Guest Editors' Introduction: Biochips and Integrated Biosensor Platforms

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BIOCHIPS AND INTEGRATED biosensor platforms are revolutionizing DNA analysis, clinical diagnostics, and biomolecule detection and manipulation. A biochip (or a lab on a chip) automates highly repetitive laboratory tasks by replacing cumbersome equipment with a miniaturized, integrated device that can handle small amounts (for example, nanoliters) of fluid. Thus, biochips can provide ultrasensitive detection at significantly lower cost per assay than traditional methods.

Miniaturized biochips have emerged in recent years because of the convergence of rapid advances in life sciences, sensors, microfluidics, microfabrication techniques, and IT. Collaborations between biochemists, chip designers, physicists, and system integrators are tearing down the historical boundaries that had separated these diverse fields. As a result, chip designers and test engineers have a unique opportunity to go beyond the traditional boundaries of semiconductors for computing and information processing. Smart biochips for the life sciences offer a new application area for chip designers and the electronic design automation community. They also represent a tremendous opportunity to directly benefit society in new ways and improve quality of life.

This special issue addresses design, integration, and test issues related to biochips. It covers technology issues (CMOS microarrays, dielectrophoresis, and electrowetting), chip-level integration, and exciting new applications such as live-cell manipulation, cell sorting, detection of DNA hybridization, clinical diagnostics, tissue engineering, airborne chemical detection, and DNA sequencing by synthesis. The issue also discusses emerging design automation and test techniques such as chip synthesis for droplet-based microfluidics, simulation of dielectrophoretic field flow, fault modeling, and test stimuli generation. This special issue features authors from academia, small companies with close university ties, and large companies. In keeping with the nature of the topic, the authors' areas of expertise are also wide ranging, encompassing solid-state devices, nano- and biotechnology, microfluidic simulation, chip design, electronic design automation, and test technology.

The first article in the special issue, "Chemical and Biological Applications of Digital-Microfluidic Devices," by Richard Fair et al., describes digital-microfluidic devices that use electrowetting to manipulate nanoliter liquid droplets. This article explains how digital-microfluidic technology can facilitate a wide range of chemical and biological applications, and examines open design issues for digital-microfluidic chips. The second article, "Lab on a Chip for Live-Cell Manipulation," by Gianni Medoro et al., describes dielectrophoresis for cell sorting and high-precision, live-cell manipulation. The article also discusses packaging techniques and pharmacological applications.

Next, in "Electronic Detection of DNA Hybridization: Toward CMOS Microarrays," Luca Benini, Carlotta Guiducci, and Christian Paulus describe the design of a prototype CMOS chip that integrates DNA sensor arrays with electronics for transduction, amplification, digital conversion, and signal readout. The authors expect these chips to pave the way for low-cost mass fabrication and inexpensive label-free sensor systems. In "Simulation-Based Analysis of Dielectrophoretic Field Flow Fractionation Devices," S. Krishnamoorthy, J.J. Feng, and Z.J. Chen describe modeling and simulation techniques for dielectrophoresis-based (DEP) field-flow fractionalization (FFF) devices. These devices are useful for cell sorting and

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manipulation. High-fidelity simulations of such devices can help determine optimal geometry and process parameters to enhance performance.

The final two articles describe design automation and test techniques for biochips. In their article, "Computer-Aided Design and Test for Digital Microfluidics," Fei Su and Jun Zeng highlight the reconfigurability offered by digital microfluidics and show how an automated, top-down design flow similar to what is used in microelectronics can be used for biochip design. They also describe techniques for computationally efficient simulation of droplet flow, chip synthesis, physical design, DFT, and dynamic reconfiguration. Then, in "Testing Microelectronic Biofluidic Systems," Hans Kerkhoff provides a survey of test techniques for various types of electronics-based microfluidic devices. This article describes fault modeling, test stimuli generation, test application, and optimization techniques for flowFETs and digital microfluidics.

WE HOPE THIS SPECIAL ISSUE will generate more interest in this emerging technology area and serve as a bridge between the chip design, test technology, sensors, microelectromechanical systems (MEMS), and biochemistry communities. We thank EIC Tim Cheng and the *D&T* editorial board for encouraging us to proceed with this special issue. We also thank all the authors for their submissions and prompt response to review comments. Finally, we thank the reviewers for their timely and detailed reviews. ■

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