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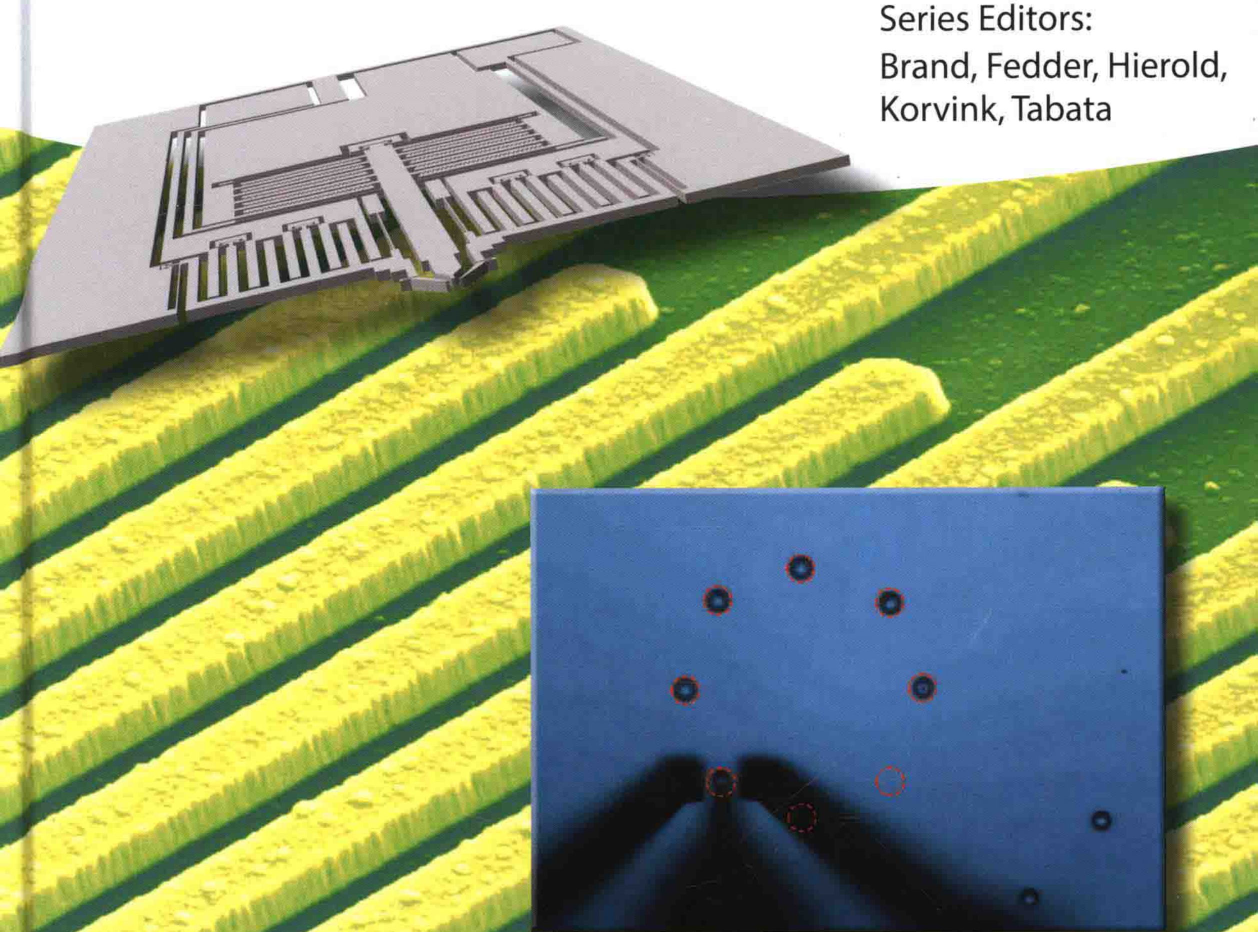

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Edited by Yu Sun and Xinyu Liu

Micro- and Nanomanipulation Tools

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Yu Sun is a Professor at the University of Toronto with cross appointments to Department of Mechanical and Industrial Engineering, Institute of Biomaterials and Biomedical Engineering, and Department of Electrical and Computer Engineering. He is the Canada Research Chair in Micro and Nanoengineering Systems. He was inducted Fellow of ASME, IEEE, and CAE for his work on micro–nano devices and robotic systems. His awards include the 2010 IEEE Robotics and Automation Society Early Career Award and an NSERC E.W.R. Steacie Memorial Fellowship in 2013.

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Series Editors Preface

Since the advent of nanotechnology in the 1980s and 1990s and the award-winning developments of instruments to explore the domain of atoms and molecules by scanning tunneling and atomic force microscopes, the manipulation of individual atoms and molecules by applying forces even at room temperature was on the agenda of scientists. Stimulated by these early experiments, researchers and engineers started to develop and commercialize instruments for surface characterization and pattern transfer with nanometer resolution, which are as easy to operate at environmental conditions as optical microscopes. These developments became possible by the unprecedented progress in microsystems technology, integrating new functional materials beyond silicon and offering a technology platform for new applications in other scientific disciplines, such as the life sciences and its biomedical applications. In addition to the application of mechanical forces on small scales, researchers learned to apply electric, magnetic, and electrodynamic forces up to the frequency of light to manipulate objects from micron scales down to nanometers.

