

# Real-time, precise and accurate parallel Dirac Point tracking of an array of electrolyte-gated graphene FETs for sensing applications

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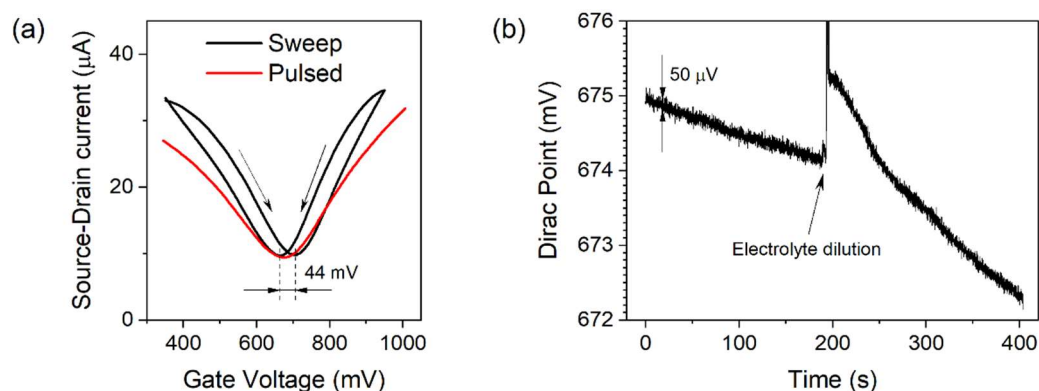
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Molecular (ion) sensing with electrolyte-gated graphene field-effect transistors (GFETs) fundamentally relies on repetitive measurements of the GFET Dirac Point (DP). Here I present pulsed GFET measurement methods [1] including Paragraf's proprietary DP tracking technique that finds and tracks the DP of a GFET with time resolution  $<100$  ms and both accuracy and precision  $<0.1$  mV, up to two orders of magnitude better than can be achieved with standard gate voltage sweep methods. Commonly, the DP is retrieved from the GFET transfer characteristic measured by means of a gate voltage sweep. Practical sweep rates less than a few V/s correspond to GFET operation at low frequencies ( $<10$  Hz), where the response of GFETs is affected by charge trapping. Charge trapping results in hysteresis, i.e. a strong dependence of the measured transfer characteristic and retrieved parameters upon the applied gate voltage history including sweep direction, rate, and range. Typical DP variation (e.g. for opposite sweep directions) can be as high as a few 10's of mV, limiting the accuracy of DP measurements and, as a result, of the measured concentration of analytes in sensing applications. Proposed methods apply gate voltage pulses far shorter than the trapping time constants [2]. Such pulsed operation facilitates the intrinsic response of a GFET, not affected by charge trapping, and enables reliable extraction of GFET parameters including DP and charge carrier mobilities. A measurement system employing the technique developed at Paragraf allows simultaneous (parallel) DP tracking of an array of GFETs (7 channels currently, with future expansion planned). Parallel DP tracking is a superior alternative to multiplexing when GFETs in an array are measured sequentially, and is vital, not only for testing a few analytes at the same time, but also for implementing reference FET measurements to deal with the reference electrode problem [3] and drift, which fundamentally limit the performance of electrolyte-gated GFET sensors.

## References

- [1] A. Nikolaenko, WO 2025/219884 A1
- [2] E. A. Carrion et al., IEEE Transactions on Electron Devices, 61 (2014) 1583
- [3] P. Bergveld, Sensors and Actuators B, 88 (2003) 1

## Figures



**Figure 1:** (a) GFET transfer characteristics; and (b) DP tracking trace of a single GFET, demonstrating unprecedented DP measurement resolution, DP drift, and a response to a minor electrolyte dilution