Column

Frontiers of Future MEMS Devices: Process Integration

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Previous columns have introduced green, white, and blue devices as applications of MEMS devices we could have twenty years from now. The processing technologies needed to support these applications will require severe specifications, such as the manufacturing of microstructures in units of nanometers over a range on the order of meters. This may be difficult to achieve through a simple top-down approach based on the "copying principle" applied to cuthing, for example. While it may be possible to manufacture nanometer-order structures according to processes applying the principle of self-assembly and the like, developing such structures directly into meter-order structures will not likely be easy.

Therefore, our workgroup has been studying the development of technologies fusing manufacturing and assembly that can be applied seamlessly across both of these orders by merging a top-down process with a bottom-up process, as shown in **Fig. 1** (members of the workgroup are listed in **Table 1**). While conventional machining and energy beam machining can conceivably be combined for larger structures, it would be necessary to control the temperature and other aspects of the environment to ensure precise positioning, for example.

In addition, imprinting or other transfer techniques would be essential to attain high-throughput, low-cost manufacturing. Device designs themselves may also be affected when one considers the possibility of further developing the framework of simple shape transfers to the transfer and assembly (integration) of specific functional materials and molecules, as well as biotechnological devices.

A self-assembly process, i.e., a bottom-up approach, will likely be required for dimensional scales on the order of nanometers or less. Moreover, rather than producing uniform monolayers, we can imagine techniques for fixing and orienting molecules based on their location. The following are three features of this process.

(1) Technology for manufacturing three-dimensional nanostructures

The so-called 2.5-dimensional structures (columns, etc.) are produced through a combination of lithography and etching. Of course, higher resolutions will be in demand. However, existing technologies are not likely sufficient to support demands for three-dimensional processing, such as the formation of tapers and free-form surfaces. It will also be necessary to develop techniques for machining periodic three-dimensional microstructures on nanometer scale.

(2) Large surface areas

Printing technologies must be applied to large surface area applications of a poster size scale, enabling high-speed mass-production. On the other hand, the printing technology most suited to smoll lot production is inkjet technology. While throughput is lower, this technology is promising for processes supporting individual, customized product designs. There remains much room for research on materials used with this technology. It is conceivable that future processes may be able to deposit actual MEMS devices containing biomaterials.

Scale extension is another important issue.

(3) Interface control

Self-assembly can be performed location-selectively by modifying the wettability at specific locations on a solid surface. For example, we expect to be able to fix functional devices to only hydrophilic portions of a substrate simply by drawing the substrate up from water in which the functional devices are dispersed. It will be necessary to develop many techniques including surface modification in order to control the assembly of a variety of functional devices. To achieve this in resolutions at the molecular level, extremely preoke interface control will be required.

As can be seen from the above issues, it will not be easy to implement comprehensive process integration. However, we believe these technologies are critical for implementing various applications and will produce a great ripple effect.

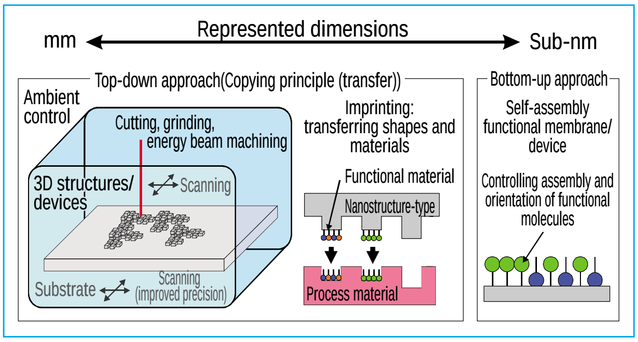

Fig. 1 Next-generation processing

Table 1 Members of the process integration workgroup

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Chieki Mizuta	Mathematical Systems Inc.
Koichi Tanaka	Sony Corporation
Nobuaki Kawahara	DENSO Corporation
Takayuki Masunaga	Toshiba Corporation
Hirokazu Hashimoto	Fujikura Ltd.
Masatsugu Tomotaka	Fuji Electric Systems Co., Ltd.
Masao Kubo	Matsushita Electric Works, Ltd.
Kazuo Asaumi	Mizuho Information & Research Institute, Inc.