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Editorial

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Wearable Bioelectronics: Opportunities for Chemistry

Guest Editorial for the Accounts of Chemical Research special issue on "Wearable Bioelectronics: Chemistry, Materials, Devices, and Systems".

The practice of human health care may be on the cusp of a revolution, driven by an unprecedented level of personalization enabled by advances in technology, specifically, the transformation of wearable devices from curiosities that provide qualitative information for fitness enthusiasts to sophisticated systems that produce clinical-grade data for physicians. A recent and highly visible example is the Apple Watch Series 4, a platform released in September 2018 that features electrocardiogram measurement capabilities cleared by the US Food and Drug Administration (FDA). Companies such as MC10, iRhythm, Vital Connect, GE Healthcare, and Philips offer next-generation devices characterized by intimate skin interfaces and FDA-approved multimodal functionalities, with the potential to allow for medical care that is highly customized to the individual. The designs range from rigid modules mounted to the body with straps and tapes, to thin, stretchable systems that adhere directly onto the skin, much like adhesive bandages or temporary tattoos. New government initiatives in the US, such as those associated with the NextFlex Alliance, the BRAIN initiative, the SPARC program at the NIH, and the Biotechnology Office at DARPA, support research programs in relevant areas via robust levels of funding, although now likely surpassed by combined investments from foundations, venture capital firms, and large corporations. The resulting accelerated rates of technology development and deployment serve as nucleation points for large, growing programs in adjacent areas, most prominently in medical data analytics at Verily, Apple, Philips, Facebook, Intel, Samsung, and others. The outcomes of these collective activities have the potential to lead to unprecedented basic insights into human physiology, with wide-ranging, positive consequences for the cost, efficacy, speed, and global availability of personalized medical care. Successful efforts will directly address an overarching grand challenge for the 21st century, defined by the US National Academy of Engineering as the need for advances in "...the acquisition, management, and use of information in health...".

This special issue highlights the central role of chemical research in establishing the foundations for wearable bioelectronics with advanced capabilities in measurements of physiological state, performed continuously, outside of hospital and laboratory settings but with quantitative correspondence to clinical gold standards. The Accounts that appear in this issue summarize recent research on key aspects, ranging from constituent materials to novel sensors, advanced power supply systems, and skin-compatible integrated platforms. The first area represents a primary focus for the materials chemistry community, where a collection of papers covers, for example, progress in stretchable block copolymers and conjugated organics for structural materials and active layers, respectively, and associated techniques in processing such as spin-casting, printing, and vapor phase deposition onto both planar and textile substrates. Other papers focus on micro- and nanoscale inorganic materials as ribbons, wires, sheets or fibers in random or organized networks, configured as planar thin films or as buckled, wrinkled, woven, or segmented structures supported by or embedded in elastomeric supports. Liquid metals and two-dimensional materials represent interesting alternatives for stretchable interconnects and active layers, respectively, as described in additional articles.

With the availability of new materials, functional subsystems such as sensors and components for power supply are possible. Some Accounts highlight examples of strain, pressure, and temperature gauges based on resistive and capacitive effects, optimized for capturing information on movements, pulsatile blood flow, and thermoregulatory processes, as physical parameters relevant to health status. Additional Accounts highlight the use of organic semiconductors as infrared photodetectors and as transduction elements in transistor-based or enzymatic sensors for measuring biomarkers in interstitial fluid, sweat, tears, and other biofluids, as well as targeted species in the surrounding environment. Power for these devices can be harvested using piezoelectric, thermoelectric, triboelectric, and photoelectric effects in textile or stretchable formats and stored in skin-compatible supercapacitors or batteries, as featured in other Accounts. Further Accounts highlight the ability to build integrated, functional wireless systems, with some emphasis on emerging skin-interfaced platforms designed for the analysis of biomarkers in sweat. Another pair of Accounts describes how extensions of some of these same ideas in materials chemistry enable flexible and stretchable devices with neuromorphic operation to mimic biological nerves and artificial muscles for soft mechanical actuation.

These Accounts capture some, but not all, of the many exciting developments in this rapidly evolving area of wearable bioelectronic systems. The centrality of novel materials, the rich range of combined topics in fundamental and applied research, and the potential to contribute to global grand challenges in health care form the basis of a dynamic, interdisciplinary space for productive research for chemists over the coming years. The future will involve not only a linear extrapolation of the sorts of capabilities in clinical-grade skin-interfaced monitoring devices that are just now beginning to emerge from laboratories around the world but also a transformation that will eventually lead to biointegrated systems with increasing levels of diversity, from systems that not only sense but also actuate, respond, and dynamically deliver therapy in synchrony with natural body processes for improved health and wellness. The role of chemistry is essential to the development of these broadly defined biotic/abiotic systems.

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