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# PREFACE

Symposium I focused on the translational applications of 1D and 2D nanomaterials in health care and disease management. Nanomaterials have been proposed as key components in biosensing, imaging, and drug delivery schemes since they confer distinctive advantages over conventional approaches. In particular, the characteristic electronic and optical properties of nano carbon materials are potentially significant in diagnostic sensing and imaging *in vitro* and *in vivo*. The unique chemical and physical properties of graphene and carbon nanotubes offer opportunities to functionalize and modify developing protein transducers, therapeutic drug delivery vehicles, gene delivery systems, and microbial diagnostics (bacteria and viruses) for use in both *in vitro* and *in vivo* modes. Carbon- and non-carbon-based nanomaterials have unique properties, including the potential for transduction mechanisms that make them extremely interesting for *in vitro* and *in vivo* sensor developments in health care. Translational clinical applications include continuous monitoring of biomarkers from body fluids, which are signatures of diseases, in static and dynamic modes for home, physician's office, and hospital use which are wirelessly transmittable by wearable devices, for example, the smart watch. The same principles can be extended to genome sequencing with major adaptation.

The complexities of managing patients with chronic diseases increasingly require a balance between care in the home and care in a clinical setting. Diabetes is just one example in which self-monitoring has been shown to be practically achievable by patients in a home setting. Glucometers are point-of-care (POC) devices that have become standard equipment at home and in clinical settings. Similarly, many other POC biosensors have also been developed [1-5]. Target enzymes, as disease-specific biomarkers, are often used as diagnostic indicators in such sensors because of their specificity, signal amplification, and the resulting reaction which can be electrochemically transduced or charge transfer detected by field-effect transistor (FET) for the measurement of the specific target biomarker. When these target enzymes (proteins) are immobilized on an electronically active substrate, the enzymatic reactions can be transduced by direct electron transport. This includes modifying enzymes for improved performance, developing methods to conjugate them to the nanomaterial surface, incorporating the functionalized graphene on a field-effect transistor, and integrating the process into a microfluidic device suitable for home, physician's office, and hospital use.

Point-of-care (POC) devices [6-11], continuous biomedical monitoring systems, implantable devices, and non-invasive monitoring systems have significantly improved over the last twenty years. A good example is glucose sensors, which have been developed and refined significantly. However, even with substantial effort, there continue to be several challenges related to accuracy and reliability[12, 13]. Under an

international standard, glucometers are required to produce results within a 20 percent margin of error, and the U.S. Food and Drug Administration (FDA) is contemplating more stringent standards [14]. 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.

Graphene protein sensors combine the remarkable electrical properties of graphene and the selectivity of proteins with the processing power of nano-electronics and fabrication to offer new, powerful diagnostic tools with much greater precision in medical science. Protein- carbon nanotube (CNT) sensors are on average several orders of magnitude greater in their sensitivity. Integrated, highly efficient, lab-on-a-chip devices based on graphene protein FET sensors that will measure clinically relevant analytes from a few µl of blood would have broad applications in bedside monitoring of patients. The nano-dimensions of graphene and its electronic properties make it an ideal candidate for anchoring the protein substrates for biochemical sensing.

Research and development for clinical diagnostic systems based on lab-on-a-chip technologies have proliferated significantly. Miniaturization can save reagents, enable rapid and inexpensive assays, and reduce the need for skilled personnel. These characteristics are important for monitoring patients at home. Home-based diagnostics and therapy monitoring simply cannot require large samples of blood plasma.

Lab-on-a-chip microfluidic devices [6-9, 15] designed by integrating graphene and other emerging nanomaterials with improved target proteins can exploit the full potential of proteins in acting as nanosensors and nanofilters. The excellent electrical properties of graphene auger 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 multi-media, these hand held devices might be able to transmit the information to the physician or hospital for timely intervention. For instance, early detection of infections in patients via home monitoring could minimize chronic cases and allow those infections to be addressed early 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 [16]; such detection could enable treatment prior to metastasis, increasing the odds of survival.

In general, proteins and biological macromolecules offer extreme stereo-specificity and sensitivity, and can be incorporated into cutting-edge, protein-based microfluidic devices [17, 18], allowing the possibility of using them for any pathological/metabolic disorder that has enzyme detection or assay titration as the basis for diagnosing, monitoring and treating diseases. This could include comprehensive metabolic panels such as liver enzymes [19], microRNA [20], aspartate aminotransferase [21], alanine aminotransferase [22] (AST/ALT), blood urea nitrogen/creatinine [23], blood ketone testing [24], cardiac biomarkers [25], prostate cancer specific biomarker PSA [26], thyroid function tests [27]

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and urinary biomarkers [28] – the prospects are endless. Saliva [29], as well as other intra and intercellular bodily fluids, could be explored for health and disease surveillance; modifying approaches described here for salivary diagnostics, which would be especially useful in pediatrics.

The dawn of personalized medicine will herald a paradigm shift in our lives [30], just as the Internet and personal computers transformed information collection and as a result, many aspects of our professional and personal lives have been changed forever. We are moving from the inefficient medicine of today towards the data-driven medicine of tomorrow. Soon, diagnosis, prognosis, treatment, and most importantly, prevention will be tailored to individuals' genetic and phenotypic information.

During the second decade of the 21st century, investments in molecular biology, bioinformatics, structural biology of biological macromolecules, disease management and the unraveling of the human genome [31] will converge and finally bear fruit. Personalized medicine promises to revolutionize the practice of medicine, transform the global healthcare industry, and ultimately lead to longer and affordable healthier lives. Miniaturization of genome sequencing by emerging technologies such as nanopore sequencing [32] are contributing towards rapid genome sequencing, which will accelerate the development of personalized medicine.

Recent years have witnessed the advancement of nanotechnology within healthcare, and it pervades many aspects of a new era aptly labeled 'nanomedicine.' Equally, it has generated safety concerns among the scientific community. Novel properties that differentiate nanomaterials from bulk materials generally develop at a length scale of ~100 nm. However, the size at which materials display different properties to the bulk material is material dependent. From the biological point of view, nanomaterials match the typical size of naturally occurring functional units or components of living organisms, and for this reason, enable more effective interaction with biological systems. The application of nanomaterials in medicine which may enhance quality of life can be understood from state-of-the-art knowledge on nanoscale features of biological systems in order to learn how to design nanodevices for biomedical uses. Nanomaterials have a large surface area and therefore are more chemically reactive. In addition, the nano-scale has a marked effect on the strength and electrical properties as the quantum effects dominate the behavior of materials with respect to their optical, electrical, and magnetic properties. Basically, nanomaterials fall into three categories: one-, two-, and three-dimensional. Three-dimensional nanomaterials like carbon nanotubes (CNTs) have generated considerable interest, and a significant amount of research has been done during the past decade on their potential biomedical applications. Boron nitride nanotubes (BNNT) have generated immense curiosity in view of their piezo-electric properties through which they are able to acquire an electric charge on exposure to ultrasound and polarized light.

Clinical translational research includes two areas of translation. One is the process of applying discoveries made in the laboratory (e.g., in test tubes or in animals) to the development of clinical studies using human subjects. The second area of translation refers to research intended to discover how best to apply the clinical findings to the community.

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This symposium has brought together frontline researchers in a single forum.

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