**EPFL**

MICRO-721     **Advanced micro- and nanomanufacturing: top-down meets bottom-up (2019)**

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| Cursus | Sem. | Type |
|---|---|---|
| Microsystems and Microelectronics | | Obl. |

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|---|---|
| Language of teaching | English |
| Credits | 1 |
| Session | |
| Exam | Multiple |
| Workload | 30h |
| **Hours** | **12** |
| Courses | 9 |
| Exercises | 3 |
| **Number of positions** | **25** |

**Frequency**

Every year

**Remark**

Next time: 16-17 October 2017

**Summary**

This course introduces advanced fabrication methods enabling the manufacturing of novel and micro- and nanoscale systems. Both top-down (stenciling, scanning probes, additive techniques) and bottom-up approaches (self-assembly) are presented, which complement established fabrication tools.

**Content**

The course aims to present most advanced micro and nanofabrication methods that go beyond the well established techniques such as lithography and thin film processing. These new methods are emerging and are useful for PhD students to be aware of in order to design and fabricate novel micro and nanosystems, involving new, functional materials, and achieveing resolutions, shape and throughput that are of importance for the target application. Both techniques that are rather used as rapid prototyping as well as scalable method for high throughput manufacturing will be addressed.
A list of topics that will be shown in the course is shown below. The topics will be updated in time to address also the most relevant and timely issues related to advanced micro and nanomanufacturing.
Guest speakers from other academic institutions and/or industry will complement the lecture to give insight with first-hands experience to share with the students. In this first edition, following two experts have confirmed to take part: Dr. Massimo Mastrangeli (now Max-Planck, moving to TU Delft), Prof. Francesc Perez-Murano (CNM Barcelona)

List of topics:
Top-down fabrication: a) Fabrication through stencil, b) inkjet printing, c) micro 3D printing incluiding 2-photon lithography, d) (thermal )scanning probe lithography
Bottom-up fabrication: a) principles of self-assembly, b) capillary self-assembly, c) fluidic self-assembly, d) capillary assembly of nanoparticles

The course starts by presenting a map of currently available options for fabricating micro- and nanosystems, which includes both established techniques (electron beam lithography, nano-imprint lithogrpahy), covered in prior courses, and non-standard or advanced ones. This provides a recapitulative bridge to the students' background before focusing on the core of the course, which is the latter techniques.
We then proceed by introducing the advanced techiques in details. For each technique, a brief overview about history and background theory is provided, before focusing on recent developments and applications. The relative place of each technique with respect to the map is emphasized, so that advantages, limitations and complementarities are evidenced.
The second part of the course focuses on techniques that rely on the contactless and/or unsupervised placement of micro- or nanocomponents within a pre-existing templating substrate, i.e. where the structure arises from the directed organization of the constituting components - a family of approaches that can be broadly defined as "self-assembly". A

theoretical framework inspired by equilibrium thermodynamics is briefly presented, before exemplifying three main applications within this family, namely: the integration of 2D microelectronic systems and self-folding of 3D MEMS by capillary self-alignment, the fluidic self-assembly of 3D systems including polymeric, liquid-filled microcapsules, and the topographically-templated capillary assembly of nanoparticles.

Another topic of the course is a combination of top-down and bottom using directed self-assembly (DSA) of block copolymers. It is emerging as a suitable possibility for high volume manufacturing of nanostructures and nanodevices. It is strongly being considered as a complementary nanopatterning technique by the semiconductor industry. DSA takes advantage of the properties of block co-polymers to self assembly, resulting in patterns with characteristic dimensions determined by the size of the molecules. In this way, resolution is only dictated by the molecular weight. It will be presented the main aspects of state-of-the art DSA including: materials, processing details, kinetics of self-assembly and applications.  Special attention will be devoted to the creation of the guiding patterns that allows to position and orientate the molecules in the correct position.

## Note

This course merges two prior doctoral course, respectively on self-assembly of microsystems  (MICRO 620) and emerging nanopatterning methods (Micro 600).

## Keywords

MEMS, NEMS, self-assembly, additive manufacturing, printing nanofabrication

## Learning Prerequisites

### Required courses

Microfabrication, basic physics, chemistry, engineering and material science

## Learning Outcomes

By the end of the course, the student must be able to:
- Explain the fundamentals of modern nanofabrication
- Present the major recent innovations in micro/nanomanufacturing
- Argue about their advantages and limitations, and their difference or complementarity with respect to established techniques

## Resources

### Bibliography

Madou, MEMS MOOC

### Ressources en bibliothèque

- Ajouter au Panier Fundamentals of microfabrication and nanotechnology / Madou