Graphene-based active neural sensors for brain monitoring and mapping

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A large effort is being dedicated to the integration of novel materials into neural interface devices capable of providing an efficient and consistent performance during their functional lifetime. Recording capabilities need to cover the wide temporal scales of brain activity; from very low frequencies (particularly relevant for diagnosing and studying certain brain pathologies and neural disorders) to fast spiking activity from individual and populations of neurons over large brain areas and with a relatively high spatial resolution. Additionally, these devices must be biocompatible and mechanically compliant with neural tissue. Graphene and graphene-based materials, because they are two-dimensional, exhibit a rather unique combination of physicochemical properties which make them an attractive and versatile platform for neural technologies [1].
This contribution will focus on the recording capabilities of active sensor technology based on single-layer graphene (SLG), highlighting its potential for contributing to the next-generation of high density neural prostheses and brain-computer interfaces [2]. Taking advantage of the semimetal properties of single-layer graphene, it is possible to develop sensors based on an active device configuration. In contrast to typical electrode materials (metals or conductive polymers) that exhibit a metallic nature, the conductivity of single layer graphene can be effectively modulated by an external electric potential. With this capability, we have recently pioneered the use of solution-gated field-effect transistors (SGFET) based on graphene as novel transducers for neural signals [3]. The electrochemical stability and high charge mobility of carriers in SLG as well as its facile integration with flexible substrates have triggered the interest in developing flexible neural probes for brain interfacing.
Further, this presentation will discuss how SGFET-type sensors allow the implementation of multiplexing strategies, time-domain and frequency-domain multiplexing, that reduce the footprint of connectivity, permitting an scaling up the number of recording sites [3]. We will also discuss how the transistor configuration of SGFETs has a distinctive capability to expand the temporal resolution of classical electrocorticography technologies, allowing the recording of the relatively unexplored infra-slow brain activity and, thus, potentially enabling the study of novel biomarkers for monitoring neurological disorders [5,6].

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