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Editorial

Trends in Nano and Micro-Electro-Mechanical Systems and Training Recommendations for Highly Qualified Personnel (HQP) in This Field

Mustafa Yavuz*, Andrew Brzezinski, Bo Cui, and Eihab Abdel-Rahman

Waterloo Institute for Nanotechnology, University of Waterloo, ON, Canada

***Corresponding author:** Mustafa Yavuz, Waterloo Institute for Nanotechnology, University of Waterloo, ON, Canada, E mail: myavuz@uwaterloo.ca

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N/MEMS apply to all types of miniaturized devices that are fabricated from silicon- and polymer-based materials using techniques derived from the nano/microelectronics industry. These techniques include isotropic and anisotropic etching, various thin film deposition methods, bonding, masking, and doping techniques employed in integrated circuit (IC) manufacturing. Micro-sensors, micro-actuators, 'lab-on-a-chip' and micro-TAS (micro-total analytical systems) devices can be referred to generally as N/MEMS [1]. N/MEMS consist of nano and micro scale mechanical components such as grippers and cantilevers, which move in response to certain stimuli (sensors) or are activated to perform certain tasks (actuator), and nano and micro components to control that motion (robotics and fluidics) [2].

N/MEMS offers advantages in many fields such as automotive control and safety systems, communication, satellite control, medical devices and health monitoring [3-14]. However, challenges exist in the fabrication and operation of these devices. For instance, in the operation of N/MEMS sensors, the actuation and detection of their sub-nanometer displacements at high frequencies, in addition to the bandwidth, and robustness and accuracy requirements make the tasks challenging [15].

Moreover, N/MEMS devices are usually designed to perform tasks in several domains (e.g., electro-mechanical, chemical, photonic, biological and thermo-hydraulic). Therefore, failure mechanisms of these devices vary significantly from one type to another. For this reason, there are systems architecture and control issues, plus design and fabrication challenges apparent before introducing them into the market, in addition to reliability problems in packaging, testing and cost analysis that also represent a major issue in any industrial and consumer product development. The central issue of reliability is that no matter how sophisticated a product is designed and manufactured, it becomes less useful if it is not able to deliver the designed performance during the expected lifetime [16].

The market for N/MEMS-based products in 2005 had a value of $8 billion. Those products included nano and micro devices such as nano/microfluidic integrated N/MEMS devices and RF-IC chips with embedded inductors. Growth projections are estimated to be $40 billion in 2015 and $200 billion in 2025 [6].

The Emerging Technologies Program of the National Science Foundation (NSF) and Defence Advanced Research Projects Agency (DARPA) selected N/MEMS as a research focal point and, consequently, their funding increased dramatically. Similar investments have also been made in Europe and Asia, causing the manufacturing of N/MEMS devices to become a substantial part of the high-tech manufacturing technologies [11,17]. However, there are current unsolved problems in N/MEMS device design and manufacturing:

Integration, packaging and full system feedback are current bottlenecks. For example, the detailed function of a N/MEMS chip is critical to the design of the package, and cost effective packaging and robust reliability are two critical factors for successful commercialization of N/MEMS devices [16].Therefore, preparation of N/MEMS devices to market in required volumes for suitable costs is a challenge that must be overcome. [6,11,18-20]

Strategic thinking is needed to determine the mix of analytical and numerical tools used in N/MEMS design [11]. For instance, the design insights provided by analytic models are invaluable, specifically the insights into the effects of varying either device dimensions or material properties. However, in the commercial N/MEMS world, particularly as devices enter high-volume manufacturing, there is increased emphasis on numerical tools at all levels.

Global trends in the field of N/MEMS (nano and micro-electro-mechanical systems) are driving research for the rapid miniaturization of low-power, high-bandwidth and high density devices for health technologies, wireless communication and smart sensor systems, and for applications to detect and manipulate anomalies such as pathogens, tumors, etc.

Training students for industry and academia to meet these current and future demands for innovation in the manufacturing of high-tech, smart and market-ready N/MEMS devices are vital to be competitive on the world stage in these important technologies.

A current gap exists in the steps linking research development to product innovation. When dealing with high volume production, strategic decision-making is the current missing element to accurately plan proportions.

To solve the problems mentioned above, a research community could be formed that will be built upon strategic collaborations and will foster a professional and entrepreneurial spirit to produce future HQP (highly qualified personnel) with a comprehensive background

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in technological and professional leadership. Commercial or market readiness among HQP will enhance the investment potential and success of start-up companies. For this reason, job readiness to ease and speed the transition of trainees into the workforce, and student 'mobility' among universities (national and international) and research institutes are two important milestones in training the HQP.

The training program could be derived based on detailed discussions with prospective and on-going employers to ensure that it meets their needs for HQP.

The recommended path for the training could be based on (a) developing cutting edge enabling nano and micro-scale manufacturing systems through interactions among this team of researchers and trainees and with industry and national and international collaborators; (b) delivering these enabling technologies to the local and national industry by training future work force as potential scientists, engineers, designers, and technical/executive managers; (c) providing the students with professional skills that are valued and required by industry, including communication skills, intellectual property protection and management, project management and ethics to be taught through workshops short courses and/or summer schools.

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