Precision ion sensitive transistors enabled by wafer scale graphene

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Abstract

Accurate, real-time measurement of ion concentration is of broad importance to the management of fresh water resources, effective waste water treatment, and industrial process control. I will present recent work on large-area graphene based ion sensitive field effect transistors (ISFETs), employing metal oxide layers or ionophore based membranes and wafer scale graphene processing methods [1-4]. Large-area graphene ISFETs benefit from the combination of high mobility charge transport (μ = 5000 cm^2 V^{-1} s^{-1}), reduced low-frequency noise with increasing transistor channel area ($K = f \langle \Delta v^2 \rangle / v_0^2 = 5\times10^{-13}$ for a 5 mm x 5 mm device), and facile integration with ion sensitive layers (for example, sensitive to H^+, K^+, Na^+, NH_4^+, Cl^-, NO_3^-, HPO_4^{2-} and SO_4^{2-}). The combination of Nernstian limited sensitivity with low 1/*f* noise enables concentration resolution of r ~ 0.003 log M. The stability and resolution of graphene ISEFTs allows simultaneous, real-time measurement of multiple analytes through the application of Nikolskii-Eisenmann analysis to an array of graphene ISFETs, improving selectivity over that achievable with a single ISFET. I will conclude with a discussion of challenges and prospects for future development of graphene ISFETs for water quality monitoring applications.

REFERENCES
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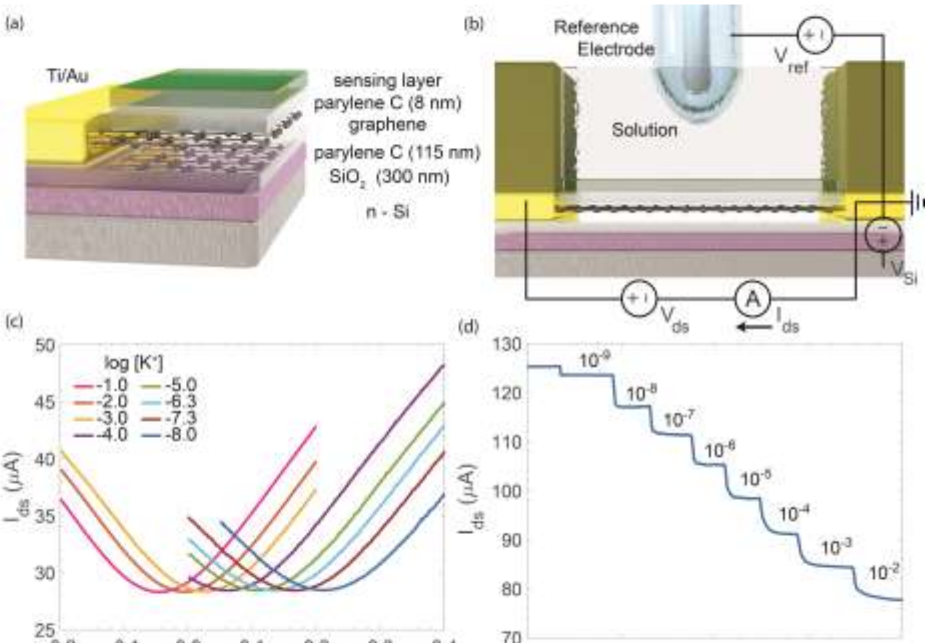

Fig. 1. (a) Schematic of a graphene ISFET encapsulated with parylene and a sensing layer on a SiO_2/Si substrate. (b) Electrical schematic for measuring the current through the graphene channel I_{ds} for different electrolytic solutions, with bias V_{ds}, and reference electrode V_{ref} (c) The measured channel current, I_{ds}, versus V_{ref} , for a representative K^+-sensitive graphene ISFET. (d) Continuous real-time measurement of I_{ds} of a K^+-sensitive graphene ISFET while increasing K^+ molar concentration in decade steps.