CLEAN-ROOM PROCESSING

LAAS: THE ORGANISATION

LAAS is a CNRS laboratory (UPR 8001)

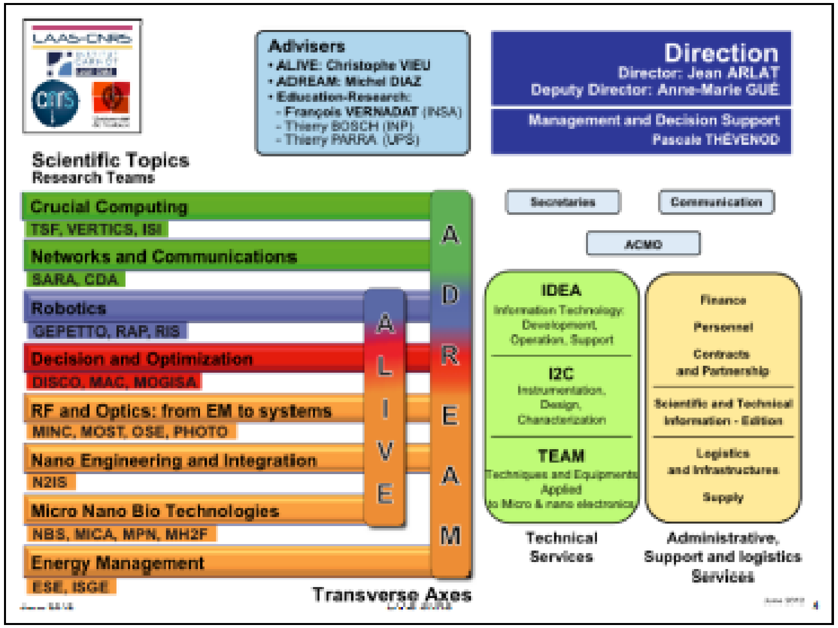
- Information sciences and systems institute
- Computing sciences institute and Physics institute

LAAS is associated to all the members of PRES Université de Toulouse

- Université Paul Sabatier
- Institut National des Sciences Appliquées de Toulouse
- Institut National Polytechnique de Toulouse
- Institut Supérieur de l'Aéronautique et de l'Espace
- Université Toulouse Capitole
- Université Toulouse Le Mirail

LAAS is member of:

- RTRA Sciences & Technologies for Aeronautic and Space
- Competivity poles
  - Aerospace Valley
  - Cancer Bio Santé
  - Agrimip Innovation
  - System@tic
  - Capdigital



LAAS TECHNOLOGY PLATFORM A BRIEF HYSTORY

- **Third generation of technological platform in LAAS**
  - **The first in academics in France**
  - **1968 : clean room**

- **1978 : white room**

- **2006-2007 : technological platform**

LAAS TECHNOLOGY PLATFORM MEMBER OF THE BTR NETWORK

- 6 CNRS Laboratories (RENATECH)
  - IEMN (Lille)
  - LAAS (Toulouse)
  - FEMTO (Besançon)
  - FMNT-INAC (Grenoble)
  - LPN (Marcoussis)
  - IEF (Orsay)
- 1 CEA Laboratory
  - LETI (Grenoble)
- **International level platforms to support academic and industrial partners**

THE LAAS TECHNOLOGY PLATFORM

- 3.7 M€ (700 m² + offices)
  - CPER 2000-2005
  - Opening 2005

- 3.9 M€ (800 m²+ offices)
  - BTR funding
  - LAAS ressources
  - Affiliates club
  - Opening may 2007

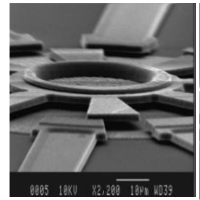
- 1500m²

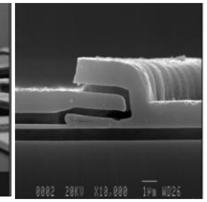
- Classes 10 000 and 100
  - Dedicated rooms
  - Localy

- Adaptable structure
  - FFU
  - 4 levels

LAAS TECHNOLOGY PLATFORM
THE TECHNOLOGIES

- 30 M€ equipment total value
- Flexibility
  - Manuals / Semiautomatic /Automatic equipments
- Si and III-V technologies
- 4'' Si wafers (upgradeable to 6 '')
- Developments in substitution technologies





To **Characterization**

Packaging

Ion implantation

Electrochemical deposition

Plasma Etching

Metallization

M.B.E.

Infrastructure and support

Wet Etching

Chemistry

Thin films deposition

Electronic lithography

Optical photolithography

From **Mask fabrication**

A virtual visit : http://www.cnrs.fr/cnrs-images/multimedia/laas/

Clean-room processing

Pierre-François CALMON

CONTENT

- About clean-room facilities
  - Definition & classification
  - Structure & facilities
  - Environment & controls
- About clean-room technologies
  - Materials & techniques
  - Micro & nano fabrication

Clean-room facilities

CLEAN-ROOM ENVIRONMENT

Definition:

Rooms where the air temperature, air humidity, air purity and air pressure conditions are controlled.

Objectives:

Reduction of the contamination caused by particles and improvement of the process repeatability.

PARTICLES SIZES

Particles: small quantity of solid or liquid matter

Origin	Nature	Sizes (µm)
Ambient air	Soot, sand, pollens	1-1000 0.005-30
Persons	Skin, hairs, cosmetics, clothes	0.5-100
Equipments	Metal and plastic shards	0.5-50
Process	Undesirable reaction products	0.05-5
Chemical and gas products	Corrosion, metals	0.5-100
Water	Bacteria	0.01-10

CLEAN-ROOM CLASSIFICATION

Classification « Federal Standard 209d »

Class	Air purety
100 000	Maximum of 100 000 particles whose dimension is superior to 0.5 µm by feet-cube
10 000	Maximum of 10 000 particles whose dimension is superior to 0.5 µm by feet-cube
1000	Maximum of 1000 particles whose dimension is superior to 0.5 µm by feet-cube
100	Maximum of 100 particles whose dimension is superior to 0.5 µm by feet-cube
10	Maximum of 10 particles whose dimension is superior to 0.5 µm by feet-cube
1	Maximum of 1 particles whose dimension is superior to 0.5 µm by feet-cube

CLEAN-ROOM CLASSIFICATION

Classification « ISO »

	Number of particles per Cubic Meter by Micrometer Size					
CLASS	0.1 µm	0.2 µm	0.3 µm	0.5 µm	1 µm	5 µm
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1000	237	102	35	8	
ISO 4	10 000	2370	1020	352	83	
ISO 5	100 000	23 700	10 200	3520	832	29
ISO 6	1 000 000	237 000	102 000	35 200	8320	293
ISO 7				352 000		
ISO 8				3 520 000		
ISO 9				35 200 000	8 320 000	293 000

