Towards Graphene-based heterojunction devices for microelectronic applications

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The integration of dielectrics or semiconductors on Graphene is of critical importance for the development of a new generation of Graphene-based hetero-junction devices. The deposition of a high-k dielectric, like Al_2O_3 or HfO_2 or of Silicon on top of Graphene is still challenging due to Graphene's lack of dangling bonds. In this paper, two strategies for the dielectric-Graphene and Silicon-Graphene integration will be presented.
Atomic Layer Deposition (ALD) or Atomic Vapour Deposition (AVD) processes have been explored to deposit high-κ dielectrics on Graphene with negligible damage of the Graphene layer. However, the nucleation of the dielectric film is hindered by the chemical inertness of the Graphene surface[1,2]. Therefore, the initial ALD or AVD growth on Graphene requires a functionalization of the pristine Graphene surface with reactive groups. A functionalization by Xenon difluoride (XeF_2) has been found to provide additional nucleation sites resulting in conformal films without pinholes[3]. However, XeF_2 is a toxic and strong oxidizing agent, therefore the scope of our study was to test alternative fluorinating agents like Nitrogen trifluoride (NF_3) or perfluorodecyltrichlorosilane (FDTS) which are widely established in the microelectronics industry.
We present the impact of NF_3 pre-treatments on transferred Graphene layers prior to the ALD of Al_2O_3 films. In addition, we investigated a pre-treatment of graphene with FDTS prior to the HfO_2 growth by AVD. We demonstrate that the FDTS self-assembled monolayer (SAM) significantly improves nucleation of HfO_2 on graphene. Wafer scale compatibility of the proposed pre-treatment can enable fast adoption for the fabrication of graphene-based devices on large-diameter wafers.
Plasma enhanced CVD (PECVD) is of interest for applications requiring low thermal budgets such as the back end of line (BEOL) (< 450°C). However, high energy ion bombardment related to plasma exposure readily correlates with worsening of material properties[4]. Heintze et al. have demonstrated, that the ion energy in the plasma decreases with increasing frequency[5]. We demonstrate, that by the use of PECVD at a very high frequency of 140 MHz, thin a-Si:H layers can be grown softly without changing the properties of the underlying Graphene significantly.
The herein presented deposition strategies for dielectrics and semiconductors on Graphene surfaces demonstrate a significant progress towards a complete fabrication scheme of Graphene-based heterojunction devices in microelectronic technologies.

References

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