Microfluidics Beyond Basic Biology – From Fertility Monitoring to Artificial Respiration*

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Over the past two decades, microfluidics has greatly expanded from a technology to miniaturize capillary electrophoresis for chemical and biological sample detection to a set of tools applied to nano- and microscale processes in diverse fields ranging from theoretical physics to protein engineering. Rapid prototyping has accelerated the evolution of microfluidic devices with increasingly sophisticated functions, including gene assembly, photonic crystal synthesis, and optofluidic switching. Emphasizing the trend towards diverse technology integration in microfluidics, this presentation will highlight recent laboratory work in the areas of microfluidic device design and automation.

As examples of advanced microfluidic design concepts, microfluidic oxygenator devices for challenging *in vitro* and *in vivo* applications will be discussed. As an *in vitro* example, work in the development of artificial "teeth" to study complex biofilm growth that leads to tooth decay and bacteremia will be highlighted. Our microfluidic "artificial teeth" platform has been developed for the culture of dental bacterial isolates to study *in vitro* biofilm formation on saliva-coated substrates contained within microchambers. The elastomeric microfluidic devices with the valving mechanism supports the spatiotemporal control over multiple parameters, such as nutrients concentration, oxygen level and microorganism composition. As an *in vivo* microfluidic oxygenator platform, we have been developing a microfluidic artificial lung capable of generating oxygen from water present in blood plasma. The core technology couples an optoelectronic metal oxide film with a microfluidic capillary network to facilitate oxygen exchange with flowing blood and replicate pulmonary capillary respiration. This technology is intended to provide a self-contained, mobile oxygen supply suitable for implantation or extracorporeal oxygenation in support of an acute or chronically disabled lung.

The talk will conclude with a discussion of microfluidic device automation tools under development in the laboratory. Both software and hardware-based tools will be discussed, highlighting the use of software to automate complex laboratory protocols as well as next-generation solid-state electrowetting-based pumps for programmable fluid manipulation on a chip.

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As applied examples, our work on the development of devices for monitoring the health and suitability of embryos for *in vitro* fertilization and for the profiling of cancer cells for drug inhibition studies will be presented.

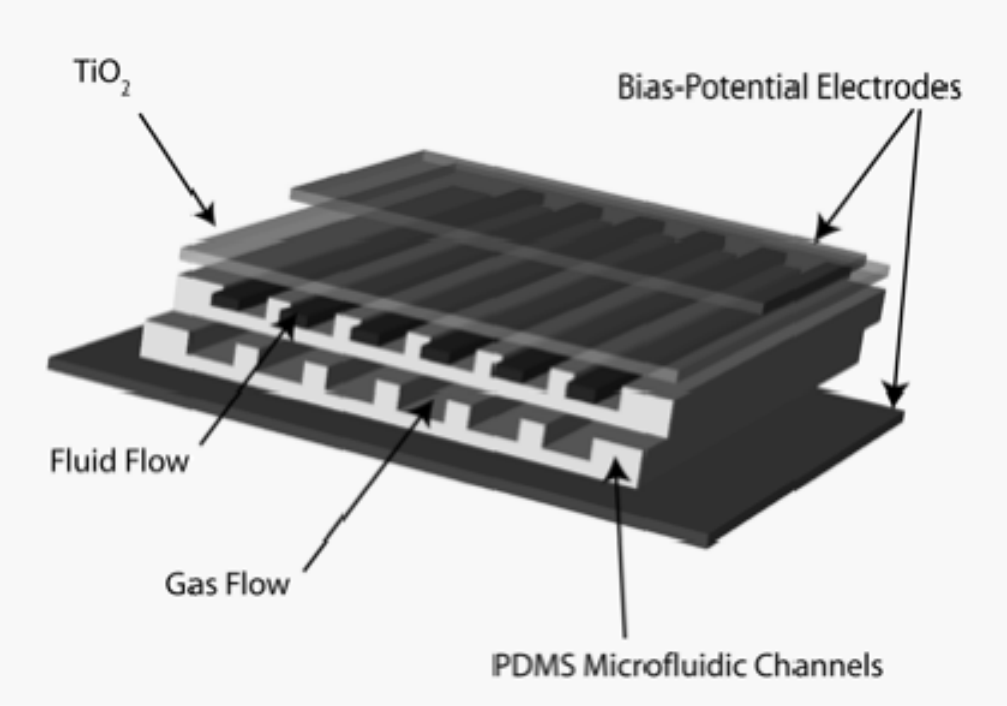

Figure 1. Concept model for integrated microfluidic photolytic oxygenation module. Multi-layer PDMS microfluidic channels are sandwiched between photolytic elements. The total thickness of the structure is on the order of several millimeters, meaning that multiple elements could be stacked back to back, achieving extremely high channel densities.

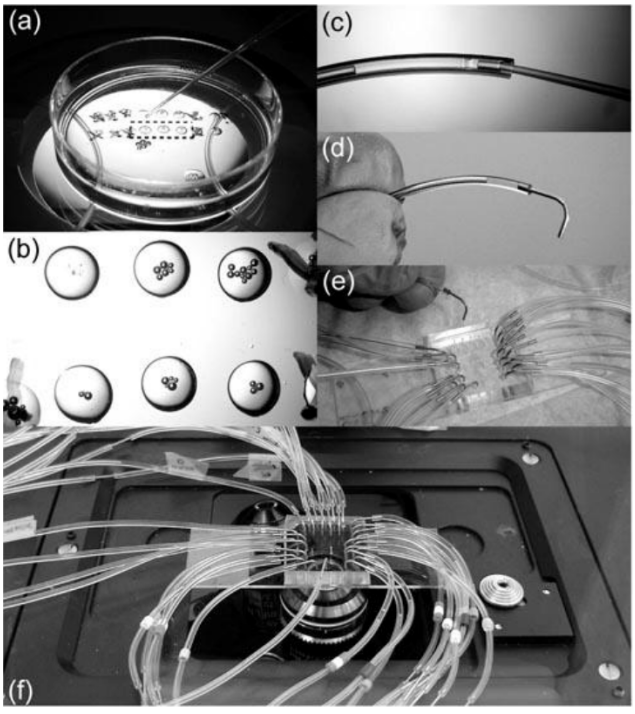

Figure 2. Sample loading sequence for metabolite analysis for on-chip fertility monitoring. (a,b) Pre-collected murine embryo media samples are stored in a Petri dish under oil to prevent evaporation. (c,d) A gel loading tip transfers media samples (1-5 µl) to Tygon tubing. (e) Tygon tubing containing samples and reagents interfaced with chip. (f) Fully assembled chip on microscope for automated assay run.