# EPFL CENTER OF MICRONANOTECHNOLOGY

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CMi EPFL Center of MicroNanoTechnology

# EPFL CENTER OF MICRONANOTECHNOLOGY


Des technologies de microfabrication
de pointe accessibles aux PME

Cyrille Hibert, **EPFL**

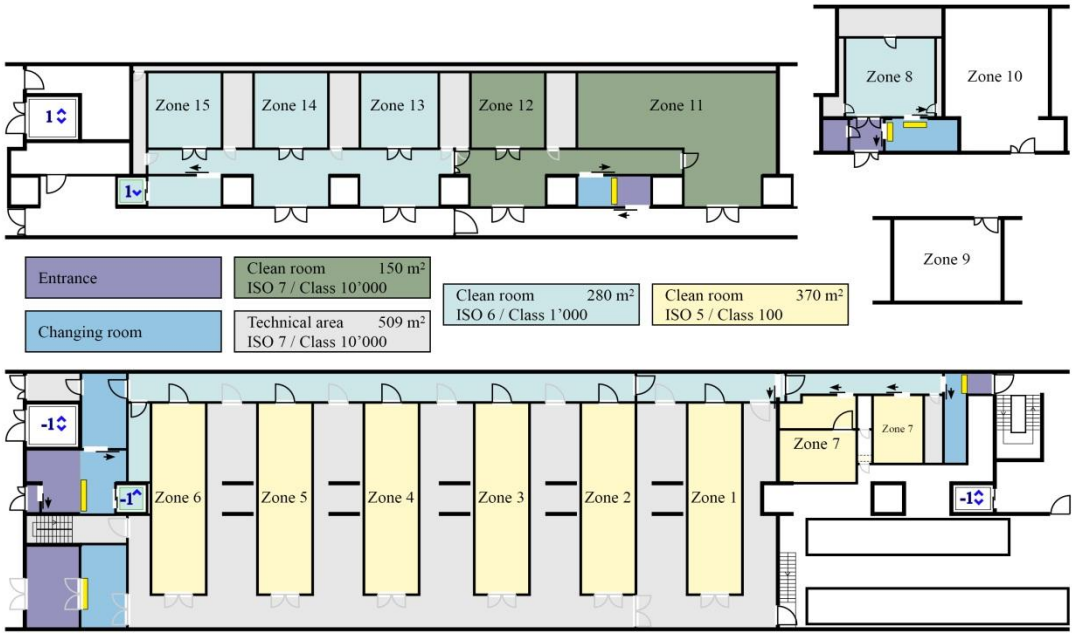
# CMI MISSION

- Support Education
- Support Research
- Provide Access to NanoFabrication Processes

# CLEANROOM

- CMi BM+1

- CMi BM-1




2 levels

connected by elevator

Cleanrooms are full

What about the Future?

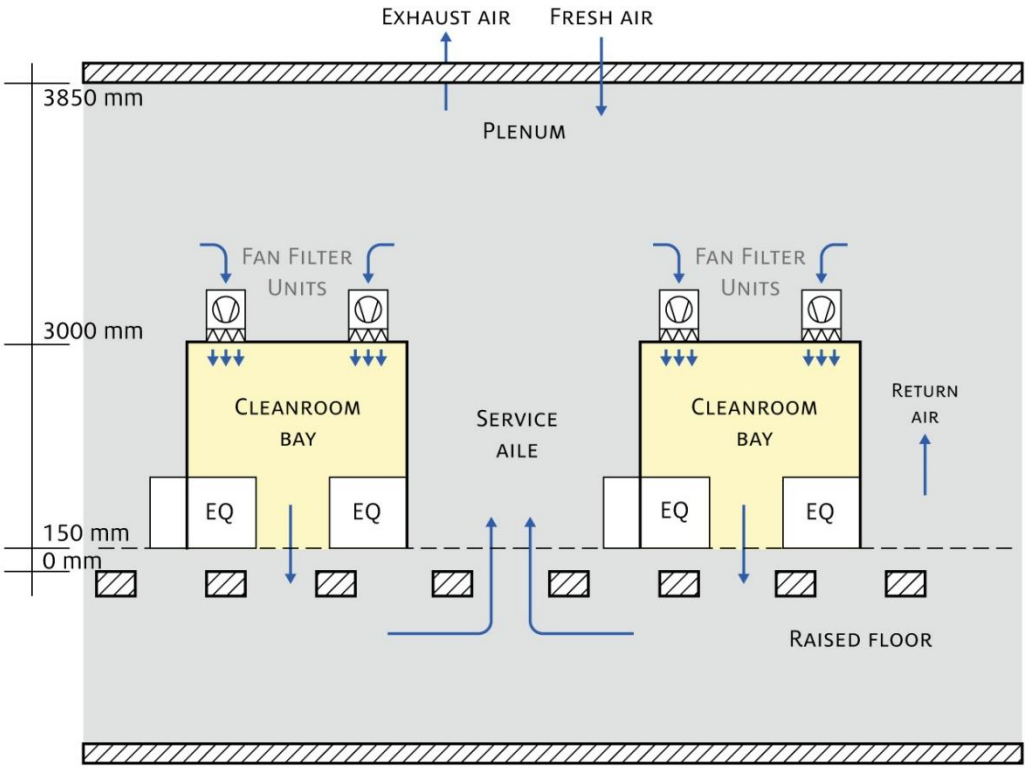
| Initial surface (1998) | Extension (2010) | Total surface |
|---|---|---|
| 1000m$^2$ | 300m$^2$ | 1300m$^2$ |

Any extension of nanofabrication facilities should be built in connection with the CMi.

# CMI CLEANROOM

## Description of the Cleanroom

Air filtration and circulation in class 100




ACTUAL VALUES (2/3 of maximum capacity)

- FRESH AIR
  - 60'000 $m^3/h$
  - filter efficiency: 99.97% for
  - particles size: 0.1-0.3 µm
- EXHAUST
  - 36 '000 $m^3/h$
- FFU
  - ISO 5 : 189 units
  - ISO 6 and 7 : 46 units
  - 0.7 $m^2$ active area
  - total: 189'000 $m^3/h$
  - filter efficiency : 99.999% for
  - particles size 0.1-0.3 µm

# CMI CLEANROOM

# CMI CLEANROOM

Bay and Chase Cleanroom Arrangement

# CMI CLEANROOM

- Electricity consumption CMi (2014) :
  - 2’519’878 kWh (CHF 348’191.-)
- Nitrogen consumption (2014) :
  - 356’646 m3 of gas (CHF 65’706.-)
  - (1lt of liquid = 700lt of gas)
- Heating energy BM (2014)
  - 1’571’083 kWh (CHF 146’925.-)
- Water consumption BM (2014)
  - Reverse Osmosis : 16’936m3 (CHF 62’726.-)
  - Cooling : 595’025m3 (CHF 141’043.-)

**Total Energy & Fluids : CHF 764’591.-**

# CMI CAPITAL INVESTMENT

- Processing Equipment

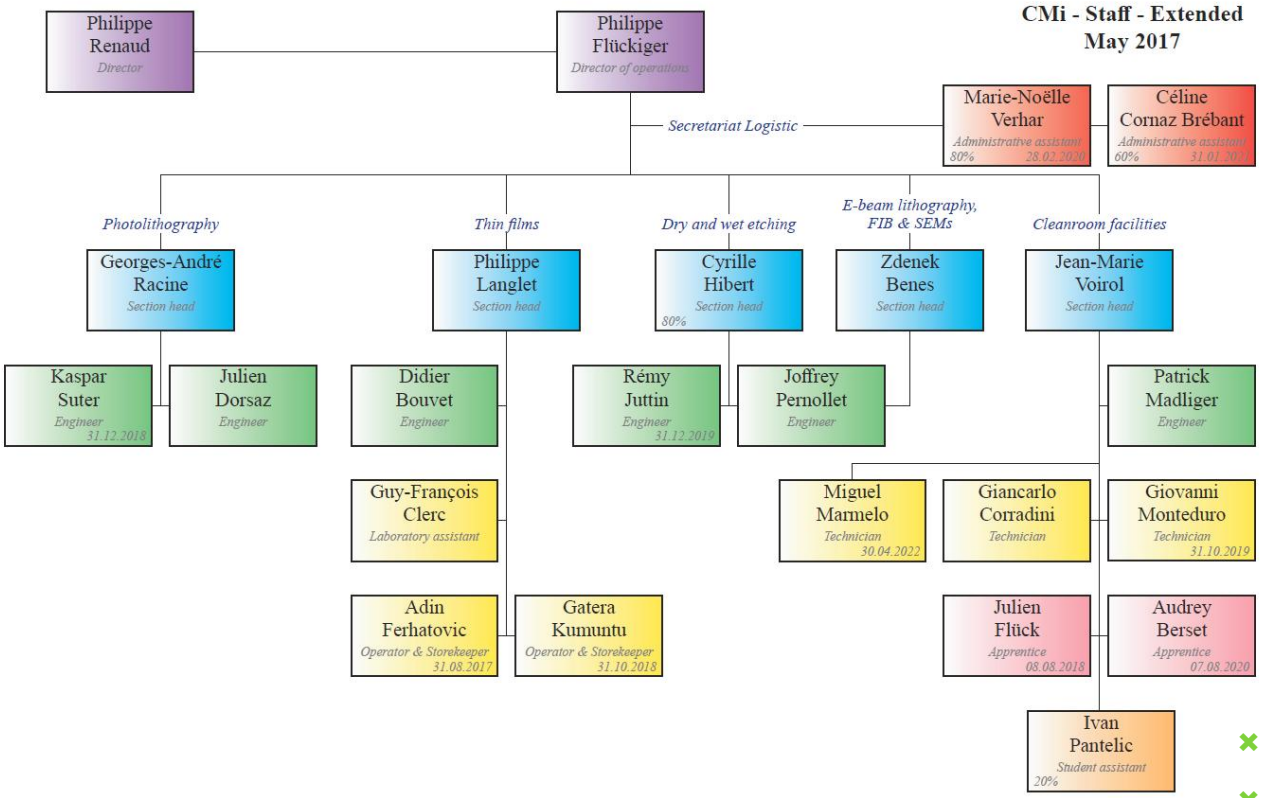
| | |
|---|---|
| Scientific Equipment Level -1 | 28 MCHF |
| Scientific Equipment Level +1 | 3 MCHF |
| **Total** | **31 MCHF** |

- Cleanroom Infrastructures

| | |
|---|---|
| Cleanroom Infrastructures Level -1 | 12 MCHF |
| Cleanroom Infrastructures Level +1 | 7 MCHF |
| **Total** | **19 MCHF** |

