Supplementary Information for

In-situ observations of gas phase dynamics during graphene growth using solid-state carbon sources

Jinsung Kwak,[a, ‡] Tae-Yang Kwon,[a, ‡] Jae Hwan Chu,[a] Jae-Kyung Choi,[a] Mi-Sun Lee,[b] Sung Youb Kim,[a,c] Hyung-Joon Shin,[a,c] Kibog Park,[c,d] Jang-Ung Park,[b,c] and Soon-Yong Kwon *,[a,c,d]

[a]School of Mechanical and Advanced Materials Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 689-798, South Korea

[b]School of Nano-Biotechnology and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 689-798, South Korea

[c]Opto-Electronics Convergence Group & Low Dimensional Carbon Materials Center, Ulsan National Institute of Science and Technology (UNIST), Ulsan 689-798, South Korea

[d]School of Electrical and Computer Engineering, Ulsan National Institute of Science and Technology (UNIST), Ulsan 689-798, South Korea

‡ These authors contributed equally to this work.

*To whom correspondence should be addressed. Email: sykwon@unist.ac.kr

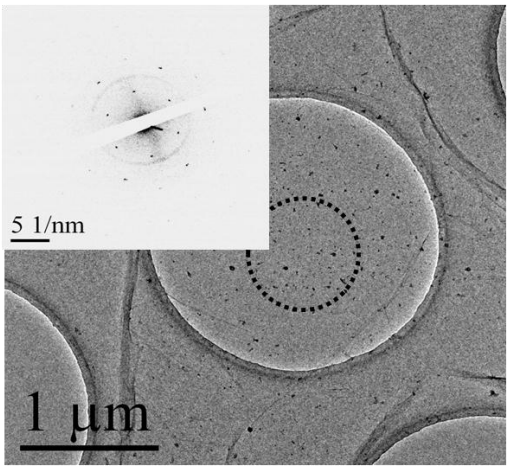

Figure S1. Representative low-magnification plan-view TEM image of graphene film grown at 1000 °C for 3 min then transferred to TEM support hole. Inset is selected area diffraction pattern obtained from a dotted circle region.

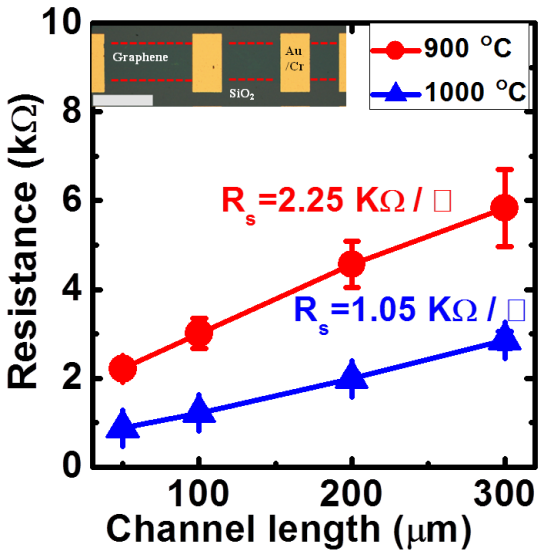

Figure S2. Sheet resistance measurement using TLM method. The plot shows total resistance of the TLM structure as a function of distance. The distance between the contacts on the TLM structure are 60, 100, 150, and 300 μm, respectively. The inset shows an optical microscopy image of patterned graphene layer on SiO_2 with Au (60nm)/ Cr (10nm). The scale bar in the inset is 200 μm.

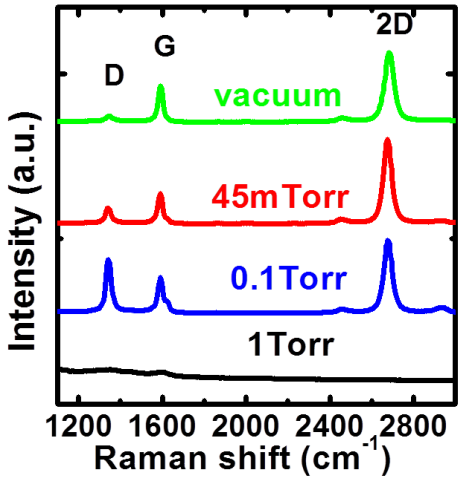

Figure S3. Typical Raman spectra of resulting layers on Cu foils after heating the 10 wt. % PMMA/Cu foil at 1000 °C for 3 min under a different total pressure in a process chamber. In case of the vacuum, the total pressure in the process chamber was ~ 1×10^{-3} Torr. With increasing the total pressure, intensity of the D band increases, suggesting that the amount of efficient carbon sources may not be enough. If the total pressure was larger than 1 Torr, the Raman spectrum (black line) do not exhibit any carbon-related characteristics over a range of 1000-3000 cm^{-1}, indicating that no graphitic layers were produced.

