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Abstract

Stimuli-Responsive Materials and Biomimetic Fluidics: Fundamental Building Blocks of Chemical Sensing Platforms with Futuristic Capabilities †

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Since the initial breakthroughs in the 1960s and 1970s that led to the development of the glucose biosensor, the oxygen electrode, ion-selective electrodes, and electrochemical/optochemical diagnostic devices, the vision of very reliable, affordable chemical sensors and bio-sensors capable of functioning autonomously for long periods of time (years) remains unrealized. This is despite massive investment in research and the publication of many thousands of papers in the literature. It is over 40 years since the first papers proposing the concept of the artificial pancreas, by combining glucose monitoring with an insulin pump [1]. Yet even now, there is no chemical sensor/biosensor that can function reliably inside the body for more than a few days, and such is the gap in what can be delivered (days), and what is required (years) for implantable devices, it is not surprising that in health diagnostics, the overwhelmingly dominant paradigm for reliable measurements is still single-use disposable sensors. Realising disruptive improvements in chem/bio-sensing platforms capable of long-term independent operation requires a step back and rethinking of strategies, and considering solutions suggested by nature and materials science, rather than incremental improvements in existing approaches [2]. Through developments in 3D fabrication technologies in recent years, we can now build and characterize much more sophisticated 3D platforms than was previously possible. We can create regions of differing polarity and hydrophobicity, mix passive and binding behaviours, and regions of differing flexibility/rigidity, hardness/softness. In addition, we can integrate materials that can switch between these characteristics, enabling the creation of biomimetic microfluidic building blocks that exhibit switchable characteristics such as programmed microvehicle movement (chemotaxis), switchable binding and release, switchable soft polymer actuation (e.g., valving), and detection. These building blocks can be, in turn, integrated into microfluidic systems with hitherto unsurpassed functionalities that can contribute to bridging the gap between what is required for many applications, and what we can currently deliver [3]. The emerging transition from existing engineering-inspired 2D to bioinspired 3D fluidic concepts represents a major turning point in the evolution of microfluidics. Implementation of these disruptive concepts may open the way to realise biochemical sensing systems with performance characteristics far beyond those of current devices. A key development will be the integration of biomimetic functions such as self-diagnosis of condition and self-repair capabilities to extend their useful lifetime [4].

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