- Total 50MCHF

# THE STAFF



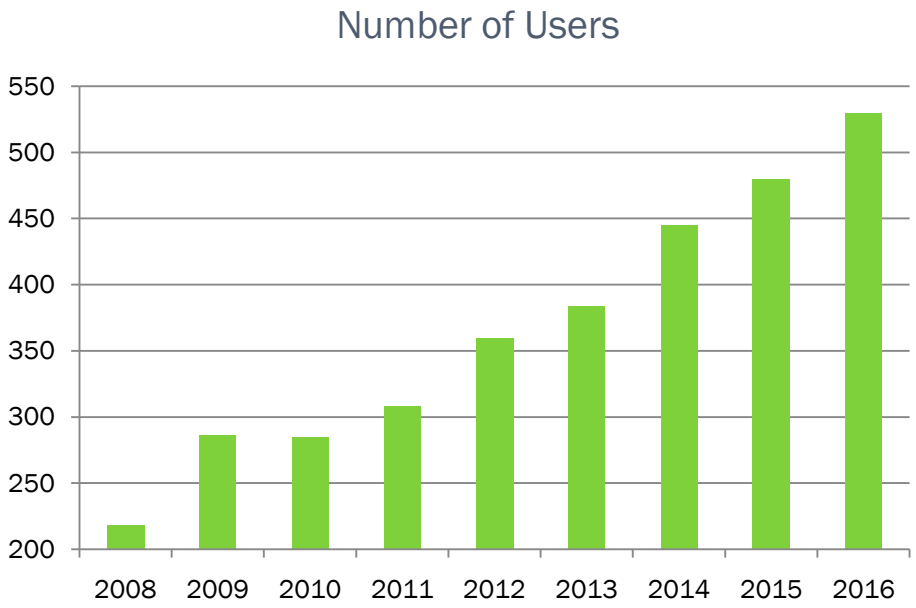

- 19.2 FTE staff members
- + Student assistants
- + Apprentices

# USERS IN 2016

| EPFL Engineering Sc. | | Basic Sc. | Life Sc. | Ext. Ac. | Companies | |
|---|---|---|---|---|---|---|
| CMi | STI-IMT-LMIS2 | SB-CMNT-GE | SV-GHI-UPKIN | EXT-CERN | EXT-Aleva | EXT-SilMach |
| STI-IBI-BIOS | STI-IMT-LMIS4 | SB-IPHYS-GCMP | SV-IBI-LDCS | EXT-CSEM-T1 | EXT-Asulab | EXT-SwissTo12 |
| STI-IBI-CLSE | STI-IMT-LMTS | SB-IPHYS-LASPE | SV-IBI-LLCB | EXT-CSEM-T3 | EXT-Bruker | EXT-Synova |
| STI-IBI-LBEN | STI-IMT-LO | SB-IPHYS-LOEQ | SV-IBI-LMRP | EXT-CSEM-Mut. | EXT-Colibrys | EXT-TESCAN |
| STI-IBI-LBNC | STI-IMT-LOB | SB-IPHYS-LPMC | SV-IBI-UPDEPLA | EXT-EMPA | EXT-Efficonseil | EXT-Tronics |
| STI-IBI-LBNI | STI-IMT-LPMAT | SB-IPHYS-LPMV | SV-IBI-UPLUT | EXT-ETHZ | EXT-EXALOS | EXT-ValFleurier |
| STI-IBI-LHTC | STI-IMT-LSBI | SB-IPHYS-LPN | SV-IBI-UPNAE | EXT-HEIG-VD | EXT-Hamamatsu | |
| STI-IBI-LNE | STI-IMT-NAM | SB-IPHYS-LPQM1 | SV-ISREC-CDTSO | EXT-HESGE | EXT-Hightec | |
| STI-IEL-GR-SCI | STI-IMT-NE-PV-LAB | SB-IPHYS-LUMES | SV-PTBIOEM | EXT-HESNE | EXT-Intel | |
| STI-IEL-LANES | STI-IMT-OPT | SB-ISIC-LCPM | | EXT-Bucharest | EXT-Karmic | |
| STI-IEL-LEMA | STI-IMT-PV-LAB | SB-ISIC-LEPA | | EXT-Inst-Pasteur | EXT-LémanMicro | |
| STI-IEL-LSI2 | STI-IMX-FIMAP | SB-ISIC-LND | IC-IINFCOM-LSI1 | EXT-Belo-Horiz. | EXT-LESS_SA | |
| STI-IEL-LSM | STI-IMX-LC | SB-ISIC-LPI | | EXT-UNIBE-Phys. | EXT-LSPR | |
| STI-IEL-NANOLAB | STI-IMX-LMGN | SB-ISIC-LSCI | ENAC-IIC-LESO-PB | EXT-UniFribourg | EXT-Lunaphore | |
| STI-IEL-PHOSL | STI-IMX-LMM | SB-ISIC-LSPM | | EXT-UNIGE-GAP | EXT-Mackinac | |
| STI-IEL-POWERLAB | STI-IMX-LMOM | SB-ISIC-LSU | | EXT-UNIGE-Sugi. | EXT-Meister-Abrasive | |
| STI-IGM-LRESE | STI-IMX-LMSC | SB-SPC-PP | | EXT-UNIL | EXT-Morphotonix | |
| STI-IGM-MICROBS | STI-IMX-LP | | | EXT-Wyss_Cent | EXT-Nanoworld | |
| STI-IMT-ESPLAB | STI-IMX-LTP | | | | EXT-Novagan | |
| STI-IMT-GR-LVT | STI-IMX-SMAL | | | | EXT-Piemacs | |
| STI-IMT-GR-QUA | STI-IMX-SUNMIL | | | | EXT-Qwane | |
| STI-IMT-LAI | STI-SCI-CD | | | | EXT-Rolex | |
| STI-IMT-LAPD | STI-SCI-PM | | | | EXT-Samtec | |
| STI-IMT-LMIS1 | | | | | EXT-Sigatec | |
| 342 (47) | | 65 (17) | 37 (11) | 40 (18) | 46 (30) | |

- Total: 530 users (+10%) operating the CMi tools
- Total: 123 labs or companies (+23%)

# USERS IN 2016



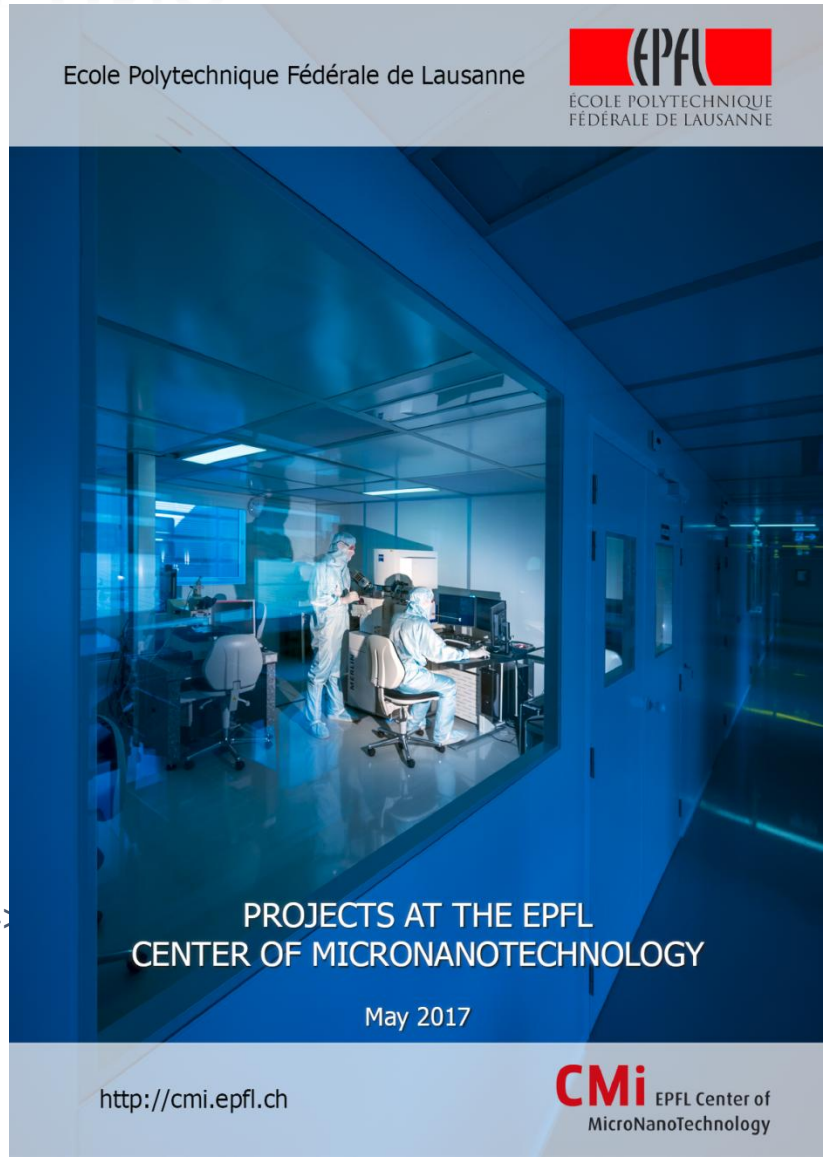

Nanofabrication plays an increasing role in modern science.

- The number of Users is steadily increasing at an average rate of 12% per year since 2008
- Our prevision is to maintain the growth rate at around 10% per year for the next 5 years (new labs)

# ANNUAL REVIEW MEETING

- 18th edition on May 2nd 2017
- More than 488 participants
- 203 abstracts

- Global companies
- Local industry
- Startups
- Many Suppliers
- Government Agencies
- Researchers
- Faculties
- Other academic cleanrooms
- -> Traveling from over 15 countries

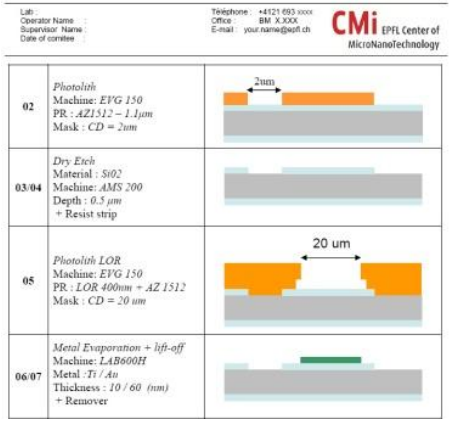


# BECOME A MEMBER

## Procedure to access the cleanroom

### 1. Cleanroom Introduction Course (0.5 day)

- Formal presentation of CMi facilities and CMi rules
- Cleanroom visit
- Email from CMi secretary (username, password, process flow template)




### 2. Process Flow

- You send a process flow or a draft to infocmi@epfl.ch
- Process flow review with a technical committee (with CMi engineers, advices on design and process, training plan on equipment)

### 3. Start working in the cleanroom

- Trainings
- Rights to book equipment
- Work on your own following a process flow

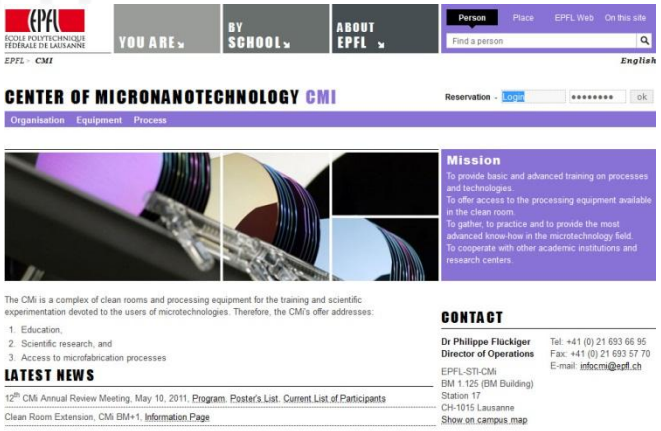
  (reservation, login, processing, logout…)

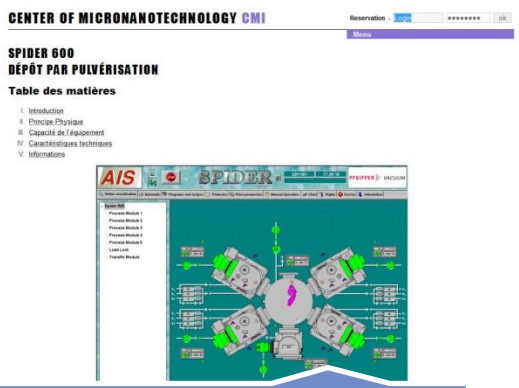
# BECOME A MEMBER

**CMi Website**

**CMi website tour :**

http://cmi.epfl.ch/




Equipment user manual


Equipment reservation


Material ordering…

# FEES

- Since October 1st 2016
- **No** more **cap** per user and per month (previously CHF 1600.- / academic user / month)
- **No** more **free access** (for master & semester projects)
- 18 categories of tools (instead of uniform price per tool) :
  - with fees ranging from 20.- to 126.- CHF/h for internal EPFL Users
  - with fees ranging from 21.- to 171.- CHF/h for External Academic Users
  - with fees ranging from 30.8 to 323.40 CHF/h for Industrial Users

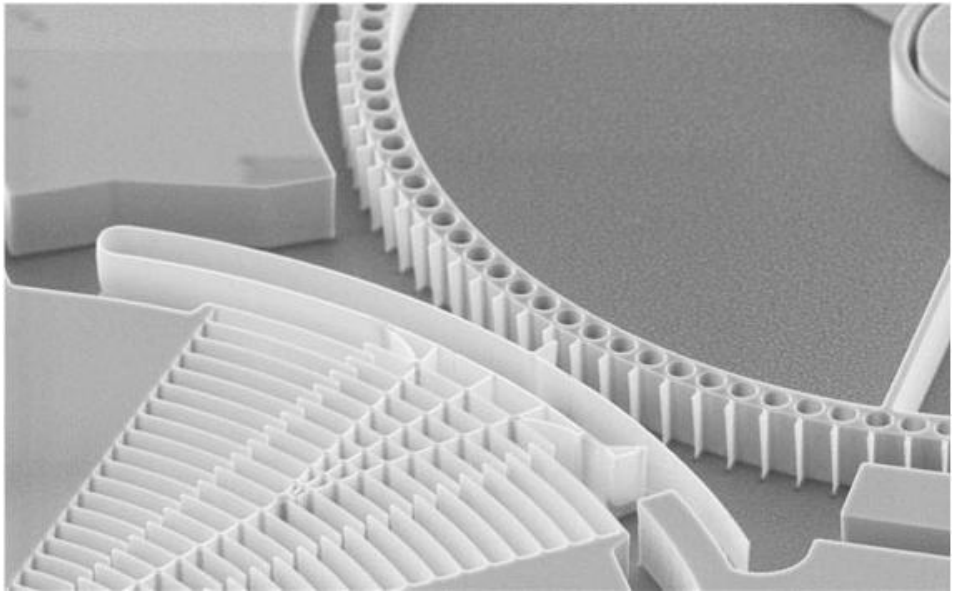
- In general new system cheaper for occasional users and more expensive for heavy users

- Globally no budget change for the operations of the CMi


# CMi cleanroom technologies tour

# CMi cleanroom technologies tour

- Lithography
  - Ebeam lithography
  - Photo lithography
- Thin Films
- Etching
- Misc. Processes
- Metrology
- Some examples

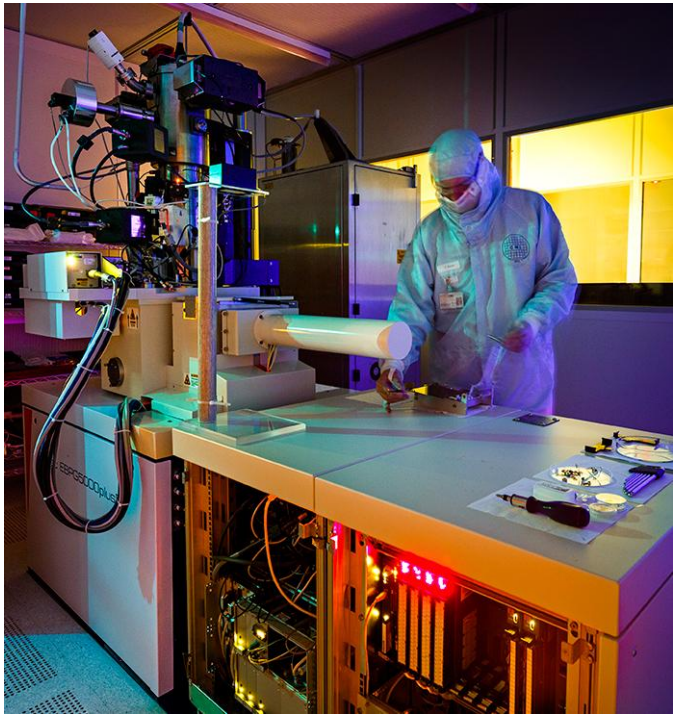


Courtesy of Silmach SA (Besançon)

# Ebeam Lithography

**Key Features:**

- 100keV Thermal Field Emission Gun
- High Resolution Gaussian Beam System
- 50MHz Intelligent Pattern Generator
- 1.25nm minimum pixel size
- Robust Direct Write Mark Detection & Alignment Software
- 2 position load lock for batch processing of multiple substrates
- Holders for 50mm, 100mm, 150mm wafers and smaller piece parts
- Housed in a custom cleanroom which maintains a temperature of 21°C ± 0.1°C