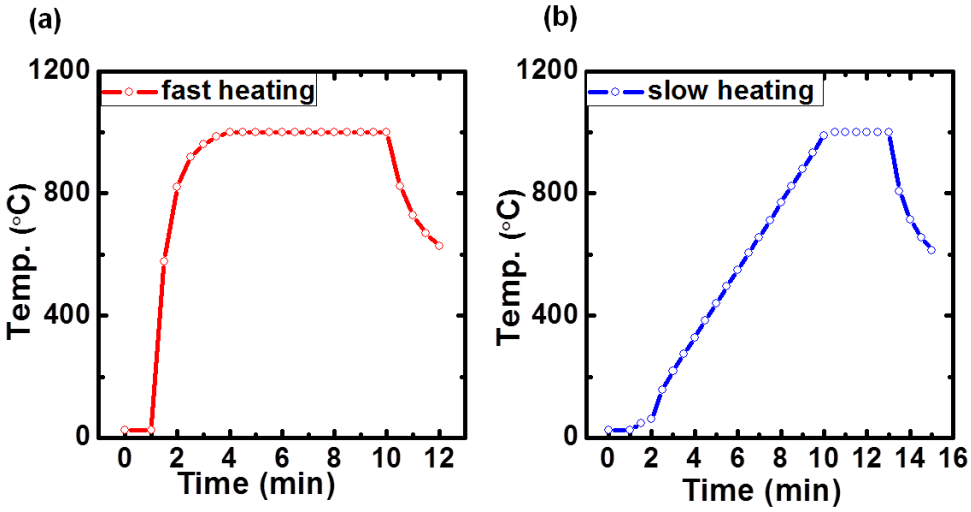

Figure S4. Temperature profiles as a function of time during heating. (a) At the fast heating temperature profile, heating started at 1 min and the temperature was reached around 1000 °C at 4 min. (b) At the slow heating temperature profile, heating started at 1 min and the temperature was reached around 1000 °C at 11 min.

