MEMS and MOEMS
Technology and Applications
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Editor
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Preface

The silicon age that led the computer revolution has significantly changed the world. The invention of the transistor and the integrated circuit began a technological revolution—the miniaturization of electronics. Today, unprecedented increases in productivity are largely coming from the computer revolution. The next thirty years of the silicon revolution will incorporate new types of functionality onto the chip—structures that will enable the chip to reason, sense, communicate, and act. This new revolution will allow the silicon chip to affect their surroundings and to communicate the data to the world in new and dramatic ways. Besides processing data, the chips of tomorrow will process such things as chemicals, motions, light, and knowledge. This will be the basis of the next silicon revolution, and it will have a profound effect on the quality of life in this new century.

Mechanical systems are now poised for a similar revolution with its own miniaturization. The driving forces for the miniaturization of mechanical systems include cost, size, speed, weight, and precision while providing an effective interface between the macro and the microdynamic world. Micromachining technologies offer a wide range of possibilities for active and passive devices. Many of these technologies are based on surface micromachining evolving from the silicon integrated circuits technology. This book is written by experts in the field and it contains useful details in design and process, and can be utilized as a reference book or a textbook. It contains eight chapters covering all aspects of MEMS (microelectromechanical systems) and MOEMS (micro-optoelectromechanical systems) technologies.

Chapter 1 gives an overview of the subject and discusses the wide range of possibilities micromachining technology offers. Fabrication of three-dimensional structures by micromachining based on deposition and etching techniques is gaining momentum. The devices have been considerably scaled down in size, and many new applications from sensors to actuators to optical systems are emerging.

Conversion from one form of energy to another is the essential purpose of many micromachined devices. Chapter 2 reviews the operation and the design of micromachines using devices such as sensors and actuators. The design of these devices involves use of the basic principles of operation, microsystem and process modeling, circuit design, process technology, application environment, packaging, and manufacturing. For such multidisciplinary systems to work effectively, the design issues must be approached globally from the beginning, rather than trying to integrate the individual components at the end. Several examples of pressure sen-
sors, accelerometers, resonant devices, and deformable mirrors are used to illustrate many of the factors encountered in MEMS design.

Chapter 3 reviews the growth of TCAD (Technology Computer-Aided Design) and modeling capabilities for MEMS and MOEMS. Commercial quality tools, similar to those available in the microelectronics industry, would aid in the rapid growth of the micromachining technology and microsystems. Further work is necessary to combine existing MOEMS simulation tools with an integrated TCAD simulation environment.

Chapter 4 describes the development of digital light processing (DLP) technology and production of digital micromirror devices (DMD) at Texas Instruments. The DMD is a semiconductor-based array of fast, reflective digital light switches that precisely controls a light source using a binary pulse-width modulation technique. Several DLP designs allow the technology to be used in compact and lightweight applications such as portable projectors, as well as in very high-brightness fixed installation applications such as digital cinema and boardroom projectors. Unlike most MEMS devices, the DMD is fully integrated and monolithically fabricated on a mature SRAM CMOS address circuitry. Thus, both the mirrors and the drive circuitry are integrated on a single silicon wafer.

Chapter 5 discusses the emerging technology of guided wave MOEMS and planar waveguides. For these applications silicon micromachining can be used to manufacture and assemble perfectly aligned optical components, as well as for the construction of optical modulation interfaces using the physical properties of thin-film multilayer structures.

In Chapter 6, interesting new micromachines that enable design and fabrication of optomechanically integrated circuits, and subsystems whose capabilities can facilitate the explosive growth in bandwidth and networking features of lightwave systems, are discussed. A variety of lightwave network applications benefit from the small size, scalability, low power consumption, and low cost of MEMS optical circuits. To date no optical devices in MEMS have been used in an active lightwave network, but many have potential for commercial applications.

Chapter 7 provides an in-depth treatment of the critical subject of assembly and test for MEMS and MOEMS. Packaging affects the operation of devices like pressure sensors and must be compatible with the design and operation of the system. Packaging and testing can represent over 50% of the product cost for microsystems. Die size and wafer cost are being reduced by the integration of control circuitry and MEMS/MOEMS. Custom packaging and testing will continue to keep the cost high for MEMS/MOEMS devices. Several examples of packaging for pressure sensors, accelerometers, micromirrors, other MOEMS, microfluidics, microvalves, and microswitches are discussed. This chapter provides an overview of several practical issues for the commercialization of microsystems.

MEMS and MOEMS technologies hold almost limitless possibilities for applications, including emerging fields such as biotechnology, medicine, telecommunications, and wireless RF applications. Recent systems estimates for year 2002 market valuations have ranged from $38 billion (US) to as high as $100 billion.
8 focuses on commercialization and discusses industry activities that could accelerate the commercialization of the technology. Some of the roadblocks to commercialization include industrywide differences in nomenclature, manufacturing and marketing infrastructure, and inherent problems that companies face trying to gain competitive advantage in such a broad interdisciplinary field. Despite many impediments, growing global interest will lead to widespread use of micromachining technology in the twenty-first century.

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