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Supplementary Material

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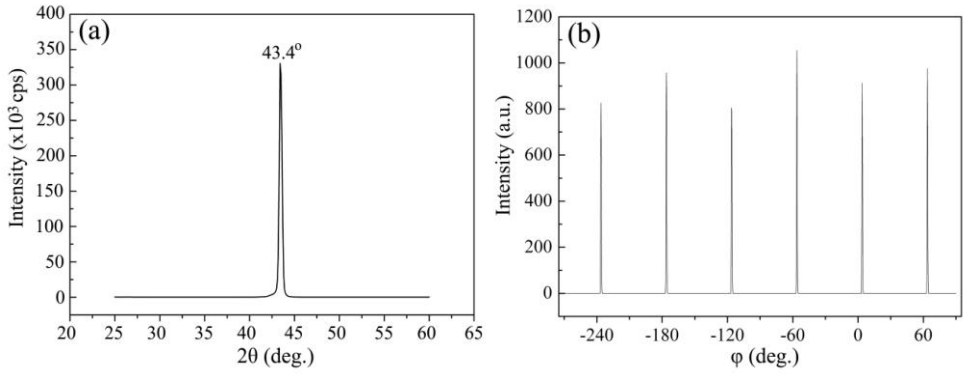

Fig. S-1 (a) θ-2θ profile, and (b) φ scan of XRD for as-grown graphene/Cu/c-plane Al_2O_3 at 1000 °C CVD.

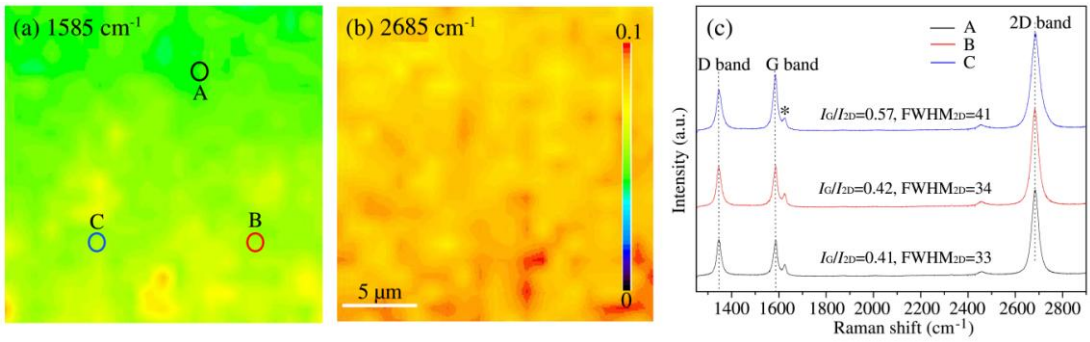

Fig. S-2 Raman mapping images of (a) G band (~1585 cm^{-1}) and (b) 2D band (~2685 cm^{-1}) intensities of transferred graphene which was grown at 900 ºC. (c) Raman spectra of 3 highlighted points with circles in (a). The symbol "*" at around 1620 cm^{-1} in (c) indicates the defect-related D' peak.

