Analysis of the interaction of multi-phases flow of fluids through internal micro flow channels of a microfluidic chip using THz image sensing technology.

July 28, 2021

Feroz Ahmed Atsuya Mahana, Katsuya Taniizumi, Jin Wang Kenji Sakai Toshihiko Kiwa

Graduate School of Interdisciplinary Science and Engineering in Health Systems, Department of Medical Bioengineering, Okayama University 3-1-1, Tsushima-naka, Kita-ku, Okayama, 700-8530 Japan

---

Research Report

Transport phenomena on the micro scale level have drawn special attention to test biological and chemical samples for the early medical diagnosis and quality control in the microfluidic platform. Despite the laminar flow condition through the internal micro flow channels of a microfluidic chip, it is still necessary to visualize internal fluids' flow patterns by the experimental and nearly an identical simulation scale procedures. Moreover, the internal fluid flow parameters like diffusion coefficient, heat transfer, pressure drop, velocity etc. inside the micro flow channels are unpublished without performing the visualization of experimental and simulation works to reveal their individual flow patterns. Hence, it is required to design 3D structures of microfluidic chips, tested the flow of fluids within the said structures in a simulator to simulate the flow patterns of fluids within identical simulation scale. Consequently, the experimental visualization can be performed according to the simulation scale using laser scanning technology [1] to get an idea of flow patterns of fluids thoroughly. As a result, nature of fluids (e.g. samples of livable cell and abnormal cell) can be identified and distinguished whether they can show any abnormal behavior from the trace of flow patterns of them through the micro flow channels of microfluidic chips. Therefore, Terahertz (THz) image sensing technology [1] would be a breakthrough for the trace of internal nature of microfluidic parameters with high spatial resolution criteria to reveal the flow patterns for the sake of intensive fluid dynamics–based analysis of fluid samples through micro-devices that provide efficient output with the assurance of substantial health benefits for the next generation.

In this research work, capillary-design concept based a microfluidic chip (height of 4 mm) with two inlet wells and one outlet well was designed, drafted and printed to prepare the replica mold of a PDMS-made microfluidic chip. Then, using digital pressure machine, two acid and base dominant pH buffer fluids injected via syringes-connected tubes through the internal micro flow channels of the designed microfluidic chip to measure fluid flow parameters like pressure drops, velocity and estimate them statistically according to the laws of fluid dynamics. ANSYS Fluent software influenced by computational fluid dynamics (CFD) tool was used to visualize the interaction of two dimensional flow patterns of two pH fluids with the identical simulation scale. Then, simulation data obtained from ANSYS simulator were compared and validated with experimental measurement data [2]. In addition, THz laser directed image sensing technique with higher spatial resolution of 333 μm was applied to capture images of the interaction of flow patterns of two above mentioned pH buffer fluids inside the micro flow channels of the designed chip with respect to the peak amplitude of THz data [1].

At present, with channel height of 100 μm is designed, drafted and printed to prepare replica mold of a PDMS-made microfluidic chip for performing the experimental measurement which is in progress. At a time, three dimensional simulation is performing to realize the particles distribution of fluids inside the micro flow channels with the presentation of concentration profiles of individual regions of internal channels paths (e.g. outlet surrounded region, two fluids flow interactive common channel path etc.). Moreover, Terahertz imaging technique will be applied inside the new height based microfluidic channels to capture images of the interaction of different fluids like antigen, antibody, tissue samples etc. The objective of such investigation with new proposed height of the channel paths is to bring more close interaction of biological samples for the sake of more critical and intensive analysis of parameters of fluid dynamics.

This analysis can reveal the traces of interactions of flow of fluids, such as chemical solutions and abnormal biological cell division inside tissue and blood samples. As a result, the designed microfluidic chip can detect pH imbalances in the human body due to the malfunctioning of metabolism, respiration processes, and cancer cells, enabling early medical diagnosis. In addition, this analysis is expected to be effective for the pH control of foods in food industries, tablet coatings in pharmaceutical industries where pH control is highly important.

References

[1] Feroz Ahmed, Atsuya Mahana, Katsuya Taniizumi, Jin Wang, Kenji Sakai, and Toshihiko Kiwa. Terahertz imaging technique for monitoring the flow of buffer solutions at different ph values through a microfluidic chip. *Japanese Journal of Applied Physics*, 60(2):027003, 2021.

[2] Feroz Ahmed, Yuichi Yoshida, Jin Wang, Kenji Sakai, and Toshihiko Kiwa. Design and validation of microfluidic parameters of a microfluidic chip using fluid dynamics. *AIP Advances*, 11(7):075224, 2021.