Engineering micro and nano systems with alternative methods

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The manufacturing of silicon-based micro and nano systems today is well advanced because the micro-electro-mechanical devices for automotive, domestic, health-care and consumer electronics can be fabricated with methods from IC industry. Polymer-based MEMS have a great potential for flexible electronics and biomedical applications and considerable progress has been made in process and integration technologies for such demanding applications. But we must admit that up to now the techniques to engineer functional polymers into reliable 3D microsystems for daily use are still at their beginning. One reason for that is that a coherent (= standardized) fabrication platform with the appropriate tools and processes does not yet exist. The field however begins to benefit from increased efforts in soft and polymer materials applications. Additive manufacturing, (e.g. 3D printing) and associated processing (e.g. sintering) have already started to transform traditional industry, and much more is expected in the near future. These novel approaches however are difficult to scale below a micrometer because the thermal processing is either done macroscopically using furnaces or on the surface of the material using lasers. Both approaches are not scalable to the sub-micrometer.

This talk will provide an overview of recent achievements in advanced manufacturing at the micro/nanoscale and associated key techniques than can be applied in particular to fragile materials, where harsh process steps using charged beams and etch chemistry can be harmful. I will in particular present nanostencilling, printing, capillary based self-assembly and local thermal processing that may form part of the gentle toolbox for future micro/nano-manufacturing of fragile material systems.

High-resolution stenciling [1] is a quite old technique, but it keeps allowing us to study new and highly localized material deposition phenomena without the need for high-energy beam exposure and etching or development steps. Examples include metallic nanostructures (<50nm) on rigid and flexible polyimide, parylene, SU-8 and PDMS substrates for biosensors. More recently the reduced flux through stencils in PVD allows controlling surface crystallization of molecules for organic electronic [2]. Drop-on-demand **printing of functional inks** is a wet additive manufacturing approach for SU-8 [3], nanoparticle based inks with multicolor luminescent [4] or with magnetic properties [5]. **Capillary assisted assembly** is a particularly mild (water based) method to position loads of prefabricated nanostructures from a colloidal solution into a deterministic surface layout, with high yield and a control down to a few nanometer precision on individual position, orientation and interparticle gap [6]. Finally, **local thermal processing** of functional material with sub-micrometer resolution is a quite new technique that uses a thermal scanning probe lithography tool. It can be used for writing topographic and fluorescence patterns into supramolecular polymers [7] and into silk, as water solvable resist material [8].

All these methods are part of a new mild toolbox have in common that they permit the use of delicate materials to engineer new types of MEMS. One upcoming target is (biodegradable) implantable MEMS. They are the most challenging to fabricate, but if successful, they also have an enormous impact for future wearables and implantables. The paper will show the advantages and limits of each technique and provide some guidance how they could be combined in mix-and-match approaches with conventional methods and to be part of the manufacturing platform for soft material MEMS and NEMS.

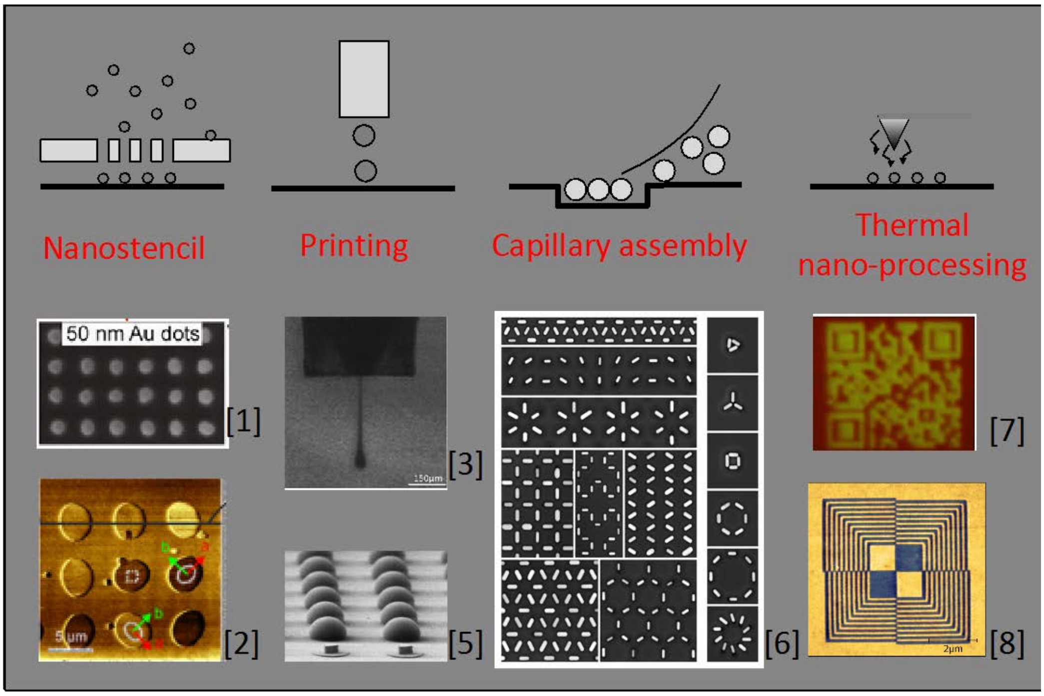

Figure combo showing some mild patterning methods that are part of a new toolbox for shaping fragile material at the micro and nanometer scale. Reference numbers correspond to the listed papers.

References:

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