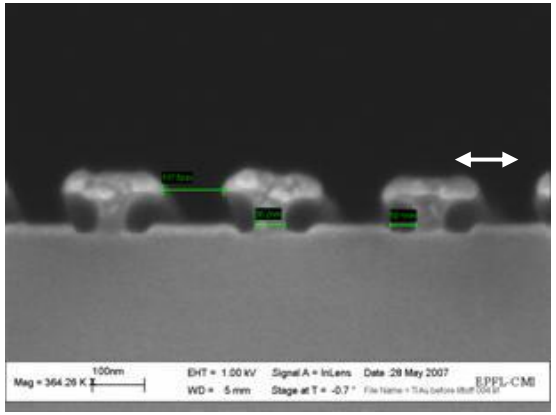
# Ebeam Lithography: resist

**Positive tone:** MMA, PMMA, ZEP
*(what gets exposed is removed in develop)*

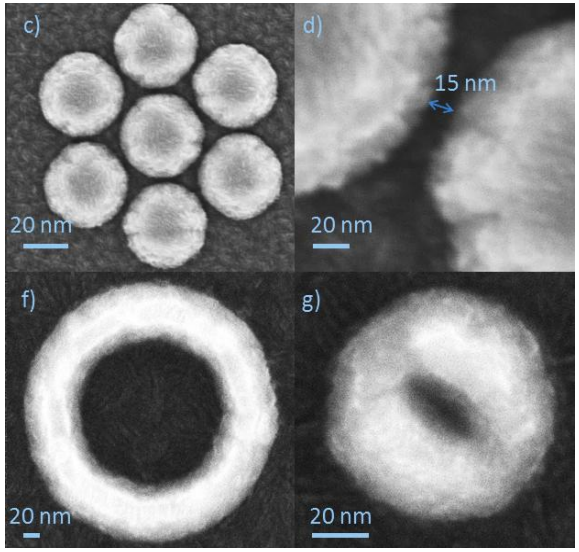
**Negative tone**: HSQ, nlof
*(what gets exposed stays,
the rest gets removed in develop)*

**Resists for lift-off:** MMA, PMMA
*(typical use, but used for etching for specific applications)*

**Resists for etching:** ZEP, HSQ, nlof
*(typical use, but used for lift-off for specific applications)*




100nm lines after development of MMA/PMMA bilayer. Metalised with 5nm Ti and 15 Au




Au dots direct etch with HSQ mask

*Courtesy of B. Abasahl*

# Photo Lithography: coating / development

- Automatic coating & development tools:

  ***EVG150, Ritetrack 88, ACS200***

- Manual coaters:

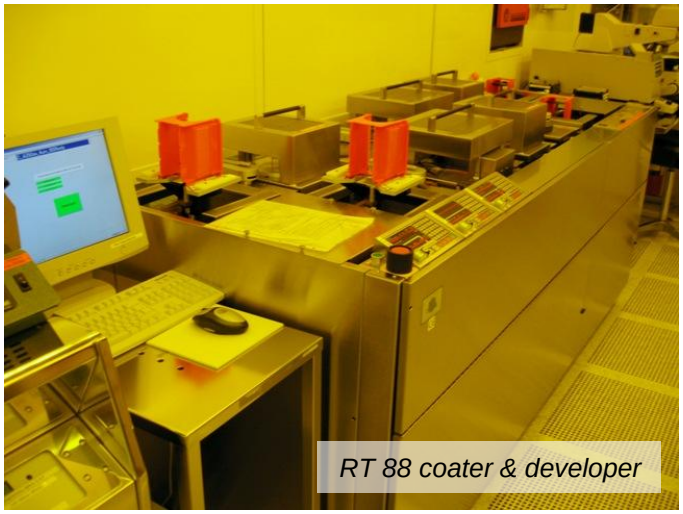
  ***Sawatec LSM 200/250,***
  ***SSE SB20, Karl Süss RC-8***

- Developer station:

  ***Karl Süss DV10***

- HMDS priming, Dehydration


EVG 150 coater & developer


RT 88 coater & developer

# Photo Lithography: exposure

- 2 Direct LASER lithography

  ***Heidelbergh VPG200 & DWL200***

- 2 Broadband mask-aligners

  ***Karl Süss MA/BA6 & MA150***

- I-line mask-aligner (Su8 soft lithography):

  ***Karl Süss MJB4***

*MJB4 mask-aligner*

*MA/BA6 mask-aligner*


*Heidelberg VPG200 Laser writer*

| Write Mode | 0 | I | II | III | IV |
|---|---|---|---|---|---|
| Minimum structure size [µm] | 0.6 | 0.75 | 1 | 2 | 4 |
| Write time for 100x100mm² [min] | 210 | 38 | 12 | 4 | 2 |

# Photo Lithography: thin PR

- Thin positive resists (wet etch & high resolution):

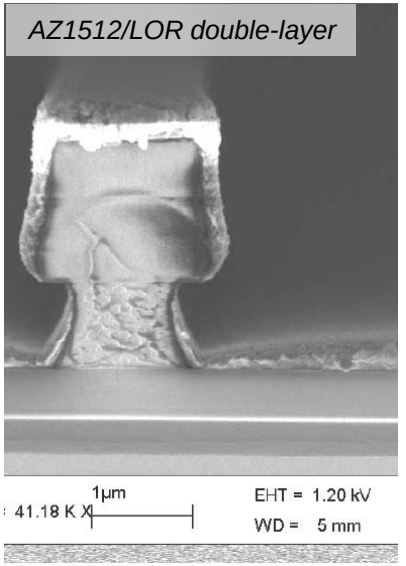
  ***AZ1512, AZECI3007***

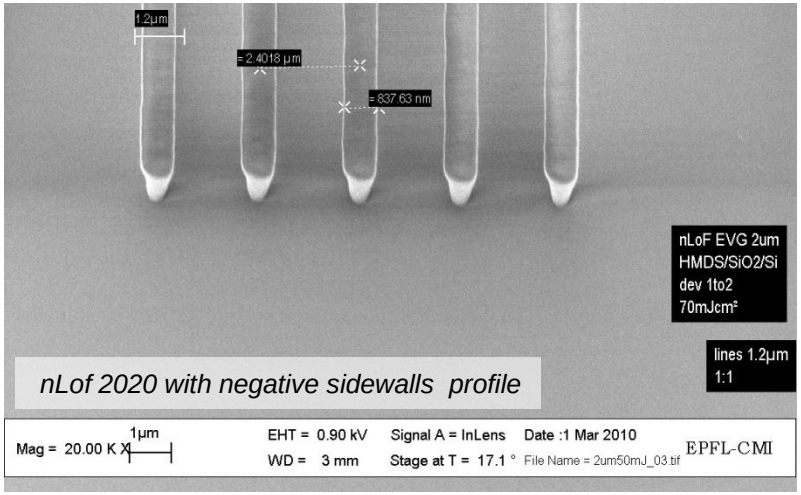
- Negative (liftoff):

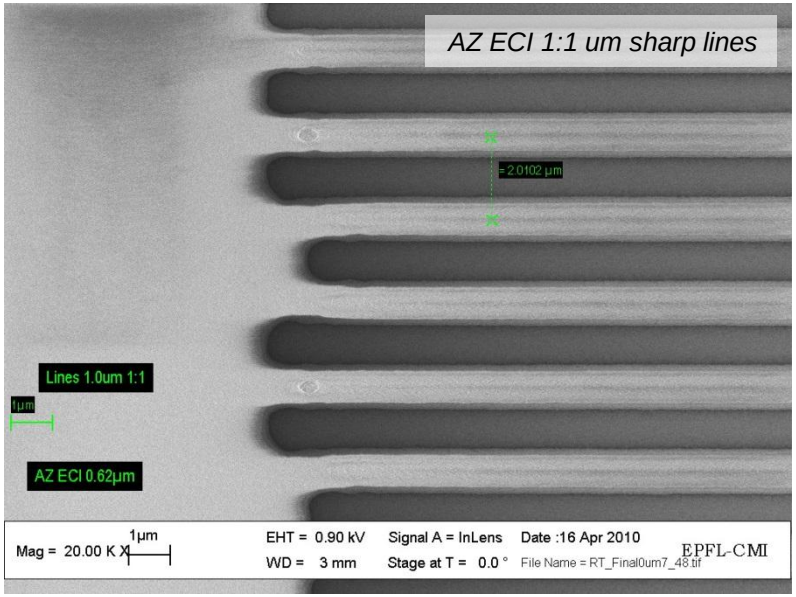
  ***AZ nLof2020***

- Sacrificial (double-layer liftoff):

  ***LOR 5A***



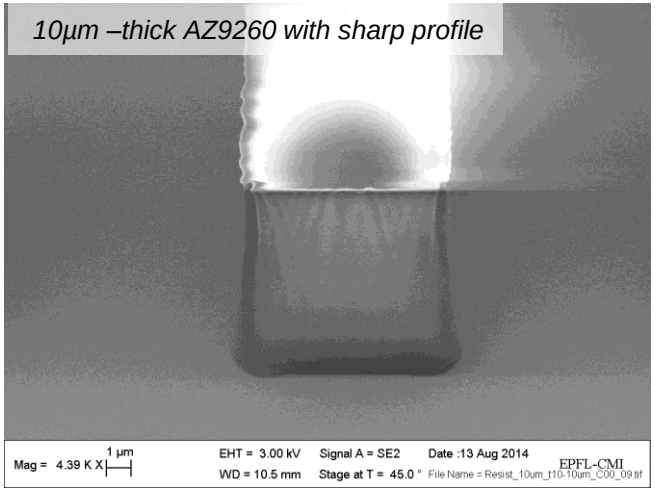
# Photo Lithography: thick PR

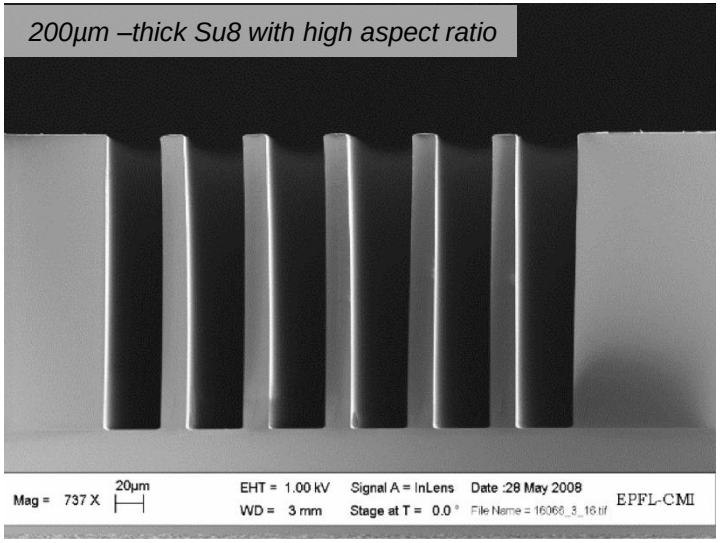
- Thick positive resists (dry etching & galvano):

  ***AZ9221, AZ9260***
  ***AZECI 3027***

- Thick negative Su8 resist:

  ***Gersteltec GM series***
  ***MCC 3000 series***



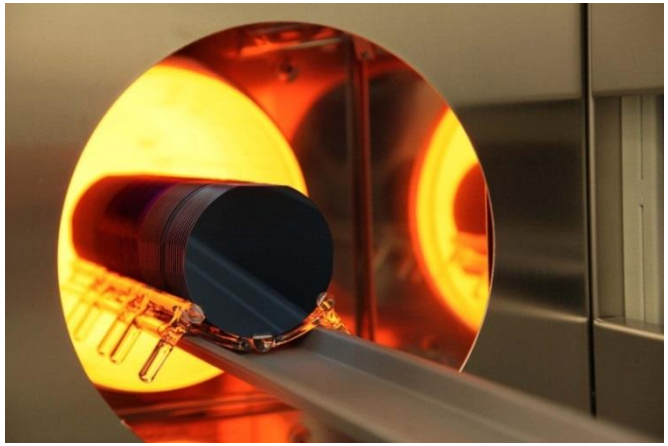
# Thin Films: Furnaces

LPCVD: aSi, PolySi ; $Si_3N_4$ ; Low stress SixNy ; LTO, BPSG

Doping $POCl_3$ & dopant diffusion: up to 1250°C

Oxidation: dry and wet

Annealing: forming gas ($H_2$)

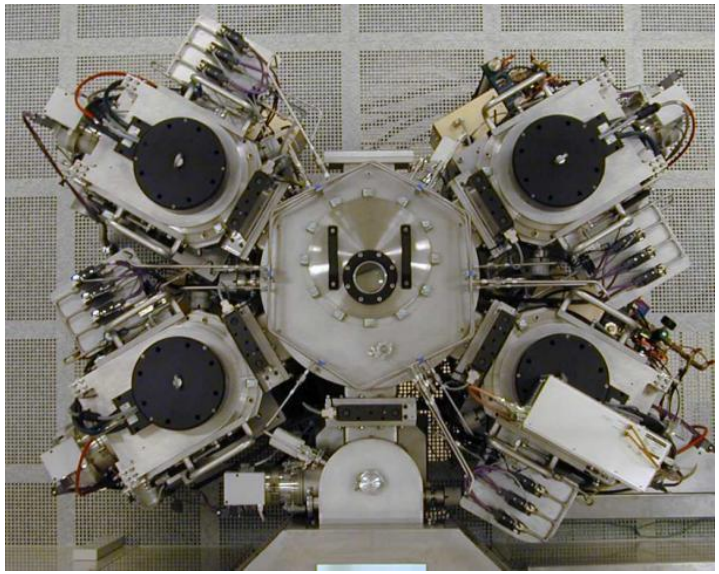


# Thin Films: PVD materials available

| LAB 600 H | EVA 600 | EVA 760 | Vaco 250 | Spider 600 | DP 650 | BAS 450 |
|---|---|---|---|---|---|---|
| Ag | Ag | Al | Ag | Al | Ag | Al |
| Al | Al | Au | AgCl | Al:Si 1% | Al | Al:Si 0.5% |
| $Al_2O_3$ | Au | Cr | Al | Al:Si 2% | Al:Si 1.0% | Al:Si 0.8% |
| Au | Bi | Ti | Au | Al:Si 4% | Au | Al:Si 1.0% |
| Cr | Co | | Bi | $Al_2O_3$ | Cr | Al:Si 1.2% |
| Ge | Cr | | Cr | AlN | Cu | Al:Si 1.5% |
| In | Cu | | Cu | AlScN | IGZO | Al:Cu:Si 4%,1% |
| ITO | Fe | | In | $GeO_2$ | Mo | Au |
| $La_2O_3$ | Ni | | $MoO_3$ | ITO | Ni | Cr |
| MgO | NiCr 19% | | | MgO | Pd | Cu |
| Mo | NiFe 19% | | | Mo | Pt | Hf |
| Nb | Sn | | | Nb | Si | Mo |
| Ni | Ti | | | Pt | Ta | Nb |
| NiFe 19% | Y | | | Ru | TaN | Pd |
| Pd | | | | $RuO_x$ | Ti | Pt |
| Pt | | | | Si | TiN | Sb |
| $SiO_2$ | | | | $SiO_2$ | $TiO_2$ | Ta |
| Ta | | | | Ta | W | Ti |
| Ti | | | | $Ta_2O_5$ | W:Ti 10% | W |
| $Ti_2O_3$ | | | | Ti | | $WSi_2$ |
| $Ti_3O_5$ | | | | TiN | | W:Ti 10% |
| Y | | | | $TiO_2$ | | Zr |
| $Y_2O_3$ | | | | $TiO_x$ | | $SiO_2$ |
| $ZrO_2$ | | | | $V_2O_5$ | | Si |
| | | | | W | | $TiO_2$ |

