Improved Protein Detection Performance in Liquid-Gated Graphene Field-Effect Transistors

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ABSTRACT: Graphene field-effect transistors (gFETs) are seen as promising tools for highly sensitive biosensing [1]. However, when used in liquid-gated setups, their performance often suffers from electrical drift and unstable interfaces. These issues can hide real biomolecular signals and reduce selectivity [2]. Solving these problems is crucial to the use of graphene biosensors in real-world applications. In this study, we found that conditioning the electronics and stabilizing the liquid-gated gFET surface greatly improves their reliability in detecting proteins. Before adding biological molecules, we thoroughly cleaned and balanced the graphene devices to reduce baseline changes and unwanted electrostatic effects. After stabilization, we modified the graphene surface via π–π stacking with PBASE and attached antibodies targeting the SARS-CoV-2 receptor-binding domain (RBD) [3]. After functionalization, the devices showed a consistent Dirac voltage shift of about 110 mV, which confirmed that the antibodies were successfully attached. When exposed to RBD protein at concentrations from 1 fM to 10 pM, the devices gave clear, concentration-dependent electrical signals. In contrast, tests with non-specific protein controls showed almost no change. Besides the usual Dirac-point analysis, we also measured the transconductance of both the hole and electron branches to provide an additional means of sensing proteins. Significant changes in transconductance occurred only with the target protein, while negative controls showed little change, supporting the platform's selectivity. Overall, these results suggest that poor device stabilization, rather than problems with the biorecognition layer, has been a main obstacle in liquid-gated graphene biosensors. The conditioning method we describe here improves signal accuracy and provides practical advice for reliable gFET-based sensing.

References

[1] Silvestri, A., et al. *Nanoscale,* 15 (2023) 1076–1085
[2] Mouro, J., et al. *npj 2D Materials and Applications,* 9 (2025)
[3] Premkumar, L., et al. *Science Immunology,* 5 (2020)

Figures

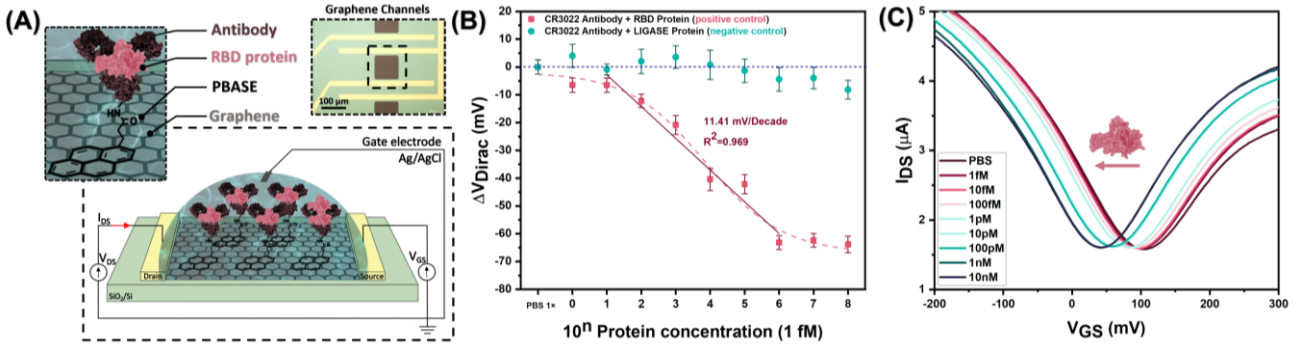

Figure 1: (A) Schematic of the GFET-Chip functionalized with the antibody for protein detection. (B) Calibration curve showing ΔV_{Dirac} as a function of protein concentration for the positive control (pink) and negative control (blue). (C) Graphene transfer curves for different RBD protein concentrations.