Plasma-enhanced atomic layer deposition of Al_2O_3 on graphene using monolayer hBN as interfacial layer

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We demonstrate that a monolayer of hBN on-top of graphene can act as an effective protective and interfacial layer on graphene for plasma-enhanced atomic layer deposition (PEALD), enabling the high-quality deposition of 10 nm thin Al_2O_3 encapsulating films.
Similar to graphene, hBN has no dangling bonds, which could prevent proper nucleation in a thermal ALD process. However, PEALD is expected to create dangling bonds due to plasma damage and therefore no additional seeding layers or pre-treatments are needed on graphene or hBN. The major advantage of PEALD over thermal-based ALD processes is that the growth of higher quality oxides is possible, enabling thinner gate oxides with higher breakdown fields. [1] However, PEALD on graphene has a significant negative impact on the structural and electrical properties because of the corresponding damage generation. Therefore, a protection layer, in this case monolayer hBN, is needed to preserve the properties of graphene. Damage analysis performed by Raman spectroscopy [2,3] of different samples after PEALD is shown in Figure 1. The results show that a monolayer of hBN in combination with an optimized deposition process can effectively protect graphene from damage, while significant damage was observed without an hBN layer. Electrical characterization of double gated graphene field effect devices confirms that the graphene did not degrade during the plasma deposition of Al_2O_3. The leakage current densities were consistently below 1 pA/µm² for electric fields across the insulators of up to 8 MV/cm, with irreversible breakdown happening above. Such breakdown electric fields and low leakage currents are state-of-the-art for PEALD deposited Al_2O_3 and can be seen as an indicator for high quality dielectric films.

References

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Figures

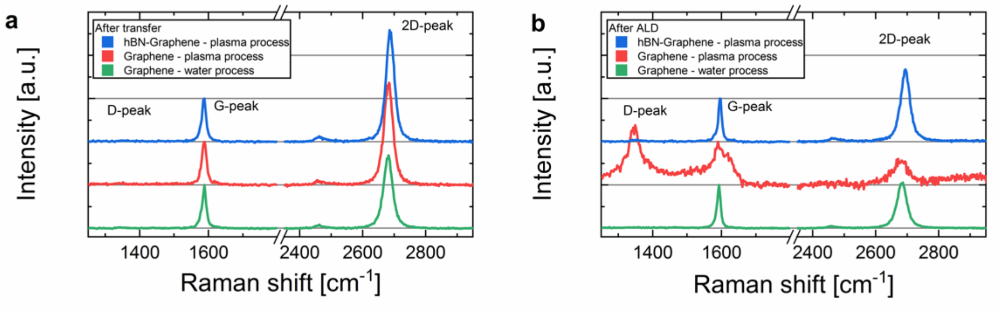

Figure 1: Raman analysis for Gr/SiO_2/Si and hBN/Gr/SiO_2/Si before and after Al_2O_3 deposition. a) Raman spectra for Gr/SiO_2/Si and hBN/Gr/SiO_2/Si after transfer. b) Raman spectra for Gr/SiO_2/Si and hBN/Gr/SiO_2/Si after Al_2O_3 deposited by PEALD and TMA-H_2O ALD.