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MEMS Design Benefits from Nano-enabled Modeling and Simulation

Development of microelectromechanical systems (MEMS) is being accelerated with the help of advances in computational modeling and simulation. At Sandia National Laboratories, these advances are aided by improved knowledge and better understanding of how nano-scale phenomena affect the more general behavior of these tiny silicon machines.

In the past two decades, MEMS has spawned an exciting cross-disciplinary surge of interest, attracting new talent from a number of disciplines, from mechanical engineering to microbiology. Understanding the science at the nano-scale and using unique MEMS properties can increase energy efficiency, improve healthcare, and strengthen national security. The technical community is fairly well agreed that, with time, micro- and nano-scale devices will revolutionize engineering, and that the manufacture of micro-scale devices will be transformed by nano-scale assembly. However, progress in developing complex MEMS devices has been slow. The more successful MEMS innovations are relatively simple devices like mass-produced airbag sensors, ink-jet printer heads, and accelerometers. In the case of more complex systems with multiple components, problems of reliability begin to appear.

When engineers attempt to apply traditional methods at such small scales, they often find themselves face-to-face with the unexpected – situations for which the macro-world design experience can no longer provide all the answers. One of the great discoveries of engineering at the micro- and nano-scales is that one cannot scale down confidently from macro-dimensional assumptions when the final product is measured in micrometers rather than centimeters or fractions of an inch. For example, the dominant force at micro-scale is usually surface tension or friction, not inertia. Hence a micro-steam engine has been developed that's based on interfacial forces. In recent years, MEMS engineers have recognized that a new strategy is needed when designing MEMS devices. At Sandia, engineering at the microscale is benefiting from an appreciation of the complex physics at the feature scales of the devices and full acknowledgment of the importance of nano-phenomena that run from van der Waals forces to the collision of phonons with grain boundaries.

In short, excellence in MEMS requires an understanding of processes and interactions at the nanoscale as well as the micro-scale. Because many of the physical phenomena at nano-scale are very complex, micro-scale engineering is expected to reap considerable benefits from computational modeling and simulation to assess design performance, while relying less on conventional engineering problem solving. "We are moving from the early, relatively unenlightened days of 'making macro solutions smaller' to doing things a new way, through micro-scale enabled solutions," wrote Art Ratzel, director, Engineering Sciences Center 1500, in the March 2007 issue of *Mechanical Engineering,* flagship magazine of the American Society of Mechanical Engineers. "Engineering at the microscale introduces an appreciation of the complex physics at the feature scales of the devices. It demands the appreciation of a ground-up approach to design and problem-solving."

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