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Editorial

Multiscale and Multimaterial Fabrication: The Challenge Ahead

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In the editorial in March 2016, I mentioned that one of the aims of Micromachines is to cover topics and technologies beyond silicon-based microsystems and microdevices [1]. In fact, broadening application areas of micromachines beyond the traditional silicon-based sensors and actuators brings new challenges to the development of microfabrication technology. Conventional Micro Electro Mechanical Systems (MEMS) and Nano Electro Mechanical Systems (NEMS) have their size in the range of micrometres and can be fabricated in batch using the well-established photolithography and etching processes. Even with the integration of microelectronics, devices are often self-contained and easy to be packaged. Novel applications such as those in the areas of microfluidics and lab on a chip (LOC) requires device features with size scale that differs with orders of magnitude. The mismatch in feature size and the multiscale nature of these devices bring new challenges to the device design as well as the development of economic and large-scale fabrication processes. Imagine that one has to fabricate centimetres large devices with precise features in the submicron scale. The large footprint and the precision required would make even batch fabrication on silicon substrate economically prohibitive. Thus, the next challenge would be the integration of different materials or device components made of different materials into the final product. The hybrid integration approach of traditional packaging provides a solution for this challenge. Recent papers published in Micromachines illustrate how diverse solutions for multiscale and multimaterial challenge could be.

Esashi and Tanaka [2] reported stacked integration methods as wafer-level packaging solution for large scale integration (LSI) electronics and MEMS devices. The stacking methods require good wafer-to-wafer alignment and an adhesive layer to transfer a thin silicon device layer to an existing LSI wafer. Electrical contacts could be made in the same fabrication process for the MEMS device or as the last fabrication step. Another method transferred a different device material (lithiumniobate) to the LSI silicon wafer through gold bumps. Selective transfer can be achieved using a laser beam to burn out the polymeric adhesive holding the MEMS device. These transfer methods are suitable for devices made of different material systems but of the same size scale.

Kim et al. [3] demonstrated a solution for the multiscale challenge in the fabrication of a LOC device for axon growth. While the guiding channel for the axons have to be a few micrometre deep, the reservoir for the culture medium could be as large as one centimetre, and the compartment for the neuronal soma could be in the millimetre scale. The authors reported a fabrication approach called micro-macro hybrid soft lithography master fabrication method. A model of the device was made in poly(methyl methacrylate) (PMMA). While the millimetre scale features were fabricated with precision milling, the micrometre scale features were transferred from a micromachined silicon master through hot embossing. A polydimethylsiloxane (PDMS) master mould was then casted from the PMMA model. The Master mould had both micrometre scale and millimetre scale features and was used for casting the actual device in PDMS. The elastic PDMS master allows for the fabrication of multiple through holes by pressing to a solid glass slide. Thus, not only multiscale fabrication, but also large-scale fabrication of microfluidic access holes were realised with this approach.

PDMS has not only been used as master and device material, but also as a convenient medium for the integration of different materials in a multimaterial device. Ma et al. [4] used PDMS to package grating structures made of the thick-film resist SU-8 and a conventional glass waveguide to make long-period fibre grating for strain measurement. The combination of rather “exotic” materials could provide a novel solution for long standing problems. Chen et al. [5] used a thermo-reversible gel to support high-aspect ratio structure, which are prone to collapse due to capillary force. For subsequent process such as electroplating, the gel can simply dissolved by increasing the temperature of the liquid bath.

Examples from the last three issues of Micromachines (July-September 2016) indicated that the reseach community has already provided the first solutions for the challenge of multiscale/multimaterial fabrication. It seems that pattern transfer through moulding or hot embossing could be a practical and

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economic approach. The integration of more complex functional devices made of different technologies could learn from the ongoing development in wafer-level packaging. As current solutions are rather ad-hoc for specific applications, more research and development would be needed in the near future to provide a more systematic solution for the challenge of multiscale/multimaterial fabrication.

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