GENERAL STRUCTURE

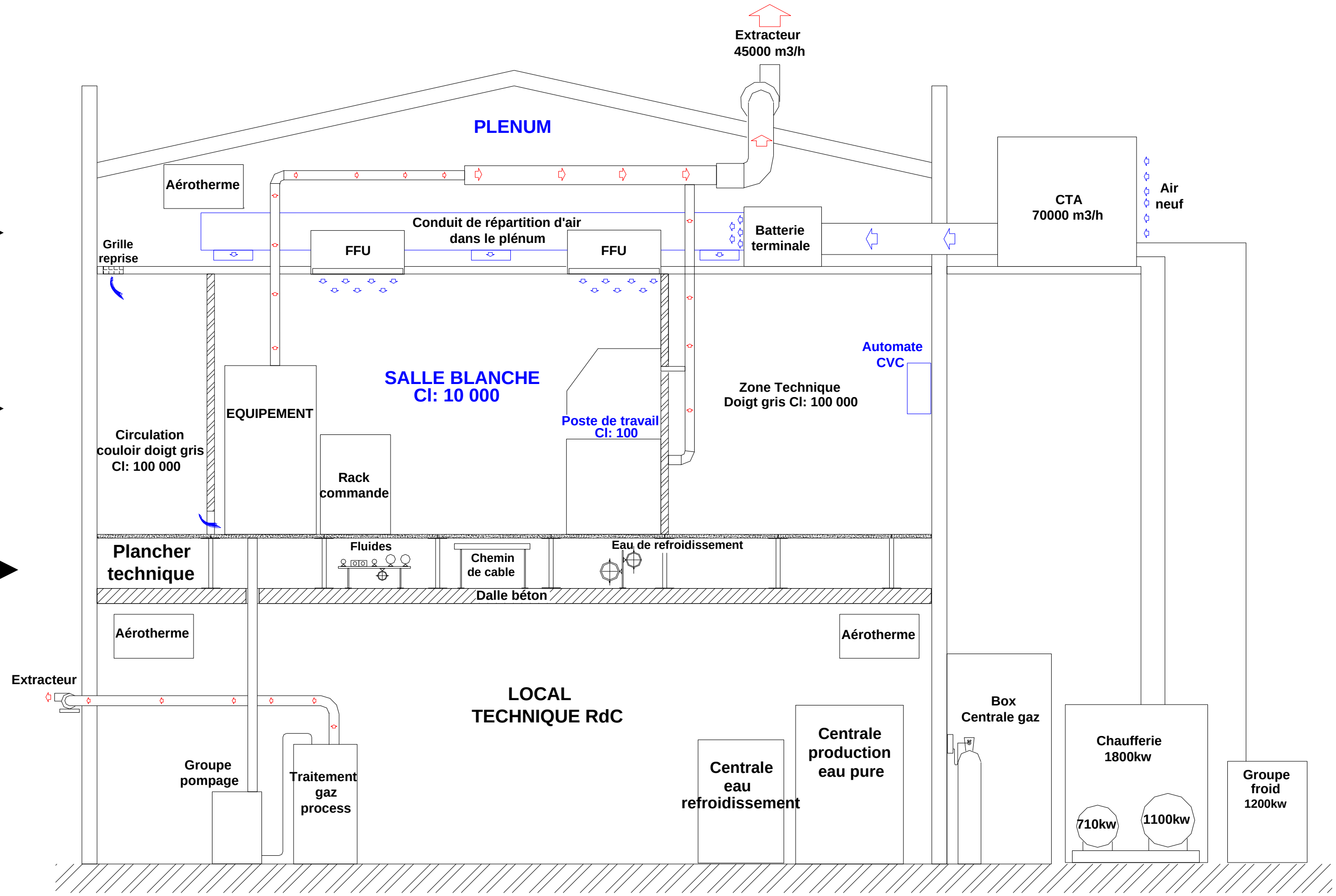
4 LEVELS

4 : Plenum

3 : Clean room

2 : Fluid circulation

1 : Facilities



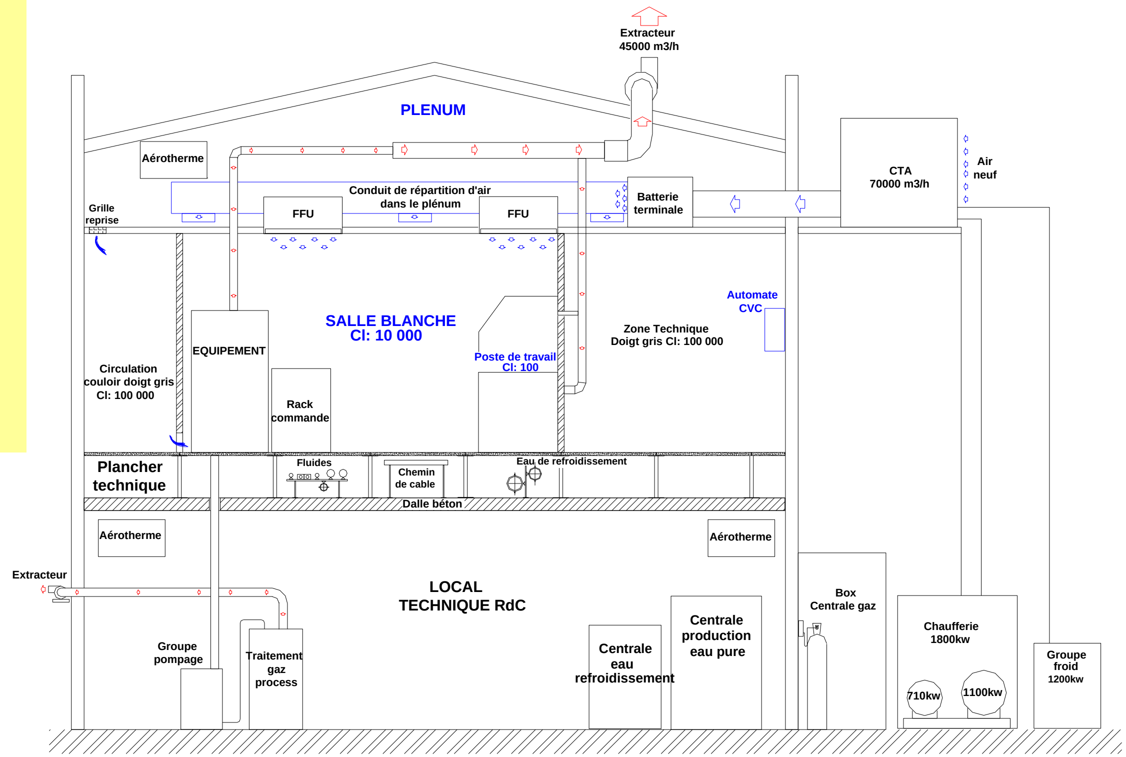
GENERAL STRUCTURE

Upper structure :

- Walls : 100 mm iron sandwich with polyurethan foam
- Partition walls:
  - 60 mm iron sandwich with polyurethan foam
  - 40 mm iron sandwich with Al honeycomb stitch

Lower structure :

- Walls reinforced concrete
- Floor reinforced concrete
- Fluids evacuations



FACILITIES LEVEL

PUMPING PRODUCING VACCUUM FOR EQUIPMENTS

- More than 70 pumps in the platform
- More than 40 of them in the facilities level

DI WATER PRODUCTION

- Water softener
- Reverse osmosis
- Dual pumps Circulation system
- Water polishing with nuclear resists
- Uv lamp to kill bacteria
- Down to 0.2µm filters
- 700l/hour
- 18 MΩ resistivity

COOLING WATER CIRCULATION AND CONTROL

- Dual pumps circulation system
- Heat exchanger
- No waste water
- 16 m^3 /hour
- 17°C < Temperature < 22°C

FACILITIES LEVEL

EFFLUENTS TREATMENT

- Scrubber for pyrolysis of dangerous gaz
- Neutralization tank for acids and bases

CENTRALIZED ASPIRATION FOR CLEANING

- Connections all over the clean room
- Just for dust and small particles

GENERAL VACUUM PRODUCTION

- For the general vacuum network

MAINTENANCE FACILITIES

- Workshop for repear
  - Welding, Cleaning, dicing
  - etc

STOCKS

- Industrials gazes in specific boxes
- Process gazes in specific boxes
- Process gazes with security system in clean room if necessary
- Chemicals products in a dedicated room

NITROGEN TANKERS

- Liquid nitrogen dispatched through a gravitation system to MBE
- Vapour nitrogen for general network (from 300 to 600 l/h)

FALSE FLOOR

A 40 cm height false floor for distribution of fluids

- Electricity
- Gaz (industrial, process)
- DI water (PVDF material)
- Cooling water
- Pumping pipes

Access

- Upper : through 60cmx60cm non openwork flags all over the clean room
- Lower : holes in the concrete flag
  - Important effort in the conception of the platform to predetermine the positions
    - Minimum number
    - Structure calculation
  - Specifics drillings if necessary

CLASSIFICATION

1500 m²

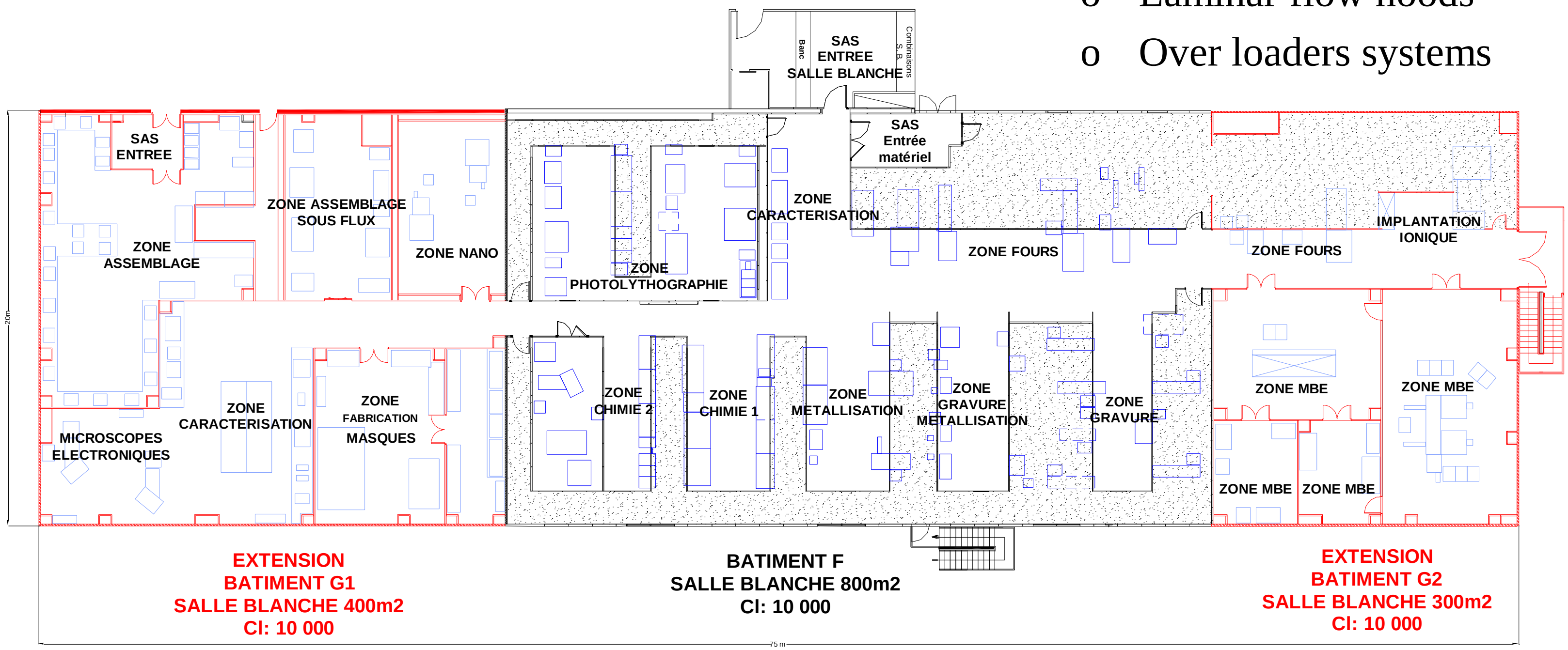
- Controled areas ≈ 1100 m²
  - Class 10 000
  - Class 100
- « grey » areas ≈ 400 m²

