Direct atomic layerdeposition of aluminium oxide on graphene for metal-insulator-graphene capacitors

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Abstract

The excellent properties of graphene such as ballistic transport and high mobility make it an ideal material for nanoelectronics. [1-3] Furthermore, its optical absorption is only 2.3% and the Young's modulus of graphene is 1 TPa, which are ideal for transparent electrodes and flexible optoelectronics.[2] To realize graphene-based devices, high-quality dielectric films on top of graphene are required as electrostatic gate dielectrics or tunnel barriers for spin injection. With the purpose of effectively controlling channel carriers, dielectric layers should be as thin as a few nanometers, and of uniform coverage on graphene without any pinholes. Fortunately, Atomic layer deposition (ALD) can satisfy these requirements. However, the surface of graphene is chemical insert and there are no dangling bonds, which are necessary for surface chemical reactions during the conventional ALD processes. Surface functionalization have been pursued by researchers to improve the uniformity of gate dielectrics grown on graphene by ALD, including the deposition and oxidation of metal films, functionalization of graphene via plasma or oxidizing gas, and the spin-coating of polymer films as seeding layers. Nevertheless, functionalization either introduces undesired impurities into graphene or breaks the chemical bonds of the graphene lattice, which results in significant degradation in its carrier mobility. Here we report a H_2O-assisted atomic layer deposition method for aluminium oxide films on graphene, where physically adsorbed H_2O molecules on graphene surface act as nucleation sites and oxidants, and self-limit react with metal precursors to form aluminium oxide graphene directly. After Al_2O_3 and HfO_2 growth, no raise of defect-related D band was detected, implying no damage was introduced to the sp^2 hybridized carbon structure of graphene. The C–V measurements showed the expected broad V-shape induced by the quantum capacitance of graphene. The capacitances of Al_2O_3 on graphene was 0.71 μF/cm^2 and the relative permittivity of Al_2O_3 was 7.2, indicating high quality of high-κ films grown on graphene by ALD.

References

[1] D. Li et al., Science 2008, 320, 1170-1171.
[2] K. S. Novoselov et al., Nature 2012, 490, 192-200.
[3] A. Das et al., Nat. Nanotechnol. 2008, 3, 210-215.

Figures

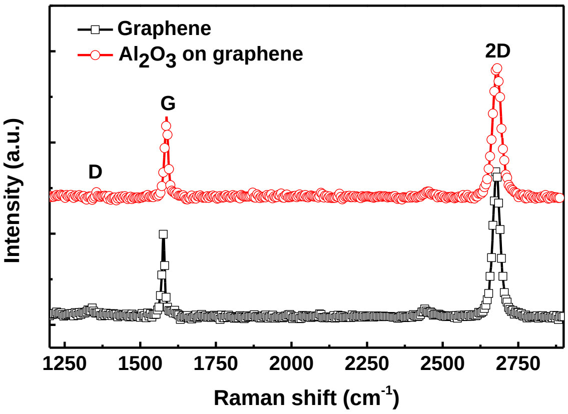

Fig.1 Raman spectra of graphene with and without Al_2O_3 deposition. No D band increase was detected after Al_2O_3 deposition.

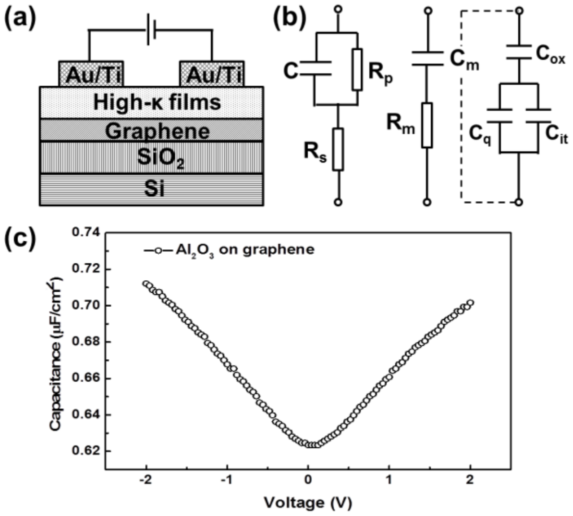

Fig.2 (a) The MOG capacitor. (b) The accurate model (left) and the series model (right) of the MOG capacitor. (c) C–V measurements of Al2O3 on graphene.