

MEMS for

QUALITY *of Life*

Introduction to a collection of articles by MEMS Industry Group (MIG) members

MEMS technology is a great match for new biomedical applications that improve quality of life (QoL) in a variety of ways. Providing intelligent sensing and actuation — which can be combined with electronics processing 'muscle' like ASICs, microprocessors and even DSPs — MEMS enables a high degree of interactivity with the environment. MEMS packs this intelligence into a small footprint, making it the ideal companion for resource-constrained applications.

Today MEMS is helping engineers to accomplish what we never thought possible. We asked some top innovators in biomedicine to describe how they use MEMS in life-enhancing and even life-saving QoL applications. In his article, "The MEMS Revolution in Biomedicine," Dr. Jeffrey Borenstein of Draper Laboratory explores the BioMEMS' connection to some amazing developments in tissue engineering, organ-assist devices and drug delivery systems. Donna Sandfox of Omron offers an inside look at SynCardia's bridge-to-transplant Total Artificial Heart in "MEMS Technology in Real Life: A Critical Part of the Total Artificial Heart."



**Karen Lightman,
Managing
Director, MEMS
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*MEMS Industry
Group is the trade
association
advancing MEMS
across global
markets.*

Dr. Dan Siewiorek of Carnegie Mellon University's Quality of Life Technology Center gives us a fascinating glimpse of some QoL Technologies (QoLT's) designed to allow seniors to live healthier, more independent lives in "Making Sense of our Aging World."

And we didn't stop there. Dr. Randy Goodall of NanoMedical Systems and Michael Lee of SVTC turn the concept of traditional pharmaceuticals on its head with their article on Personalised Molecular Drug-delivery Systems titled "Quality of Life from MEMS."

We are also enormously pleased to have Analog Devices' contribution, "Inertial MEMS, from Life-Enhancing to Life-Saving," by Bob Scannell, which gives an excellent overview of what can be "measured, monitored and ensured" with MEMS-enabling medical devices.

If the MEMS-QoL connection has you in its thrall — as it does me — I hope that you will consider joining a number of our authors and me at the MEMS Industry Group Symposia, "Quality of Life and Medical Applications" at Microtech 2011 in Boston, 14th June, 2011. For more information, please visit the MEMS Industry Group website: <http://www.memsindustrygroup.org/QoL>

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Dr. Randy Goodall, CEO of NanoMedical Systems; and Michael Lee, Director of Marketing, Life Science, SVTC

Quality of Life from MEMS

The semiconductor industry has been driven to constantly challenge the boundaries of material and manufacturing capabilities to meet market demand and continue to obey Moore's Law. Ever finer geometries and scales of device production are targeted to build memories with larger capacities and faster processors with higher levels of integration, all while decreasing cost per bit/transistor. Semiconductor processing equipment and material innovations are now being applied to situations that are not in the realm of memories and processors but rather in markets such as energy, life science research and drug delivery, to name a few. This innovative application of semiconductor technology has been described best as 'More than Moore,' and it will have as dramatic an impact on quality of life as Moore's Law has had on productivity.

Quality of life is defined by many factors but none so intimate and immediate as our health. It is inevitable that defects, disease, damage and decline of our biological systems will occur. Modern medicine has developed an arsenal of increasingly sophisticated drugs and biological molecules to treat these. However, the chemo-psychological balance of our systems can be significantly disrupted by the treatments themselves. Challenges of conventional drug delivery include: lowered efficacy and side-effects from the ups and downs of pills and injections; non-personalised dosing, duration and behaviour; poor compliance with treatments that are lifestyle-invasive and produce physical or emotional discomfort; and higher healthcare costs to society.

Personalised Molecular Drug-delivery Systems

The NanoMedical Systems (NMS) Personalized Molecular Drug-delivery System (PMDS), Figure 1, is a family of small implantable drug-delivery devices that slowly release a therapeutic agent from a reservoir over a period of weeks to months. A nanochannel delivery system (nDS) embodied on a silicon chip regulates the flow of therapeutic molecules out of the device. The PMDS is a new alternative to current treatments that require frequent and routine injections, clinical visits or other compliance-lowering complications. The

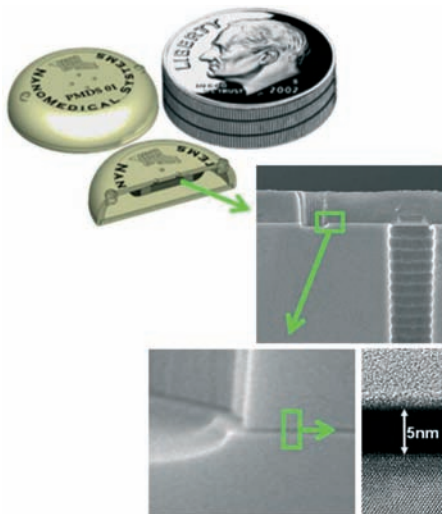


Figure 1: Example of the NanoMedical Systems PMDS device. Once implanted just under the skin, this small capsule releases a drug for many months. As seen in the cross-section, the nano channel chip, fabricated at SVTC, regulates the out-flow of the drug molecules. Electron-microscope images show details of one of more than a half-million 5 nm channels on the chip. In the lower right, an image of a nano channel magnified 2 billion times shows the atomic structure of silicon on the bottom and the amorphous ceramic layer above. Only with advanced MEMS and nano fabrication can this technology be made available in a size so small that it does not interfere with a patient's lifestyle.

first-generation PMDS, now in product feasibility assessment, is intended to increase efficacy and safety while reducing side effects. It supports a wide range of potential therapeutic agents with minimal formulation requirements. The ultimate PMDS embodiment represents a new pharmaceutical paradigm: a smart, communicating, actively controlled in-body system that functions like an artificial gland.

At the core of the nDS technology is the nano channel. In the NanoMedical Systems device, the nano channels are fabricated at densities of $\sim 100,000/\text{mm}^2$. While the nanochannels are a few microns wide and long (the 'big' dimensions), they are literally fabricated in the range of 2—50 nanometers in height — precision-sized according to the drug molecule or nano particle of interest. University research has demonstrated that nano channels offer a constrained release to drug molecules in high concentration when the nano channel dimension is near the size

of the particular molecule, providing constant delivery over a long period. Because the NMS nano fluidic chip is built on silicon with advanced deposition and etching technologies, integration of micro-scale wiring is straightforward. This enables modulation of the kinetics of molecules moving in the device. These capabilities of the NMS device are enabled by the advanced semiconductor capabilities at SVTC.

The MEMS Connection

Historically, MEMS arose on old equipment sets. At SVTC, however, the most leading-edge semiconductor equipment, processes and materials are used to create revolutionary devices like the implantable nDS nanofluidics chip. SVTC's IP encompasses deep ultraviolet (DUV) lithography and chemical-mechanical polishing (CMP) as well as a wide array of ceramics available via atomic layer and thin film deposition. The ceramics are essential to protecting other conventional MEMS/NEMS structural materials that body chemistry would otherwise dissolve — making them particularly important for in-body systems. It also includes on-conventional CMOS materials as diverse as III-V compounds, carbon nanotubes, and molecular vapour deposition of organic compounds for biocompatible surfaces support a variety of application requirements.

SVTC has successfully collaborated with customers in deploying 'More than Moore' technologies in the semiconductor, life science, aerospace and defense, renewable energy, consumer and communications markets.

Quality of life improvements should be available to everyone. In order to realise this vision in healthcare, we must seek to evolve low-cost, sophisticated treatment systems out of today's simple therapeutic concepts. As it did in the electronics industry, advanced semiconductor processing will lead the way, converging with nano technology and biotechnology to create new paradigms of treatment that we can only imagine today. NanoMedical Systems and SVTC are working together to make this convergence a meaningful and commercial reality.