Specific rooms in class 100

- Photolithography
- Electron beam lithography
- Alternative technologies

Local areas class 100

- Laminar flow hoods
- Over loaders systems



STRUCTURE

Specific rooms due to

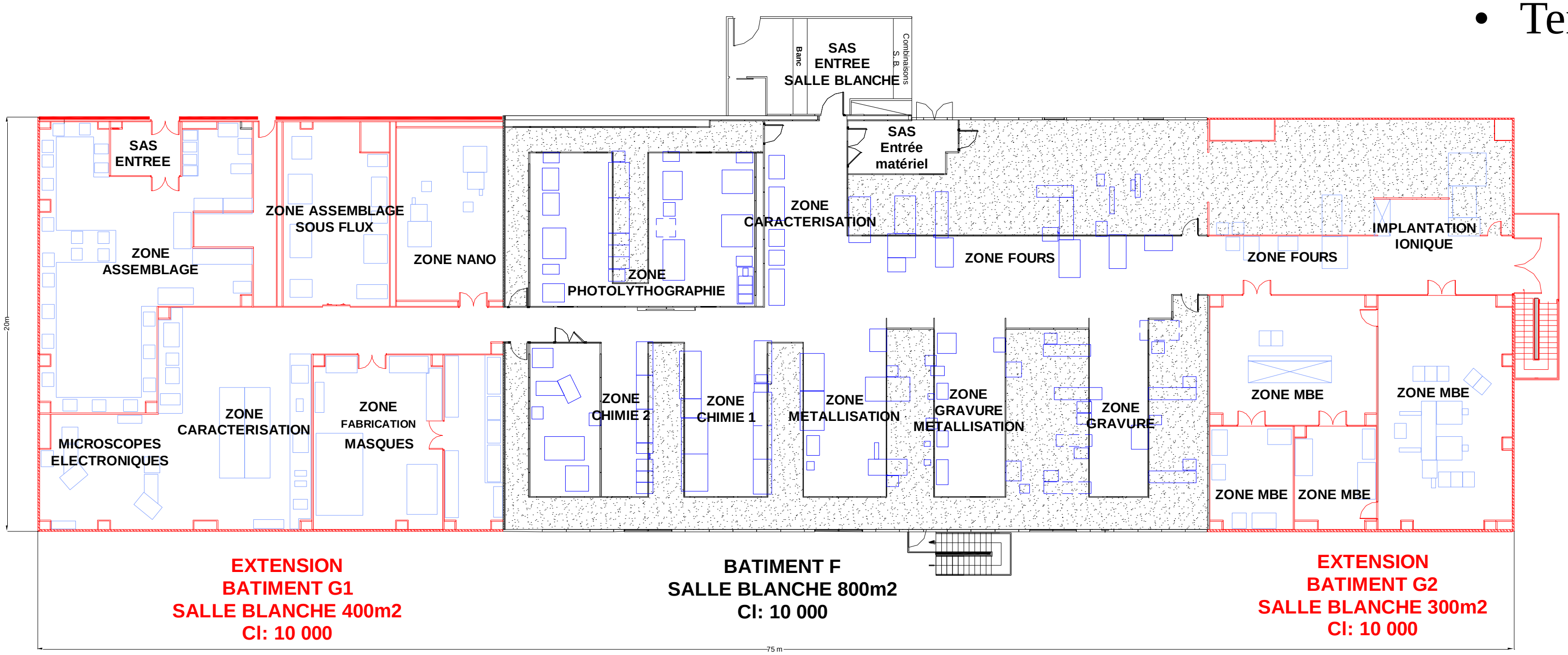
- Class
- Inactinic light
- Security
- Specific activities

Finger gloves structure

- Easy to enhance
- Reduce the volume of air treatment
  - Reduce construction and operating costs

Entry locks for

- The people
- Small equipements
- Middle equipements
- Big equipements
  - Temporary lock



PLENUM

Dedicated to distribution of the air issued from in air treatment stations

- Empty space
- nearly air tight space

- All over the platform
- With specific areas depending on the class of the room under
- Walkable
- Already in class 10 000

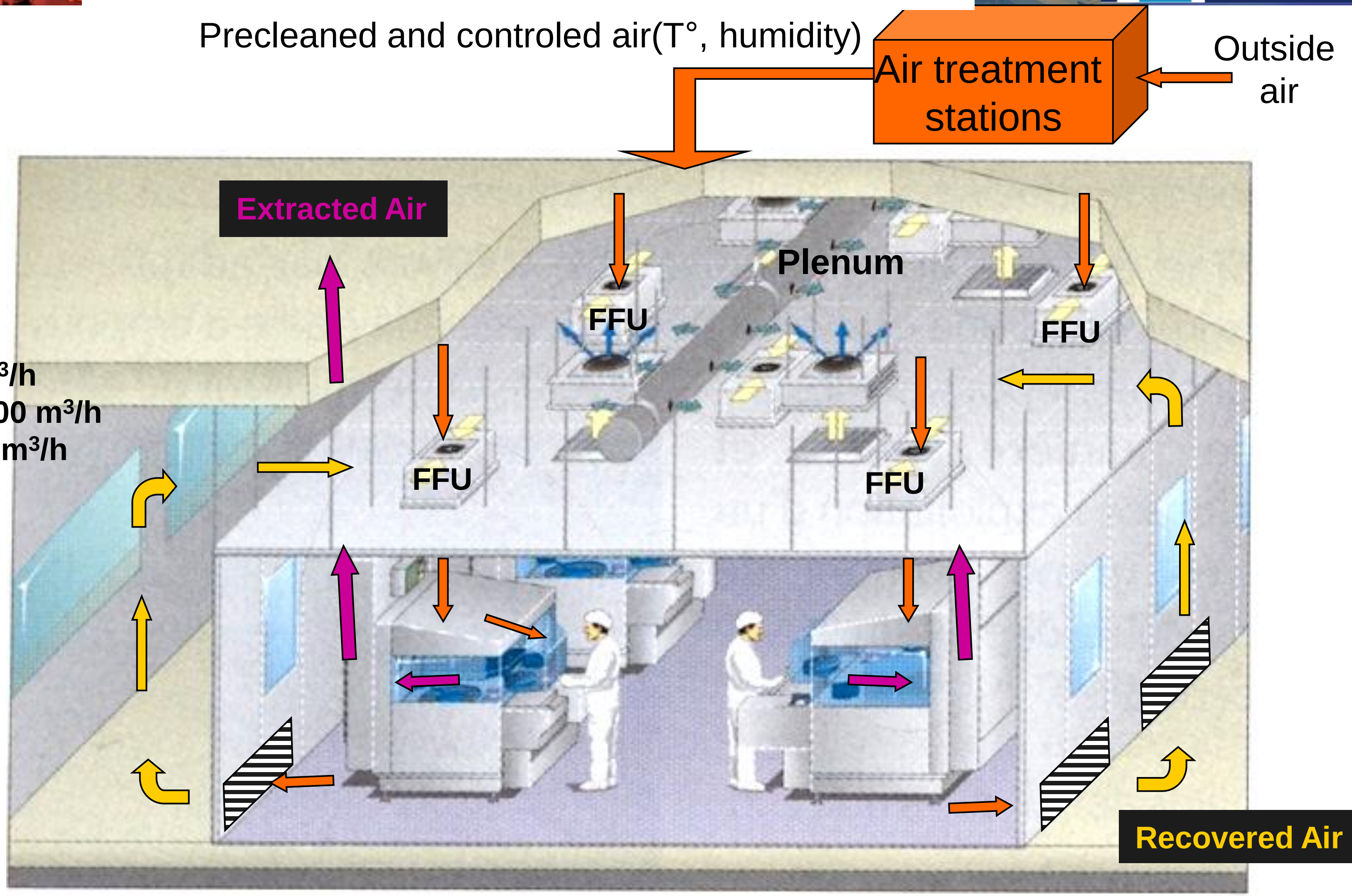
AIR TREATMENT SYSTEM

Filter Fan Unit :

