Proceedings of the 5th World Congress on New Technologies (NewTech'19)
Lisbon, Portugal – August, 2019
Paper No. ICNFA 136
DOI: 10.11159/icnfa19.136

Atomic Layer Deposition of High-k Films on Graphene Surface

Hyeok Jae Lee, Kang Min Lee and Sang Woon Lee
Department of Energy Systems Research and Department of Physics, Ajou University
Suwon 16499, Republic of Korea
gurwoqod154@ajou.ac.kr; leekigg@ajou.ac.kr; slee01@ajou.ac.kr

Extended Abstract

Graphene has received considerable attentions because of its unique band structure and high electron mobility (>20,000 cm^2/Vs). Especially, the electronic characteristics of graphene is suitable as a channel material for the high performance metal-oxide-semiconductor field effect transistor. A growth of high-k film is necessary on graphene surface for top-gated graphene transistor.[1] However, graphene has no surface functional groups such as hydroxyl groups (-OH group) except for defects and graphene edges, which caused a failure of high-k film deposition on graphene surface even using state-of-the-art thin film deposition technique, i. e., atomic layer deposition (ALD). Thus, various methods were proposed to deposit dielectric films uniformly on graphene. For example, a growth of dielectric thin film by oxidation treatment after forming a metal seed layer using physical vapor deposition (PVD). In addition, a use of perylene-tetracarboxylic acid (PTCA), and pre-H_2O treatment were attempted. Unfortunately, impurities such as the perylene molecules remain on the graphene surface and the pre-H_2O treatment and post-oxidation treatment become somewhat complicated.[2, 3] In the meantime, enhancement of nucleation sites on graphene surface using ozone degraded the chemical state of graphene because of a defect formation on the graphene.[4] However, the chemical and electrical properties of the graphene must be preserved after the growth of high-k films.[5]

Here, we propose a novel graphene surface treatment method that allows an enhanced nucleation and growth of high-k thin films by ALD via a graphene surface treatment using trimethylaluminum (TMA) and H_2O prior to the deposition of HfO_2 film on the graphene. Then, high-k thin films such as Al_2O_3 and HfO_2 were deposited on the surface-treated graphene sample using ALD. These graphene surface treatment methods generate Al_2O_3 nuclei through physical adsorption on the surface of graphene, which enhanced the growth and nucleation of high-k film through ALD on the graphene surface. As a result, additional defects were not created after surface treatment on graphene and HfO_2 ALD. And significant amount of Hf-C bond was observed after HfO_2 ALD, which was decreased substantially with surface treatment. Nucleation delay in HfO_2 ALD decreases from 70 to 10 ALD cycles with graphene surface treatment and dielectric constant of HfO_2 film is higher using the surface treatment (k ~14.5) than that without the surface treatment (k ~5.6). Also, a leakage current (with a capacitor fabrication) was decreased by a factor of 10^5 compared to without surface treatment. The graphene surface treatment method enhanced the nucleation and the electrical properties of the HfO_2 film without deteriorating the properties of graphene, thus providing promising opportunities in graphene electronics.

References

[1] F. Schwierz, "Graphene transistors," *Nature nanotechnology*, vol. 5, pp. 487-496, 2010.
[2] B. Fallahazad, K. Lee, G. Lian, S. Kim, C. Corbet, D. Ferrer, L. Colombo, and E. Tutuc, "Scaling of Al_2O_3 dielectric for graphene field-effect transistors," *Applied Physics Letters*, vol. 100, p. 093112, 2012.
[3] X. Wang, S. Tabakman, and H. Dai, "Atomic layer deposition of metal oxides on pristine and functionalized graphene," *Journal of the American Chemical Society*, vol. 130, pp. 8152-8153, 2008
[4] B. Lee, S.-Y. Park, H.-C. Kim, K. Cho, E. M. Vogel, M. J. Kim, R. M. Wallace, and J. Kim, "Conformal Al_2O_3 dielectric layer deposited by atomic layer deposition for graphene-based nanoelectronics," *Applied Physics Letters*, vol. 92, p. 203102, 2008.
[5] Y. H. Park, M. H. Kim, S. B. Kim, H. J. Jung, K. Chae, Y. H. Ahn, J.-Y. Park, F. Rotermund, S. W. Lee, "Enhanced Nucleation of High-K Dielectrics on Graphene by Atomic Layer Deposition," *Chemistry of Materials*, vol. 28, pp. 7268-7275, 2016.