# Thin Films: Sputtering

- BAS 450
- SPIDER 600
- DP 650



# Thin Films: Evaporation

- EVA600
- LAB600
- EVA760

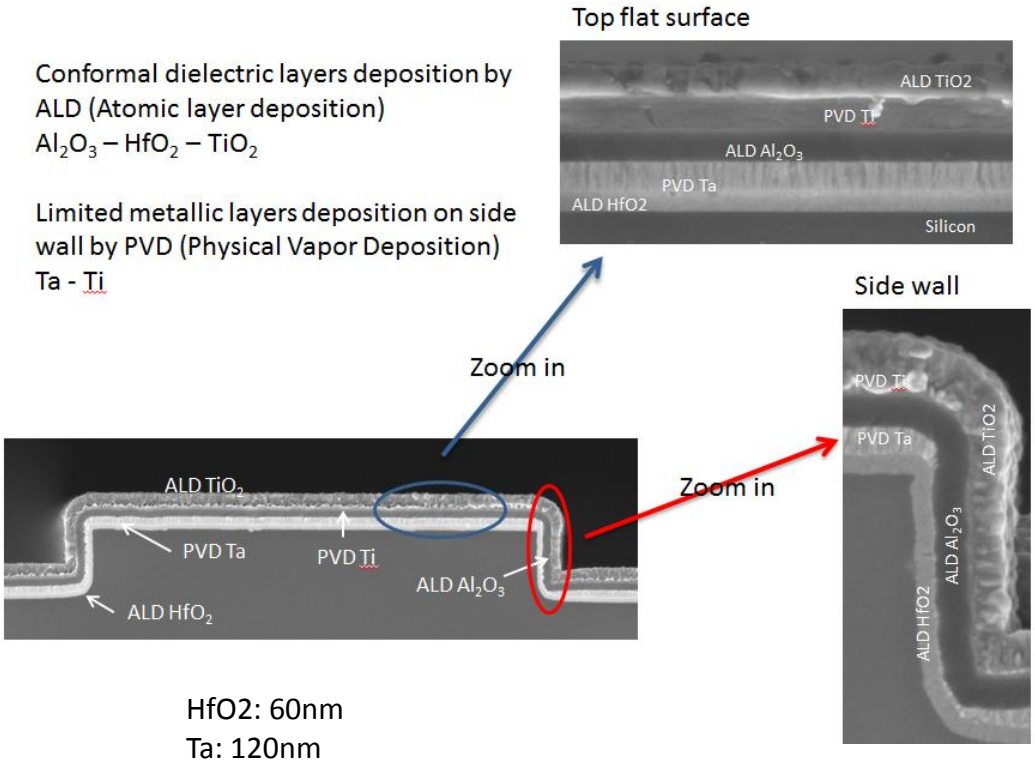

# Thin Films: ALD Beneq TFS200


Available layers:

- $Al_2$
- Hf
- $TiO_2$
- Pt
- Ru (on request)
- AlN (on request)

Conformal dielectric layers deposition by ALD (Atomic layer deposition)
$Al_2O_3$ – $HfO_2$ – $TiO_2$

Limited metallic layers deposition on side wall by PVD (Physical Vapor Deposition)
Ta - Ti

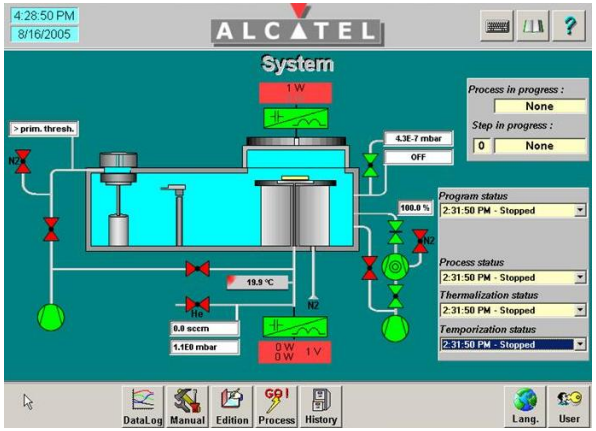


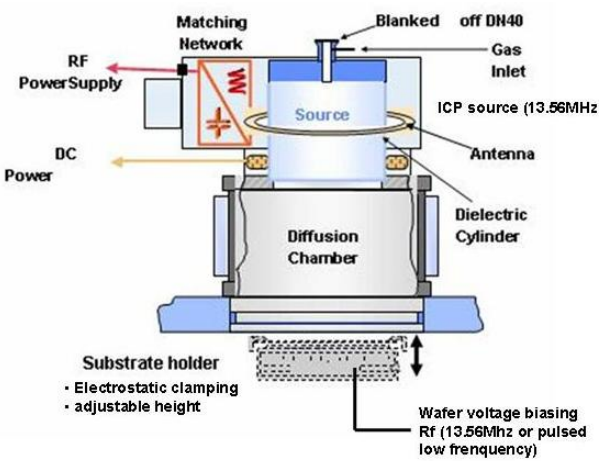

HfO2: 60nm
Ta: 120nm
Al2O3: 100nm
Ti: 90nm
TiO2: 85nm

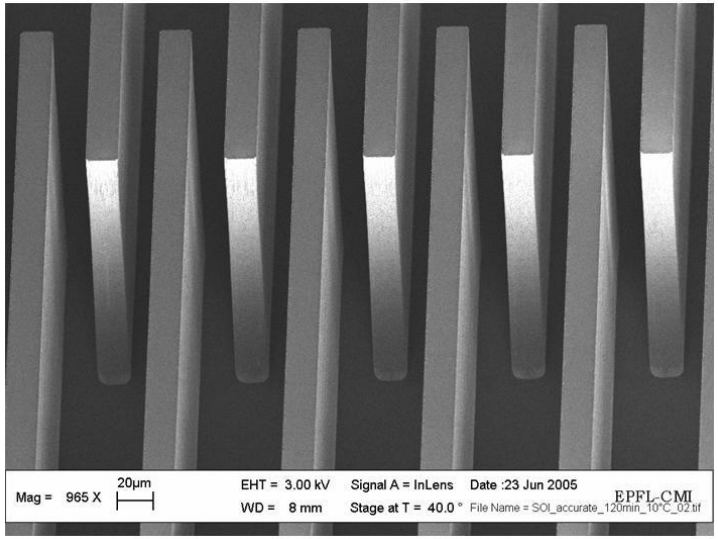
# Plasma Etching and IBE

- STS Multiplex ICP (1997): metal etcher
- TEL  Unity Me (2017 refurbished): DRM (100sccm), SCCM (200mm)
- AMS200 (2005): DRIE etcher (SOI, high AR, low ARDE)
- SPTS APS (2012): new dielectric etcher
- VEECO IBE NEXUS 350 (2013)

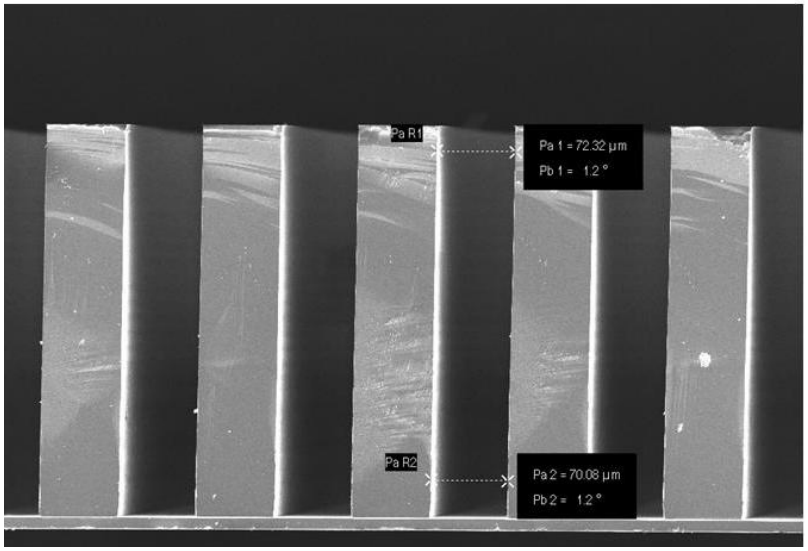
# Silicon Etching with Fluorine chemistry (Adixen AMS200)



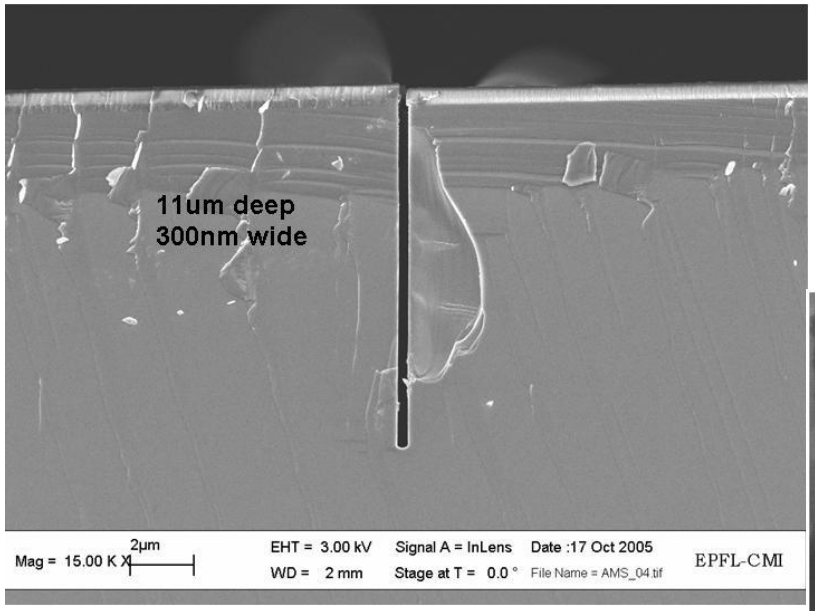




SOI 200um deep

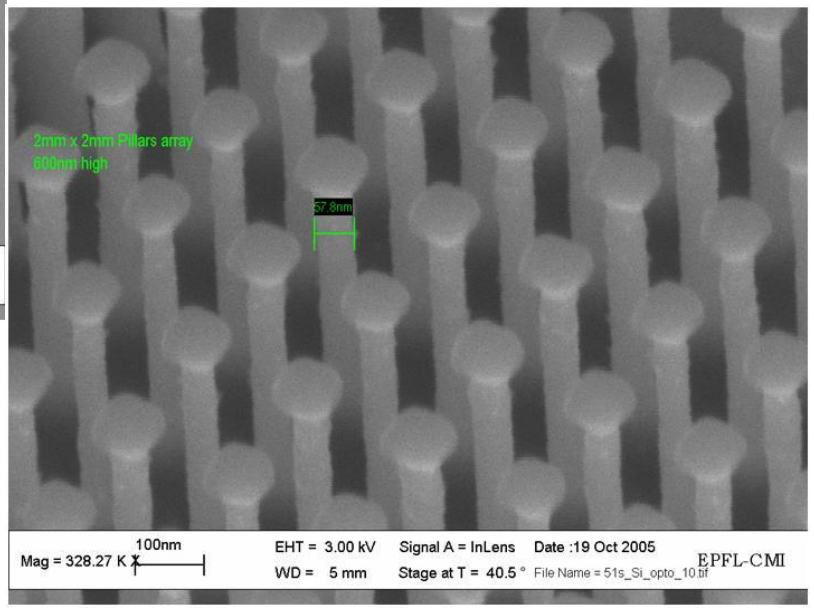



SOI 400um deep

# Silicon Etching with Fluorine chemistry (AMS200)

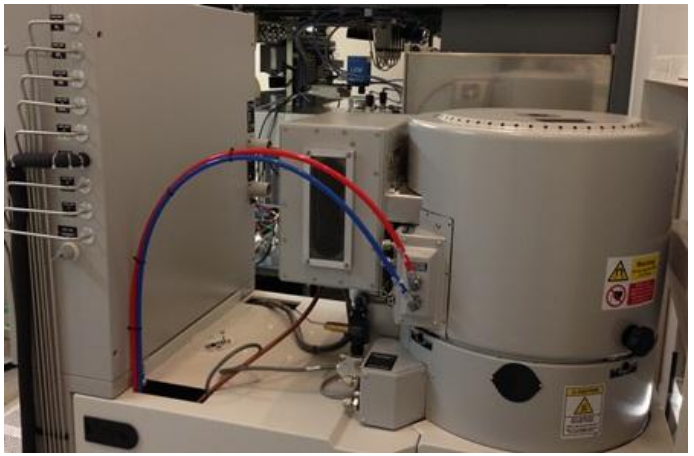


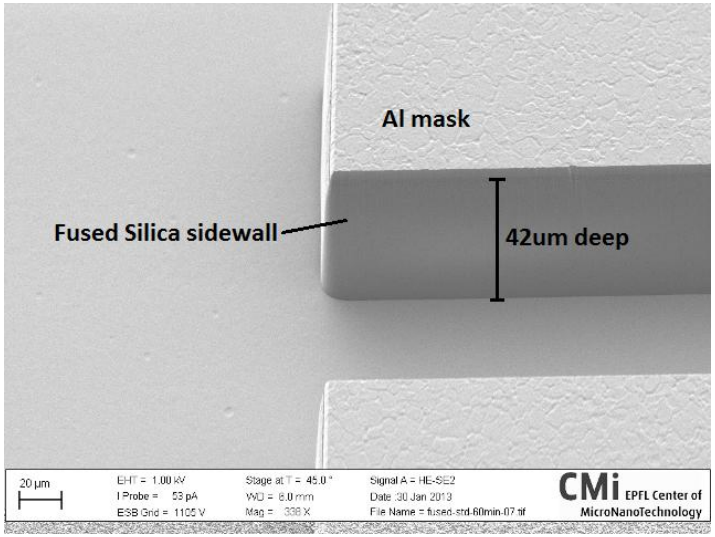

High AR etching (37:1)
of submicron features



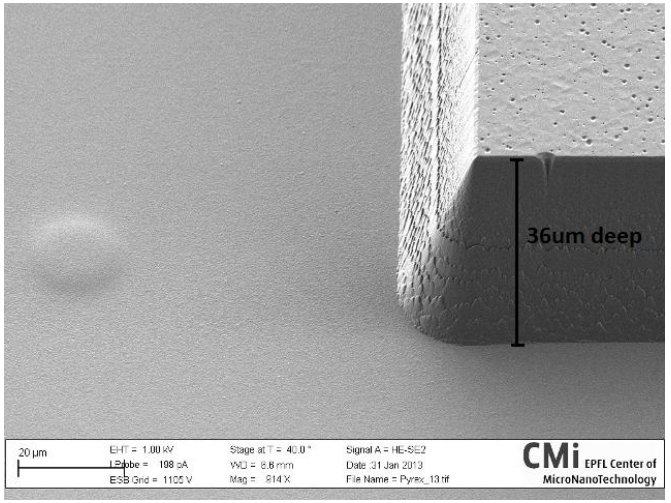

Nanopillars in Si (57nm diam. 600nm high)