Final filtration depending on
- **Filter class**
- **Number of filter/m²**

Volumes

Treated air : 45 000 m³/h
Recovered air : 200 000 m³/h
Extracted air : 36 000 m³/h



EQUIPEMENTS FACILITIES

Process gaz

From gaz stock via gaz lines in the false floor
From local bottles in gaz cabinet with extraction system

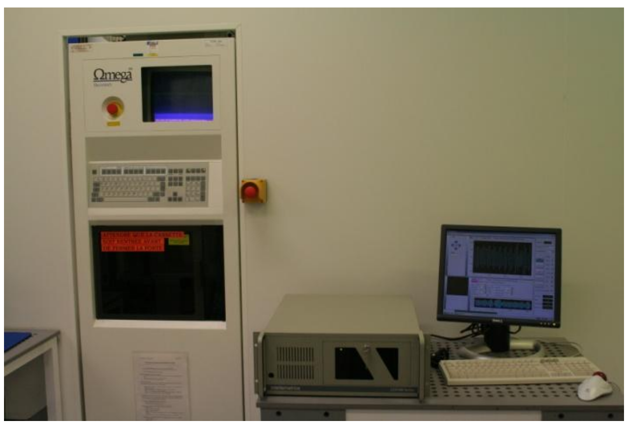
Electricity

From divisional panel via false floor

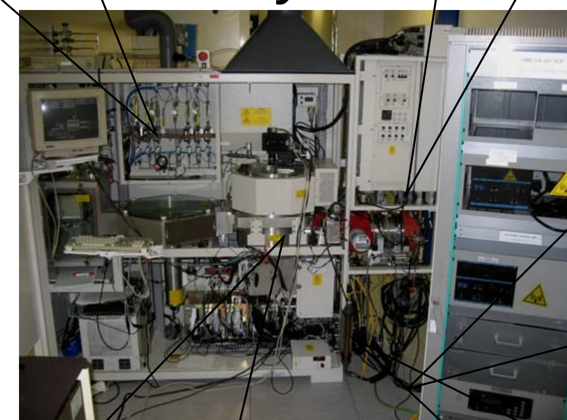
Cooling water

From first level through concrete flag and via false floor

Clean room



« Grey » area



Dedicated water control system

industrial gaz

From gaz stock via gaz lines in the false floor

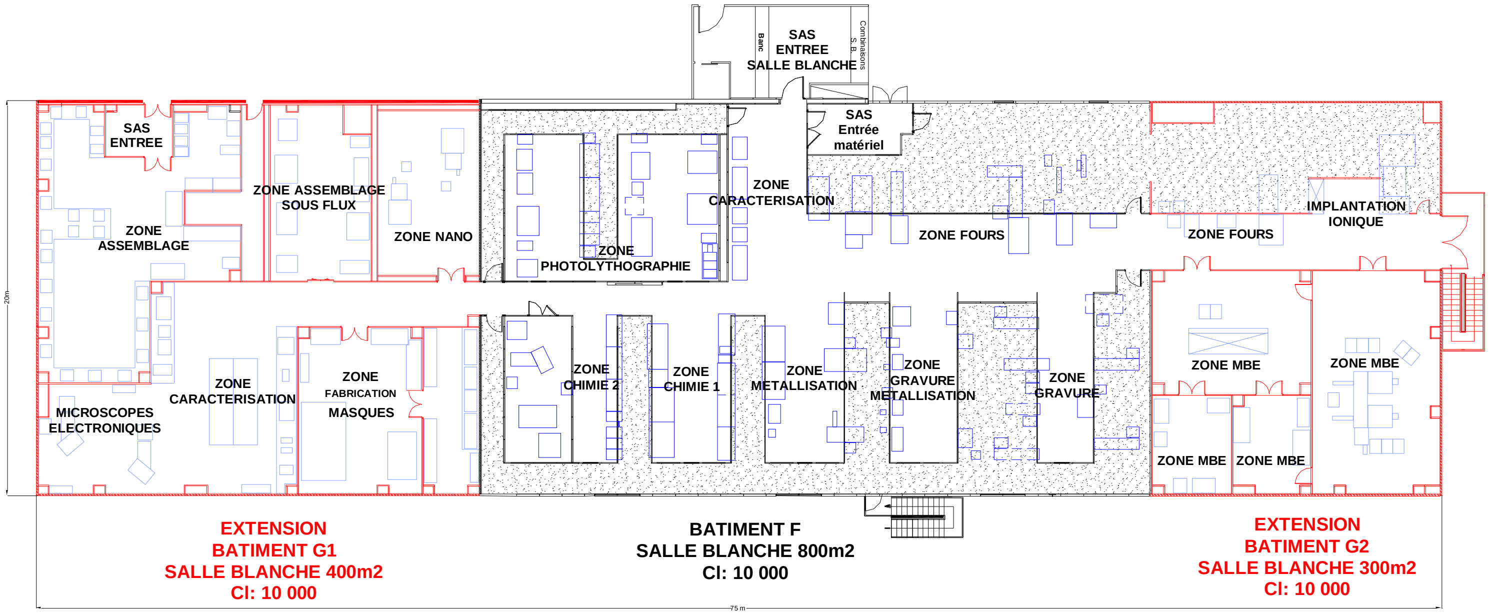
Pumping pipes

From first level through concrete flag and via false floor (shorter distance)

EQUIPEMENTS DISTRIBUTION

To reduce the fabrication and maintenance costs

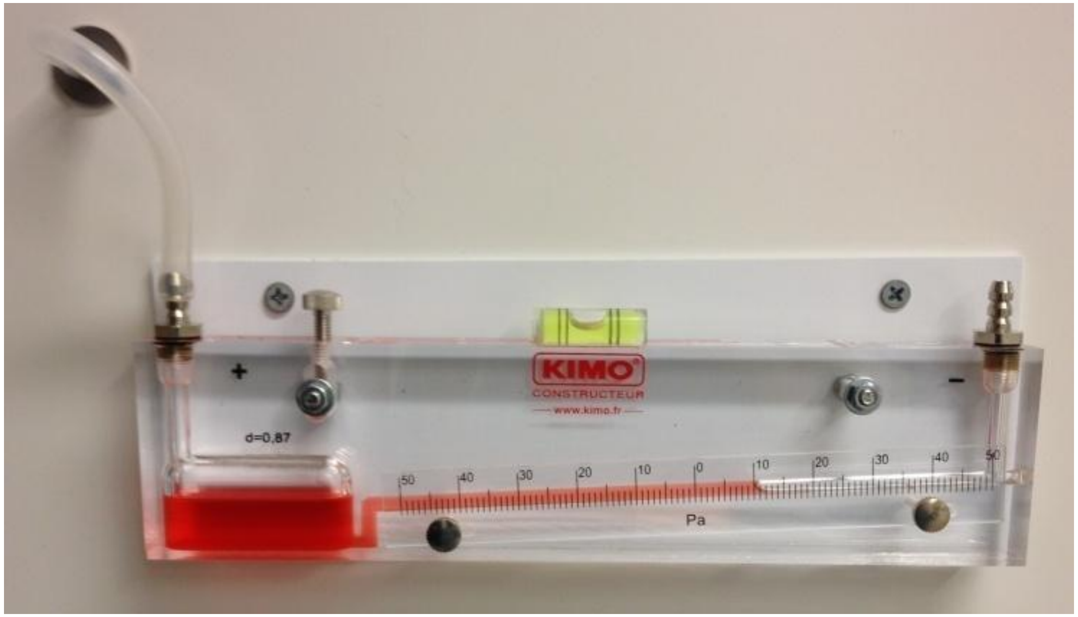
- Local specific areas
- Shortest networks for fluids
  - DI water
  - Cooling water distribution



PHYSICAL SENSORS

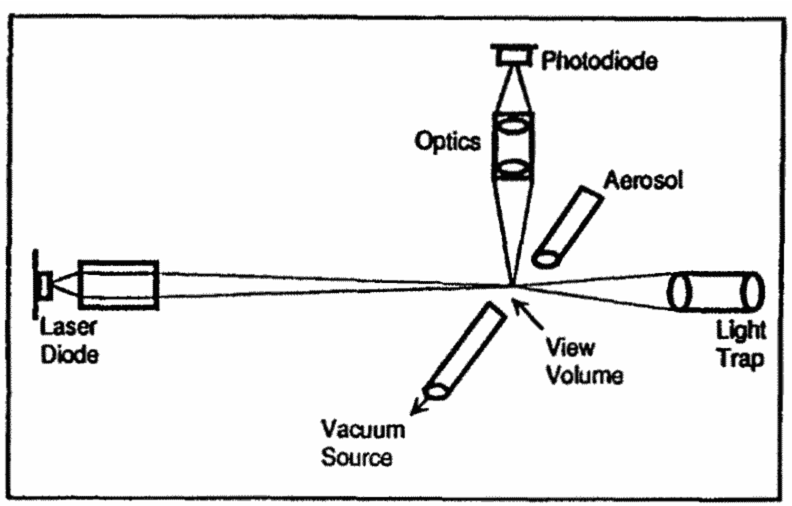
Flush-mount multi-channel displayer to control pressure, humidity and temperature

