Introduction to Micro and Nanotechnologies

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2013 Participant by affiliation

- 38 Participants in total

- McGill, 22
- Quebec Universities, 5
- Montreal Universities, 5
- Ontario, Industry, 6
2013 Participants by job/studies

- PhD students, 20
- Master students, 10
- Professional, 6
- Post-docs, 1
- Professor, 1
2013 Participant by Area

- Chemistry, 10
- Electrical and computer engineering, 7
- Industry, Manufacturing, 3
- Industry, R&D, 3
- Neurosciences, 3
- Physics, 2
- Physiology, 2
- Mechanical Engineering, 2
- Physics Engineering, 1
- Biomedical Engineering, 1
- Biology, 1
- Biochemistry, 1
- Chemical Engineering, 2
Goals of the course

- Learn about Micro- and nano(bio)technologies – potential and limitations

- Get hands-on experience with microfabrication, soft lithography and microfluidics.

- Reflect on how micro- and nanotechnologies may help leverage your research,

- Brainstorm and discuss different ideas for your project

- Apply your knowledge in the design challenge.

- Learn about other participants and the micro- and nanofabrication infrastructure and services @ McGill,
Schedule and locations

Monday
04-Mar
8:30-9:00
Welcome & Registration
Rutherford 103

9:00-10:00
Module 1: Introduction to Microfabrication
Rutherford 103

10:00-11:00
Module 2: Microfabrication
Rutherford Microfab

11:00-12:00
Lunch (Provided)

12:00-1:00

1:00-2:00

2:00-3:00

3:00-4:00

4:00-5:00

5:00-6:00

Tuesday
05-Mar

Wednesday
06-Mar

Thursday
07-Mar

Friday
08-Mar

Module 3: Microfluidics
Genome 6500

Brainstorming Session
Genome 6001

Keynote Lecture
Rutherford 112

Sponsor Presentations
Rutherford 103

Module 2: Microfabrication
Rutherford Microfab

Brainstorming Session
Genome 6001

Sponsor Presentations
Rutherford 103

Module 2: Microfabrication
Rutherford Microfab

Brainstorming Session
Genome 6001

Sponsor Presentations
Rutherford 103

Rutherford 011
Clean room

Innovation Centre 6500 (740, Dr. Penfield)

Rutherford 103

Rutherford 103

Rutherford 112
Locations

1. Innovatio
   2. n Centre
   3. 740, Dr.
   4. Penfield

Rutherford

Locations
Course Modules

- Module 1: Introduction to Micro and Nanotechnology
- Module 2: Clean Room Microfabrication (Hands-on)
- Module 3: Microfluidics and Microcontact Printing (Hands-on)
- Module 4: Discussion and Brainstorming (small group)
- Module 5: Design Challenge
Outline

- What is Micro & Nano? The concept of miniaturization
- Integration and scalability
- Patterning:
  - Self assembly: Bottom up
  - From macroscale to nanoscale
- Original Patterning techniques
- Pattern replication and transfer techniques
- The techniques you will learn and use in this course
The vision of micro- and nanotechnology

“There is plenty of room at the Bottom”

Richard P. Feynman, December 29th, 1959
Nobel Prize in Physics, 1965
Micro & Nano: Why?

- Higher density
- Portability
- Integration
- Multiplexing
- Nano: New properties
- Enabler
Length scales and patterning methods


Source:
http://www.nikon.com/about/feelnikon/universcale/index_f.htm
What is Nanotechnology?

A debatable definition of Nanotechnology by Mihail Roco from the National Nanotechnology Initiative in the USA:

- Structures that have at least one dimension below 100 nm
- Are designed and made through a process that provides fundamental control of physical and chemical attributes
- Can be combined to form larger structures
Nanorevolution vs Nanoevolution vs Nanohype?

Microelectronics?

Intel SRAM Test Chips

- 130 nm
  - 2.45 μm² cell
  - 103 mm²
  - March '00
- 90 nm
  - 1.0 μm² cell
  - 50 Mbit
  - February '02
- 65 nm
  - 0.57 μm² cell
  - 70 Mbit
  - April '04
- 45 nm
  - 0.346 μm² cell
  - 163 Mbit
  - January '06

Power?

Nanophosphate™ Batteries
www.A123systems.com

Candle soot?

Automotive?

Tata NANO, 100,000 Rupee

Nanobiomachines

- Drawings by D. S. Goodsell from Bionanotechnology and Molecular biology of the cells
Miniaturization: Properties and consequences

- Large surface-to-volume ratio.

