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TWO-DIMENSIONAL NANOMATERIALS FOR BIOSENSORS

This special issue of the Journal of Materials Research contains articles that were accepted in response to an invitation for manuscripts.

Introduction

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Biomolecules functionalized on the surface of atomic thickness single layer 2D materials combine the exceptional electronic properties and the stereospecificity of host and guest molecular entities. However, it is a challenge to functionalize biomolecules retaining their 3D structural integrity after deposition or conjugation to the surface of a 2D nanomaterial. Engineering the interface between electronic materials and biomolecules is critical in integrating functional bio-inspired devices and realizing new technologies like in vitro Point-of-Care (POC) sensors for disease detection and monitoring. Much more challenging are sensors for implantation into living systems.

The electronic characteristics of graphene are highly sensitive to adsorbed or covalently linked molecules via chemical doping. Inspired by biology, DNA, RNA, and proteins have been designed that spontaneously form exquisite molecular architectures on solid surfaces by self-assembly dictated by intermolecular forces. There are several facets of the integration of graphene and biomolecules like DNA that require much more understanding. Deeper understanding of these interfaces will enable engineers to bridge medical science and materials science in a meaningful way. Specific applications involve designing smart -POC devices for personalized precision medicine.

Biosensors and POC devices for monitoring of multiple biomarkers, implantable devices, and non-invasive monitoring systems have significantly improved in accuracy over the last twenty years. A good example is glucose sensors, which have been developed and refined significantly for over five decades. However, even with substantial effort, there continue to be several challenges related to accuracy and reliability. In accordance with international standards, glucometers are required to produce results within a twenty percent margin of error, and the U.S. Food and Drug Administration (FDA) is contemplating even more stringent standards. For this reason, coupled with knowledge gained from the previous research on glucose measurement, the ability to combine the exceptional electrical properties of emerging nanomaterials, both carbon and non-carbon-based, with the stereospecific functionality of biological macromolecules offers promising new avenues in diagnosis and treatment.

Multiplexed lab-on-a-chip microfluidic devices designed by integrating graphene and other emerging nanomaterials that can sense and detect target biomarkers can exploit the full potential of proteins acting as nanosensors and nanofilters. The excellent electrical properties of graphene augur well for the next generation of handheld, ultra-portable devices for personal health-care monitoring by the patient. One could envision that with the revolution in wireless-based mobile multimedia, these handheld devices might be able to transmit the information to a physician or hospital for timely intervention. For instance, early detection of infections in patients via home monitoring could allow early medical response rather than later when they are at an acute phase. This type of monitoring would minimize costs and hospitalizations, resulting in overall savings for the economy. Another potential application is screening tests for early detection of cancer biomarkers, and early diagnosis could enable treatment prior to metastasis, increasing the odds of survival.

Emerging cell—based biosensors that incorporate living materials like a pancreas-on-a chip are naturally endowed with ultra-sensitive detection of a host of biomarkers and are capable of maintaining an equilibrium in situ. Much future research will be targeted towards

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technologies to enable these and the next generation of point of care devices.

The papers included in this JMR Focus Issue present both reviews and original research papers on these topics from leading research groups around the world.

This collection of papers is dedicated to Suraj Renugopalakrishnan.

ON THE COVER:

Electrostatic potential plots for graphene-ammonia, graphene ammonium, and FG-ammonium. Ammonia/ammonium (ionic form) is identified as an important analyte to be detected in ultra-small amount and recently graphene/fluorographene has been identified as an ultra-high sensitive ammonia/ammonium ion sensing platform.

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