Microfluidic Devices in Biomedical Research – The Present and Future

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Abstract
Microfluidics, a technology aiming to manipulate fluid streams in a submillimeter scale, has sparked as an alternative tool in biomedical research for a decade. The present and future roles of them in this research field are discussed.

Introduction
Microfluidics is a network of small channels of 10 to 100 µm dealing with fluids on the nanoliter or picoliter scale. It has a size comparable to an animal and plant cell, making it a possibly new tool for biomedical research. Basically, the flow inside the microchannel is dominant by viscous forces. For instance, fluids flowing alongside each other in a microchannel will not mix well (except by diffusion); therefore, a variety of techniques are required in microfluidic platforms to enhance mixing and actuate fluid flows.

Conceptually, the idea of microfluidics is that fluids could be precisely manipulated using a micro-scale device consisting of several tiny components such as micro-pump, micro-valve, micro-mixer, micro-separator and micro-electrodes. These devices, commonly referred to as miniaturized total analysis systems (µTASs) or lab-on-a-chip (LOC) technologies, could be applied to biology research to reduce the sample volume as well as reagents; to enhance the detection ability of screening applications; and to precisely manipulate cells to a certain location where a micro-scale sensing unit is located. In addition, the most important advantage probably is an ability to investigate of the complexity of cell-to-cell or cell-to-surface interactions in the presence of toxins, pharmaceutical compounds and nano-materials, for which conventional tools could not offer effectively.

Although the microfluidics has developed progressively in the last decade, the utilization is mostly limited in an engineering field. Only small group of them has spread to biomedical research as there were roughly ten times more microfluidic publications in engineering journals compared to biology and medicine (or biomedical) journals.6 Regarding this issue, several scientists suggest that a “killer application” that propels microfluidics into the mainstream as yet to emerge.

Fabrication and materials
This micro-scale device has been built with technologies first developed by the semiconductor industry and later expanded by the micro-electromechanical systems (MEMs) field. To resolve some limitations of semiconductor materials, e.g. silicon and glass, in biology research, Whitesides and his research group employed poly(dimethylsiloxane) (PDMS) - an optically transparent, gas- and vapour-permeable elastomer - for the fabrication of complex microfluidic devices and later on helped “soft lithography” become the most widely adopted method for fabricating microfluidic devices since 1998.3 Despite of its popularity in research work, PDMS has several limitations such as un-crosslinked compounds could have harmful effects and the material has been shown to absorb small molecules or cells.7 The issues have little influence in the research work; however, they might cause trouble in a real implementation of the devices. Therefore, new material that is more appropriate and cheaper should be acquired for the future research work as well as commercialized products.

The present
In the early stage of the development, many research groups have tried to fully integrate many tiny components to enable a multitasking function on to a single microfluidic device, but that attempt was not really successful due to its difficulty and limitations of the system fabrication. Apparently, the device that is the most successful nowadays is designed to perform only one or two tasks.

In cell research, microfluidic devices in a variety of study such as cell sorting, cell monitoring or cell detection could be commonly found in the literature. A manipulation of blood-cell samples for biology research, e.g. Hematology, to diagnose disease probably is one of applications which a microfluidic device has compelling advantages over the conventional methods. Recently, few examples of applications that the community keeps an eye on are an isolation of circulating tumor cells from whole bloods5,6 and an ability to investigate a cell behavior in a single-cell level.7
**The future**

There are many possibilities to increase the adoption of microfluidic technologies in mainstream biomedical research in the future. One of them is an ability of integration of numerous tiny components on a single device and development of a friendly user-interface, which are mainly relied on an advancement of the fabrication technologies. In addition, low-cost device developed from a cheap material and ease of fabrication technique might help increasing the utilization as a low-cost diagnostic such as HIV, TB and malaria in countries with low-resource settings. Most importantly, it is all about finding the right or niche application that only microfluidic technology could be applied.

**Conclusions**

Microfluidic devices have been employed and became one of promising technologies for biomedical research for a decade. However, the real impact of microfluidics in this field is yet to come. There are several issues needed to be improved such as an ability to integrate numerous tiny components on a single device, low-cost and reliable platform as well as materials.

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