Electronic Supplementary Information (ESI)

Catalyst-free bottom-up growth of graphene nanofeatures along with molecular templates on dielectric substrates

Misook Min,^{a,b} Sohyeon Seo,^{*a,c} Yeoheung Yoon,^{c,d} Kyungjune Cho,^b Sae Mi Lee, ^{a,c} Takhee Lee,^b and Hyoyoung Lee^{*a,c,d}

^aDepartment of Chemistry, Sungkyunkwan University, 2066 Seoburo, Jangan-gu, Suwon, Gyeonggi-do, Korea. ^bDepartment of Physics and Astronomy and Institute of Applied Physics, Seoul National University, 08826 Seoul, Korea. ^cCentre for Integrated Nanostructure Physics (CINAP), Institute of Basic Science (IBS), Sungkyunkwan University, 2066 Seoburo, Jangan-gu, Suwon, Gyeonggi-do, Korea. ^dDepartment of Energy and Science, Sungkyunkwan University, 2066 Seoburo, Jangan-gu, Suwon, Gyeonggi-do, Korea



Fig. S1. Fourier transform infrared spectra of (a) ferric stearate and (b) polypyrrole (PPy) films trapped between multiple stearic layers. Line profiles of AFM images in Figures 2c and 2d: (c) a single PPy layer exhibiting small roughness and (d) a multiple PPy layer exhibiting large roughness and an uneven surface level marked with the red dotted lines. X-ray photoelectron spectra of (e) wide scan and (f) Fe 2p for PPy films trapped between multiple stearic layers.

For the ferric stearate layer, asymmetric (CH₂) and symmetric (CH₂) methylene vibration modes are assigned at 2889 and 2852 cm⁻¹, respectively. The CH₃ deformation mode was observed at 2931 cm⁻¹.^[S1] A small peak at 1670 cm⁻¹ was assigned to the C=O stretch, indicating the presence of acid. The more prominent peak at 1596 cm⁻¹ is assigned to the carboxylate asymmetric vibration. For the PPy layers,^[S2,S3] the typical C=C stretching modes of PPy ring vibrations are assigned at 1514 and 1463 cm⁻¹. The C-N (stretching vibration in the ring) and C-H (C-H in-plane deformation) are assigned to 1317 and 1166 cm⁻¹, respectively.



Fig. S2. X-ray photoelectron spectra of (a) a wide scan (Inset: N 1s spectrum) and (b) Fe 2p for GNRs after graphitization.



Fig. S3. Raman spectra of few-layered GNRs synthesized by our new process on SiO₂ substrates after graphitization of PPy layers trapped between multiple stearic layers at 900, 1050 and 1200 °C as a function of annealing time. The positions of the G peak shifted as a function of the annealing time at >1000 °C, which is probably due to an effect of stacked graphitization.



Fig. S4. (a) Raman spectrum of few-layered graphene nanoribbons (GNRs) with FWHM of 2D Peak at 1200 °C, (b) Optical microscopy (OM) image of the narrow and long strips of GNRs and (c) plots of the peak positions for the D, G and 2D peaks, which were obtained by 5 places. As shown in Fig. 2d, the formation of GNRs is associated from the uneven PPy film, which may result in topologically uneven surfaces of GNRs in (b).



Fig. S5. (a), (b) AFM images of a large bundle of GNRs. (c)~(e) Histograms of GNRs in the width, length, and height for 45 representative GNRs.



Fig. S6. Transmittance electron microscopy (TEM) image showing single layered graphene in a nanoporous graphene sheet synthesized by our new process on the SiO_2 substrates after graphitization of a single PPy layer at 1200 °C.



Fig. S7. Optical images of FET devices of (a) a bundle of GNRs with source-drain (Au(50 nm)/Ti(5 nm)) electrodes by using a conventional lithographic method and (b) nanoporous graphene with source-drain (Au(60 nm)/Ti(5 nm) electrodes by using a shadow mask. The dotted square indicates a patterned graphene area.



Fig. S8. I_{ds}/V_{ds} characteristics of the multi-layered GNRs FET at $V_g = 0$ V. The measurement was performed at room temperature under vacuum.

Table S1. Raman and XPS spectra analysis for GNR vs nanoporous graphene synthesized from a multiple PPy layer and a single PPy layer, respectively at 1200 °C.

	Raman (Wavenumber (cm ⁻¹))			XPS (Bonding energy (eV), Contents (%))			
	D	G	2D	C 1s		N 1s	
Graphene nanoribbon	1359	1583	2719	eV	%	eV	%
				284.4 (sp ²) 285.5 (sp ³)	71.1 17.4	399.8 (pyrrolic) 401.0 (graphitic)	60.7 39.3
Nanoporous graphene	1350	1594	2694	284.4 (sp ²) 285.5 (sp ³)	65.1 22.8	398.5 (pyridinic) 399.6 (pyrrolic) 401.0 (graphitic)	13.2 31.4 55.4

SUPPORTING REFERENCES

[S1] Ren, S.-L.; Yang, S.-R.; Wang, J.-Q.; Liu, W.-M.; Zhao, Y.-P. Chem. Mater.2004, 16, 428-434.

[S2] Omastová, M.; Trchová, M.; Pionteck, J.; Prokeš, J.; Stejskal, J. Synth. Met.

2004, *143*, 153-161.

[S3] Kato, H.; Nishikawa, O.; Matsui, T.; Honma, S.; Kokado, H. J. Phys. Chem.1991, 95, 6014-6016.