Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information

Non-destructive n-doping method for graphene with precise control of electronic properties via atomic layer deposition

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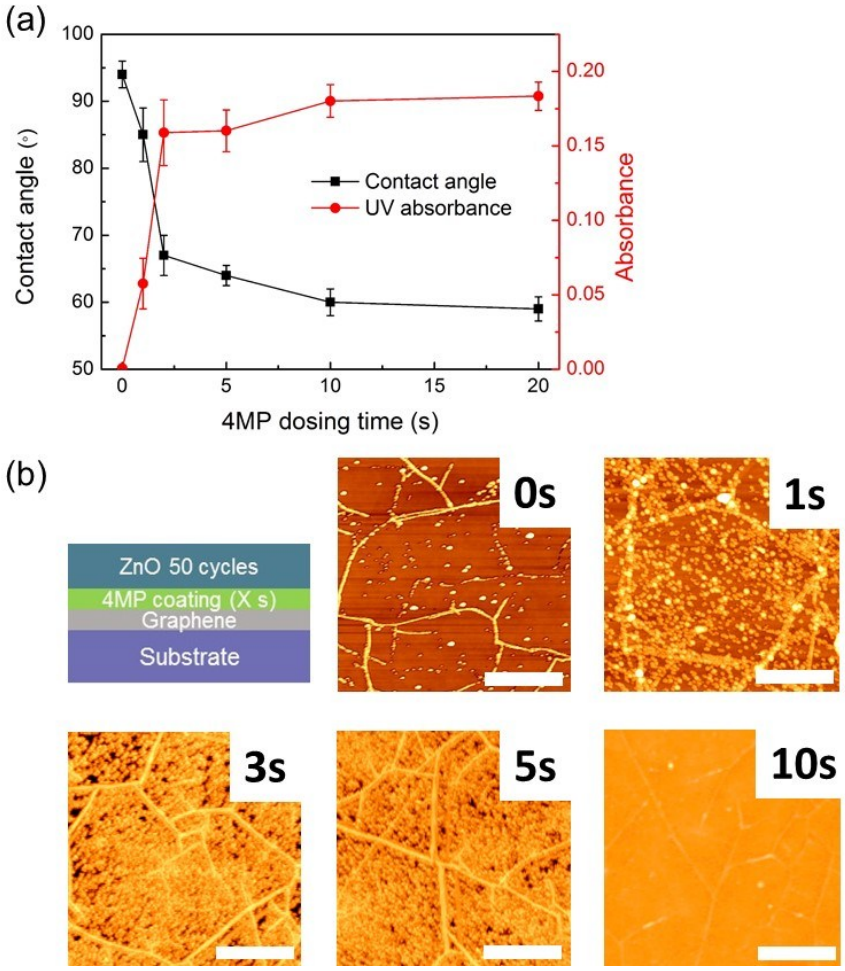

Figure S1. (a) The contact angleas of CVD graphene as a function of 4MP functionalization time and UV absorbance of CVD graphene with 50 cycles of ALD ZnO thin film as a function of dosing time of 4MP. (b) AFM images for CVD graphene with 50 cycles of ALD ZnO thin film as a function of dosing time of 4MP. The scale bar is 2μm. First, ZnO ALD only occurred on grain boundaries and defects of CVD graphene. After 4MP dosing for 1 s, islands of ZnO appeare on the graphene basal surface, and the surface coverage and UV absorbance increase with the 4MP dosing time. After a dosing time of 10s, the graphene surface became smooth and UV absorbance is saturated, suggesting the saturation of 4MP functionalization for uniform ZnO deposition on entire graphene surface.

