Atomic Layer Deposition of High-k Films on Graphene Surface

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Extended Abstract
Graphene has received considerable attentions because of its unique band structure and high electron mobility (>20,000 cm²/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-H₂O treatment were attempted. Unfortunately, impurities such as the perylene molecules remain on the graphene surface and the pre-H₂O 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 trimethylaluminium (TMA) and H₂O prior to the deposition of HfO₂ film on the graphene. Then, high-k thin films such as Al₂O₃ and HfO₂ were deposited on the surface-treated graphene sample using ALD. These graphene surface treatment methods generate Al₂O₃ 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 HfO₂ ALD. And significant amount of HF-C bond was observed after HfO₂ ALD, which was decreased substantially with surface treatment. Nucleation delay in HfO₂ ALD decreases from 70 to 10 ALD cycles with graphene surface treatment and dielectric constant of HfO₂ 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 HfO₂ film without deteriorating the properties of graphene, thus providing promising opportunities in graphene electronics.

References