# Dielectric Etching (SPTS APS)

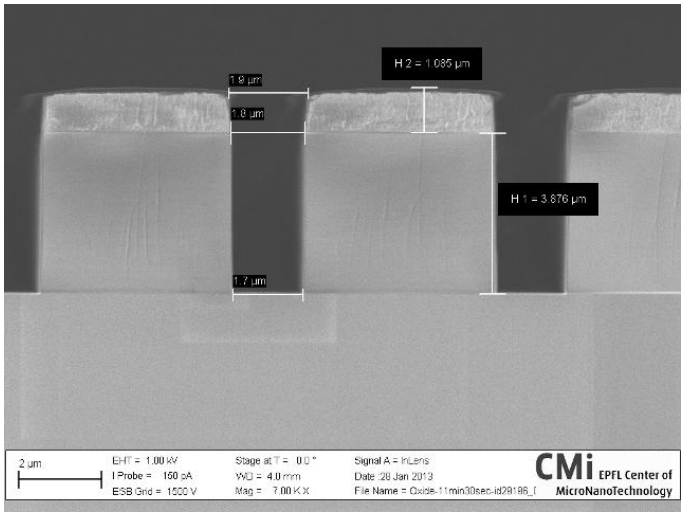



Deep Fused silca etching

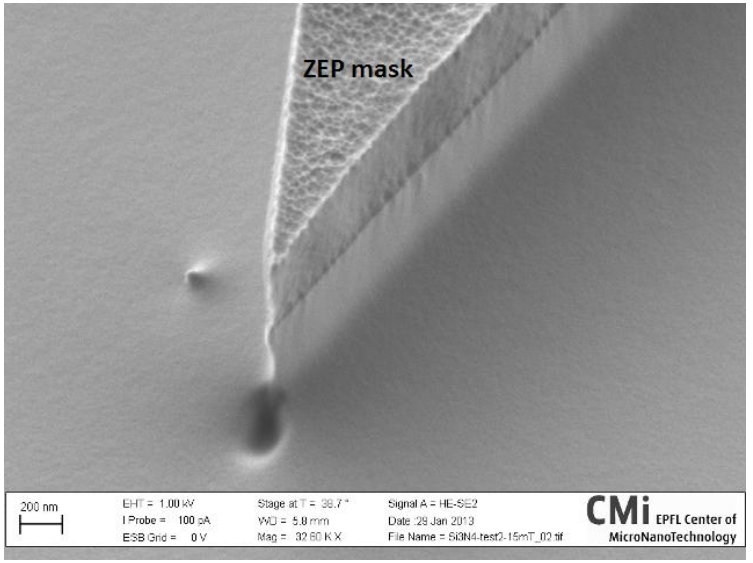



Deep Pyrex etching

# Dielectric Etching (SPTS APS)

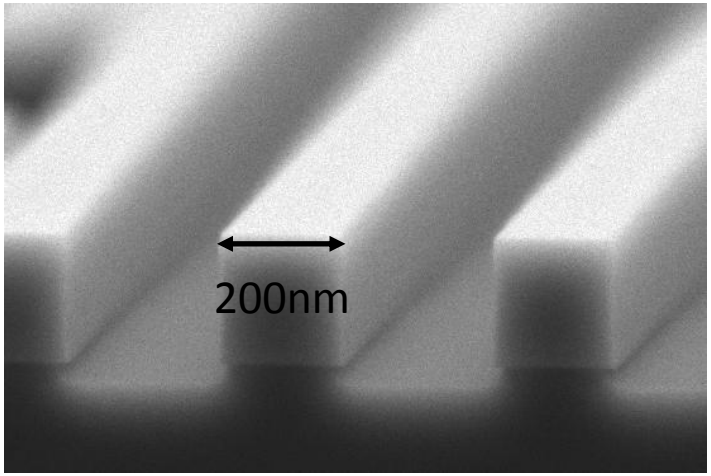



SiO2 etching on Si with PR mask

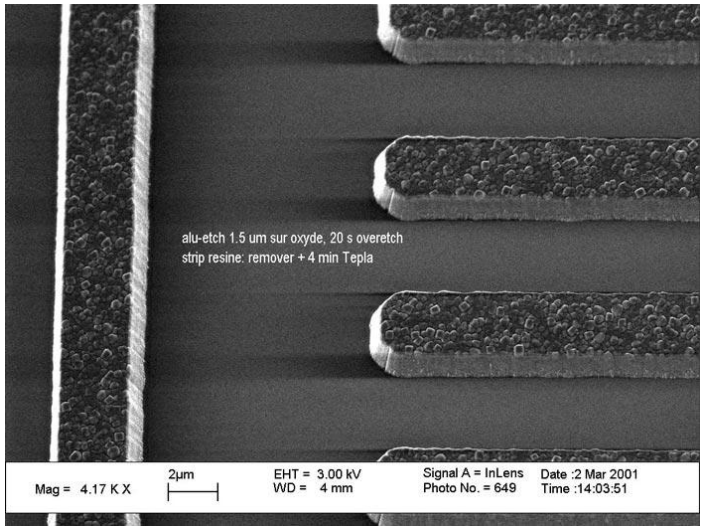



Smooth Si3N4 etching with ZEP resist

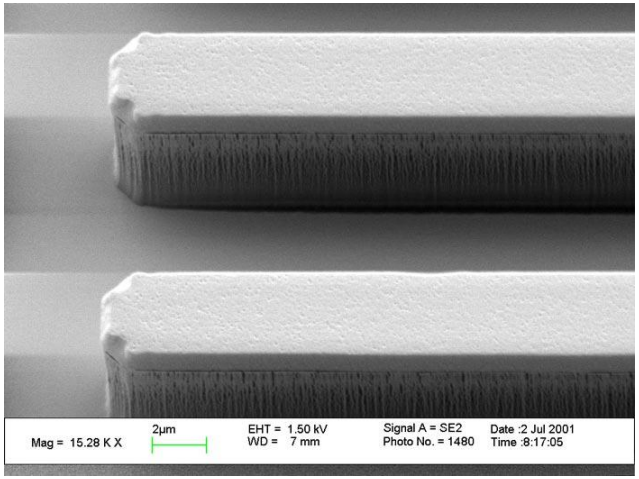
# RIE etching (STS Multiplex ICP)




Si submicron features (HBr/O2)




Al etching (Cl2/BCl3)




Polyimide deep etching (O2)

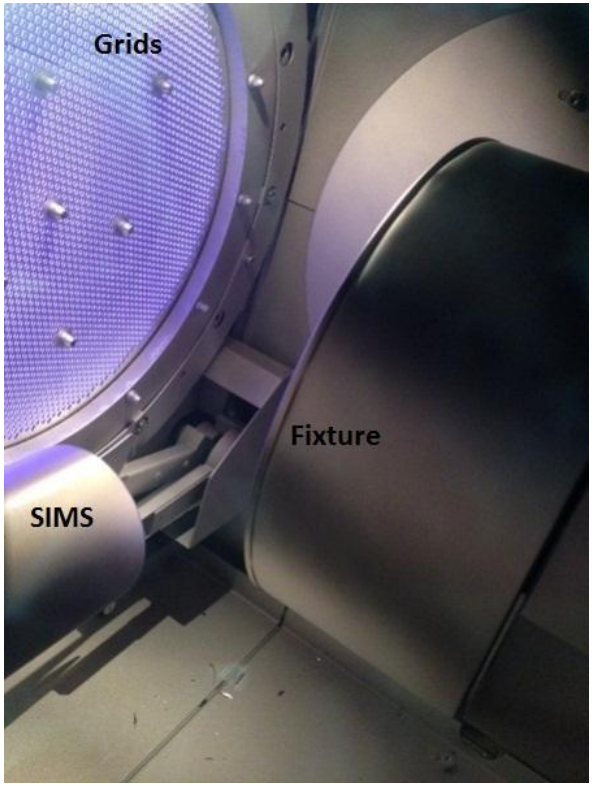
# IBE etching (Veeco Nexus IBE 350)

- Etch accuracy: adjustable ER + shutter
- ER uniformity: less than 2% (100mm wafers, 49 points, 8mm edge exclusion)

CONFIDENTIAL

Veeco Standard Parameters – 5-zone grids

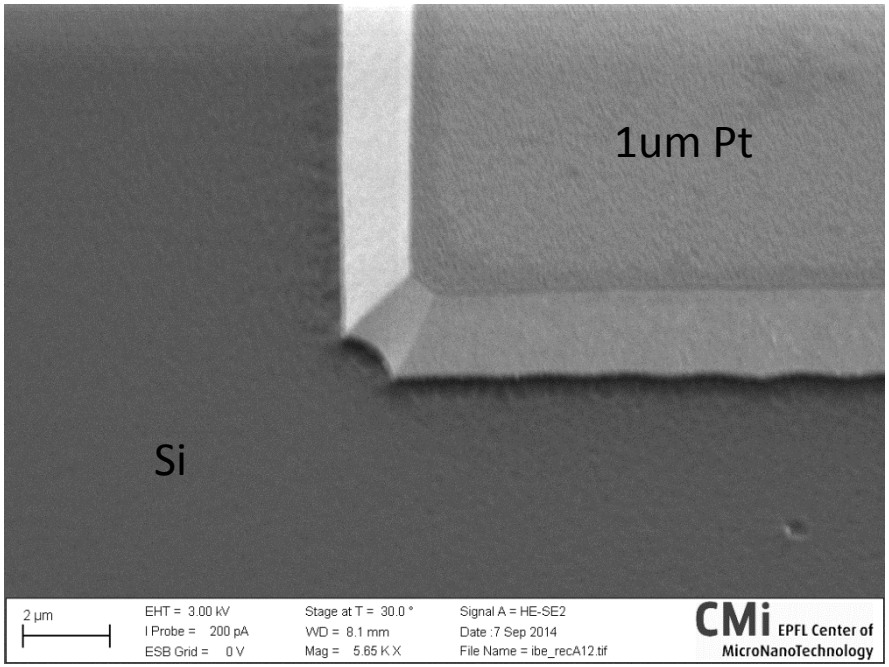
| Beam Voltage (V) | Beam Current (mA) | Suppressor Voltage (V) | Ib/(Vb+Vs)^3/2 |
|---|---|---|---|
| 170 | 350 | 400 | 0.026 |
| 300 | 500 | 400 | 0.027 |
| 500 | 800 | 400 | 0.030 |
| 700 | 1100 | 400 | 0.030 |
| 800 | 1200 | 400 | 0.029 |



# IBE etching (Veeco Nexus IBE 350)

| Etch Rates of Common Materials utilizing 700 eV Ar ions (1.2 mA/cm2) at Normal Incidence | |
|---|---|
| Material | Etch Rate (Angstroms / Minute) |
| Au | 3036 |
| Pt | 1310 |
| Cu | 1666 |
| Al | 1063 |
| Ti | 404 |
| TiW | 613 |
| Cr | 808 |
| $Al_2O_3$ | 323 |
| NiFe (81/19) | 852 |
| TiN | 388 |
| Photoresist (AZ) | 480 |
| PZT | 500 |
| Si | 750 |
| $SiO_2$ | 720 |
| Ta | 535 |
| GaAs | 1800 |
| Ag | 3000 |
| PtMn | 1390 |

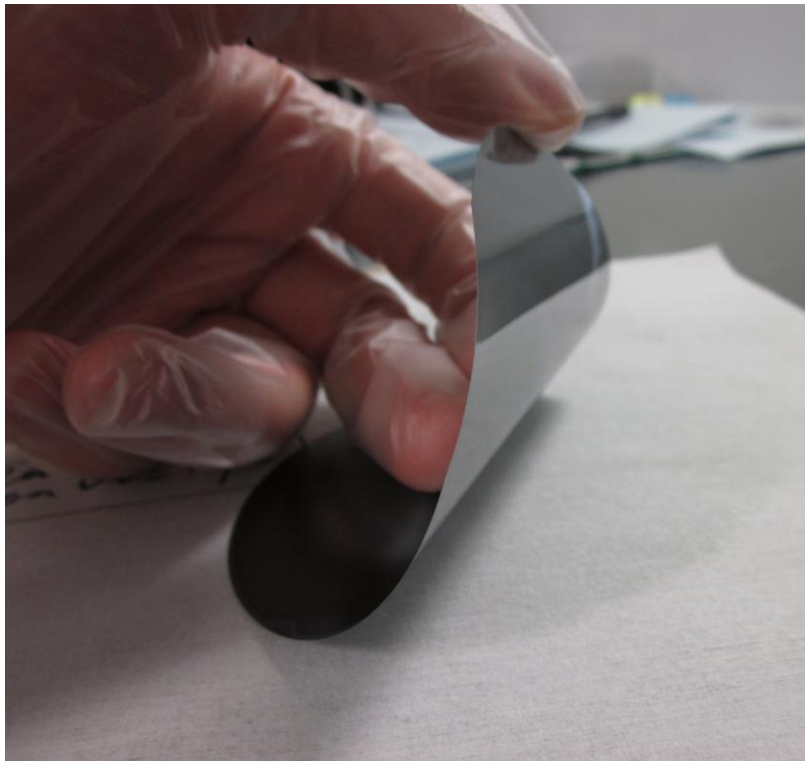
Wide variety of material




Thick Pt etch in IBE

# Misc processes

- Grinding / CMP
- FIB
- Parylene
- Electroplating
- PDMS



50um thick Si wafer after grinding

# **Misc processes:** Grinding / CMP

CMi EPFL Center of MicroNanoTechnology **GRINDING REQUEST**

date of request :

**CONTACT INFORMATION:**

Name :

Lab or Organization :

email :

☐ I would like to be present during the process and/or to hand over my wafers personally.