We present the 13th volume of Advanced Micro & Nanosystems (AMN), entitled Micro and Nano Manipulation Tools.

Prof. Yu Sun, University of Toronto, and Prof. Xinyu Liu, McGill University, are both renowned experts in this domain. They were very successful in coordinating a number of leading researchers and authors to present a book on micro and nanomanipulation. This book will be of great benefit for not only scientists and graduate students, entering the field or looking for specific information, but also industry researchers, technology strategists, and deciders in companies, who want to get a quick, but comprehensive access to the exciting and emerging field of micro and nanomanipulation in instruments, new processes, and fabrication technology.

June 2015 *Zürich, Christofer Hierold*

Preface

The capability of manipulating micrometer and nanometer-sized objects, such as cells and nanomaterials, enables new discoveries in biology, medicine, and materials science as well as industrial applications. Emerging robotics and microdevice technologies are proven to be effective in achieving high accuracy, precision, and throughput in micro and nanomanipulation tasks.

This book introduces recently developed tools for micro and nanomanipulation and presents example applications such as biomolecule screening, clinical diagnostics, surgery, and semiconductor packaging. These tools manipulate micro and nano objects using a multitude of physical means, including mechanical field, magnetic field, thermal field, fluidic field, acoustic field, optical field, surface tension, dielectrophoresis, electrostatics, and piezoelectricity. Some of these tools perform manipulation directly on microdevices while others manipulate objects using off-chip approaches. Microdevices are often integrated into robotic systems to combine their unique on-chip and off-chip manipulation capacities to tackle challenging tasks that cannot be fulfilled using a single method.

The topics in this book fall into two themes: "On-Chip and Device-Based Micro and Nano Manipulation" and "Robotic Tools and Techniques for Micro and Nano Manipulation."

- Chapter 1 reviews microfluidic techniques for performing high-speed cell manipulation tasks such as separation, sorting, characterization, weighing, lysis, and stimulation.
- Chapter 2 summarizes optical-induced electrokinetic techniques for on-chip manipulation and assembly of micro/nano objects.
- Chapter 3 discusses the physical behavior of DNA molecules in nanoslit confinement and slitlike nanofluidic devices for DNA manipulation.
- Chapter 4 summarizes microfluidic approaches for the manipulation and assembly of one-dimensional nanomaterials with applications in device construction.
- Chapter 5 reviews microfluidic platforms utilizing optically induced dielectrophoresis for cell and molecule manipulation.
- Chapter 6 reviews the design, fabrication, characterization, and biomedical applications of magnetically driven microrobots operated inside microfluidic channels.

- Chapter 7 discusses MEMS-based nanotweezers for the manipulation and characterization of molecules and cells.
- Chapter 8 summarizes untethered surgical devices at small scales and the corresponding localization, actuation, powering, and control techniques.
- Chapter 9 describes a new single-chip scanning probe microscopy technique and its image performance.
- Chapter 10 provides an overview of untethered magnetically driven microrobotic devices for manipulating micro objects.
- Chapter 11 presents a robotic micro-compression system for measuring and mapping stiffness and topography of plant cell walls.
- Chapter 12 discusses a micromanipulation technique employing magnetotactic bacteria as microactuator swarms for the manipulation and transport of micro/nano objects.
- Chapter 13 reports the stiffness and kinematic analysis of a compliant parallel micromanipulator for biomedical manipulation.
- Chapter 14 reviews robotic systems and techniques for the manipulation of cells and small organisms.
- Chapter 15 summarizes commercially available tools for micromanipulation and highlights opportunities and market barriers.
- Chapter 16 presents a robot-aided micromanipulation system integrating optical tweezers and microfluidic devices for cell sorting and transportation.
- Chapter 17 describes the application of atomic force microscopy (AFM) to investigating molecular interactions involved in rituximab targeted therapy of lymphoma.
- Chapter 18 discusses an AFM-based dual-probe robotic system for the manipulation and characterization of cells and nanostructures.
- Chapter 19 reviews nanorobotic manipulation tools and techniques for the manipulation and characterization of helical nanostructures.
- Chapter 20 summarizes automated micro and nano handling techniques inside scanning electron microscopes (SEMs).
- Chapter 21 reviews robotic cell manipulation with microfluidic devices and under environmental SEM imaging.

Thanks to advances in tool and technique development, manipulation tasks that were not possible to achieve a couple of decades ago now have become routines; manipulation tasks that were manually done previously are now automated and executed faster, more accurately, and more precisely. As the micro-nanotechnology sector strides forward rapidly, the demand for advanced micro and nanomanipulation tools and techniques is becoming ever stronger. The strong demand virtually guarantees that more powerful micro-nanomanipulation tools will continue to emerge.

We thank all of the chapter authors and reviewers, and hope this book contributes to the education of next-generation micro-nanotechnologists and becomes a useful reference for students and researchers who develop new tools and who use micro-nanomanipulation tools to study science or solve industry challenges.

June 2015

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