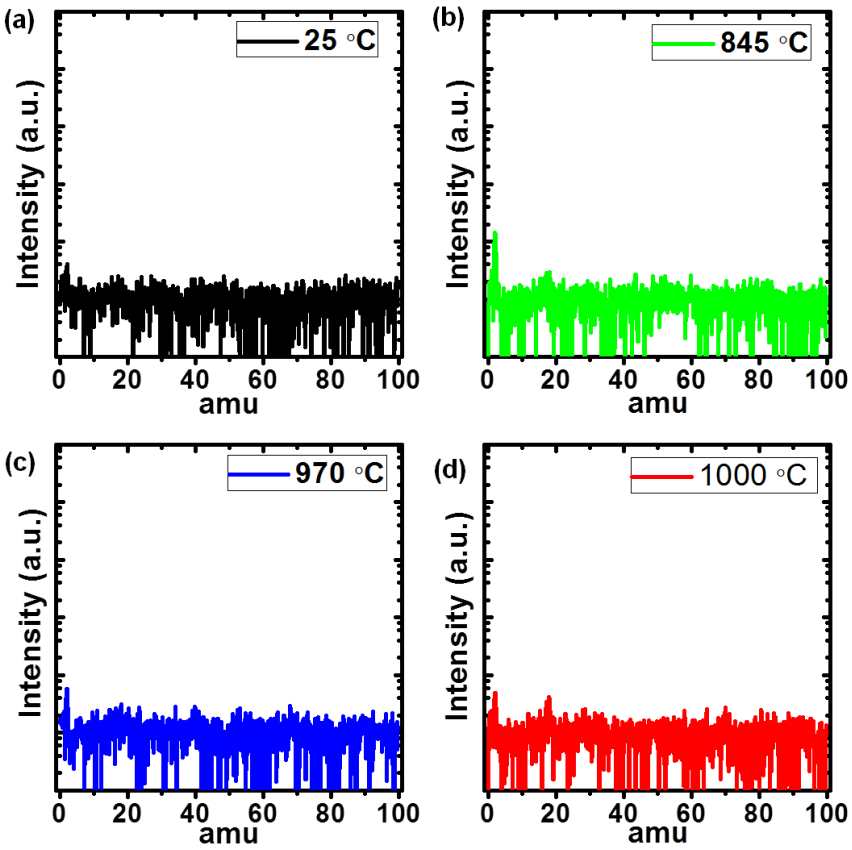

Figure S5. *In-situ* quadrupole mass spectra while ramping temperature from 25 °C to 1000 °C in vacuum (~ 10^{-9} Torr), with a bare Cu foil. The horizontal axis represents atomic mass unit and the vertical axis is the logarithm of ion current.

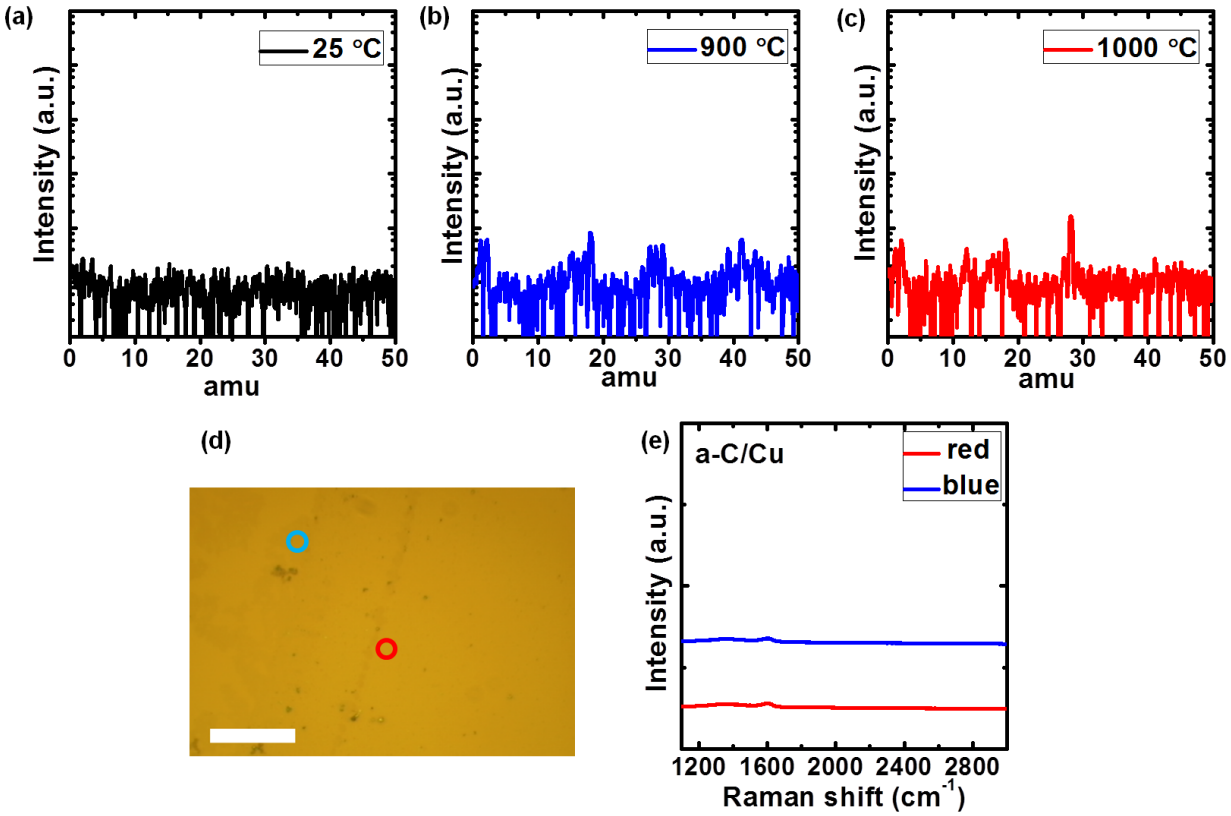

Figure S6. (a-c) *In-situ* quadrupole mass spectrum while ramping temperature from 25 °C to 1000 °C in vacuum (~ 10^{-9} Torr), with a 20 nm-thick amorphous carbon (a-C) film deposited on a piece of Cu foil. X-axis represents atomic mass unit and Y-axis is the logarithm of ion current. (d-e) Representative optical microscopy image and Raman spectrum of a 20 nm thick amorphous carbon-coated Cu foil after annealing at 1000 °C for 3 min under vacuum by using RTA then transferred into the SiO_2 substrate.

