The Chinese University of Hong Kong
Department of Biomedical Engineering

Graduate Seminar – PhD Oral Defence

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Date : 28 June, 2021 (Monday)
Time : 2:00 pm
Zoom Link : https://cuhk.zoom.us/j/99322069234?pwd=SW1DUmQ5dXNybUhWNDc5UlhBQ1JxQT09
Meeting ID : 993 2206 9234
Password : 664420

Title: Novel Strategies for Sample Manipulation and Biodetection in Centrifugal and Optical Microfluidic Systems

Recent decades have witnessed the rapid development of Lab-on-a-chip (LOC) devices as powerful tools for biomedical applications due to their advantages of low reagent consumption, short reaction time and excellent portability. Supported by microfluidic techniques which manipulate liquids at micro- or even nanoliter scale, LOC devices aim to build a sample-to-answer diagnostic system. To realize such a system, two critical functional aspects, namely reliability of fluidic sample manipulation and limit of detection, are constantly being reviewed and pushed for better performance. For most applications, sample manipulation involves sample loading and preparation, mixing, sorting and transportation within a microfluidic chip. However, the integration of multiple fluidic handling steps into a microfluidic chip has posed considerable challenges because of the limited capacity of chips. On the other hand, sample detection requires the highest possible sensitivity and immunity to external disturbances in order to ensure the possibility of detecting targets in the lowest possible concentration levels. To address these two challenging aspects of microfluidics, we summarized our exploration of novel strategies for sample manipulation and bio-detection in both centrifugal and optical microfluidic systems in this thesis.

Firstly, we proposed and investigated several new approaches for sample manipulation based on centrifugal force and optical force. In a lab-on-a-disc (LOAD) platform actuated by centrifugal force, we developed a microfluidic pressure regulator scheme for periodic generation and ratio-adjustable fusion of microdroplets. The manipulation process was highly controllable through adjusting the rotational frequency. Further, we designed a novel structure containing a magnet array to realize bidirectional droplet transportation, which can overcome the limitation of centrifugal force caused by its natural radially outward direction. Based on these manipulation techniques, we successfully demonstrated several application scenarios including cell transfection and chemical synthesis. Beyond the use of centrifugal force, we also exploited the near-field optical force of waveguides for sample manipulation. Specifically, we designed and simulated a series of functional units including storing, sorting and mixing of nanoparticles based on the optical trapping force of a tunable micro-ring resonator.

Secondly, we developed a novel sample detection system based on the surface plasmon resonance (SPR) technique. By engineering an atomically thin phase change material to induce a giant lateral position shift, a significantly enhanced sensitivity was achieved. The proposed plasmonic sensor was demonstrated to be capable of sensing extremely small refractive index changes and thus enabling the detection of cancer markers with low molecular weight at femtomolar level. Such a label-free, real-time, ultra-sensitive biosensor has great potential in monitoring chemical and biological reactions in microfluidic devices.

In summary, this work has demonstrated the performance merits of several novel manipulation strategies for complex sample handling and sensing techniques for highly sensitive biodetection in microfluidic devices. Further development of the reported designs into practical devices should lead to fully integrated microfluidic systems capable of completing sample-to-answer bioassays with short sample turnaround time, which is of great significance to biomedical analysis as well as point-of-care diagnostics.

***** ALL ARE WELCOME *****

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