Graphene technology for innovative sensing applications in health

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Graphene-based sensing technology has the potential to become the next paradigm for chemical and bio-sensing applications that require exceptionally low detection limits, high reliability, and portability, offering an easy-to-use and cost-effective platform. We propose a graphene sensing system that aims to set new standards for data acquisition speed and integration with CMOS electronics, enabling real-time data processing using artificial intelligence (AI) models. These advancements will allow the technology to achieve sample composition analysis at a level unmatched by current compact and portable systems. I will present single-layer graphene multi-transistor chips, fabricated at the 200 mm wafer scale, that are heterogeneously integrated with a CMOS front-end designed in-house and fabricated in a commercial 180 nm CMOS technology [1] or controlled by a programmable logic device (FPGA) in an embedded system. The transistors can be interrogated in the DC and AC modes. In both cases, the sensor signal is a Dirac voltage shift upon biorecognition events, which in DC appears as a shift in the minimum of the transfer curve. Under AC sinusoidal stimulation with a DC offset to compensate for unintentional doping in graphene, distortion in the frequency-doubled output curve is the transduction signal. The powerful FPGA processing unit can implement a digital lock-in amplifier for each channel at a unique frequency, thereby reducing noise and interference. The graphene transistor channels are specifically designed and chemically functionalized for their intended applications. The performance of our technology will be demonstrated through two societally relevant applications. First, the attomolar detection of single-stranded DNA containing a mutation in liquid biopsies of brain tumor cells. Second, we detect neurotransmitter concentrations in complex clinical samples from individuals with brain neuronal disorders directly within plasma and cerebrospinal fluid samples [2].

References

[1] R. Wrege *et al.*, 2025 IEEE Latin American Symposium on Circuits & Systems (LASCAS), Bento Gonçalves, Brazil (2025).
[2] M. Abrantes *et al.*, Journal of Nanobiotechnology, 20.1 (2022): 495.

Figures

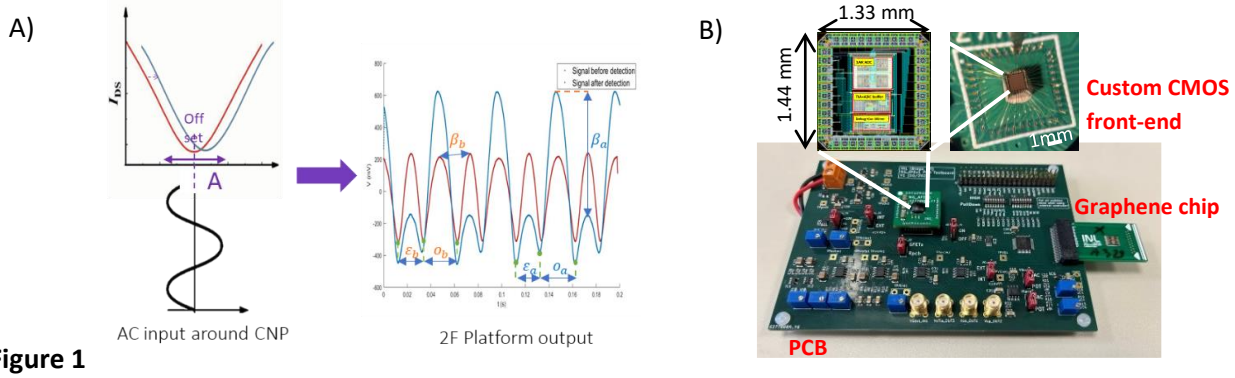

Figure 1
A) Dopamine detection in an opto-evoked animal model in AC f/2f mode. Small Greek letters refer to parameters used to measure distortion. B) Custom CMOS front-end for fast graphene multi-transistor arrays readout.