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Electronic nanobiosensors based on two-dimensional materials[1]

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Atomically-thick two-dimensional (2D) nanomaterials have tremendous potential to be applied as transduction elements in biosensors and bioelectronics. We developed scalable methods for synthesis and large-area transfer of two-dimensional nanomaterials, particularly graphene and metal dichalcogenides (so called "MX_2" materials). We also developed versatile fabrication methods for large arrays of field-effect transistors (FETs) and micro-electrodes with these nanomaterials based on either conventional photolithography or innovative approaches that minimize contamination of the 2D layer. By functionalizing the FETs with a computationally redesigned water-soluble mu-opioid receptor, we created selective and sensitive biosensors suitable for detection of the drug target naltrexone and the neuropeptide enkephalin at pg/mL concentrations. We also constructed DNA-functionalized biosensors and nano-particle decorated biosensors by applying related bio-nano integration techniques. Our methodology paves the way for multiplexed nanosensor arrays with all-electronic readout suitable for inexpensive point-of-care diagnostics, drug-development and biomedical research. With graphene field-effect transistors, we investigated the graphene/solution interface and developed a quantitative model for the effect of ionic screening on the graphene carrier density based on theories of the electric double layer. Finally, we have developed a technique for measuring low-level Faradaic charge-transfer current (fA) across the graphene/solution interface via real-time charge monitoring of graphene microelectrodes in ionic solution. This technique enables the development of flexible and transparent pH sensors that are promising for *in vivo* applications.

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