pH Measurement with Large-Area Graphene Field-Effect Transistors at the Quantum Capacitance Limit

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Graphene field-effect transistors are attractive candidates for sensing applications [1] because of their high charge carrier mobility and a relatively inexpensive fabrication process for large area devices [2]. However, it remains a challenge to integrate high quality analyte selective layers on graphene without compromising mobility or capacitive coupling [3]. We demonstrate here graphene-based ion-sensing field-effect transistors that saturate the physical limit of sensitivity. We present a model outlining the necessity for maximizing the device carrier mobility, active sensing area, and capacitive coupling in order to minimize noise. We encapsulate large-area graphene with an ultrathin layer of parylene, a hydrophobic polymer, and deposit an ultrathin, stoichiometric pH-sensing layer of either aluminum oxide or tantalum pentoxide. With these structures, we achieve gate capacitances ~ 0.6 μF/cm2, approaching the quantum-capacitance limit inherent to graphene, along with a near-Nernstian pH response of ~55±2 mV/pH. We observe field-effect mobilities as high as 7000 $cm^2V^{-1}s^{-1}$ with minimal hysteresis as a result of the parylene encapsulation. A detection limit of 0.1 mpH in a 60-Hz electrical bandwidth is observed in optimized graphene transistors [4].

References

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Figures

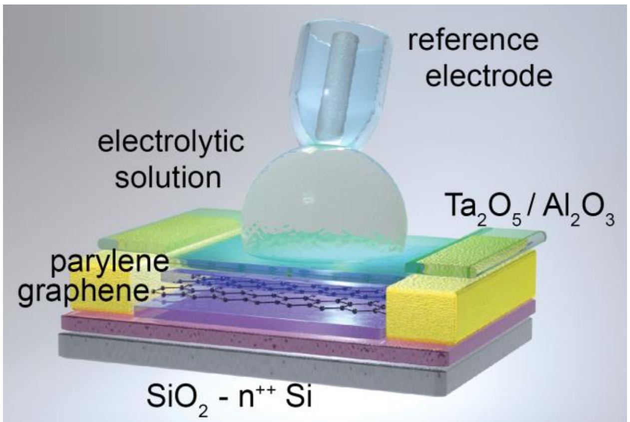

Figure 1: Schematic of graphene ISFET encapsulated with parylene and a layer of metal oxide (Ta_2O_5 or Al_2O_3) on a Si-SiO_2 substrate.

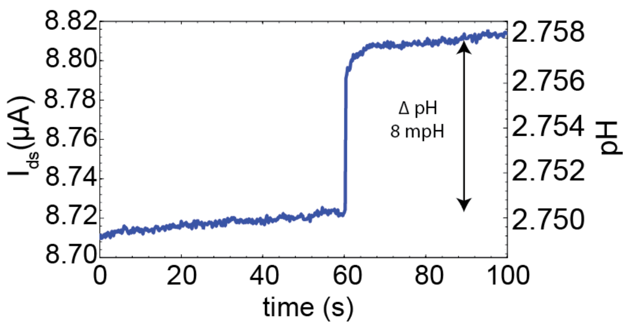

Figure 2: The change in current Ids of an ISFET with time after increasing the pH by 8 mpH at t=60 s, resulting in 85 nA of change in current.