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Title: Microscale platform technologies for biomimetics and biomedical engineering

Abstract:

Bioengineering is an emerging field of study which bridges life science and engineering. At its early stage, it has been commonly known as biomedical engineering focusing mostly on the biomedical aspects with the engineering playing only assistive roles.
Pharmaceutical researches, such as cell mechanics, vascular biology, and neuro-engineering, have been performed as its sub-categories.
Later, with increased emphasis on the engineering aspect, a new phase of bioengineering has begun. Biomimetics, the effort to mimic nature and utilize biological inspirations, is a new branch.

The advances in microfabrication techniques during the last few decades have further promoted bioengineering. Micro/electromechanical systems (MEMS) technologies to obtain microscale total assay systems
(µTAS) have led to microfluidics studies that are directly related to biomedical studies. Soft lithography and polymer MEMS have assisted the development of biomimetics.

Still, there are a lot more to be developed. Especially, miniaturization, cost reduction, and ease of fabrication in polymer MEMS technologies are necessary to empower both biomedical and biomimetic aspects. However, the broad and inclusive nature of bioengineering makes it difficult to choose a particular subject to focus on. As an alternative, we extracted a few key categories which will contribute to bioengineering synergistically: microfluidics, bio-inspired structures, polymer MEMS, and their sensor applications.
In accordance, in this work, I will present four platform technologies which explore aforementioned primary features.

First, the optofluidic waveguiding was studied to enhance sensing capability in biomedical studies. Utilization of optical components in sensing scheme has been attracting interests for its electromagnetic interference (EMI)-free nature. However, one of the biggest difficulties in optofluidic sensing is that the liquid core generally exhibits refractive index lower than the solid claddings, making total internal reflection impossible. A design which adopts anti-resonance reflection optical waveguiding (ARROW) scheme was designed and analyzed with 2D numerical simulations.

Secondly, polymer MEMS technology was investigated to make bio-inspired optical waveguiding structures. There have been growing demands for polymer microwires due to their actuator and sensor potentials. By utilizing

poly(dimethylsiloxane) and sacrificial water-soluble wax in combination, we could generate two dimensional arrays of microscale polymer waveguides that are strongly attached to the super/substrate. Mechanical and optical characterizations were performed to show its potentials.

Thirdly, a gas flow sensor was developed based on the previously developed polymer microwire. Due to its flexibility, the microwire can be elongated up to a few times of its original length, with its tension and resistance to the outside mass flow increased. By investigating their relationship, we have shown the potential of the microwire to be used as a tunable optical gas flow sensor.

Finally, we developed a new and easy method to mimic biological blood vessels with microfluidic channels, complete with circular cross-sections and 3D topologies. We have found the biomaterial which makes the fabrication simple, safe, cost-effective, and environment-friendly. As an example, we produced complex 3D assemblies of channels with their diameters ranging between 30 to 400 µm.

When integrated synergistically, these unit structures and functionalities, mainly based on optical and/or polymer technologies, will greatly facilitate the realization of future bioengineering application systems.

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