**GRINDING SPECIFICATIONS:**

Material to be ground : Silicon, GaN, PZT, Glass (fused silica), SiC, Al2O3, Si3N4

Part type : Part type : Wafer, Chip(s), Other

Quantity :

UV tape : ○ Yes

Desired thickness :

Size in mm :

Initial thickness :

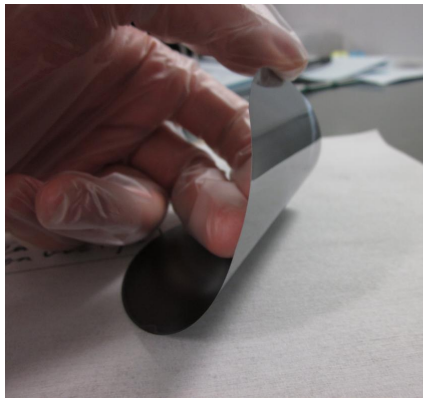
LITY:

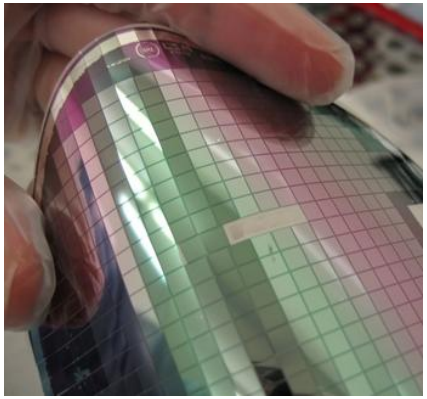
Grinding amount :

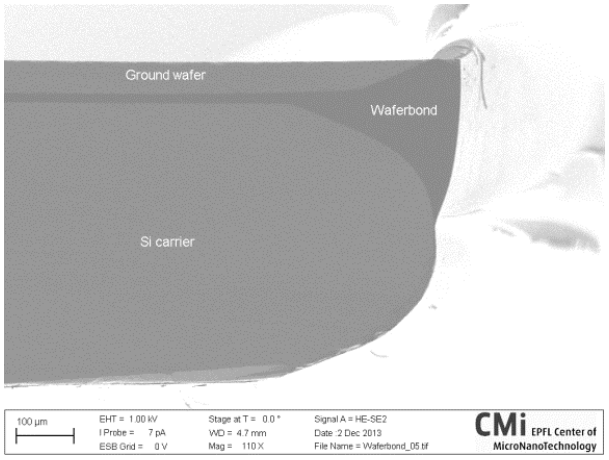
☐ Thursday afternoon

Comments / remarks

Contact : Tiago Morais (tiago.morais@epfl.ch)
Cyrille Hibert (cyrille.hibert@epfl.ch)
Joffrey Pernollet (joffrey.pernollet@epfl.ch)
Anthony Guillet (anthony.guillet@epfl.ch)



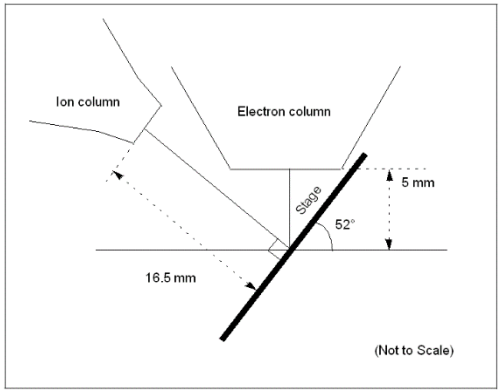


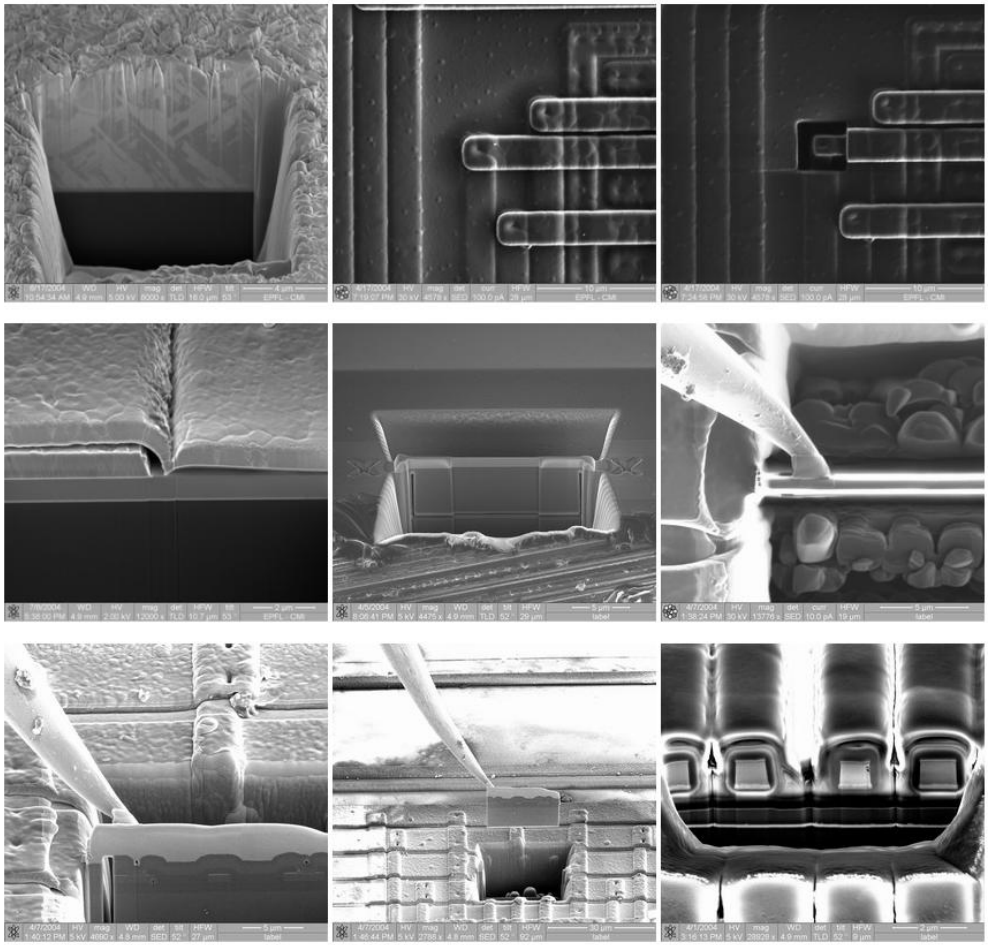



1. Variety of material
2. Variety of sample size
3. High rate (30 to 60um/min)
4. Possibilty to combine with CMP to polish

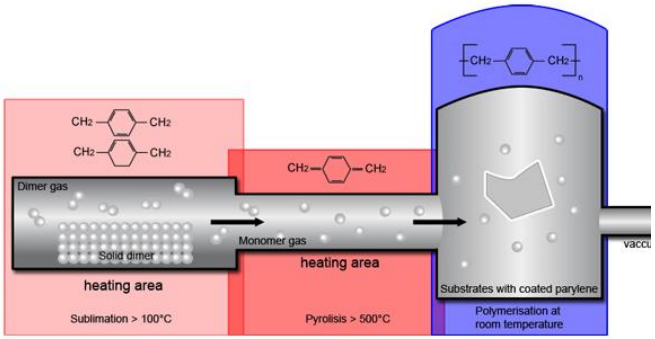
# **Misc processes:** FIB FEI Nova 600

Cross-sections
Lamellas for TEM
Chip repair
Direct patterning



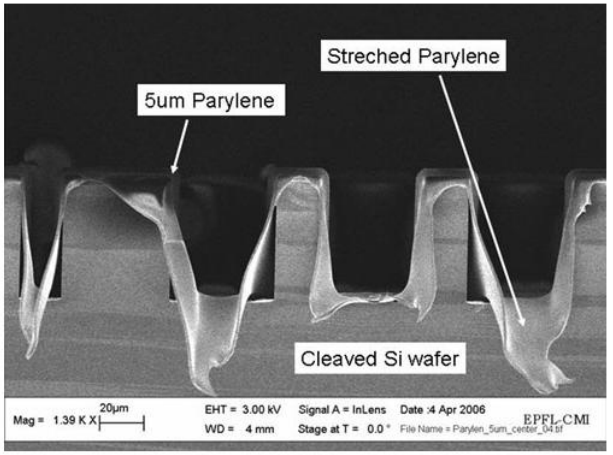
# **Misc processes:** Parylene




Parylene coating principle (Courtesy of www.comelec.ch)

Parylene front panel, 10 slots holder and processing chamber

1. Stop layer
2. Fonctional layer
3. Bonding layer
4. Sealing layer
5. Biocomp, Room T, conformal…
6. Any shape can be coated…
7. More than 50 projects rely on parylene




2: Parylene conformal coating in deep Si cavities. Parylene is delaminated after sample cleavage.

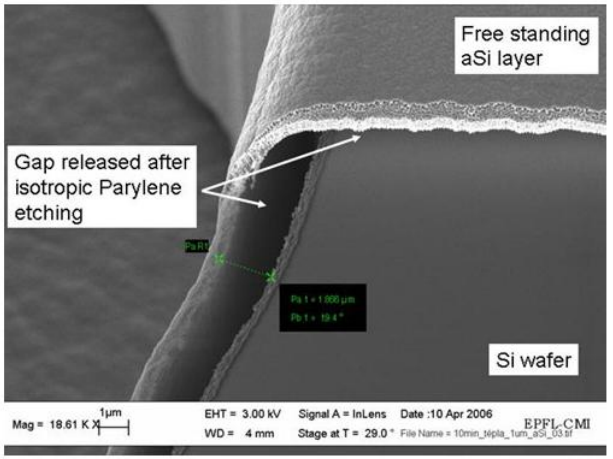
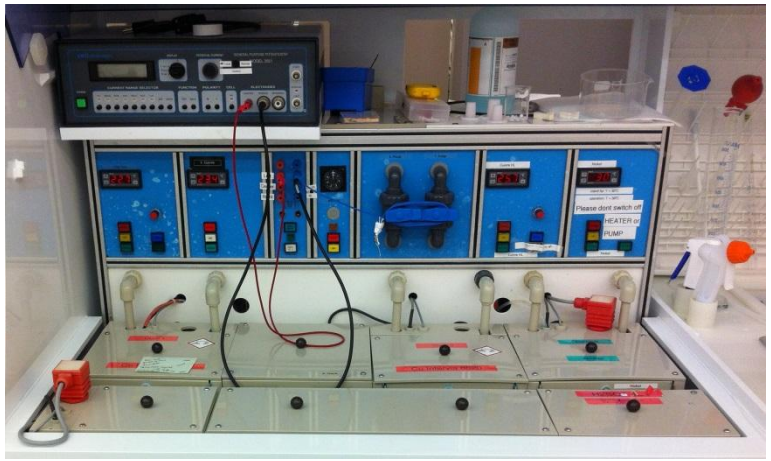
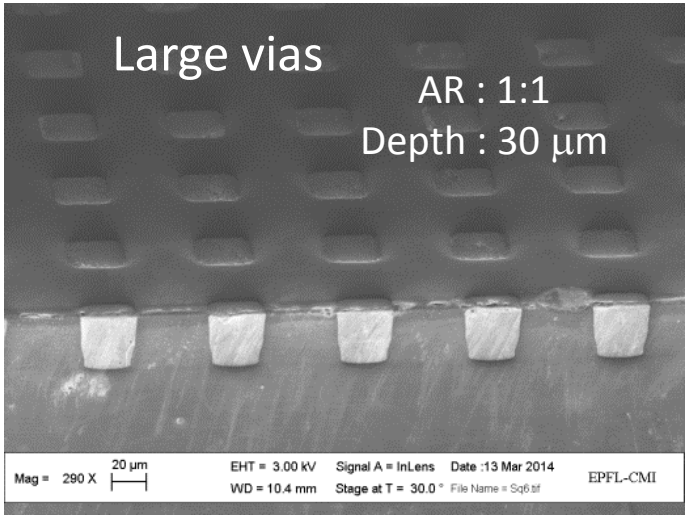
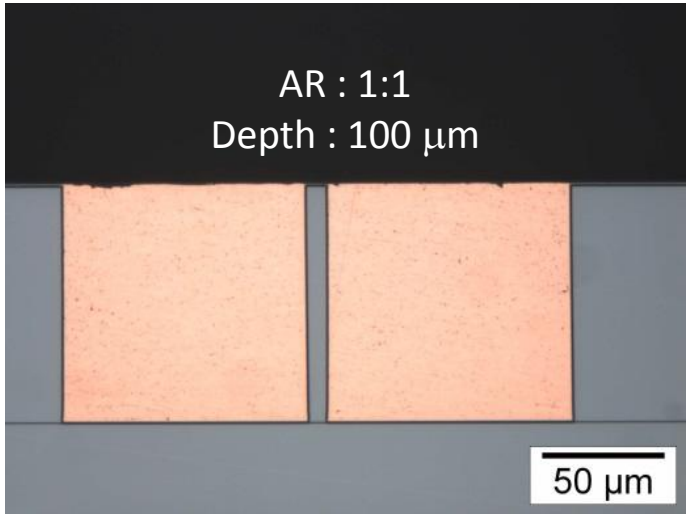


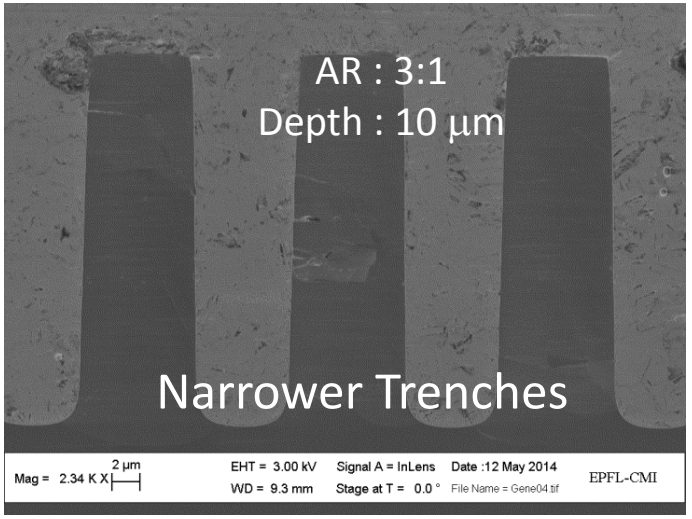

Fig. 3: Parylene isotropic etching to release aSi structures.