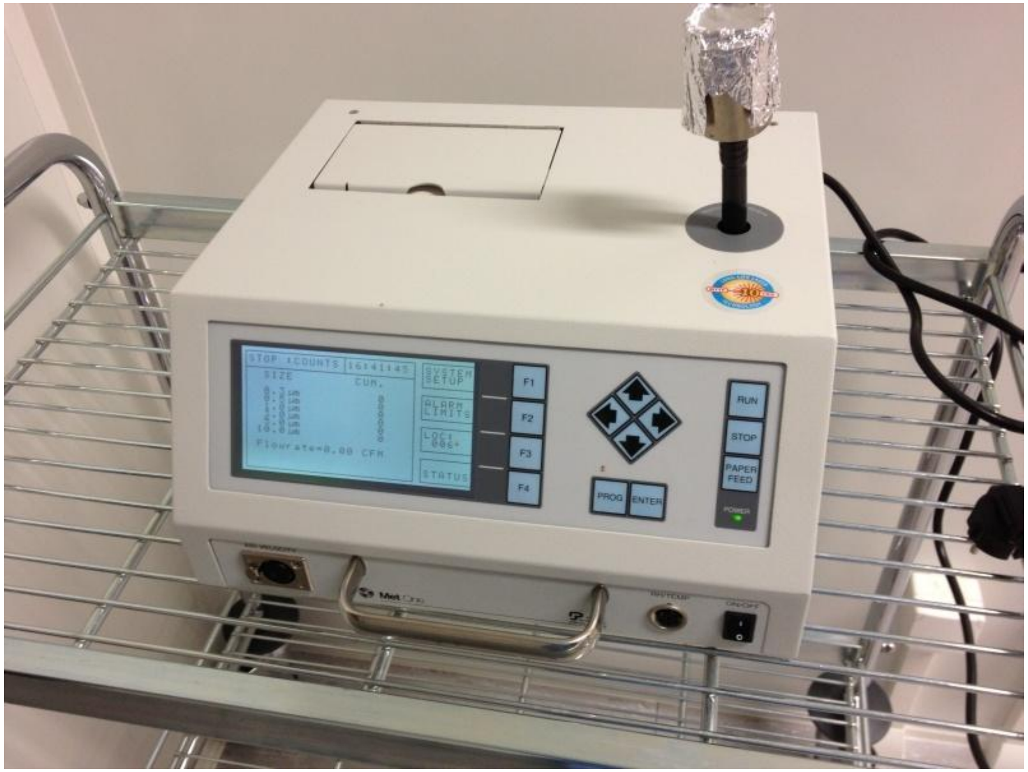
Inclined liquid column manometers for measuring overpressures in clean-rooms



OPTICAL PARTICLE COUNTER

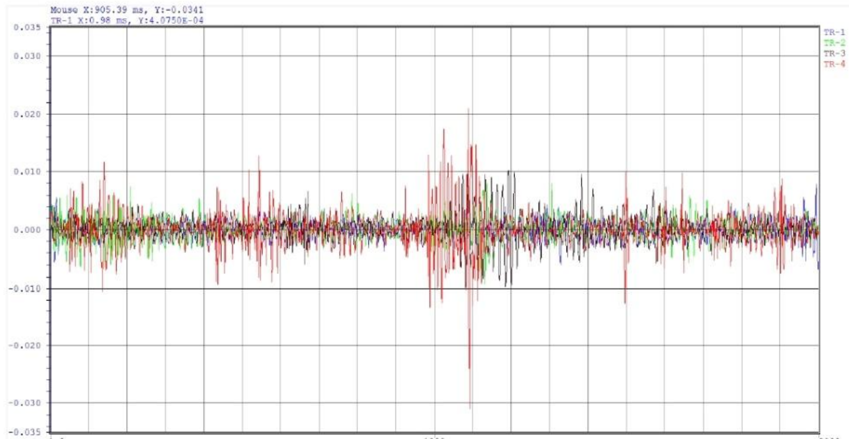
Particles counter counts and measures the size of airbome particles in clean-room environments

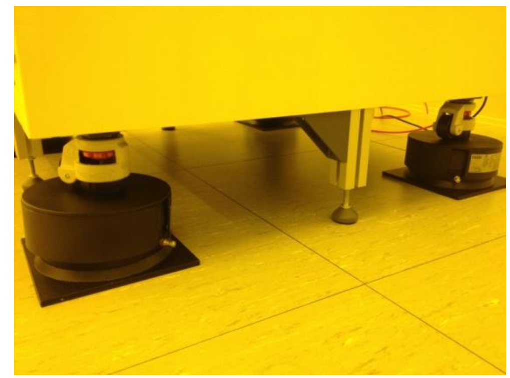




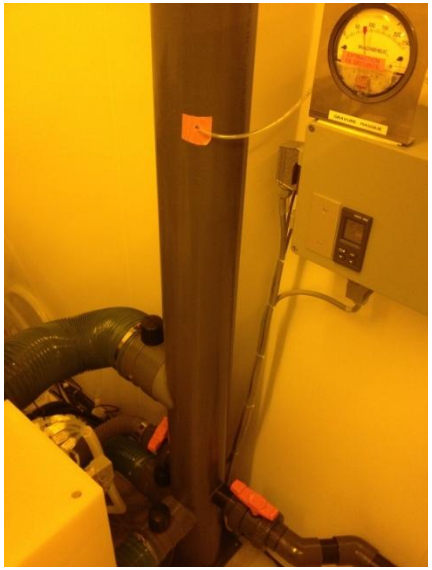
VIBRATION MEASUREMENT

Measurements of vibration and mechanical shocks to optimize the installation of equipments for lithography and characterization

