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Strain and charge doping modulation of graphene by epitaxial growth of MoO_3

Since isolation of graphene from graphite[1], graphene has attracted enormous attention because of its unique properties, such as high carrier mobility[2], outstanding flexibility and stiffness[3], and optical transparency[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[5] or electronically[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, α 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[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[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 2.0×10^{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

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Figures

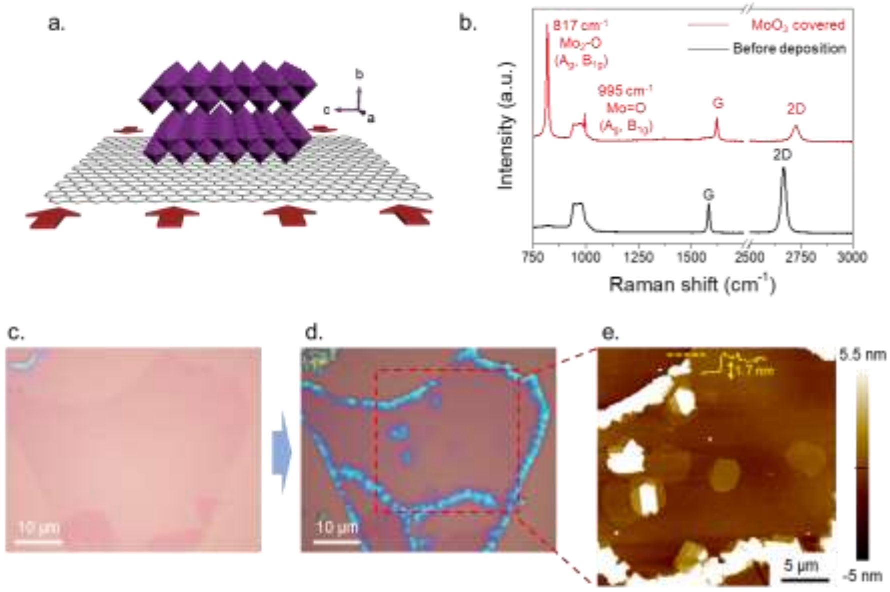

Figure 1: (a) Schematic image of graphene-MoO_3 heterostructure. (b) Raman spectra of pristine 1L graphene and graphene-MoO_3 heterostructure. (c, d) Optical microscope image of pristine graphene and graphene-MoO_3 heterostructure, respectively. (e) Atomic Force Microscope (AFM) image of graphene-MoO_3 heterostructure.

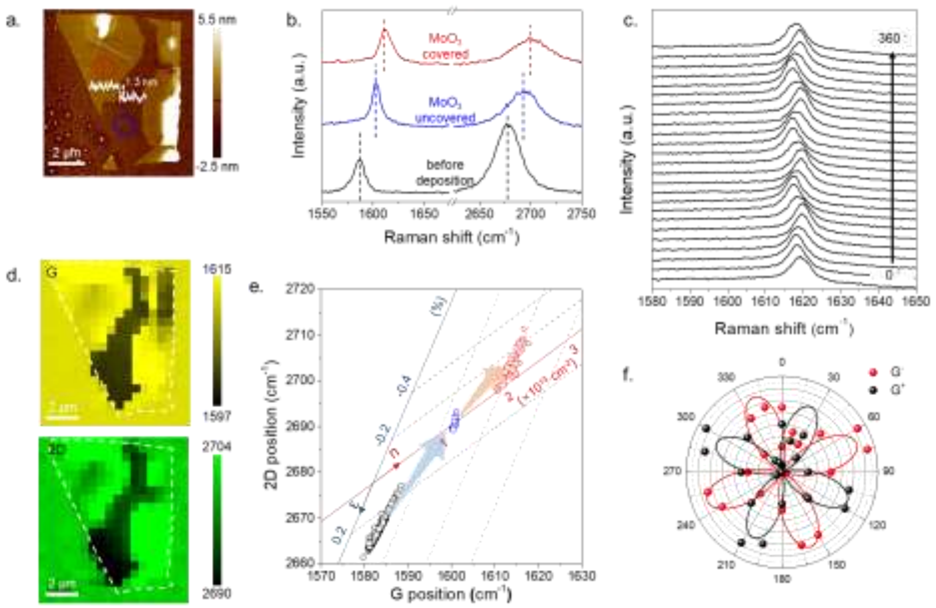

Figure 2: (a) AFM image of graphene-MoO_3 heterostructure. (b) Raman spectra of pristine (black), MoO_3-uncovered (blue), MoO_3-covered (red) 1L graphene. (c) Polarized Raman spectra of MoO_3-covered 1L graphene. (d) G and 2D peak position of graphene-MoO_3 heterostructure. (e) G and 2D peak distribution (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