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ENGINEERING ANALYSIS with BOUNDARY ELEMENTS

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Preface

Applications in micro- and nanoelectromechanical systems

Microelectromechanical systems (MEMS) are miniaturized sensors, actuators, devices and systems with a critical dimension of the order of micrometers. Advances in micromachining technology have led to significant progress in the area of MEMS. Micromachined devices such as accelerometers, gyroscopes, high performance mirror displays, pressure sensors, micromotors, microengines, RF switches, valves, pumps, thermally and chemically sensitive membranes, single-chip microfluidic systems such as chemical analyzers or synthesizers, single-chip micro-total-analysis systems (also referred to as lab-on-a-chip) and many more devices and systems have been designed and fabricated over the last one to two decades. The application domain for microelectromechanical (MEM) devices is enormous as they need low maintenance. MEMS-based systems can be used for personal monitoring and dosing, as light weight vehicle sensors, for manufacturing process control, and for just-in-time chemical synthesis requiring small quantities of hazardous substances. MEMS technology has already impacted defense, medical, aerospace, mechanical, chemical and computer areas.

On the other hand, advances in nanotechnology as well as in nanomachining techniques over the last decade have enabled development of novel Nanoelectromechanical systems (NEMS). NEMS are nanometer scale sensors, actuators, devices and systems with critical feature sizes ranging from 100 to a few nanometers. The effective masses, heat capacities and power consumption of NEMS are proportional to the critical feature size, either linearly or nonlinearly, while the fundamental frequencies, mass/force sensitivities and mechanical quality factors are inversely proportional to the critical feature size. Using state-of-the-art surface and bulk nanomachining techniques, NEMS can now be built with masses approaching a few attograms (10^{-18} g) and with cross-sections of about 10 nm. The extremely small size of NEMS provides fundamental frequencies in the microwave range, mechanical quality factors in the tens of thousands, force sensitivities at the attonewton level, active masses in the femtogram range, mass sensitivity at the level of individual molecules and heat capacities far below a yoctocalorie.

A number of computational design tools, based on finite-element, boundary-element, meshless and other sophisticated numerical techniques, have been developed over the last decade to accelerate progress in the area of MEMS. A number of these computational design tools have been optimized for specific microdevices. While significant progress has been made in the development of computational design tools for MEMS, the development of fast and very efficient computational tools for dynamic analysis of microsystems accounting for multiple energy domains (e.g. mechanical, electrical, fluidic, chemical, biological, etc.) and nonlinearities arising from various sources, still remains a significant challenge. In the area of NEMS, computational design tools are just beginning to emerge. While many NEMS devices can be modeled using MEMS physical theories or MEMS computational tools, a large class of NEMS devices demand new simulation capabilities because of the new physics encountered at the nanoscale. In addition, the break down of a continuum approximation for some NEMS devices poses new challenges. As a result, the development of quantum, atomistic, multiscale and continuum simulation tools based on advanced physical theories becomes critical.

This special issue reports on some of the latest results in the development of computational methods and design tools for MEMS and NEMS. Topics include simulations of micro- and nanoelectromechanical structures and devices, piezoelectricity, quadrupolar dielectrophoretic traps, gas separation in microchannels and multistate hydrogels subjected to electrical stimuli. We hope you will enjoy reading this special issue.

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