# **Misc processes:** Cu electroplating

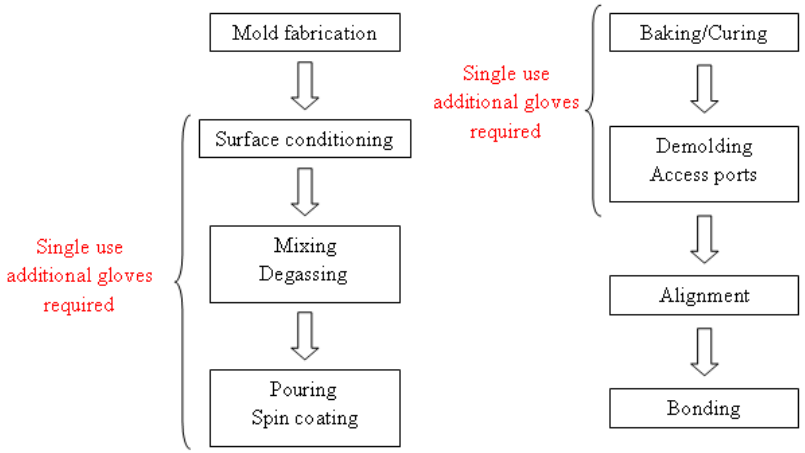


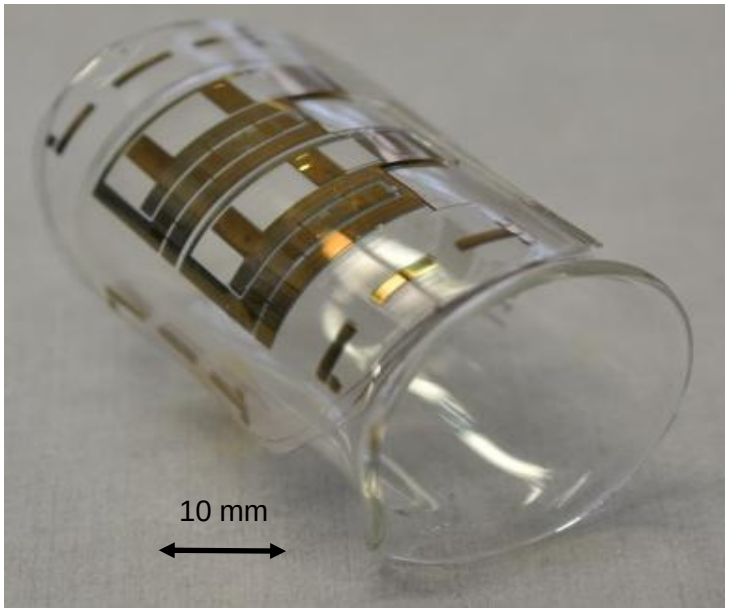


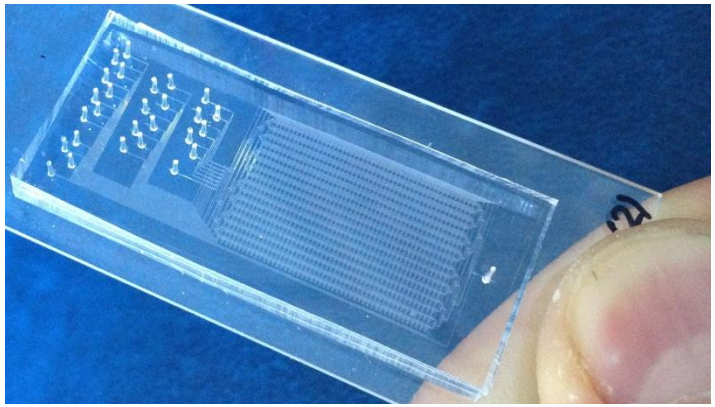



# **Misc processes:** PDMS




Courtesy of A. Gerratt / S. Lacour



PDMS mixing Matrix
Courtesy of Prof. Maerkl

# Metrology

**AFM**

view all / hide all

⊞ Bruker Atomic Force Microscope

view all / hide all

**FIB / SEM**

view all / hide all

⊞ FEI Nova 600 NanoLab, dual beam (SEM/FIB)

⊞ Zeiss LEO 1550, scanning electron microscope

⊞ Zeiss MERLIN, scanning electron microscope

view all / hide all

**Mechanical profilometers**

view all / hide all

⊞ Tencor Alpha-Step 500, surface profiler

⊞ Bruker Dektak XT, surface profiler

⊞ Nikon DIGIMICRO, feeler

view all / hide all

**Optical measurement**

view all / hide all

⊞ Krüss DSA-30E, Contact Angle Measurement tool

⊞ Sopra GES 5E, spectroscopic ellipsometer

⊞ Veeco Wyko NT1100, optical profiler

⊞ Nanospec AFT-6100, spectroscopic reflectometer

⊞ FilMetrics F20-UV, spectroscopic reflectometer

⊞ Toho Technology FLX 2320-S - Thin Film Stress Measurement tool

⊞ Bruker VERTEX70 FT-IR Spectrometer

view all / hide all

**Electrical measurement**

view all / hide all

⊞ KLA Tencor OmniMap RS75, resistivity meter four-point measurements

⊞ Süss PM8, manual prober station

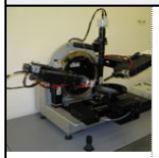
⊞ Characterization Platform (CARPLAT)

view all / hide all

**Optical microscopy**

⊞ Krüss DSA-30E, Contact Angle Measurement tool

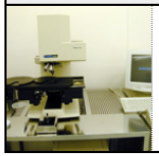
⊟ Sopra GES 5E, spectroscopic ellipsometer

| | Equipment | Documentation | Responsibles |
|---|---|---|---|
|  | • Measurement range : 1 nm and more<br>• Multi-layers measurements<br>• Standard spot diameter : 1 to 5 mm<br>• Micro spot diameter : 500 µm<br>• Location: Zone 3 | • Présentation de l'équipement<br>• Fondamentaux de l'ellipsométrie<br>• Ellipsométrie : Théorie (Restricted)<br>• Introduction to ellipsometry<br>• Introduction to software | Ph. Langlet<br>D. Bouvet |

⊟ Veeco Wyko NT1100, optical profiler

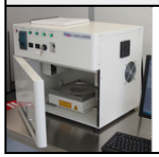
| | Equipment | Documentation | Responsibles |
|---|---|---|---|
|  | • Phase shifting interferometry (PSI) for roughness and small steps (< 160 nm)<br>• Vertical scanning interferometry (VSI) for rough surface and steps up to 1 mm high<br>• PSI vertial resolution : 0.3 nm<br>• VSI vertical resolution : 3 nm<br>• Spacial resolution : 1.0 µm<br>• Location: Zone 15 | • Manual | C. Hibert<br>G. Clerc |

⊟ Nanospec AFT-6100, spectroscopic reflectometer

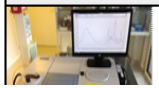
| | Equipment | Documentation | Responsibles |
|---|---|---|---|
|  | • Measurement range : 10 nm and more<br>• Spacial resolution : 10 µm and more<br>• Mono and bi-layers measurements<br>• Location: Zone 3 | • Manual | K. Suter<br>J. Dorsaz<br>G.A. Racine<br>G. Clerc<br>Ph. Langlet |

⊞ FilMetrics F20-UV, spectroscopic reflectometer

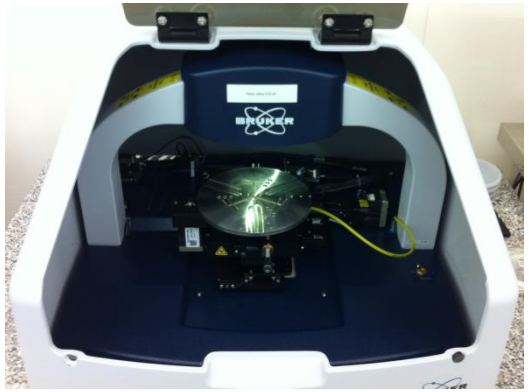
⊟ Toho Technology FLX 2320-S - Thin Film Stress Measurement tool

| | Equipment | Documentation | Responsibles |
|---|---|---|---|
|  | • Thin film stress measurement<br>• Location: Zone 15 | • Overview<br>• User manual | Ph. Langlet |

⊟ Bruker VERTEX70 FT-IR Spectrometer

| | Equipment | Documentation | Responsibles |
|---|---|---|---|
|  | • ---<br>• Location: front of Zone 14 | • Brochure | V. Brasch<br>M. Pfeiffer |

# Metrology

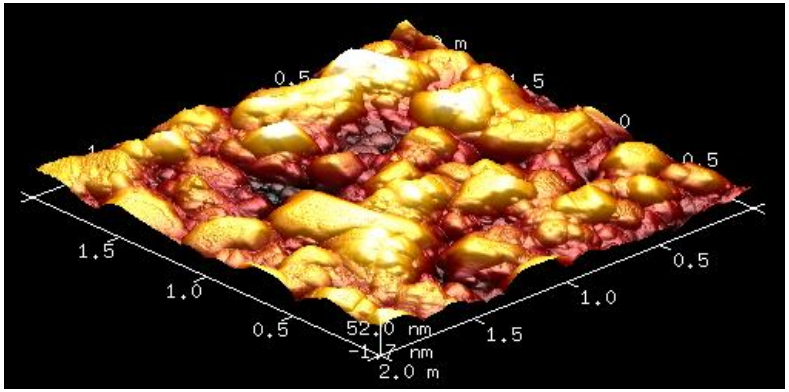



Surface profiler – DEKTAK XT

| | |
|---|---|
| Scan length : | 55 mm |
| Vertical range : | 1 mm |
| Stylus radius : | 12.6 µm, 2.0 µm, 0.7 µm |
| Step-height detection : | 20 A |
| Step-height repeatability : | 5 A |


AFM Fastscan Bruker

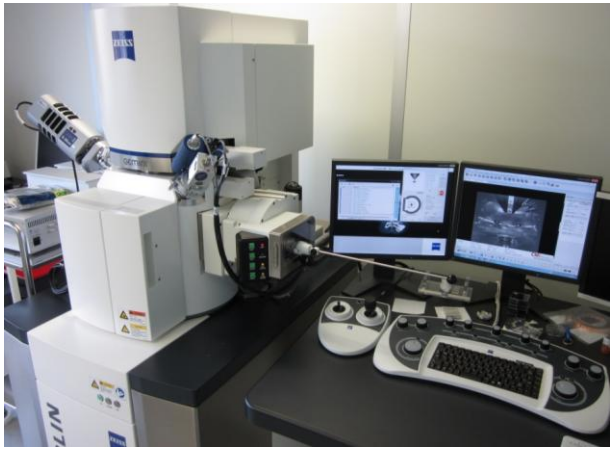
Wafer compatible
FastScan scanner
X-Y range 35 x 35 µm
Z range 3 µm

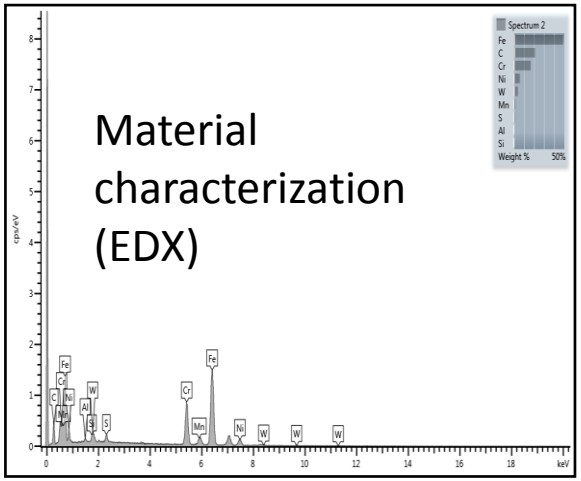


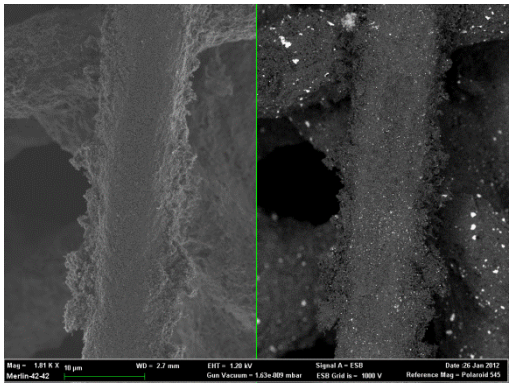

AFM view of LPCVD polysilicon as deposited

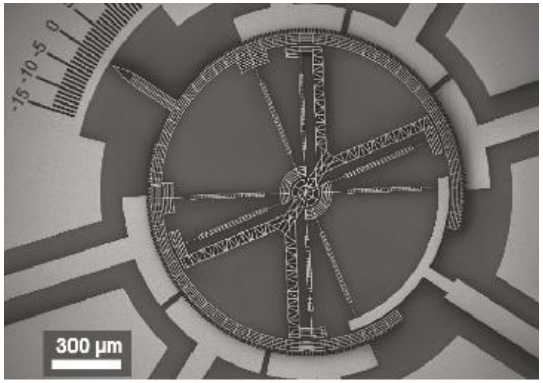
# Metrology: SEM + EDX analysis

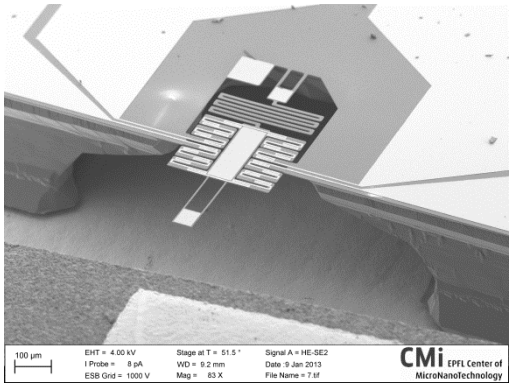
3 state of the art SEMs available in CMi: LEO1550, Zeiss Merlin and FEI (FIB)