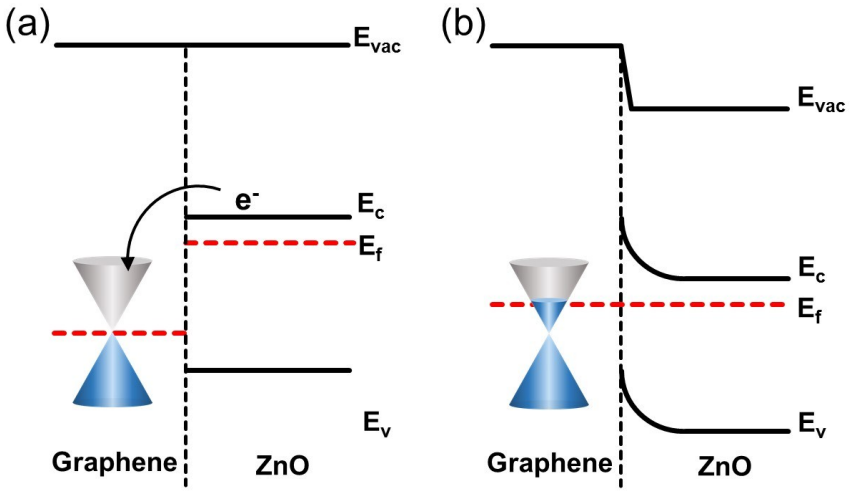

Figure S2. Schematic energy level alignment diagram of the graphene/ZnO interface. (a) Before surface transfer doping and (b) After surface transfer doping by ZnO

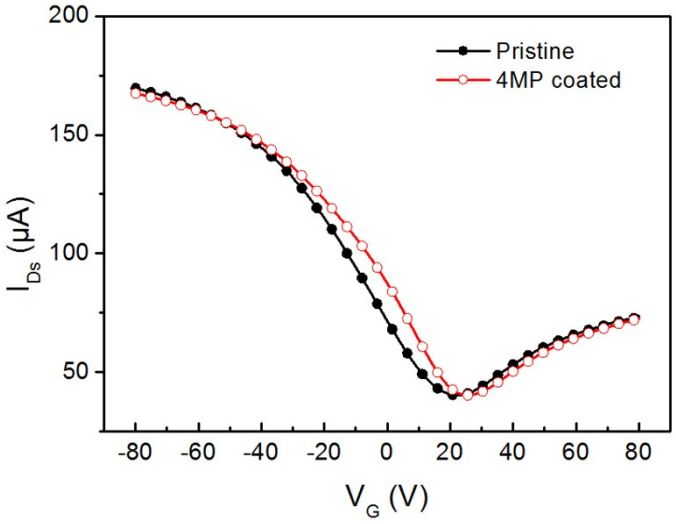

Figure S3. Graphene field effect transistor curve before and after 4MP deposition on pristine mechanically exfoliated graphene.

