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Strain and charge doping modulation of graphene by epitaxial growth of MoO$_3$

Since isolation of graphene from graphite\textsuperscript{[1]}, graphene has attracted enormous attention because of its unique properties, such as high carrier mobility\textsuperscript{[2]}, outstanding flexibility and stiffness\textsuperscript{[3]}, and optical transparency\textsuperscript{[4]}, which make graphene an emerging candidate in next-generation electronic devices. It has been reported that various method to modify properties of graphene by engineering graphene mechanically\textsuperscript{[5]} or electronically\textsuperscript{[6]}, but most of the methods are available only temporary or damaging graphene. Therefore, it is necessary to establish permanent and non-destructive method to engineering graphene.

Meanwhile, a phase molybdenum trioxide (α-MoO$_3$) is a layered oxide material, where octahedral layers are stacked along b-axis direction with weak van der Waals force\textsuperscript{[7]}. Bulk state of MoO$_3$ has been utilized as hole transport layer of solar cell and light emitting diode due to its high work function\textsuperscript{[8]}, but it is not studied sufficiently about growth or characteristics of its 2D form.

Here we demonstrated engineering of graphene by epitaxial growth of MoO$_3$. Bi- to few-layer MoO$_3$ is synthesized on exfoliated graphene by proximity evaporation of Mo thin film in ambient condition. Strong interaction between graphene and the grown MoO$_3$ is observed because graphene/MoO$_3$ interface forms an ultraclean heterointerface with a crystalline correlation. When few-layered MoO$_3$ is grown on monolayer graphene, graphene is compressed by ~ 0.2 % due to large lattice mismatch of graphene and MoO$_3$. In addition, graphene is p-doped up to 2.0 $\times 10^{23}$ cm$^{-2}$ due to extraction of electrons from graphene to MoO$_3$ which is originated from high work function of MoO$_3$. More interestingly, we observed asymmetric doping level between top graphene layer and bottom layers in MoO$_3$-deposited multilayer graphene, which is probably originated from screening effect of graphene. Our work shows a possibility of graphene engineering by using epitaxial growth of 2D oxides, including strain modulation and permanent and non-destructive doping control.

References

Figures

Figure 1: (a) Schematic image of graphene-MoO$_3$ heterostructure. (b) Raman spectra of pristine 1L graphene and graphene-MoO$_3$ heterostructure. (c, d) Optical microscope image of pristine graphene and graphene-MoO$_3$ heterostructure, respectively. (e) Atomic Force Microscope (AFM) image of graphene-MoO$_3$ heterostructure.

Figure 2: (a) AFM image of graphene-MoO$_3$ heterostructure. (b) Raman spectra of pristine (black), MoO$_3$-uncovered (blue), MoO$_3$-covered (red) 1L graphene. (c) Polarized Raman spectra of MoO$_3$-covered 1L graphene. (d) G and 2D peak position of graphene-MoO$_3$ heterostructure. (e) G and 2D peak distribution (black: pristine, blue: MoO$_3$-uncovered, red: MoO$_3$-covered) of graphene-MoO$_3$ heterostructure. (f) Polar plot of G’ and G peak intensity of graphene-MoO$_3$ heterostructure.