PREFACE

Many of the devices and systems used in modern industry are becoming progressively smaller and have reached the nanoscale domain. Nanofabrication aims at building nanoscale structures, which can act as components, devices, or systems, in large quantities at potentially low cost. Nanofabrication is vital to all nanotechnology fields, especially for the realization of nanotechnology involving traditional areas across engineering and science. This is the first book of its kind dedicated solely to examining the manufacturing technology of nanoscale structures, devices, and systems, and is designed to satisfy the growing demands of researchers, professionals, and graduate students. In this monograph, both bottom-up and top-down fabrication technologies are introduced, with an emphasis on multidisciplinary principles, methodologies, and practical applications.

Bottom-up fabrication strategies involve manipulation or synthetic methods of biochemistry in directly assembling subnanoscale building blocks, such as atomic, molecular, and supramolecular elements, into required nanoscale patterns, of which bio-medical, chemical, and physical sensors and actuators are obvious applications. More ambitious is work in large-scale molecular electronics and computers, aimed at constructing circuitry in which individual atomic or molecular parts serve as wires and transistors. However, performing only one atomic or molecular reaction at a time using non-molecular machines, such as scanning probe microscopes, is impractical for making large quantities of a product. It appears that whether the strategy is manipulation, chemical synthesis, or self-assembly, the fabrication must occur in parallel or in arrays to self-form groups of atoms or molecules fast enough to produce useful structures of macroscopic size. Six chapters in this monograph are primarily devoted to examining recent developments in bottom-up approaches.

The top-down strategies have basically evolved from conventional lithographic techniques, in which nanoscale structures or semiconductor chips are fabricated from a bulk material by gradually removing or subtracting bits of the material in series. A key difference from the bottom-up approach is that, in the top-down approach, the parts or chips are both patterned and built in place, so that no assembly step is needed. The top-down approach has been proven to be a critical tool for the sustained evolution of the electronic, computer, photonic, and microsystem industries. However, there continue to be many obstacles and challenges that confront top-down

techniques as these techniques approach their fundamental size limits. Accordingly, I have included ten chapters in this book mainly to address these obstacles and challenges.

Eventually, the most promising strategy for the development of nanofabrication processes in large quantities will a hybrid approach, a combination of the bottom-up and conventional top-down techniques, and an integration of biological and chemical nanoelements in future devices. For example, through the use of the conventional lift-off technique, biological molecules, such as proteins and immunoglobulins with sizes of a few nanometers, have been immobilized in thin-patterned films. In fact, several chapters of this book involve the hybrid strategy.

Each chapter in this volume has been authored by well-known researchers, to whom I am grateful for their contributions. I am also indebted to a large number of reviewers, whose critical reviews have ensured that each chapter is of the highest quality. I would also like to thank Dr. Walt Trybula of Sematech for his advice in editing this book. Finally, I hope that readers will find this book both stimulating and useful.

Ampere A. Tseng
Arizona State University
Tempe, Arizona USA
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