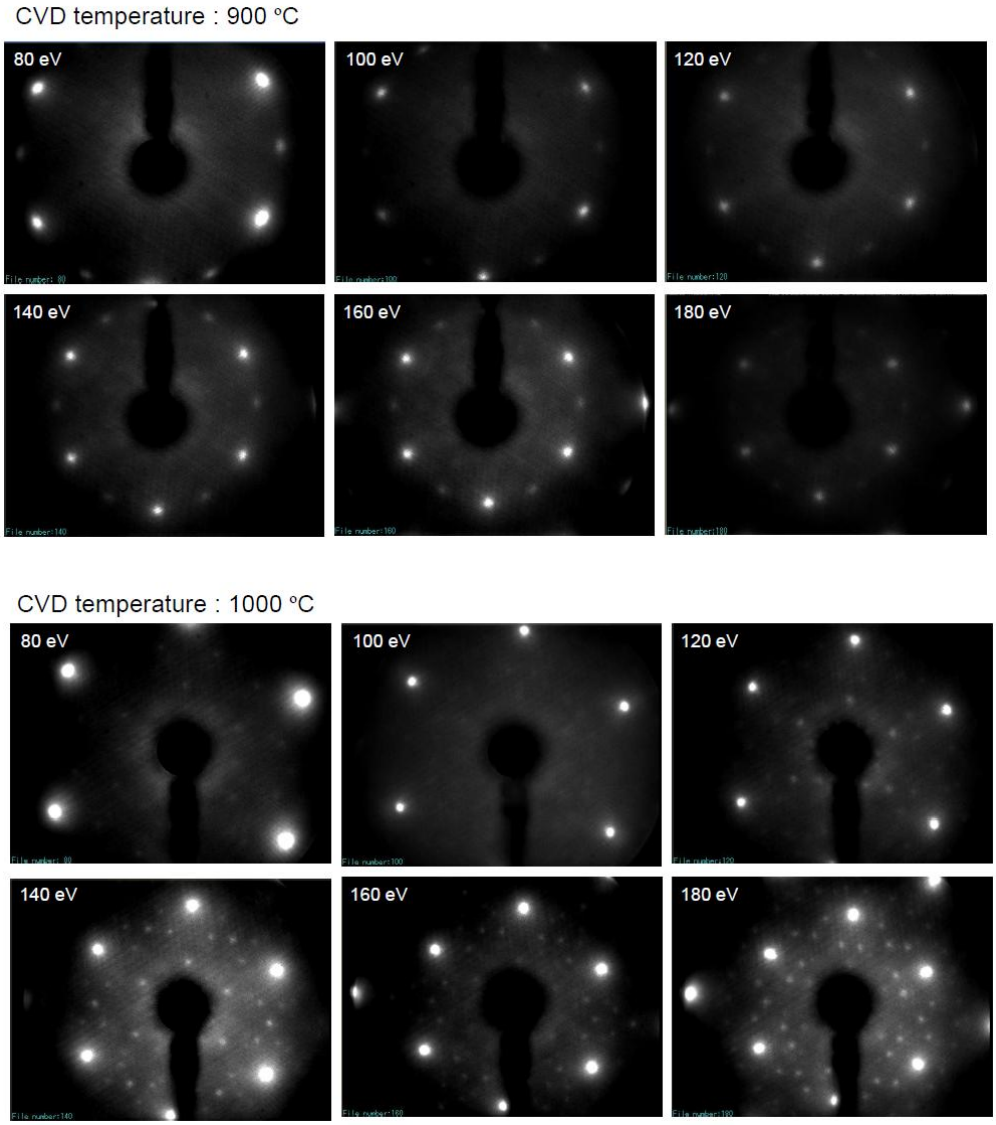

Fig. S-3 LEED patterns of the graphene/Cu/c-plane sapphire samples measured at different electron energies.

