DIGITAL MICROFLUIDIC BIOCHIPS: TOWARDS FUNCTIONAL DIVERSITY, MORE THAN MOORE, AND CYBERPHYSICAL INTEGRATION

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IEEE CAS DISTINGUISHED LECTURE

ESRC SEMINAR

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Abstract

Advances in droplet-based "digital" microfluidics have led to the emergence of biochip devices for automating laboratory procedures in biochemistry and molecular biology. These devices enable the precise control of nanoliter-volume droplets of biochemical samples and reagents. Therefore, integrated circuit (IC) technology can be used to transport and transport "chemical payload" in the form of micro/nanofluidic droplets. As a result, non-traditional biomedical applications and markets (e.g., high-throughout DNA sequencing, portable and point-of-care clinical diagnostics, protein crystallization for drug discovery), and fundamentally new uses are opening up for ICs and systems.

However, continued growth depends on advances in chip integration and design-automation tools. Design-automation tools are needed to ensure that biochips are as versatile as the macro-labs that they are intended to replace, and researchers can thereby envision an automated design flow for biochips, in the same way as design automation revolutionized IC design in the 80s and 90s. Biochip users (e.g., chemists, nurses, doctors and clinicians) and the biotech/pharmaceutical industry will adapt more easily to new technology if appropriate design tools and in-system automation methods are made available.

This lecture will first provide an overview of market drivers such as immunoassays, DNA sequencing, clinical chemistry, etc., and electrowetting-based digital microfludic biochips. The audience will next learn about design automation, design-for-testability, and reconfiguration aspects of digital microfluidic biochips. Synthesis tools will be described to map assay protocols from the lab bench to a droplet-based microfluidic platform and generate an optimized schedule of bioassay operations, the binding of assay operations to functional units, and the layout and droplet-flow paths for the biochip. The role of the digital microfluidic platform as a "programmable and reconfigurable processor" for biochemical applications will be highlighted. Finally, the speaker will describe dynamic adaptation of bioassays through cyberphysical system integration sensor-driven on-chip error recovery.

Bio

Krishnendu Chakrabarty received the B. Tech. degree from the Indian Institute of Technology, Kharagpur, in 1990, and the M.S.E. and Ph.D. degrees from the University of Michigan, Ann Arbor, in 1992 and 1995, respectively. He is now Professor of Electrical and Computer Engineering at Duke University. He is also a Chair Professor at Tsinghua University, Beijing, China, a Visiting Chair Professor at National Cheng Kung University in Taiwan, and a Guest Professor at University of Bremen in Germany. Prof. Chakrabarty is a recipient of the National Science Foundation Early Faculty (CAREER) award, the Office of Naval Research Young Investigator award, the Humboldt Research Fellowship from the Alexander von Humboldt Foundation, Germany, and several best papers awards at IEEE conferences.

Prof. Chakrabarty's current research projects include: testing and design-for-testability of integrated circuits; digital microfluidics, biochips, and cyberphysical systems; optimization of digital print and enterprise systems. He is a Fellow of IEEE, a Golden Core Member of the IEEE Computer Society, and a Distinguished Engineer of ACM. Prof. Chakrabarty was a 2009 Invitational Fellow of the Japan Society for the Promotion of Science (JSPS). He served as a Distinguished Visitor of the IEEE Computer Society during 2005-2007 and 2010-2012, and as a Distinguished Lecturer of the IEEE Circuits and Systems Society during 2006-2007. Currently he serves as an ACM Distinguished Speaker and a Distinguished Lecturer of the IEEE Circuits and Systems Society (2012-2013).

Prof. Chakrabarty served as the Editor-in-Chief of IEEE Design & Test of Computers during 2010-2012. Currently he serves as the Editor-in-Chief of ACM Journal on Emerging Technologies in Computing Systems. He is also an Associate Editor of IEEE Transactions on Computer-Aided Design of Integrated Circuits and Systems, IEEE Transactions on Computers, IEEE Transactions on Circuits and Systems II, and IEEE Transactions on Biomedical Circuits and Systems. He serves on the Steering Committee of IEEE Transactions on VLSI Systems.

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