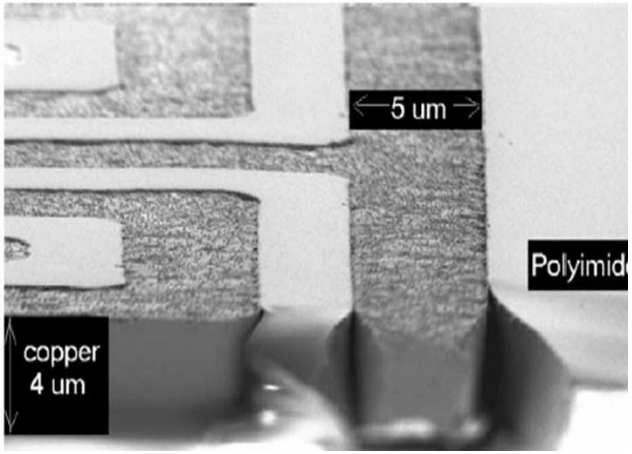


# Example 1: Damascene process

Technologies:

- Polyimide coating and anisotrpic dry etching,
- diffusion barrier /seed layer
- Cooper electroplating,
- Cooper CMP,




4um copper embedded in 4um lowK Polyimide (EPFL-CMI source)

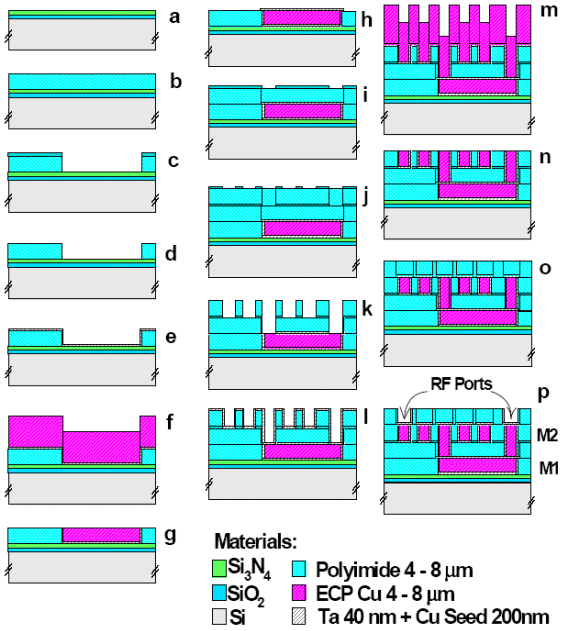
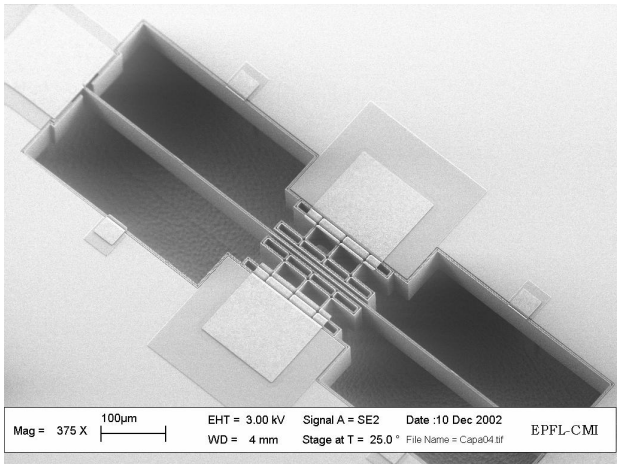



*Fig. 3.1: Established process flow for the fabrication of thick-Cu / polyimide embedded passive devices on top of silicon wafers.*

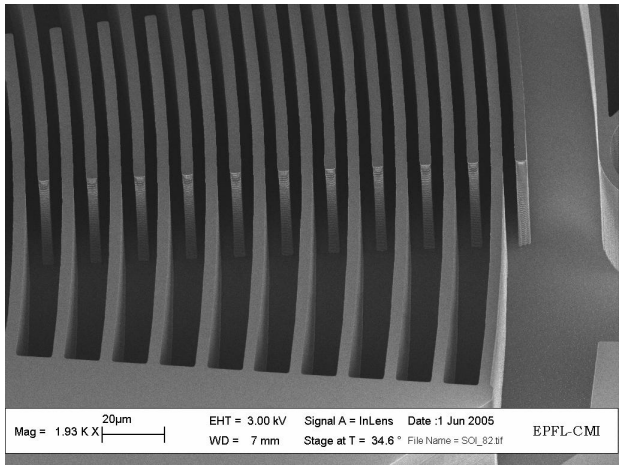
# Example 2: Si MEMS

Process flow:

- Photolithography
- DRIE
- oxidation
- Releasing steps
  - Isotropic Si etching
  - Or HF etching + Critical Point Dryer to avoid sticking




Bulk Si micromachining (EPFL-CMI source)

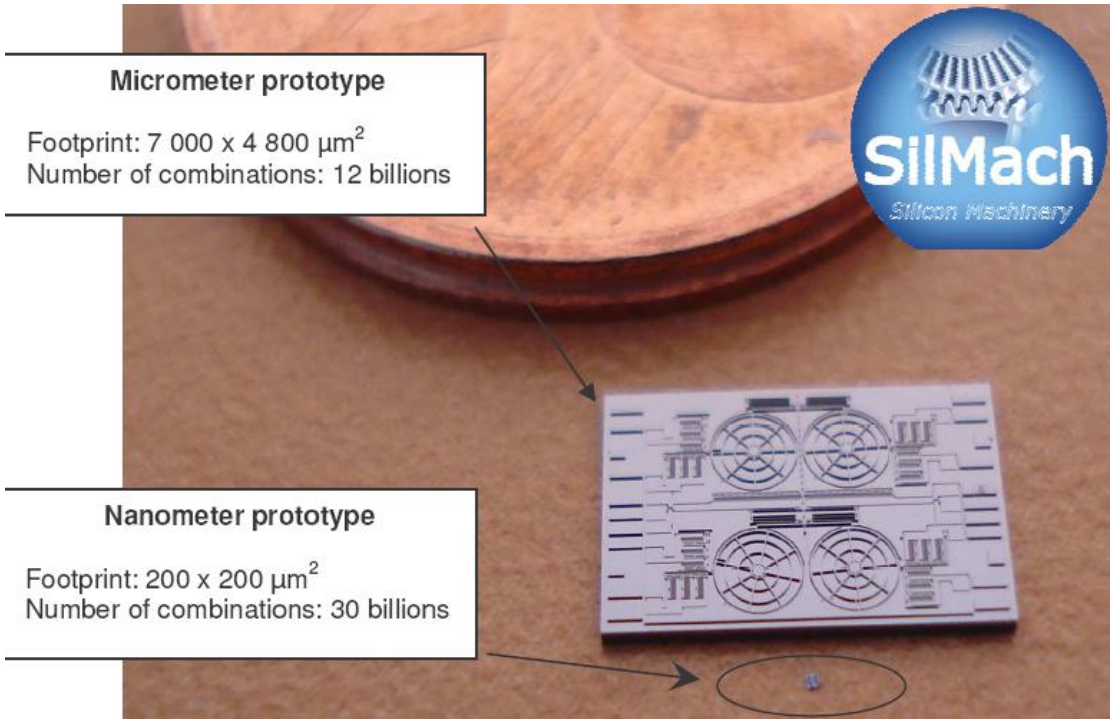


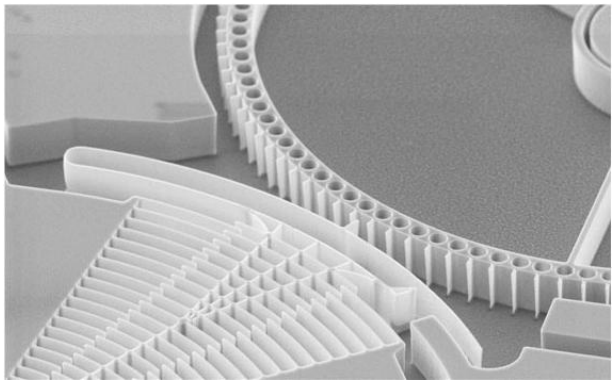

SOI DRIE etching (EPFL-CMI source)

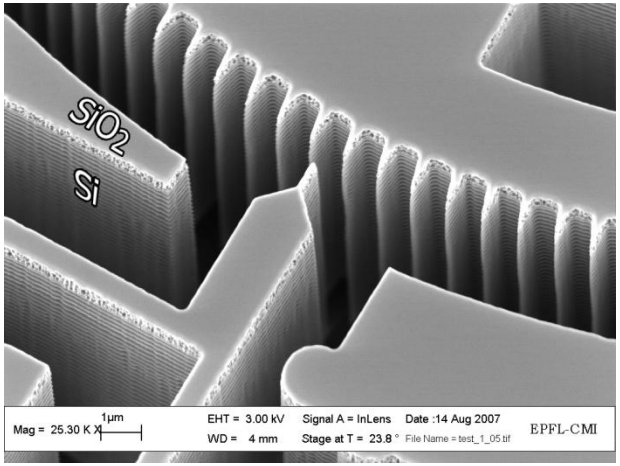
# Example 3: nano Si MEMS

Technologies:

- Ebeam lithography
- DRIE with Sharp process

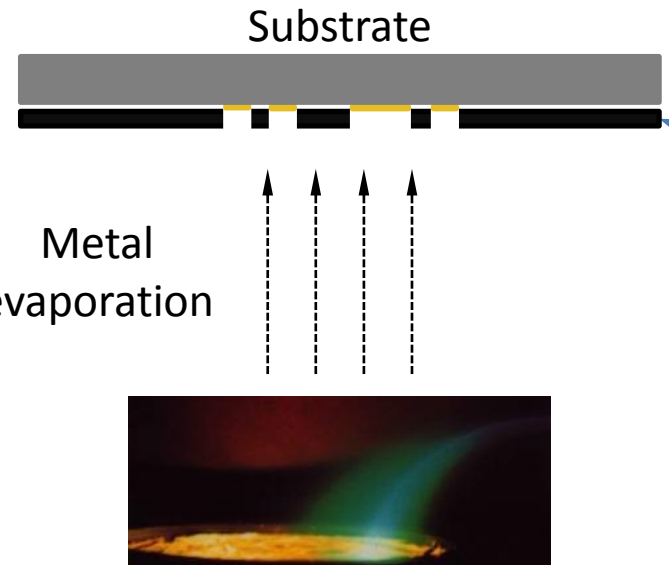





Courtesy of Silmach SA (Besançon)

# Example 4: shadow masks

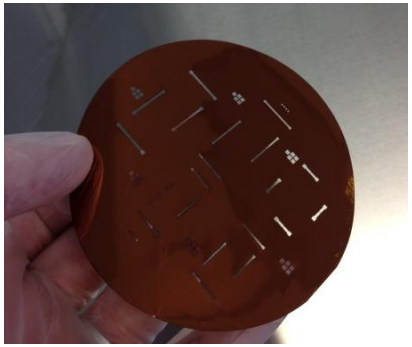



Direct deposition/patterning technique

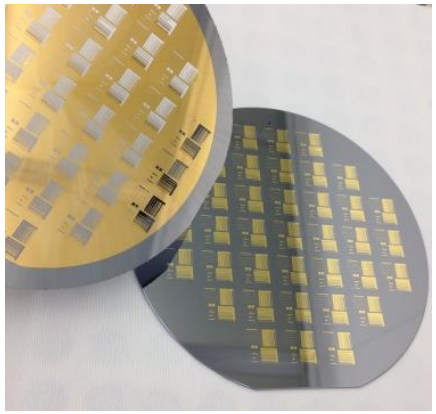
- *No resist mask*
- *No subsequent etching*
- *Targeted deposition*

## Shadow mask

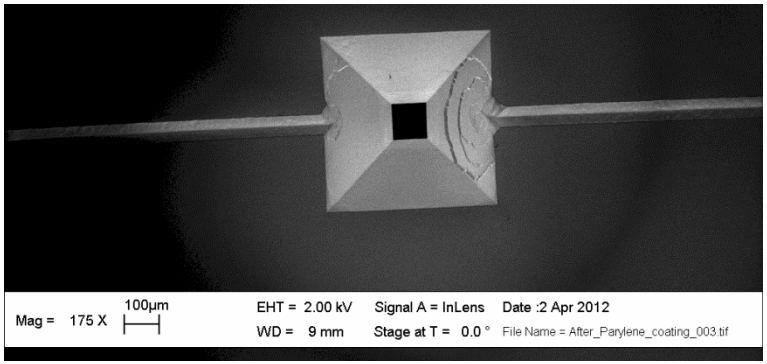
| Resolution | Aspect | Material | Technique | Alignment |
|---|---|---|---|---|
| Low (500µm) | Flexible | Kapton foil | Automatic cutter | No |
| Medium (10µm) | Rigid | Silicon bulk | DRIE + grinding | Yes (10µm) |
| High (200nm) | Rigid | SiN membrane | RIE + wet etching | Yes (1µm) |



Kapton foil



Silicon bulk




Back side: Si KOH etch to SiN

# THANKS FOR YOUR ATTENTION