Epitaxial Graphene Surface Preparation for Atomic Layer Deposition of Al_2O_3

N.Y. Garces, V.D. Wheeler, J.K. Hite, G.G. Jernigan, J.L. Tedesco, L.O. Nyakiti, C.R. Eddy, Jr., and D.K. Gaskill

Electronics Science & Technology Division, U.S. Naval Research Laboratory, 4555 Overlook Ave., SW Washington, DC 20375, USA
nelson.garces@nrl.navy.mil

High-k dielectrics such as Al_2O_3, HfO_2, Ta_2O_5, and TiO_2, are required for realizing graphene-based top-gated electronic devices and for scaling field effect transistors to sizes < 100 nm. Atomic layer deposition (ALD), a method based on two self-limiting surface half-reactions, is a preferred technique to deposit high-quality, conformal, stoichiometric dielectric films with precise thickness control. Unfortunately, direct deposition of oxides on pristine or non-functionalized graphene by ALD, using H_2O-based precursors, is hindered by the highly hydrophobic and chemically inert nature of graphene, resulting in no coverage or non-uniform coverage [1-4]. Here, a simple *ex-situ* graphene surface treatment based on wet chemistry is developed to render the otherwise chemically inert graphene surface more suitable for thin dielectric deposition. Using this approach, 30 nm thick Al_2O_3 films are deposited, using trimethylaluminum and triply-distilled H_2O as precursors, onto epitaxial graphene grown on the Si-face of silicon carbide. The resulting films show excellent morphology and uniformity over large (~8 mm^2) areas (i.e., the entire sample area), as determined by atomic force microscopy and scanning electron microscopy. X-ray photoelectron spectroscopy revealed a nearly stoichiometric film with markedly reduced impurity content. Moreover, capacitance-voltage measurements reveal an extracted dielectric constant of ~7.3 and a positive Dirac voltage shift of ~ 1V. The mobility of free carriers in the graphene layer, as determined by van der Pauw Hall measurements (1000-1200 $cm^2\ V^{-1}\ s^{-1}$), was not affected by either the surface pre-treatment or the deposited dielectric although in each case, the sheet charge density changed.

References

[1] X.R. Wang, S.M. Tabakman, H.J. Dai, Journal of the American Chemical Society 130 (2008), 8152.
[2] L. Bongki, P. Seong-Yong, K. Hyun-Chul, C. KyeongJae, E.M. Vogel, M.J. Kim, R.M. Wallace, K. Jiyoung, Applied Physics Letters 203102-1-3 (2008).
[3] F. Speck, M. Ostler, J. Rohrl, K.V. Emtsev, M. Hundhausen, L. Ley, T. Seyller, Physica Status Solidi C: Current Topics in Solid State Physics, 2 7 (2010), 398-401.
[4] Y. Xuan, Y.Q. Wu, T. Shen, M. Qi, M.A. Capano, J.A. Cooper, P.D. Ye, Applied Physics Letters 013101-1-3 (2008).