Improved Scaling of High-k Dielectric on Graphene by Utilizing Functionalized Graphene as an Ultrathin Nucleation Layer

Woo Cheol Shin, Jeong Hun Mun, Byung Jin Cho

Department of Electrical Engineering, KAIST, 373-1 Guseong-dong Yuseong-gu, Daejeon, Korea
shwc@kaist.ac.kr

Abstract

Graphene has received widespread attention as a promising candidate for the active layer of next generation high speed electronic devices due to its exceptional carrier transport property [1,2]. However, the hydrophobic nature of graphene leads to difficulty in depositing dielectric films on graphene by atomic layer deposition (ALD) [3], which is the most effective and widely adopted technique to grow an ultrathin dielectric film. In order to uniformly deposit dielectrics on graphene, interface layers such as oxidized metals or polymers have been utilized to facilitate the ALD nucleation [3-5]. However, the insertion of interface layers inevitably increases the total thickness of dielectrics on graphene even though the dielectric scaling capability is one of the most important features for realizing graphene device applications.

Here, we report a novel approach to facilitate the ALD of high-k dielectric (Al_2O_3) on chemically vapor deposited (CVD) graphene by utilizing a functionalized graphene (FG) sheet as an effective nucleation layer. The functionalized graphene was achieved by low power plasma treatment on CVD graphene, which provides an ultrathin (~ 2 nm) FG sheet with oxygen-terminated functional groups. Due to the reactive functional groups on FG sheet, the FG-embedded Al_2O_3 on graphene possesses high uniformity and low defect density. We further analyze the impact of FG nucleation layer on the dielectric scaling capability by fabricating metal-oxide-graphene (MOG) capacitors. The FG-embedded MOG capacitor shows superb EOT scaling capability and leakage current characteristics. Our findings can potentially be utilized to guide the viable graphene/dielectric integration which is a prerequisite for realizing graphene-based nano-electronic devices and systems.

References

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Figures

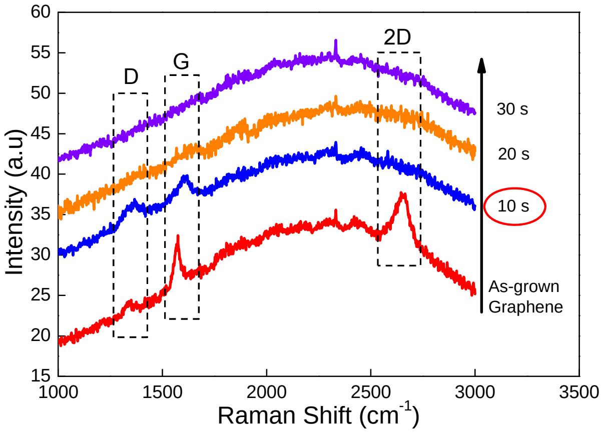

Fig.1 Raman spectra for graphene after plasma assisted functionalization process. The D/G ratio of FG is similar to that for previously reported graphene oxide

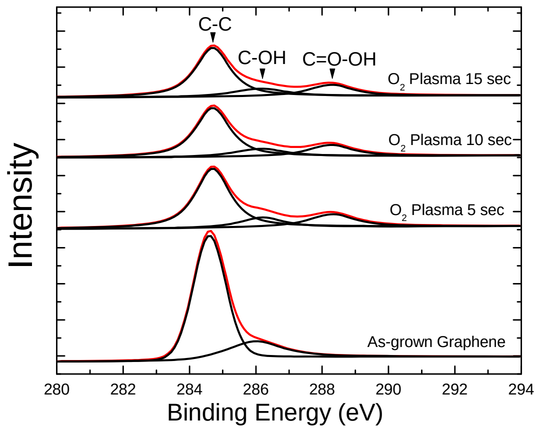

Fig.2 XPS analysis for FG sheets with different plasma exposure time. The FG possesses oxygen-terminated functional groups which would facilitate the ALD nucleation