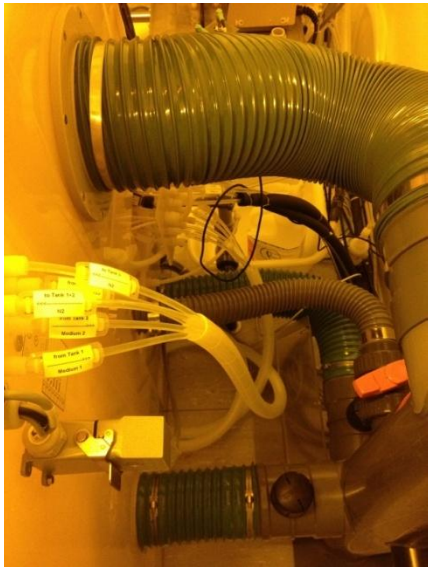




EXHAUSTS

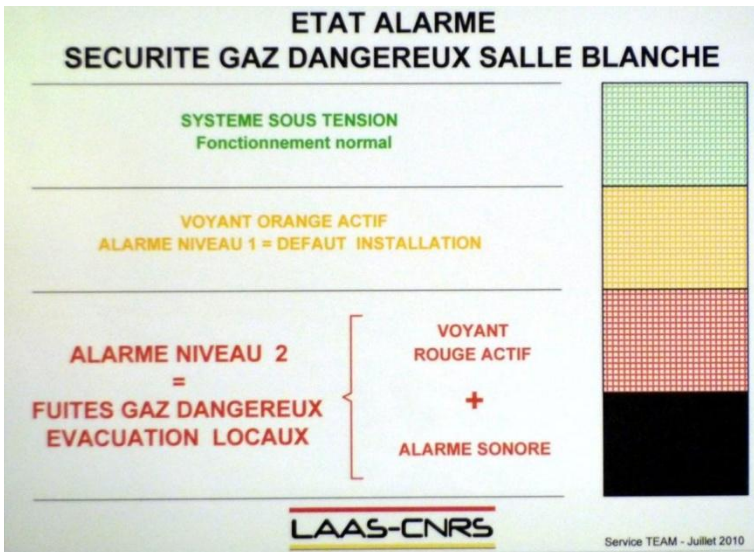


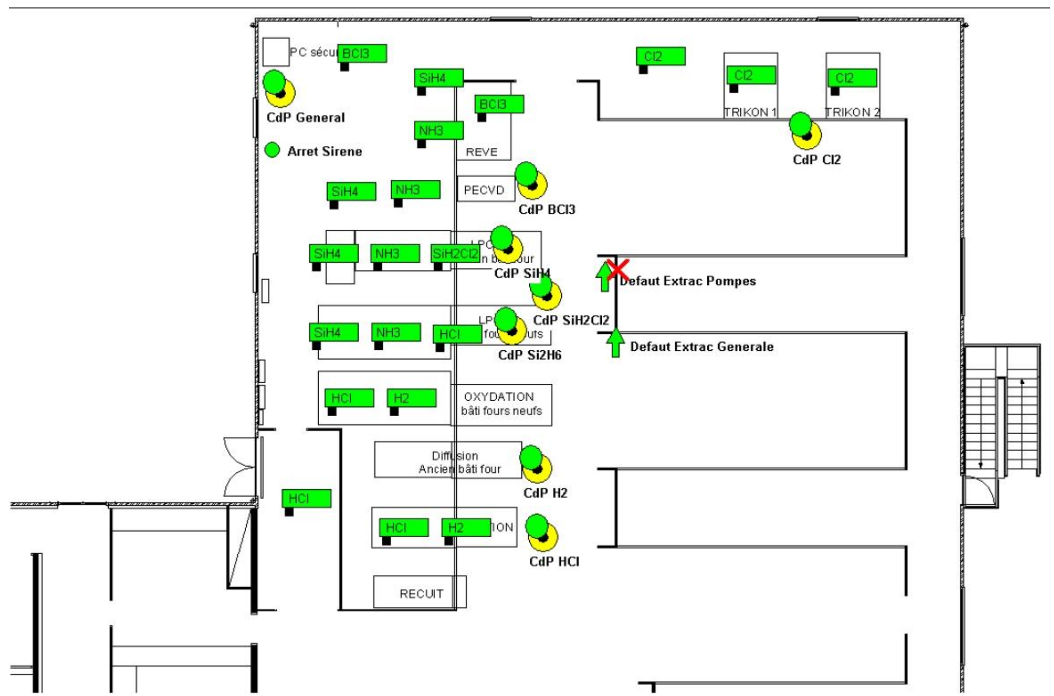
For the safety of staff in the clean-room,
the key requirement is a GOOD EXHAUST



ALARMS

A network of gas sensors analyzes sensitive areas and informs users of the clean-room state





Réseau de grandes centrales technologiques pour la Recherche Technologique de Base

CLEAN-ROOM CLOTHES

A person who is stationary generates about 100 000 particles per minute

CHEMICALS RISKS

The chemicals risks:

- Physical risks (fire, explosion)
- Chemicals burns (skin, eyes)
- Intoxication risks (acute, chronic)

Risk = Danger x Exposure

CHEMICALS PROCESSING

Each workstation is dedicated to a specific chemical process
The circulation of air over the bench is optimized for users protection

A virtual visit : http://www.cnrs.fr/cnrs-images/multimedia/laas/

Clean-room technologies

TYPICALS SUBSTRATES MATERIALS

Semiconductor substrates: Silicon, Silicon On Insulator, Galium Arsenide, Galium Nitride, Diamond,…

Insulator substrates: Quartz, Glass, Alumina, (silice fondue), Flexible substrate

Flexible substrates as PET or Polymide are associed with a hard substrate by lamination for planar technology

TYPICALS THINFILMS MATERIALS

Semiconductor thinfilms: GaAs, AlAs, $Ga_{1-x}Al_xAs$, and other III-V compounds (In, N, Sb, Bi), Si(n), Si(p), Si Poly(n), Si Poly(p)…

Insulator thinfilms: SiO_2, Si_3N_4, SiO_xN_y, Al_2O_3, HfO_2, Polymide, BCB, Su8,…

Conductor thinfilms: Ti, TiN, Au, AuGe, AuZn, Cr, Pt, Cu, Ta, Al, Ni, Ru, ITO, W,…

ELABORATION / DEPOSITION TECHNIQUES

ELABORATION OF MATERIALS

- **EPITAXY**
  - Molecular beam
  - liquid
  - Vapor phase
- **CHEMICAL VAPOR DEPOSITION CVD**
  - Atmospheric pressure APCVD
  - Low pressure LPCVD
  - Plasma enhanced PECVD
  - Atomic layer ALD
  - Metal organic MOCVD
  - Microwave plasma,….
- **PHYSICAL VAPOR DEPOSITION PVD**
  - Evaporation
  - Electron Beam
  - Sputtering
  - Pulsed laser
  - Cathodic arc Hybrid PVD/CVD …
- **« CHEMICAL » DEPOSITION**
  - Electroplating
  - Electroless

MATERIALS TREATMENT TECHNIQUES

TREATMENT OF MATERIALS

- **THERMAL**
  - **Annealing**
  - **Rapid Thermal Processing**
  - **Diffusion/redistribution**
- **PLASMA**
  - **Surface treatment /Stripping/Descumming**
  - **Implantation**
- **CHEMICAL**
  - **Cleaning**
  - **Pre-treatment**
  - **Supercritical CO_2 dryer**
  - **Molecular Vapor Deposition**

MATERIALS PATTERNING

MATERIALS PATTERNING

LITHOGRAPHY
- UV
- Laser
- Ebeam
- Nano imprint

ETCHING
- Plasma
- Wet
- Vapor
- Laser

OTHERS
- Ink jetting
- Screen printing
- Chemical Mechanical Polishing
- Grinding

MATERIALS INTEGRATION

- **INTEGRATION**
  - **DIE ASSEMBLY**
    - **discretization**
    - **Surface treatment**
    - **connexion**
  - **WAFER ASSEMBLY**
    - **Wafer bonding**

MATERIALS CHARACTERIZATION

CHARACTERIZATION

- **STRUCTURAL**
  - Transmission electron Microscopy (TEM)
  - High energy electrons diffraction (RHEED)
  - X Ray diffraction (XRD)
  - …
- **MORPHOLOGIC**
  - Profilometry
  - Scanning electron microscopy (SEM)
  - Focused ion Beam (FIB)
  - Atomic force Microscopy (AFM)
  - Ellipsometry
  - Acoustic microscopy
  - …
- **CHEMICAL**
  - IRFT
  - Secondary ion Mass spectroscopy (SIMS)
  - EDX, EDS
  - …
- **FUNCTIONAL**
  - Local electrical measurements
  - Surface functionalization
  - …

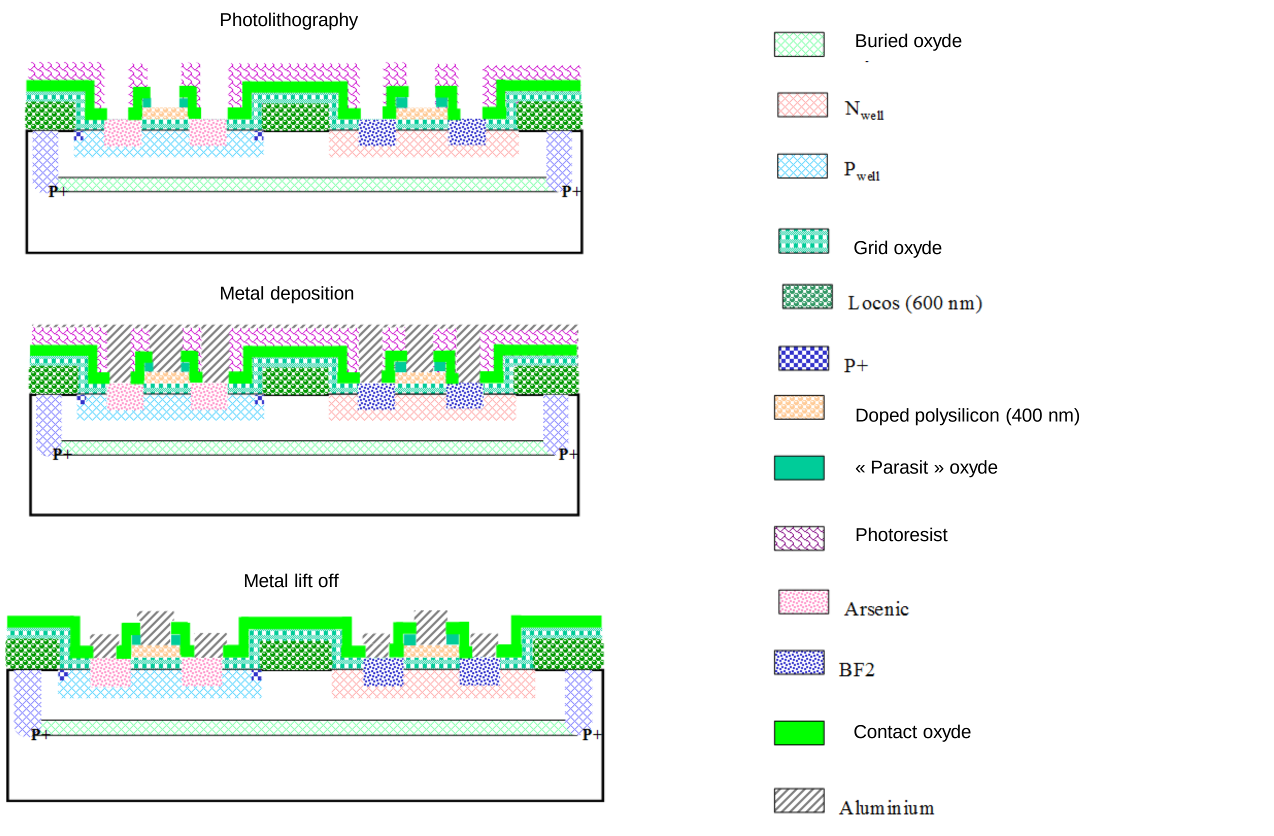
MICRO AND NANO DEVICES FABRICATION

General considerations:

- Devices: a multilayered structure
- The global flowcharts
- Lithography – Additive - Ablative process
- Differences between microelectronic and MEMS/NEMS

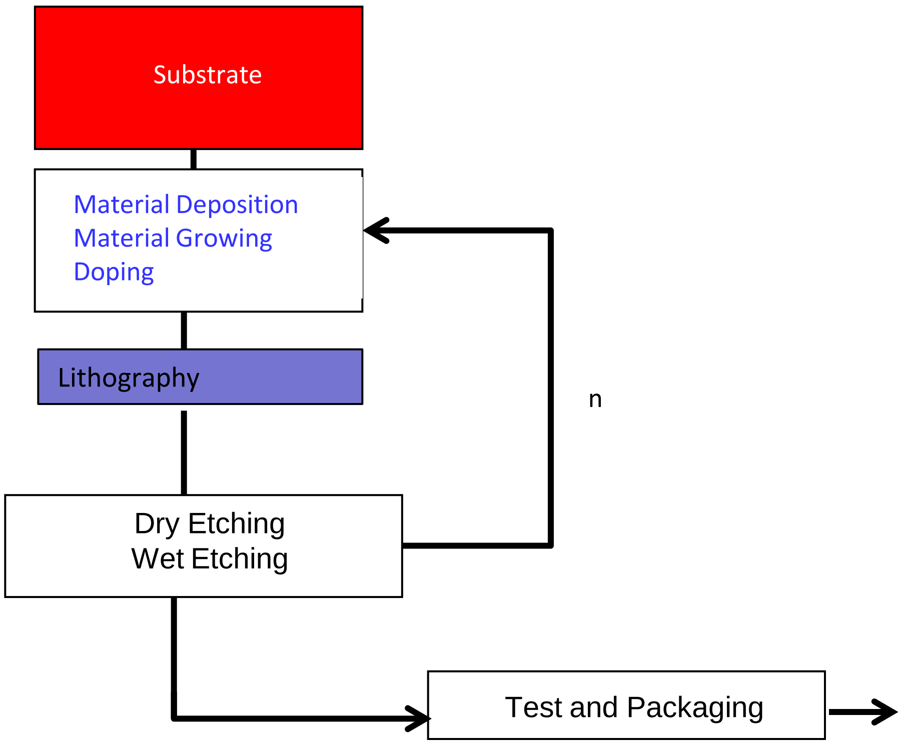
MULTILEVEL STRUCTURE OF PATTERNED LAYERS

Example of a **M**etal **O**xyde **S**emiconductor metallization

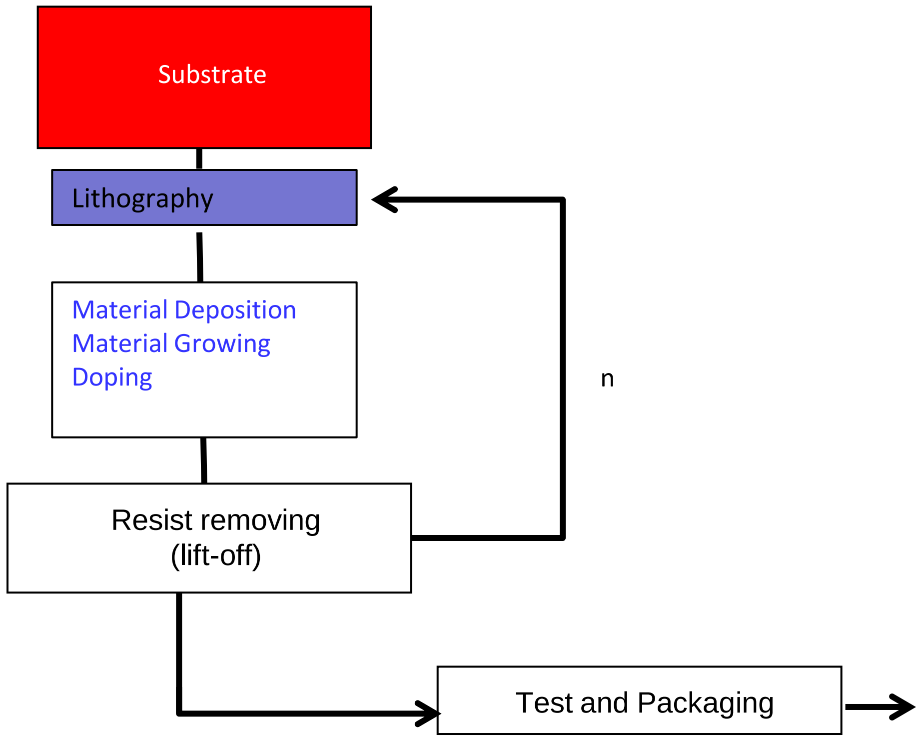


THE GLOBAL FLOWCHART

- The ablative flow



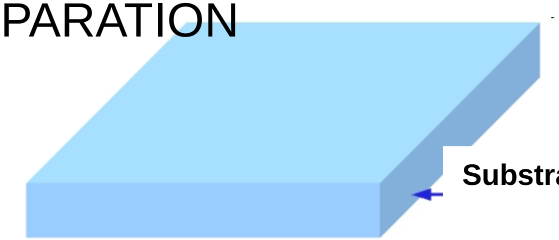
- The additive flow



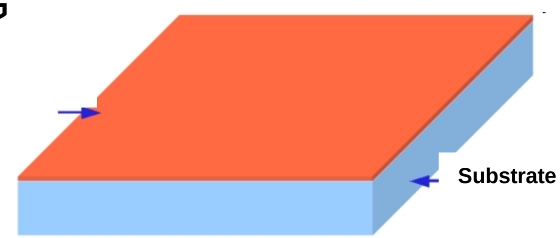
- Both flows coexist during processes
- Lithography is the key figure

