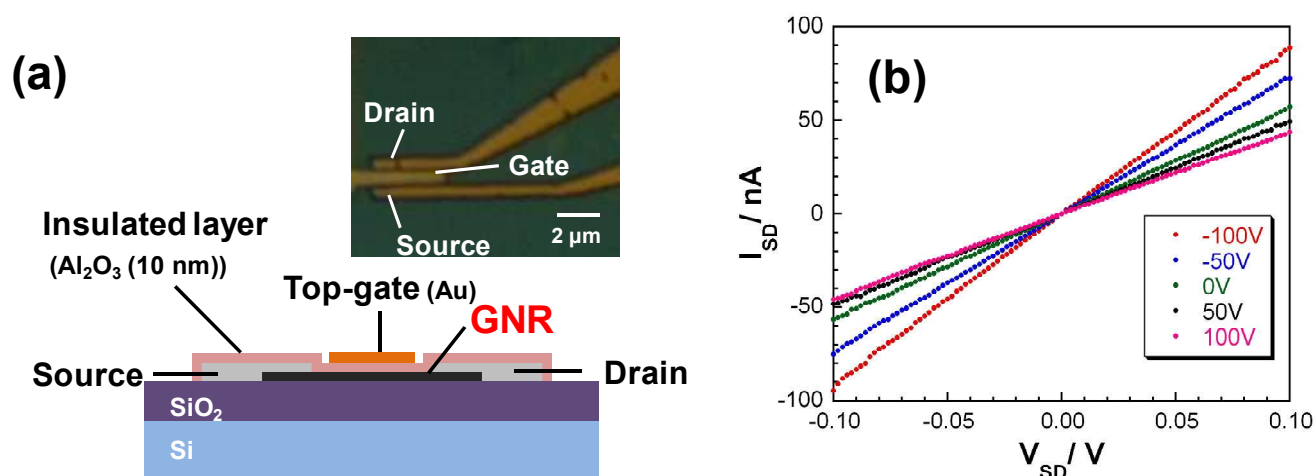


Figure S7. (a) A cross-sectional schematic of the GNR-device (inset) An SEM image of the GNR-device and (b) I - V curves of GNR device at the different gate voltages.

REFERENCES

(S1) Ismach, A.; Druzgalski, C.; Penwell, S.; Schwartzberg, A.; Zheng M.; Javey, A.; Bokor, J.; Zhang, Y. *Nano Lett.*, **2010**, *10*, 1542-1548.

(S2) Sinitskii, A., Fursina, A. A., Kosynkin D. V., Higginbotham, A. L., Natelson, D., Tour, J. M. *Appl. Phys. Lett.* **2009**, *95*, 253108.