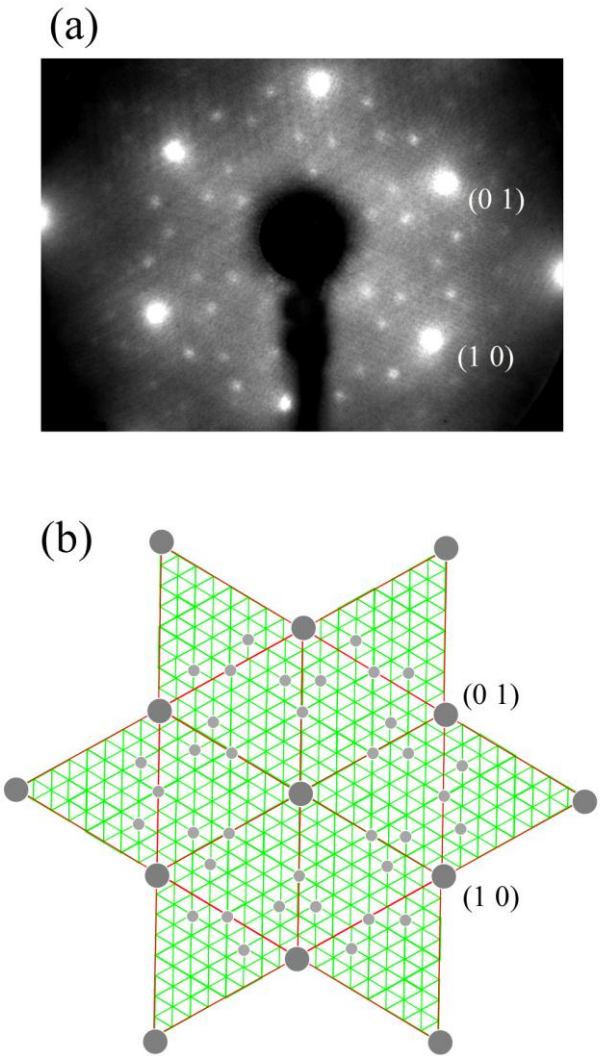

Fig. S-4 (a) LEED pattern of single-layer graphene on Cu/c-plane sapphire grown at 1000 ºC (beam energy is 190 eV). (b) Calculated diffraction spots for image (a). Red and green lines correspond to (1×1) and (8×8) structures, respectively.

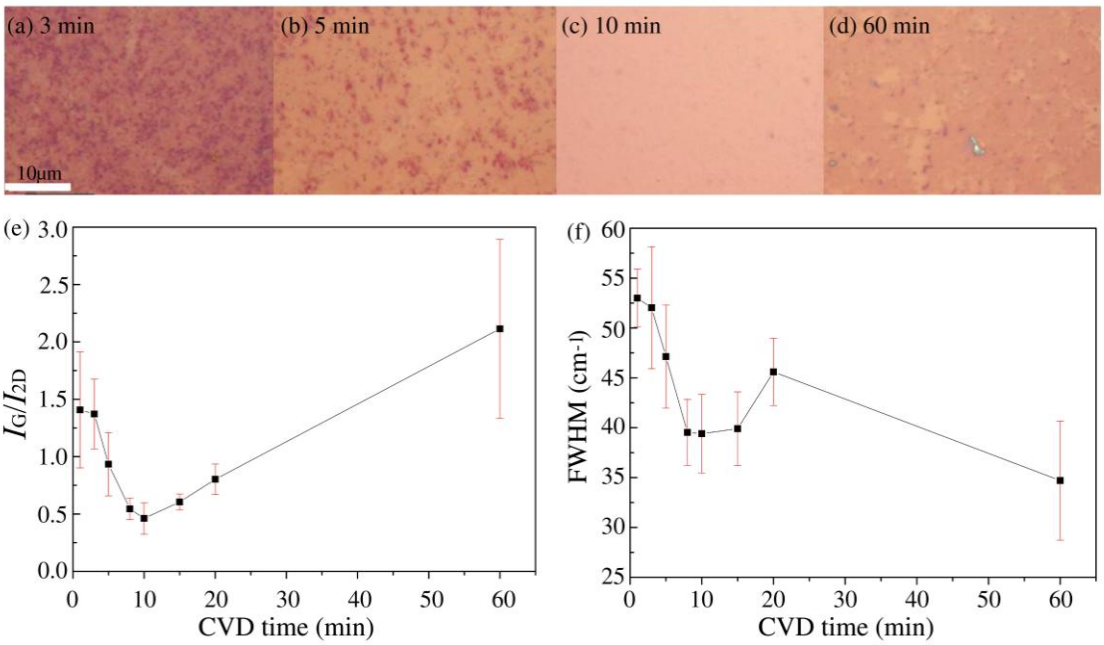

Fig. S-5 Optical micrographs (a-d) of transferred graphene sheets grown with different CVD times at 900 °C. (e) I_G/I_{2D} and (f) $FWHM_{2D}$ of transferred graphene as a function of CVD time, calculated from the Raman mapping data.