LITHOGRAPHY PROCESS

1 PREPARATION

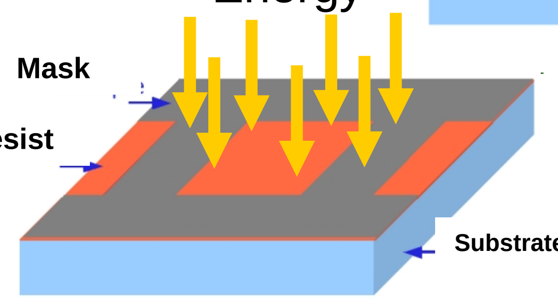


2 COATING



3 INSOLATION

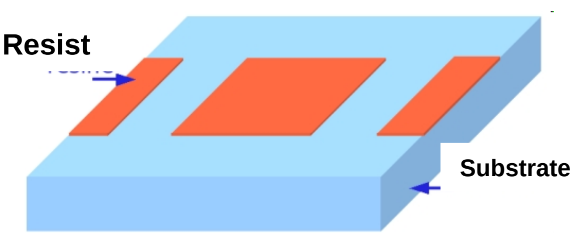
- UV
- electrons
- laser



4 AFTER DEVELOPING

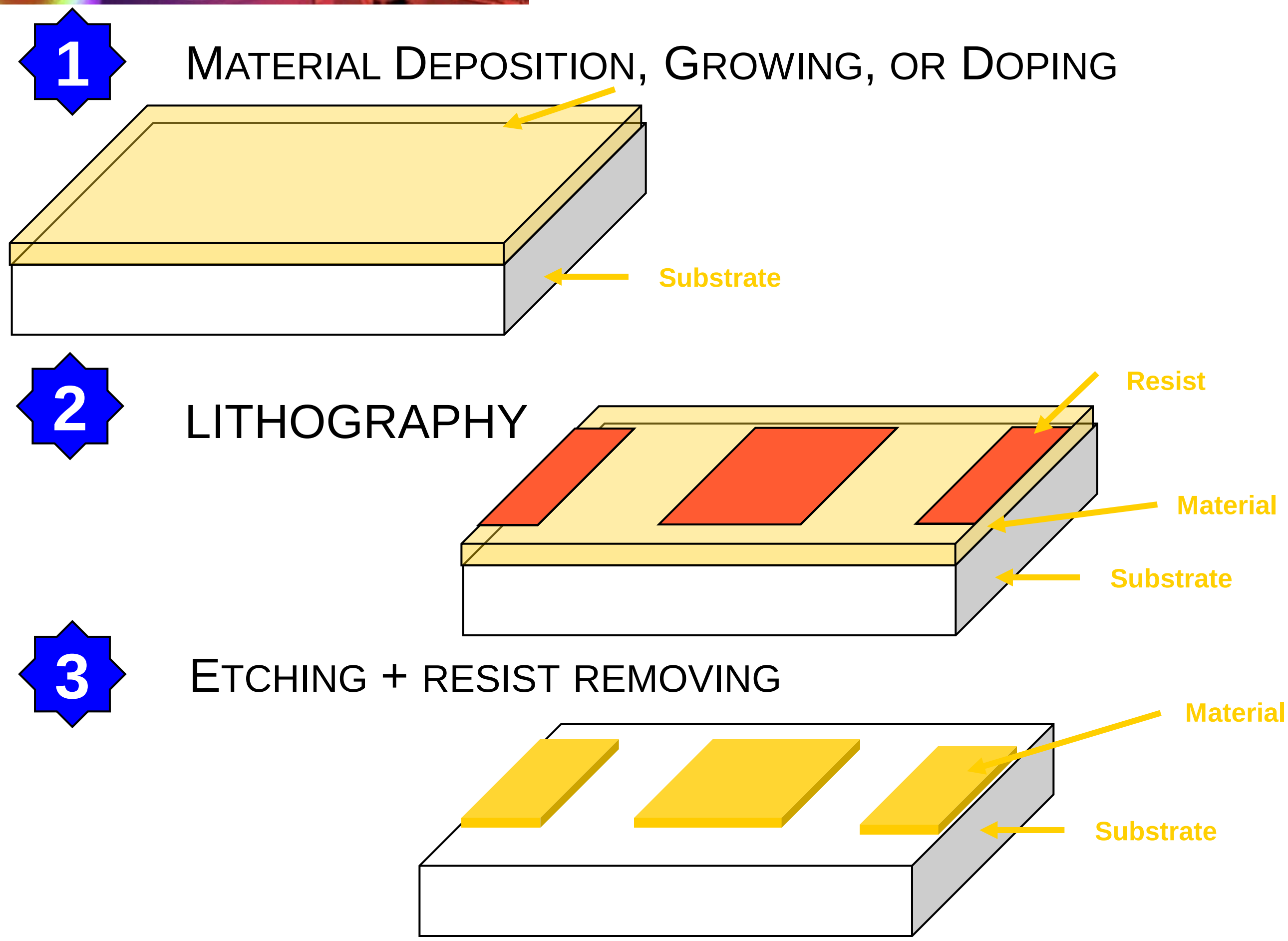
POSITIVE RESIST

NEGATIVE RESIST



THE PATTERN OF THE MASK IS TRANSFERRED IN THE RESIST ON THE SUBSTRATE

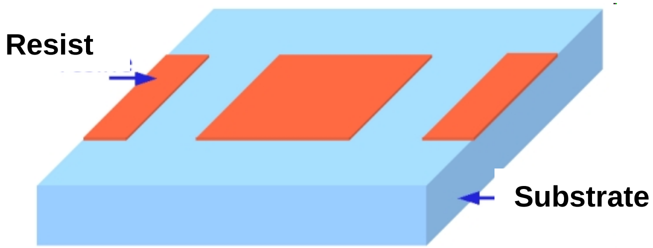
ABLATIVE FLOW



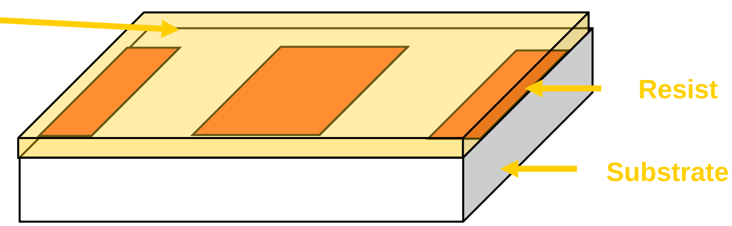
THE PATTERN OF THE RESIST IS TRANSFERRED IN THE MATERIAL

ADDITIVE FLOW

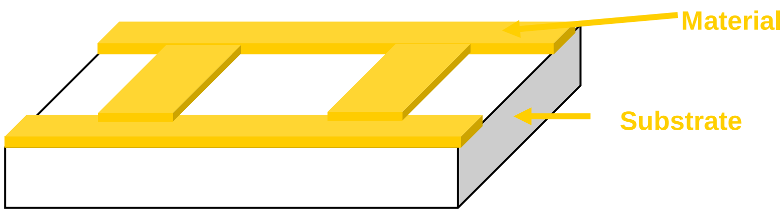
1 LITHOGRAPHY



2 MATERIAL DEPOSITION, GROWING, OR DOPING



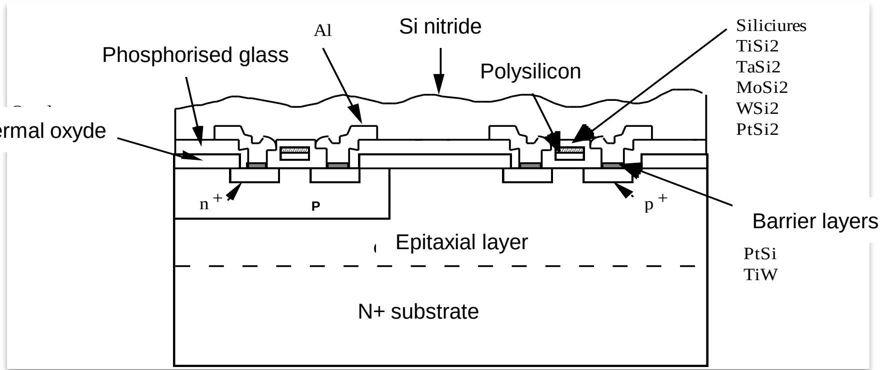
3 RESIST REMOVING (LIFT-OFF)



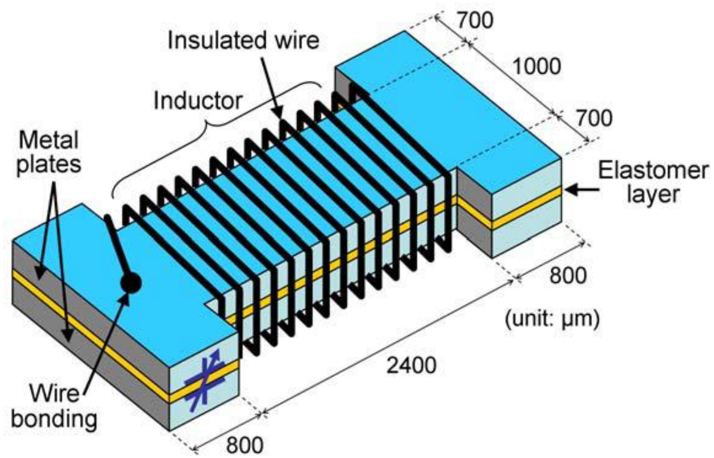
THE NEGATIVE PATTERN OF THE RESIST IS TRANSFERRED IN THE MATERIAL

MICROELECTRONIC VS MEMS/NEMS

- Microelectronic : example of the basic CMOS structure



- MEMS : example of a capacitive pressure sensor structure



From
A Micromachined Capacitive Pressure Sensor Using a Cavity-Less Structure with Bulk-Metal/Elastomer Layers and
Its Wireless Telemetry Application
Kenichi Takahata 1,* and Yogesh B. Gianchandani 2
SENSORS 2008

MICROELECTRONIC VS MEMS/NEMS

- Microelectronic manufacturing
  - Is mainly a surface patterning technology. So called PLANAR technology
  - Has a basic building block , the MOS transistor
  - Is silicon based depositing a relatively small set of materials
  - Equipment tool sets and processes are very similar between different fabricators and applications – There is a dominant front end technology base.
- MEMS/NEMS manufacturing
  - is a bulk/volume patterning technology
  - Does not have a basic building block – there is no MEMS equivalent of a transistor.
  - Some MEMS are silicon based and use sacrificial surface micromachining (CMOS based) technology
  - There is a very large number of materials depending on the application
  - There is an increase of new tools and processes.
- Today the technologies interpenetrate each other

MICROELECTRONIC VS MEMS/NEMS

Microelectronic processes	MEMS/NEMS processes
Lithography	Double side lithography
Etching (wet, Plasma) • surface	Etching (wet, plasma) • Surface • Volume (deep etching)
Deposition • Oxydation • Physical Vapor Deposition • Epitaxy • Chemical Vapor Deposition	Deposition • Ink jetting • Electroplating/electroless • Screen printing
Doping • Diffusion • Ion implantation	Wafer bonding Molding
Etc…	Etc…

Microelectronic process steps can be used in MEMS/NEMS processes
MEMS/NEMS specific process steps are not compatible with microelectronic processes

SUMMARY ABOUT MICRO/NANO FABRICATION

- Devices = multilayers patterned structures
- Two technological ways
  - Ablative way : deposited material is etched
  - Additive way : a material is added on the structure
- Lithography : basic step to pattern the materials
- Microfabrication basis were microelectronics ones but MEMS/NEMS are at the origin of many new technologies
  - MEMS/NEMS processes can integrate microelectronics ones
  - Microelectronics processes not always accept MEMS/NEMS specific ones

Thank you for your attention