- Surface properties, not bulk properties, are dominant

- Macroscopic fabrication tools don’t work

“Giving shape” at microscopic dimensions:
- *Top-down*: patterning and pattern transfer
- *Bottom-up*: Self-assembly (synthesis)
Self-assembly and pattern formation

Spontaneous pattern formation

Surface energy driven separation of Polymer PVP/PS polymer blend

“Self-organization”

Beads self-assembled in microchannels


Wu et al. JACS 124, 14508 (2002).

Self-assembled and designer nanoparticles

http://deepblue.lib.umich.edu/bitstream/handle/2027.42/62016/nano.html
Patterning: Direct Patterning

- Information (and art) readable to the human eye
Patterning: Pattern transfer

- Printing (Gutenberg Press)
- Printing (Web Press)

- Up to the 20th century: Information (and art) readable to the human eye
Direct micro- and nanopatterning techniques

- Drop-on-demand (inkjet) printers. Resolution: 10 µm
- Electro-discharge micromachining (EDM). R: 10 µm
- Stereolithography, rapid prototyping. R: 10 µm – 500 nm
- Laser writer. R: 0.4 µm
- Electron-beam writer. R: 30 nm
- Focused ion beam. R: ~ 5 nm
- Scanning probe lithography (AFM, STM, SCEMS, Dip pen) Resolution: Down to single atoms
Ink-jet

Bubble Drop

Canon, ...

Piezoelectric actuation

Epson, ...

+ Versatile.
- Drying and Clogging, solution-dependent, multiplexing.

Polymer transistors


Neurons

T. Xu et al., Biomaterials 27, 3580-3588 (2006).
E-Beam Lithography

+ High resolution,
- Serial; requires a resist.
Focused Ion Beam (FIB)

+ High resolution, etching and deposition
- Low throughput, slow setup, Vacuum
Scanning Probe Lithography

+ High resolution, versatile
- Low throughput, multi-color unsolved
Pattern transfer and replication techniques

- **Photolithography & Microfabrication (Silicon)**
  - Photoresist patterning (2D and 3D)
  - Wet, dry, surface and deep etching

- **Polymer Replication lithography (Polymers)**
  - Molding
  - Hot embossing
  - Injection molding

- **Soft Lithography**
  - Microcontact printing (Viscous, molecular and solid inks)

- **Mold Fabrication**
  - Electroplating (LIGA)
Photolithography & Microfabrication (Module 1)

- Photolithography & development of photoresists
  1. Spin-coat photoresist (SU-8)
  2. Photopattern
  3. Develop and bake
  4'. Etch
  4''. Deposit
Replica Molding (Module 2)

- Replica Molding of patterned wafer (with PDMS)

1. Pour PDMS
2. Cure in oven
3. Peel off & Trim

+ very simple, high resolution
- Slow for commercial production
Soft Lithography and Microfluidics (Module 2)

- Microcontact Printing: Ink and print

- Microfluidics: Seal first, and then fill
Hot Embossing and Imprinting

Process flow

(a) Thermoplastic foil
   Mold inserts

(b) Patterned resist

(c) Residual layer

+ Very high resolution
- slow, lack of commercial adoption

Injection molding

Process flow

+ Very high resolution, widely used commercially, fast
- High equipment costs, expensive set-up cost
Injection molding

- Mold is kept cold for rapid cooling

+ High resolution, high throughput
- Machine & molds are expensive

M. Heckele et al. 2004 J. Micromech. Microeng. 14 R1-R14
Micro and Nano underpin transformational tech

Moore’s law

DNA microarray (number of spots)

Sequencer (sequences/run)

Antibody microarrays (number of antibodies)
Conclusion

- A myriad of micro and nanotechnologies have emerged in the last 50 years.

- Two fundamental concepts: **pattern creation** (typically expensive, clean room) and **pattern replication and transfer** (low cost, in your lab)

- Micro and nanotechnologies have revolutionized computers, and recently biology and medicine, and this is only the beginning!
Homework – for the brainstorming session

You will get out of it what you are putting into it!

- Select a device or structure related to your project (or not) that you would like to fabricate using micro and nanofabrication processes.

- Think about it, and prepare some sketches on how to fabricate it.

- Discuss it during the brainstorming session
Design Challenge

- Presentation by Philippe
Thanks

Nano:

Micro:

Milli:

Abbott Point of Care

Questions?