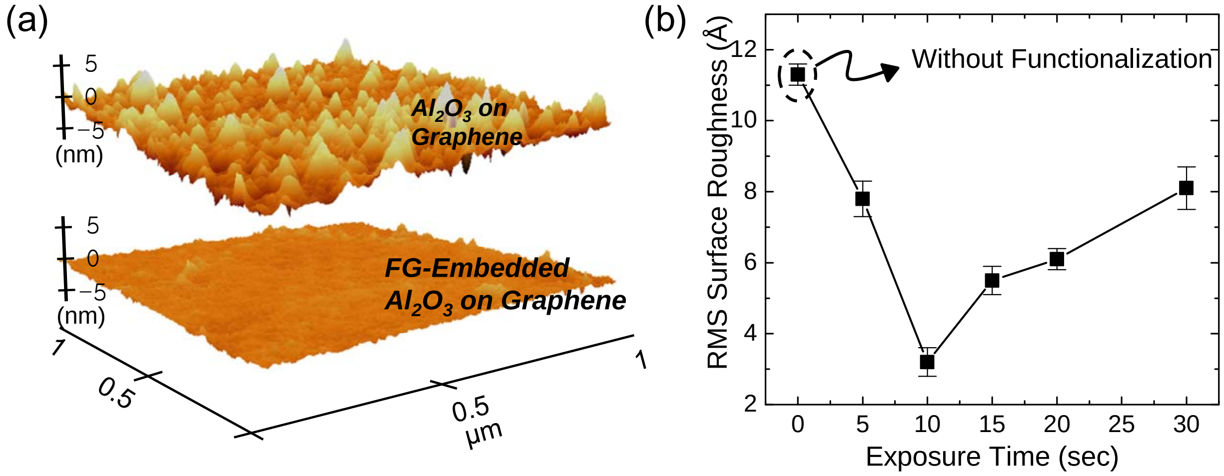

Fig.3 (a) Surface Morphology of Al_2O_3 on Graphene with and without the FG nucleation layer. (b) RMS roughness of Al_2O_3 on FG/Graphene with different plasma exposure time.

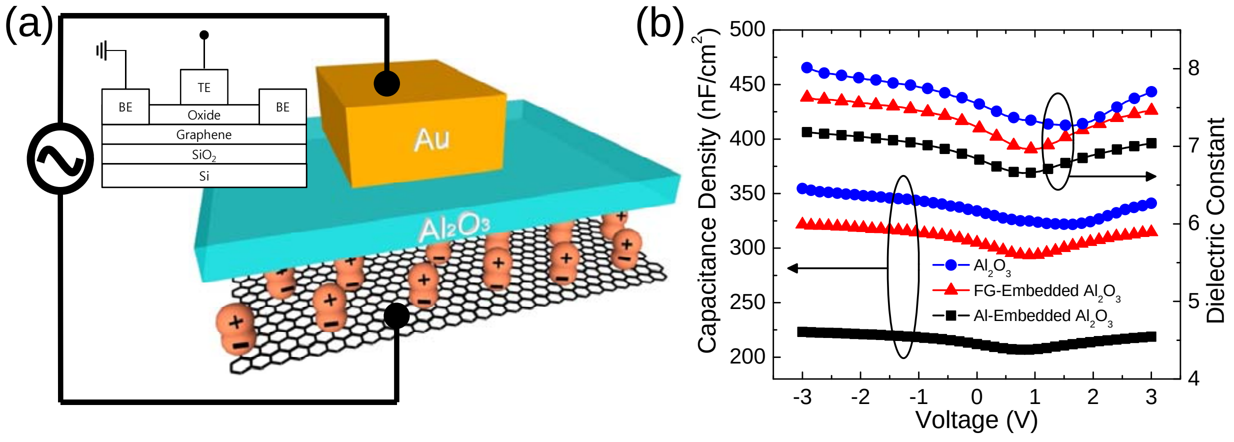

Fig.4 (a) Schematic view of metal/oxide/graphene (MOG) capacitor (b) Capacitance-voltage characteristics of MOG capacitors with and without nucleation layers (FG and Al metal)