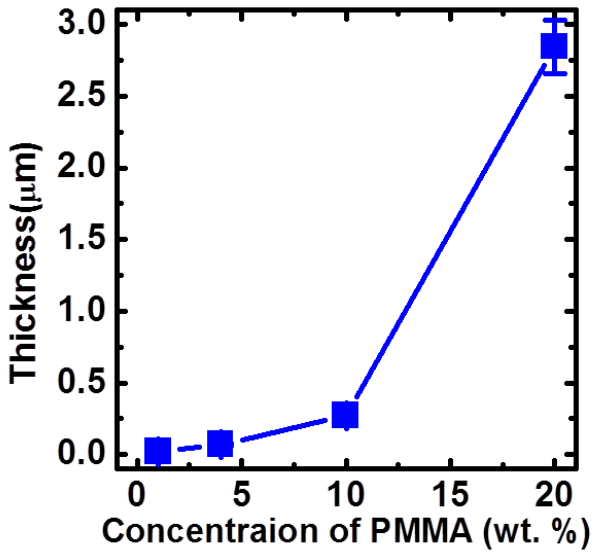

Figure S7. With a different concentration of PMMA in toluene, the thickness of the PMMA film deposited on SiO_2/Si by spin coating at 5000 rmp for 1 min. The thickness of PMMA films were determined by a surface profiler.

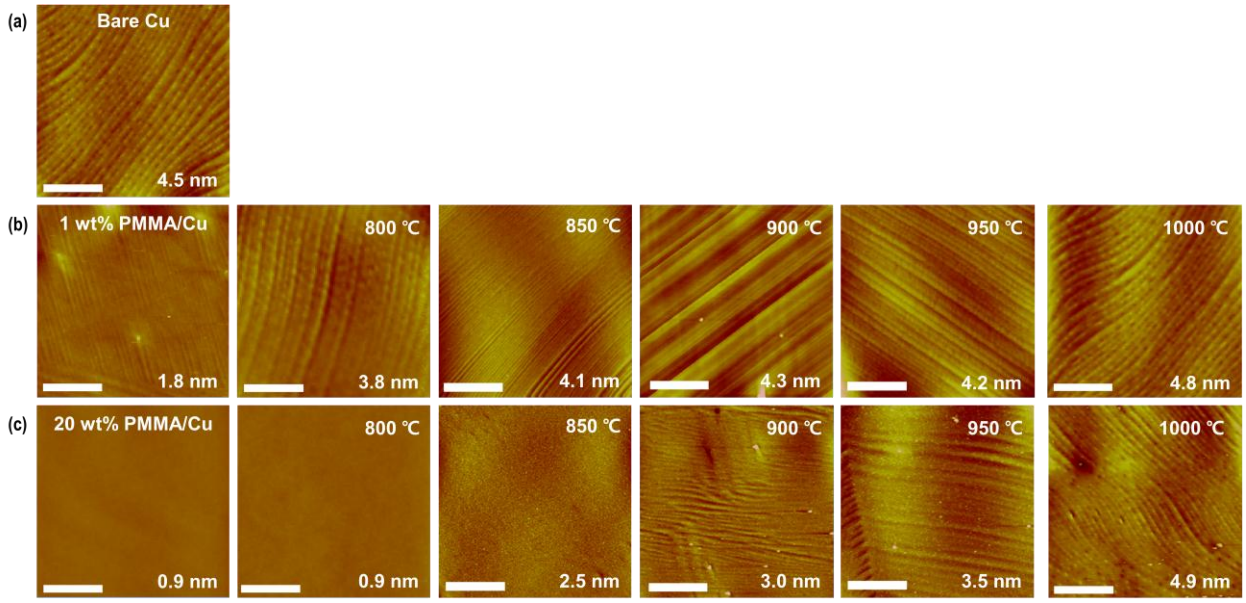

Figure S8. (a) An AFM image of a bare Cu foil. AFM images of (b) 1 wt.% and (c) 20 wt.% of PMMA-coated Cu foils and those after heating between 800 and 1000 °C (from left to right). All scale bars are 3 μm. Root-mean-square (rms) roughness from each scan is labeled.