In Pursuit of The Holy Grail of Lab-on-a-Chip Technology – from Silicon and Glass Micromachining to 3D Printing

Dr Wojciech Piotr Bula, The University of Tokyo, JAPAN
Prof. Ryo Miyake, The University of Tokyo, JAPAN

Terry et al.'s publication [1] of 1979, featuring an integrated gas chromatograph, laid the foundations of microfluidics and lab-on-a-chip technology, and the subsequent advancement of micromachining techniques and Deep Reactive Ion Etching in particular have opened up new research opportunities. Silicon became the material of choice for more than two decades. Its unique properties allowed for fabrication of sub-micrometer features. The author has utilized silicon-glass micromachining to develop systems such as chromatography capillary columns, thermoconductivity gas detectors, and sample injector of integrated gas chromatograph. The ability to manipulate liquid at microscale was recognized as a powerful tool to perform chemical reactions under conditions that cannot be achieved at lab-scale. Multiline microreactors have been manufactured which have surfaces modified by immobilized enzymes or catalysts, and with integrated desorption/ionization on silicon functionality for mass spectrometry [2]. The dawn of nanofabrication techniques enabled the development of (i) a nano-machined artificial gland for the dissipation of sex pheromones originating from *Spodoptera littoralis* as a biomimetic infochemical communication system [3], and (ii) an evaporative sample concentrator featuring a perforated membrane of 180nm thickness for a water quality monitoring system [4]. Despite all the benefits of silicon micromachining, the proliferation of this technology has been limited by its high unit cost and fabrication labor requirements. While attempts have been made to replace silicon with polymers such as PDMS, cyclic olefin copolymer, and thermoplastics, many unsolved issues remained. The introduction of 3D-printing techniques gave momentum to the microfluidics field and shifted the design paradigm. A sample concentration system based on a 3D-printed microfluidic circuit board was created [5] in which some microfluidic components were manufactured by rapid prototyping. Secondly, the author will exhibit a fully 3D-printed water quality monitoring system [6] and will discuss the pros and cons of 3D-printing in relation to alternative rapid prototyping techniques.

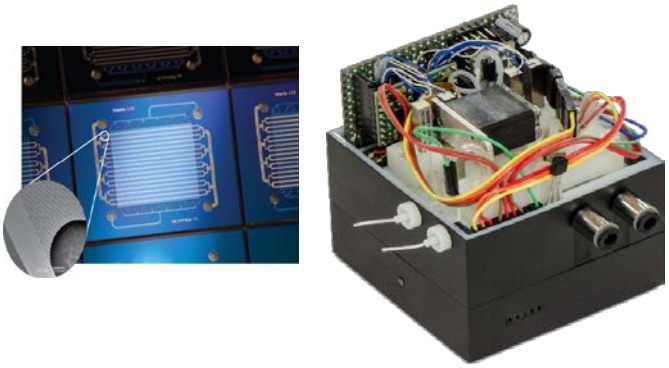


Figure 1: Photography of (left) a nanomachined silicon-glass artificial gland of a biomimetic infochemical communication system, (right) 3D printed water quality monitoring system.

1. Terry S.C., Jerman J.H., Angell J.B. (1979) A Gas Chromatographic Air Analyzer Fabricated on a Silicon Wafer, IEEE Trans.Electron Devices, ED-26, 12, 1880-1886.
2. Bula, W.P., Verdoold, V., Gardeniers, H.J.G.E. (2008) Microreactors with integrated porous silicon layer for reaction studies by matrix-free mass spectrometry, Proc. of IMRET 10th International Conference on Microreaction Technology, April 6-10, New Orleans, USA.
3. Dimov, N., Munoz, L., Bula, W.P., Carot-Sans, G., Guerrero, A., Gardeniers, J.G.E (2011) A Chemoemitter System Mimicking Chemical Communication in Insects, Procedia Computer Science, 7, pp. 142-143.
4. Bula, W.P., Aritome, K., Miyake, R. (2014) Sample processor based on 3D printed microfluidic circuit board, Proc. of the 6th Int. Symposium on Microchemistry and Microsystems (ISMM 2014), Jul 30 – Aug 1, Singapore, pp. 122-123
5. Bula, W.P., Aritome, K., Miyake, R. (2014) 3D printed microfluidic circuit board, Proc. of the 18th Int. Conf. on Miniaturized Systems for Chemistry and Life Sciences (microTAS 2014), San Antonio, USA, Oct 26-30, pp. 1524-1526
6. Bula, W. P., Aritome, K., Miyake, R. (2015) 3D printing chemical analysis system for enviromental monitoring, Proc. of the 19th Int. Conf. on Miniaturized Systems for Chemistry and Life Sciences (microTAS 2015), Gyeongju, Korea, Oct 25-29

Photograph



Dr. M.Sc.Eng. Wojciech Piotr Bula graduated in electrical engineering from Wroclaw University of Technology, Poland in 2003, and obtained his Ph.D. from University of Twente, The Netherlands in 2009. He has been involved in research of micro- and nanotechnology for the exploration of new lab-on-a-chip systems with a special focus on silicon-glass microreactor chips for liquid phase chemistry, artificial glands for infochemical system and environmental monitoring. His research activity and interests focus on the synergy of micro- and nanotechnology, biology, chemistry, computer science and rapid prototyping. From 2011 he works in Japan (Hiroshima University, The University of Tokyo) and advocates for using new rapid prototyping techniques to decrease development costs and to increase the proliferation of affordable microfluidic devices. He is a co-founder of Bisu, a non-medical diagnostics start-up focused on bringing microfluidic systems for mass market.

Email: wojciech@bisu.bio

Notes/Comments: