# Special Guest Speech: New Progress of Integration and Fusion in MEMS –Expectations for New Industry Creation–

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I would like to talk about some of the MEMS research we have been doing and consider together the future outlook for MEMS. MEMS are integrated devices much like integrated circuits, but while the in/out signals for LSI chips are electric signals, MEMS can support numerous types of quantities, including such physical quantities as electrical, mechanical, optical, and magnetic quantities; chemical quantities; and biological quantities. The characteristics of MEMS can be further exploited in the form of living (or motional) devices in which moving mechanisms have been introduced. At the International Conference on Solid-State Sensors and Actuators in 1987, a U.S. presentation introduced living devices in which gears and linkage were formed on silicon using the same method for fabricating LSIs. This triggered a boom in the research and development of MEMS throughout the world.

Now in the 21st century, we have entered an age of industrialization that no longer asks “how” to make something, but “what” to make. There is much anticipation for a fundamental device to succeed the integrated circuit and be useful in our everyday lives. With advanced integration and the introduction of nanotechnology in systems, micro and nano systems have become the standard. Microtechnology employing a top-down approach to investigate the limits of fine processing and nanotechnology employing a bottom-up approach to develop new functions by designing materials from the atomic and molecular level come together on a MEMS substrate. Hence, MEMS provides the bridge for putting nanotechnology to use for us.

MEMS devices are expected to be vital in such industrial fields as information and communications, automobiles, precision machines and biotechnology. While the market for MEMS in 2002 was about 430 billion yen, it is estimated that this value will rise to 1.3 trillion yen by 2010. The NEDO project was initiated to respond to this market demand. The MEMS project (2003–2005) has included R&D on optical MEMS with such themes as mirror flatness, angular control, and rotational life; RF-MEMS with such topics as low loss at 10 GHz, high-processing precision, and the life of RF-switch contacts; and sensor MEMS with the goal of achieving chip size packaging at a low cost. In the MEMS-ONE project (2004-2006), we have conducted research on MEMS designing tools, with which we hope to facilitate manufacturing that combines creating technologies with design technologies.

Next, I will talk about the integration of MEMS and the fusion of MEMS with other technologies based on our research.

(1) Multicellular integration: many cellular elements are assembled to produce various functions, such as ① thermopile generators capable of generating several volts with a low temperature difference by arranging hundreds or thousands of thermocouples in series, ② painless micro needles in a drug delivery system that includes 1,000 needles arranged in $1 cm^2$, and ③ pneumatic balloon actuator that uses the air pressure in an array of balloons to produce cell-like movement similar to cilia.

(2) Multiaxis integration: integrating one axis to three axes of rotation in multiple dimensions to produce ① 6-DOF (six-Degree of Freedom) force-moment sensor ② 6-DOF accelerometer for precisely measuring the movement of humans and other moving objects.

(3) Mechanical integration: combining mechanical elements in a single system to produce ① micro reciprocating engine for power generation in which a cylinder and piston are integrally processed by dry-etching silicon, ② electrostatic controlled linear inchworm actuator (ECLIA) capable of high-precision work that includes an array of piezoelectric actuators and electrostatic actuators, ③ micro/nano materials testing system employing 1,000 electrostatic actuators to create a motor, load mechanism, and measuring mechanism capable of performing tensile tests in nano-level fields such as nanotubes and nanowires, and ④ micro conveyer systems that employs electrostatic actuators for capturing, transporting, measuring, and selecting nanoparticles and cells under a microscope.

(4) Fusion with information technology: the fusion of MEMS with information technology is important. By incorporating a communication function in MEMS, leads would become unnecessary. The objective is to create MEMS as small as 0.5 x 0.5 mm that cost just a few pennies. These particle-like MEMS called “smart MEMS” would be used for sensing and measurements. By incorporating the Internet, points of data detected by this smart dust are expanded to linear data by a communication device and further expanded to planar data when transferred to the Internet. These sensors are widely anticipated for use in simultaneous measurements in agriculture, transportation, distribution, and health care.

Finally, MEMS devices are important for industry, since manufacturing technology and equipment are essential for innovation. MEMS is a platform for making nanotechnology useful in our daily lives. Thus a union with nanotechnology for producing new functions can be considered an important role for MEMS. To achieve this, an R&D center for incorporating nanotechnology in MEMS must be linked with businesses and universities in order to produce a high benefit-cost ratio. However, rather than distributing research activities among many locations, a certain degree of concentration may be necessary since distribution requires a large investment. Furthermore, improvements in the infrastructure will be necessary to provide a foundation for international competitiveness.