Advances in Microfluidic Automation and Manipulation

MOHAMMAD A. QASAIMEH

THE FIELD OF MICROFLUIDICS deals with the manipulation of liquids at the microscale, where fluid flow is laminar and thus predictable and easily controllable. Microfluidic devices are typically made of a system of microconducts designed based on application. However, the current state of the art of microfluidics is continuously evolving toward new technological advances that may exclude conventional microchannels, such as in the areas of digital microfluidics, microfluidic probes, and thread-based microfluidics. Another strong devotion is focused toward integrating microfluidics with other technologies such as electronics, photonics, and magnetics. The dedication of these technological advances and integrative efforts is geared toward accurate fluid manipulation, precision biological handling, and efficient process automation. This opens new horizons for innovation in numerous applications such as bioassays, cell sorting, tissue engineering, and biosensing as featured in the April 2020 issue of *IEEE Nanotechnology Magazine*.

In this special issue, the authors of three articles were invited to report on recent technological and integrative advances in microfluidic automation and manipulations. In the first article, Mohamed Abdelgawad discusses the field of digital microfluidics, where precise manipulation of liquid droplets on open channel-less surfaces is accomplished using electrical actuation. The technology simplifies liquid manipulation and allows for powerful automation of sample processing. Using the technology, droplets of chemicals or biological samples can be easily transported, split, and mixed in a high-throughput mode, allowing for integrative sample processing steps, including dispensing, purification, and extraction. Therefore, digital microfluidics opens the door toward miniaturizing bioassays while utilizing minute-size samples. In his comprehensive review, Abdelgawad overviews fundamental and technical aspects of the technology, including nanotechnology contributions such as the involvement of nanoparticles and nanotubes, and recent applications, including biochips for DNA sequencing and diagnostic tools for detecting viruses. The article concludes by discussing current challenges and limitations, the future outlook, and commercialization aspects of the technology.

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In the next article, Fadi Alnaimat, Sherif Karam, Betty Mathew, and Bobby Mathew confer the great potential of integrating magnetophoresis and microfluidics for the precision manipulation of biological samples, with minimal sample preparation steps and the promise of easy automation. *Magnetophoresis* refers to the motion of micro- and nanoparticles when exposed to a nonuniform magnetic field. The authors introduce fundamentals of magnetophoresis and discuss integration possibilities with microfluidics. The article provides an overview of automation using various possible sources of magnetic fields, the different microfabrication procedures involved in the integration, and the involvement of nanotechnology in terms of utilizing magnetic nanoparticles and antigen–antibody interactions. The authors highlight details of the powerful technology in bioparticle manipulation, separation, and concentration for different uses, including cell- and DNA-based diagnostic tools. The article concludes with discussions on the technology strengths and future potential.

In the final article, Sanjairaj Vijayavenkataraman, Anna Garcia-Sabaté, and Jeremy CM Teo elaborate on an emerging field where microfluidic extruders are developed for tissue engineering applications. The article discusses different approaches used in the general field of tissue engineering and focuses on the great potential of developing microfluidic-based chips for bioprinting 3D cell-laden fibers and matrices. The coaxial hydrodynamic focusing within microfluidic printheads allows for the controllable extrusion of multimaterial hydrogel fibers, encapsulating different cell types, for engineering specialized soft tissues in vitro. The authors conclude their focused showcased microfluidic extruders' technology by discussing its current challenges and possible future advances.

This issue reviews recent progresses and trending fields in microfluidic automation and manipulation and provides a review of the state of the art as well as a future outlook of the field. As several technical advances in microfluidic automation and manipulation continue to develop and evolve worldwide, we expect to see more integrative efforts in the near future that may utilize different nanotechnology advances. N

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