Multiplexed Extended-Gate Field-Effect Transistor-Based Immunosensor with Gold Nanoparticle-Amplified Potentiometric Response

Željko Janićijević[1]
Trang-Anh Nguyen-Le[1], Ahmed Alsadig[1], Rugilė Žilėnaitė[2], Taufhik Hossain Tonmoy[1], Manja Kubeil[1], Michael Bachmann[1], Larysa Baraban[1]
[1]*Institute of Radiopharmaceutical Cancer Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany*
[2]*Faculty of Chemistry and Geosciences, Institute of Chemistry, Vilnius University, Naugarduko g. 24, LT-03225, Vilnius, Lithuania*
z.janicijevic@hzdr.de

To clinically evaluate complex diseases at the point of care (POC), it is crucial to have multiplexed quantitative sensing of biomolecules. This need has led to the development of ultra-sensitive and cost-effective biosensors. Electronic biosensors based on extended gate field-effect transistor (EGFET) are promising candidates for multiplexed biosensing due to their excellent sensitivity, facile integration, and straightforward interfacing with the readout electronics. Although some high-performance biosensing applications of EGFET systems have been demonstrated [1,2], current EGFET-based biosensors still need to overcome practical issues to reach broad use in POC settings, such as readout at low current levels (~nA), limited multiplexing ability, and complex customized nanofabrication of FET transducers. We demonstrate a custom standalone multiplexed EGFET-based potentiometric biosensing platform relying on modular electronics constructed with off-the-shelf components and an innovative assay format employing bioconjugates of gold nanoparticles (AuNPs) and antibodies (Abs). Our platform comprises a disposable sensing chip containing an EG electrode array functionalized with bioreceptor molecules, a multiplexing module enabling reproducible scanning of up to 32 electrodes, and a readout module based on a commercial FET operating in constant charge mode to enable indirect monitoring of gate surface potential shifts caused by analyte binding. We observe a remarkable 5-fold amplification of the potentiometric response due to the labeling of target antibodies with AuNPs in comparison with the traditional non-labeled assay. We investigate the amplification mechanism by analyzing and modeling the impedimetric response of the system and propose that AuNPs act as localized regions of high surface charge mediating the diffusion barrier layer disruption. The AuNP-enhanced response brings the sensitivity of our platform to a level comparable with fully customized potentiometric nanobiosensors while avoiding complex nanostructuring processes and enabling accurate readout with conventional electronics. Furthermore, our EGFET-based platform exhibits ~10^4-10^6 times lower detection limits than gold-standard optical methods. Our findings indicate great promise for the development of highly sensitive and low-cost EGFET-based electronic biosensing systems suited for use at the POC.

References

[1] K. Kim et al., Nature Communications, 11 (2020) 119.
[2] H. Kim et al., ACS Nano, 15, 3 (2021) 4054–4065.

Figures

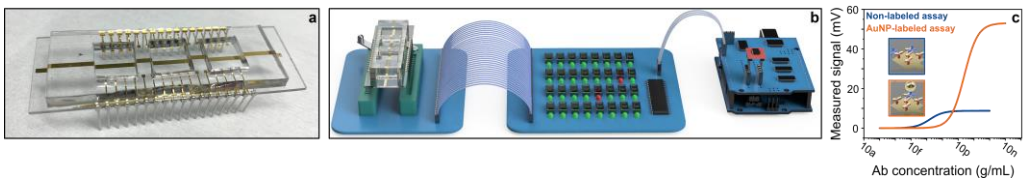

Figure 1: a) EG sensing chip; b) Multiplexed EGFET platform illustration; c) Response of the biosensor.