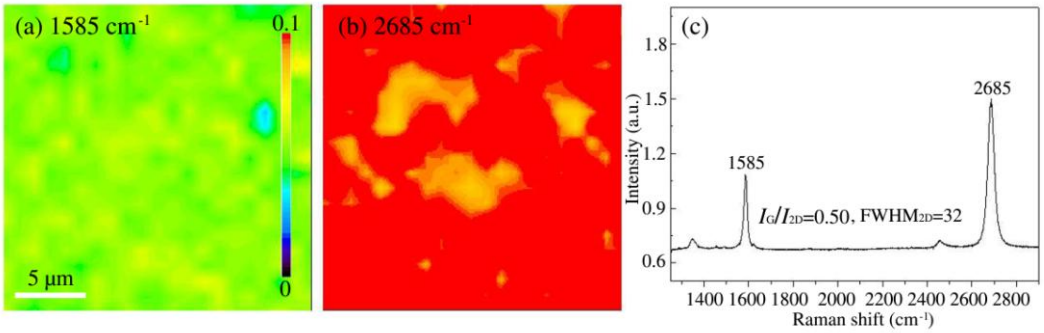

Fig. S-6 Raman mapping images of G (a) and 2D bands (b), and representative Raman spectrum of the transferred graphene on SiO_2/Si substrate. The graphene was grown on Cu/c-plane sapphire by 3 min CVD at 1000 °C.

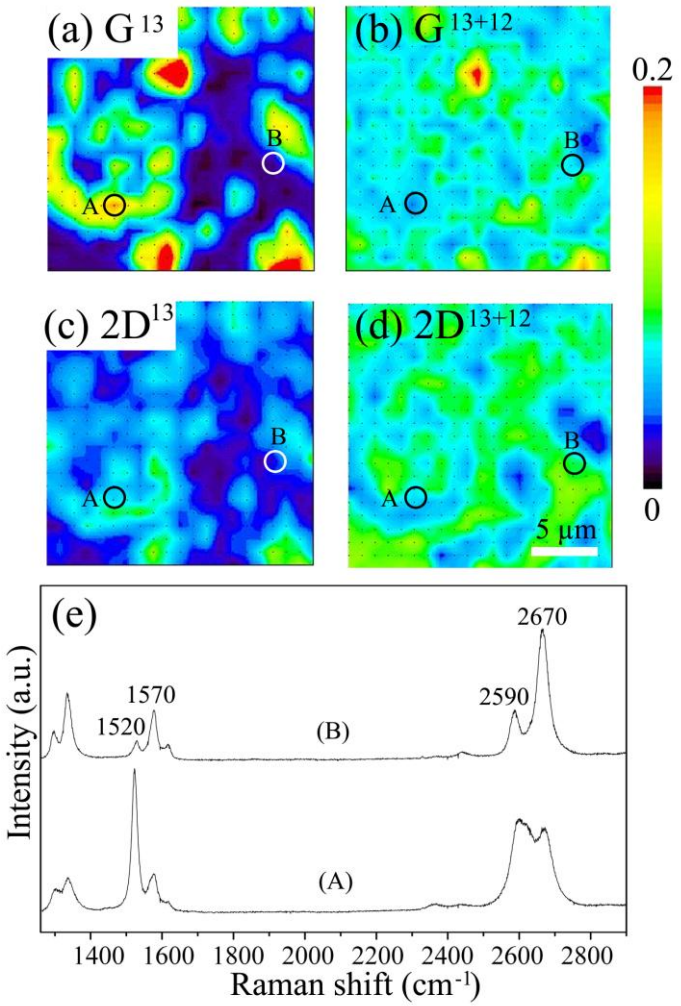

Fig. S-7 Raman measurement of transferred graphene film with $^{13}CH_4$ (0-8 min) and $^{12}CH_4$ (8-10 min) grown from 900 °C CVD. Raman mapping images of G bands at 1520 cm^{-1} (a) and 1570 cm^{-1} (b). Raman mapping images of 2D bands at 2590 cm^{-1} (c) and 2670 cm^{-1} (d). (e) Raman spectra of 2 points highlighted in (a-d).

