Benchmarking Insulators for Devices Based on 2D Materials

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Abstract

Despite remarkable advances in 2D electronic devices, their predicted performance potential remains largely untapped. A key limiting factor is the lack of scalable insulators that integrate with 2D materials as seamlessly as SiO2 does with silicon. Identifying suitable insulators for 2D nanoelectronics is a critical and complex challenge. This issue is particularly pressing as the scaling of transistors toward sub-10nm channel lengths demands gate insulators with sub-1 nm equivalent oxide thicknesses (EOT). To enable competitive device performance, these insulators must meet stringent requirements, including (i) low gate leakage currents, (ii) a low density of interface traps, (iii) a low density of border traps within the insulator, and (iv) high dielectric strength.

Over the past decade, a wide range of insulating materials has been proposed, underscoring the need for early and systematic screening. However, benchmarking these insulators presents several challenges. First, experimentally available samples often suffer from non-optimized fabrication processes and do not match the quality of commercial SiO2 and HfO2. Second, these materials typically fall short of the aggressive EOT targets required for future technologies, complicating direct comparisons. Third, theoretical predictions via atomistic simulations are hindered by uncertainties in the crystal structures of many candidates and by the strong dependence of defect characteristics on processing conditions.

In this talk, I will present our combined experimental and theoretical approach aimed at separating processing-related limitations from the intrinsic potential of novel insulator materials. This strategy enables a more reliable assessment of their suitability for achieving sub-1 nm EOT values in next-generation 2D devices. I will show examples of promising insulators and their current stability and reliability (hysteresis vs. bias temperature instability) and finally compare the most promising options.