MICRO-724

Advanced topics in micro- and nanomanufacturing: top-down meets bottom-up

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Cursus	Sem.	Type
Microsystems and Microelectronics		Opt.

Language of teaching	English
Credits	2
Session	
Exam	Multiple
Workload	60h
Hours	**28**
Courses	16
Exercises	8
TP	4
Number of positions	**24**

Frequency

Every 2 years

Remark

August 15th - September 30th 2022

Summary

This course introduces advanced fabrication methods enabling the manufacturing of novel micro- and nanosystems (NEMS/MEMS). Both top-down techniques (lithography, stenciling, scanning probes, additive techniques) and bottom-up approaches (self-assembly) are presented.

Content

The course aims to present the most advanced micro and nanofabrication methods that go beyond the well-established techniques typically used for e.g., CMOS technologies, such as lithography and thin film processing. Many of these new methods are emerging but have the potential to play an important role in future versatile nano-manufacturing. It is thus useful for PhD students to be aware of them in order to design and fabricate novel micro- and nanosystems, by involving new functional materials and by achieving resolutions, shape and throughput that are of importance for the target applications. The course will cover techniques that are on the one hand used as rapid prototyping and on the other hand also scalable methods for high-throughput manufacturing.
The list of topics that will be described in the course is shown below. The topics will be updated from time to time to address also the most relevant and timely issues related to advanced micro- and nanomanufacturing.
Guest Professors who are among the leading scientists in their respective domains will contribute to the lectures and share first-hand experience with the students. In this edition, the following three international experts have confirmed to take part:

- **Prof. Massimo Mastrangeli (TU Delft, NL)**
- **Prof. Francesc Perez-Murano (CNM Barcelona, E)**
- **Prof. Karl Bohringer (U-Washington, USA)**

List of topics:

- Top-down fabrication: a) Advanced lithography recapitulation, b) nano-fabrication through stencils, c) micro/nano printing methods, 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, e) directed self-assembly

The course will be given in a flipped classroom approach to make the best use of the presence of the teachers on EPFL campus and for dedicated classroom lectures. A precise schedule will be set up that will cover a total of about 6 weeks. It entails that the PhD students will get some reading/work assignment before the actual in-classroom lectures.

- Phase I: Introduction lecture online from each teacher (duration: 4 x 2h = 8h, ~4-5 weeks before classroom lessons)
- Phase II: group-of-4 formation, reading assignment, group project definition and preparation (duration: 4-5 weeks)
- Phase III: in-class advanced lectures by teachers (12h in 2-3 days within 1 week)
- Phase IV: group project presentations + discussion and feedback (6h)

The course starts by presenting an overview of currently available options for fabricating micro- and nanosystems, which includes both established techniques (electron beam lithography, nano-imprint lithography), 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 techniques in detail**, e.g., focused ion beam (FIB) induced fabrication of nanostructures and nanodevices and thermal scanning probe lithography (t-SPL). For each technique, a brief overview about history and background theory is provided, before focusing on recent developments and applications. For each technique the respective advantages, limitations and complementarities are discussed.
The second part of the course covers bottom-up methods and 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-up** 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 in the roadmaps of the semiconductor industry and has been added, removed and then re-added to the ITRS (now IRDS) roadmaps. 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. The main aspects of state-of-the art DSA will be presented 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 orient the molecules in the correct position.

Note

Online introduction sessions :
Tuesday, August 23: 10h-12h
Wednesday, August 24: 10h-12h
Thursday, August 25: 16h-18h
Friday, August 26: 10h-12h

Advanced lessons, discussions & presentations:
In person at EPFL, Lausanne (rooms TBC early August):
Tuesday, September 27: 9h-12h
Wednesday, September 28: 9h-12h
Thursday, September 29: 9h-12h and 15h-18h
Friday, September 30: 9h-15h

Total workload: 56h
Online lecture: 4 x 2h = 8h
In-person lecture: 4 x 3h = 12h
Student individual and group work: 30h
Group presentation and final discussion: 6h

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:

- Choose the best nano-manufacturing method for a given problem

Transversal skills

- Communicate effectively with professionals from other disciplines.
- Identify the different roles that are involved in well-functioning teams and assume different roles, including leadership roles.
- Give feedback (critique) in an appropriate fashion.
- Demonstrate a capacity for creativity.
- Manage priorities.
- Write a scientific or technical report.
- Make an oral presentation.
- Access and evaluate appropriate sources of information.

Teaching methods

- online introduction lesson
- self-study and group study
- classroom lesson
- mini-project presentation

Expected student activities

- attend introduction lecture (online for remote teachers)
- self-study
- work in a team on a mini-project
- summarize the mini-project in a report
- attend advanced lectures
- present mini-project orally to the class and teachers

Assessment methods

- mini-project report in a group of 4 students
- 30 min group presentation in front of teachers and classmates

Resources

Ressources en bibliothèque

- Fundamentals of microfabrication and nanotechnology - Vol. 2 / Madou

Notes/Handbook

- Marc Madou: Fundamentals of microfabrication and nanotechnology (see link above and in the MOODLE)
- MOOC on Microfabrication (link will be provided in the course MOODLE)

Moodle Link

- https://moodle.epfl.ch/course/view.php?id=15473