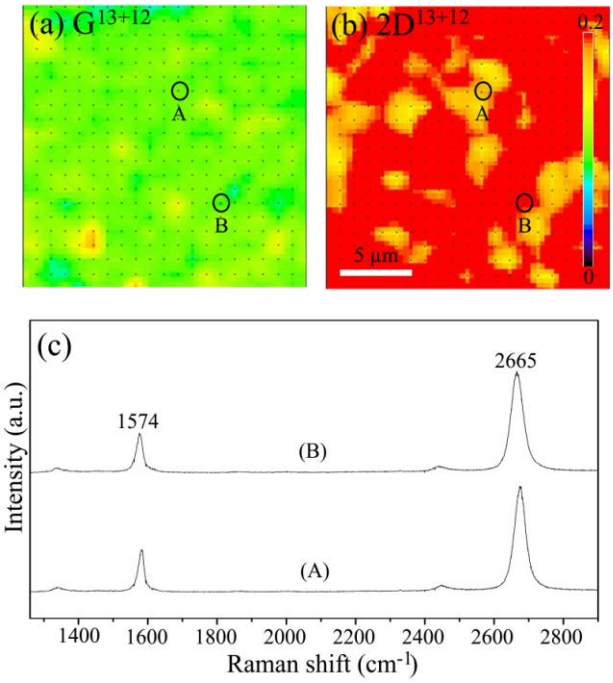

Fig. S-8 Raman data of transferred graphene with $^{13}CH_4$ (0-8 min) and $^{12}CH_4$ (8-10 min) grown from 1000 °C CVD. Raman mapping images of G bands at 1570 cm^{-1} (a) and 2D bands at 2655 cm^{-1} (b). (c) Raman spectra measured at 2 points marked with A and B in the same region as (a) and (b).

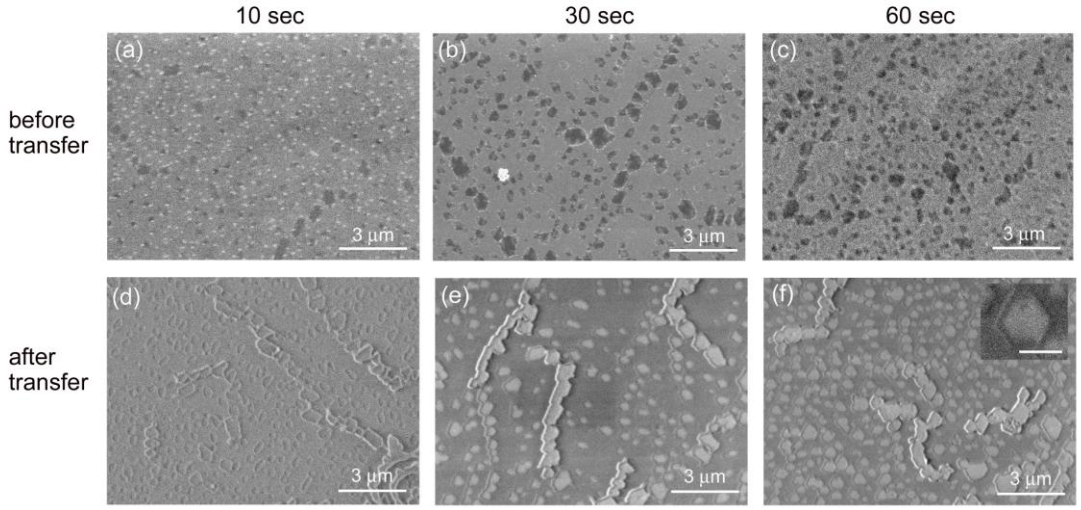

Fig. S-9 SEM images of graphene domains measured before (a-c) and after (d-f) transfer onto SiO_2/Si. The CH_4 supply time is 10 sec (a,d), 30 sec (b,e), and 60 sec (c,f). White dots seen in (a) are supposed to be originated in Cu nanoparticles. Inset of (f) shows a hexagonal graphene domain (scale bar: 500 nm).