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Preface

Microelectromechanical Systems (MEMS) are integrated devices whose characteristic dimensions are between 1 μm and 1 mm, whose operation relies on both electrical and mechanical phenomena and components, and whose manufacturing is based on appropriately enhanced microelectronic technologies. In Europe, MEMS devices are also called simply microsystems.

It is the use of semiconductors as bulk materials that enables the relatively easy integration of mechanical and electronic components in a single device. To implement the latter, MEMS design methods and technological processes share common roots with microelectronics, specifically the Very Large Scale of Integration (VLSI) Integrated Circuits (IC). Lithography can be cited as an example. However, in order to realize mechanical components, MEMS require additional processes that became to be known as micromachining. They include surface micromachining, where layers are deposed or etched at the surface of a semiconductor wafer; and bulk micromachining, which involves deep etching in the bulk of the wafer. Moreover, several techniques used in mechanical engineering have been adapted to the microscale, such as Electrical Discharge Machining (EDM).

The notion of micromachining refers to manufacturing of micromachines. The latter can be defined as micrometer-scale devices whose operation involves some form of motion (rotation or displacement). Depending on their task, micromachines fall in two categories: sensors detect and convert information carried by a non-electrical quantity into an electrical signal, which enables its further processing using electronic circuitry; actuators use electrical control signals to convert electrical energy into motion. Transducers are sensing elements whose aim is to transmit not just information but also energy; efficiency is therefore their important parameter.

Various physical domains may be involved in micromachine operation. In early MEMS, these included electrostatic, magnetic and thermal. However, technological advances have made sensors and actuators extend into the fluidic (Microelectrofluidic Systems, MEFS), optical (Microoptoelectromechanical Systems, MOEMS) or electromagnetic domain (antennas in Radio-Frequency MEMS, RF MEMS). On the other hand, miniaturization progress has led to the emergence of nanoscale devices which have become to be known as NEMS, the Nanoelectromechanical Systems.

Thanks to the constant improvement in MEMS technology, device functionalities are being enhanced or added, their dimensions are being reduced and their reliability is being improved. As a result, microelectromechanical systems are now experiencing the most intensive growth in their history. Novel devices find use in new areas of human activity while traditional applications see a rise in efficiency and popularity.

In order to keep the high pace of this growth, the MEMS industry needs skilled and educated engineers. Many universities offer courses in standard VLSI design in their curricula. However, integration of electrical and mechanical components requires specific software tools and design approaches. Multidomain 3D simulation is indispensable in this process. It provides insight into system operation with consideration of interdomain coupling while allowing investigation of various parameter effects on device characteristics. This way, it enables validation of new ideas, selection of materials as well as optimization of shapes and dimensions.

The purpose of this book is to help universities and individuals extend their traditional microelectronics education into the MEMS area. It is organized in a set of tutorials primarily aimed at electronic engineering students and practicing engineers. Based on carefully selected examples of sensors and actuators, it introduces the reader to device operating principles, modeling approaches, simulation tools and design methodologies.

Each chapter combines a description of device structure and operation principles with a tutorial-style guide to multidomain 3D model creation and use. All the tutorials have been implemented in ANSYS, one of the most widely used simulation environments in MEMS research and development. Examples appear in the increasing order of complexity of device structures, technological processes and underlying physical mechanisms. Each chapter is concluded with an exercise section, enabling the reader to consolidate and verify the acquired knowledge and gained skills.

While not an exhaustive reference on the numerous and varied MEMS devices and their applications, this book offers a systematic introduction to microelectro-mechanical systems. Its composition lets the reader follow the tutorials either under guidance or independently as a self-study. No prior knowledge of ANSYS environment is required as detailed instructions on its efficient use are contained in each tutorial.