

Preface

Flow-based microfluidic biochips constitute an emerging technology for the automation of biochemical procedures. Recent advances in fabrication techniques have enabled the development of these devices. Increasing integration levels provide biochips with tremendous potential; a large number of bioassays, i.e., protocols for biochemistry, can be processed independently, simultaneously, and automatically on a coin-sized microfluidic platform. However, the increase in integration level introduces new challenges in the design optimization and testing of these devices, which impede their further adoption and deployment.

This book is focused on enhancing the automated design and the use of flow-based microfluidic biochips and on developing a set of solutions to facilitate the full exploitation of design complexities that are possible with current fabrication techniques. Four key research challenges are addressed in the book; these include design automation, wash optimization, testing, and defect diagnosis.

Despite the increase in the number of on-chip valves, designers are still using full-custom methodologies involving many manual steps to implement these chips. Since these chips can easily have thousands of valves, a manual design procedure can be time-consuming and error-prone, and it can result in inefficient designs. This book presents the first problem formulation for automated control-layer design in flow-based microfluidic biochips and describes a systematic approach for solving this problem. Our goal is to find an efficient routing solution for control-layer design with a minimum number of control pins.

The problem of contamination removal in flow-based microfluidic biochips must also be addressed. Applications in biochemistry require high precision to avoid erroneous assay outcomes, and they are vulnerable to contamination between two fluidic flows with different biochemistries. This book proposes the first approach for automated wash optimization for contamination removal in flow-based microfluidic biochips. The proposed approach ensures effective cleaning and targets the generation of wash pathways to clean all contaminated microchannels with minimum execution time under physical constraints.

Another practical problem addressed in this book is the lack of test techniques for screening defective biochips before they are used for biochemical analysis. This

book presents an efficient approach for automated testing of flow-based microfluidic biochips. The test technique is based on a behavioral abstraction of physical defects in microchannels and valves. The flow paths and flow control in the microfluidic device are modeled as a logic circuit composed of Boolean gates, which allows test generation to be carried out using standard automatic test-pattern generation tools. Based on the analysis of untestable faults in the logic circuit model, we present a design-for-testability technique that can achieve 100% fault coverage.

Finally, this book presents a technique for the automated diagnosis of leakage and blockage defects. The proposed method targets the identification of defect types and their locations based on test outcomes. It reduces the number of possible defect sites significantly while identifying their exact locations.

In summary, this book provides a set of optimization and testing methods for flow-based microfluidic biochips. These methods are expected to not only shorten the product development cycle, but also accelerate the adoption and further development of this emerging technology by facilitating the full exploitation of design complexities that are possible with current fabrication techniques.

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Computer-Aided Design of Microfluidic Very Large Scale
Integration (mVLSI) Biochips

Design Automation, Testing, and Design-for-Testability

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2017, XIII, 142 p. 64 illus., 55 illus. in color., Hardcover

ISBN: 978-3-319-56254-4