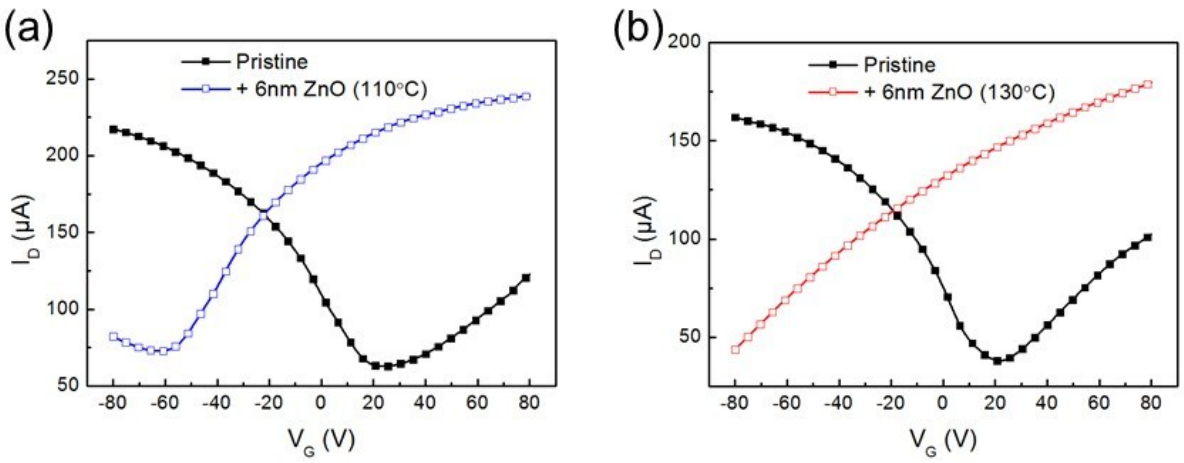

Figure S4. Transfer characteristics of transistors consisting mechanically exfoliated graphene with ZnO films at (a) 110˚C and (b) 130˚C

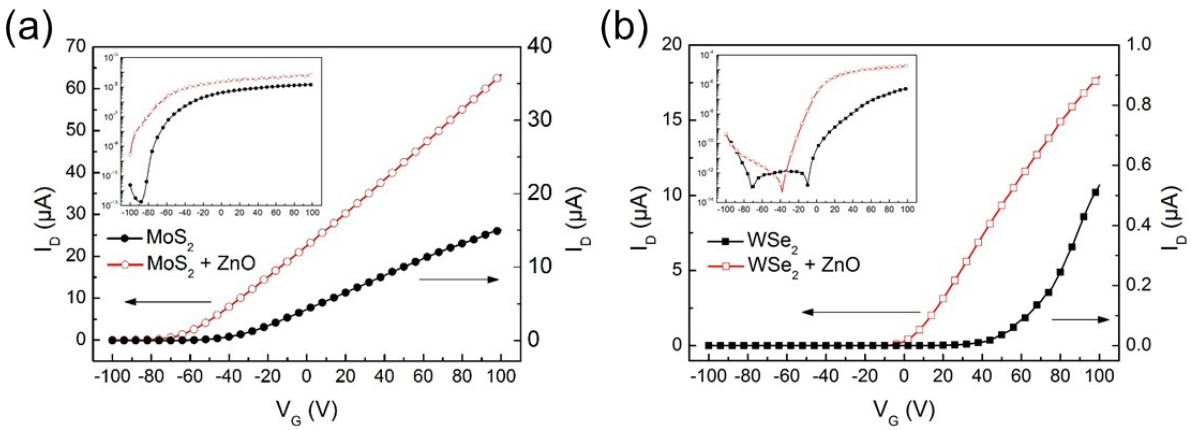

Figure S5. Transfer characteristics of transistors made of mechanically-exfoliated (a) MoS_2 and (b) WSe_2 with 6 nm-thick ZnO films. The mobility of the pristine MoS_2 and WSe_2 transistors were measured at 13.4 and 1.92 $cm^2\ V^{-1}\ s^{-1}$, respectively. The mobility of each device improved significantly following ZnO deposition (48.8 and 23.8 $cm^2\ V^{-1}\ s^{-1}$, respectively). The mobility increase is mainly due to reduction in the Schottky barrier width between the electrode and the transition metal dichacogenides (TMDs) layers, thus current through the electrode−TMDs contact is greatly enhanced by electron tunneling.[S1-S3] In addition, unlike previous studies, controlling doping level in this study is conducted without damage to the lattice of TMDs and do not suffer impurity scattering by ionized atoms, also contributing higher mobility.

References

(S1) H. Fang, S. Chuang, T. C. Chang, K. Takei, T. Takahashi, A. Javey. *Nano Lett* **2012**, 12, 3788.

(S2) H. Fang, M. Tosun, G. Seol, T. C. Chang, K. Takei, J. Guo, A. Javey, *Nano Lett.,* **2013**, 13, 1991.

(S3) L. Yang, K. Majumdar, H. Liu, Y. Du, H. Wu, M. Hatzistergos, P. Y. Hung, R. Tieckelmann, W. Tsai, C. Hobbs, P. D. Ye, *Nano Lett.,* **2014**, 14, 6275.