Scientific Committee Labex CEMAM

Center of Excellence on Multifunctional Architectured Materials

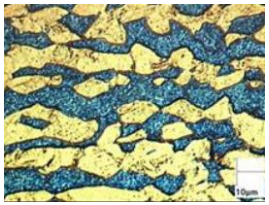
Centre d'Excellence sur les Matériaux Architecturés Multifonctionnels

2020-2024

16/11/2021

Architectured materials

Multifunctional materials designed from usage requirements and characterized by optimization usually at a scale between the microstructure and the part
(e.g. spatial distribution of matter)

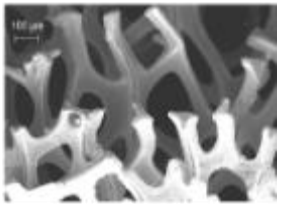


Microstructural architecturation

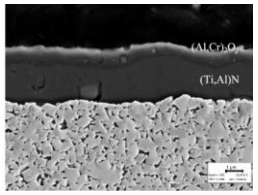
Foams

Lattice structures

Graded materials

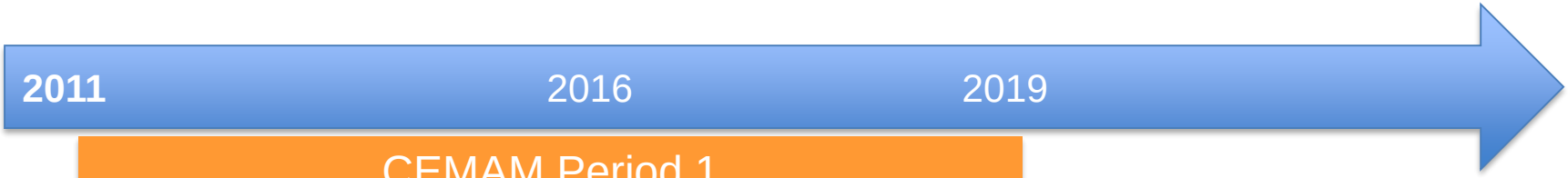


Architectured surface



Architectured coatings

CEMAM Period 1



CEMAM Period 1

IDENTITY CARD

- **10 teams** specialized in materials science and engineering (LEPMI, LMGP, SIMAP)
- 1 team in physical biology (LiPhy)
- 1 team in biomedical engineering (TIMC)
- → 130 permanent members
- **7.5 M€** (0.75 M€/year during 10 years)
- Managing entity : Grenoble INP
- Executive committee + Scientific committee

TRADEMARK : 1+1 leverage rule

- Research
- Investments
- Education
- Technology transfer

CEMAM Period 1

2011 — 2016 — 2019

CEMAM Period 1

Research

6 IRP

1. Extreme environments
2. Thin film engineering
3. Structural weight saving
4. Building thermal insulation
5. Electrochemical generators
6. Biomedical engineering

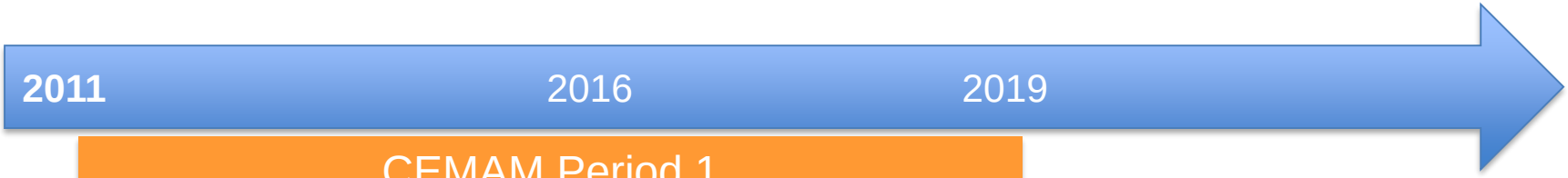
3 Shared Facilities

1. Modeling
   (CIMENT calculation center)
2. Elaboration
   (Architecturation platforms)
3. Characterisation
   (CMTC platform)

Ph.D. & Post docs

- 30 PhD and 20 post docs
- 1+1 Industrials and International
- 70 % of PhD students hired in industry
- About 60 publications / year
- 20 patents

CEMAM Period 1



CEMAM Period 1

Investments

- CEMAM support **2.0 M€**
- Total invested amount 4.0 M€

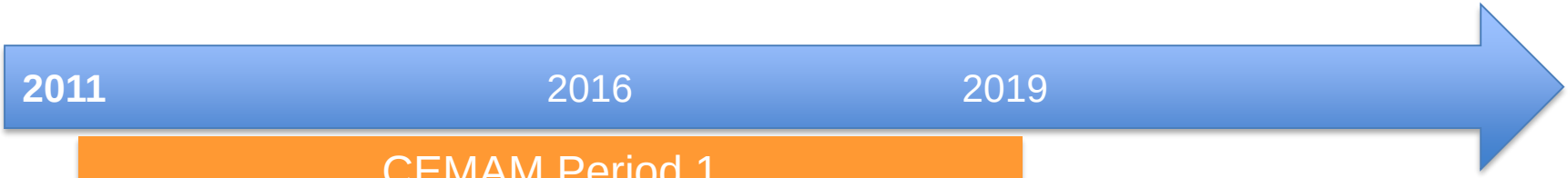
Elaboration

- Plasma Enhanced Atomic Layer Deposition
- Electro Spray Deposition
- Electron Beam Melting

Characterisation

- TEM FEG
- High resolution SEM
- X-ray tomography equipment

CEMAM Period 1



CEMAM Period 1

Education

- 50 Master Students have benefited of IRP and shared facilities
- Workshops and Summer Schools (ARCHIMAT)
- Integrated projects PHELMA
- Common option PHELMA/GI on Additive Manufacturing
- …

Technology Transfer

- VIAMECA competitiveness cluster
  (CEMAM reference labex on Advanced Manufacturing Processes)
- RAFAM network
  (Auvergne Rhône Alpes network on Additive Manufacturing)
- RAFALD network
  (French Atomic Layer Deposition network)
- Start up VULKAM
  (micro-technical parts in amorphous metallic alloys)

CEMAM New Period (2020-2024)

CEMAM Period 1

New Period

- Updated objectives
- Identity card
- Governance
- Roadmap
  - Research
  - Investments
  - Education
  - Technology transfer

Updated objectives

1. To promote **eco design** of architectured materials

2. To improve **durability** and multifunctionality of architectured materials

Identity Card

- **Project leader**
  - Alain PASTUREL

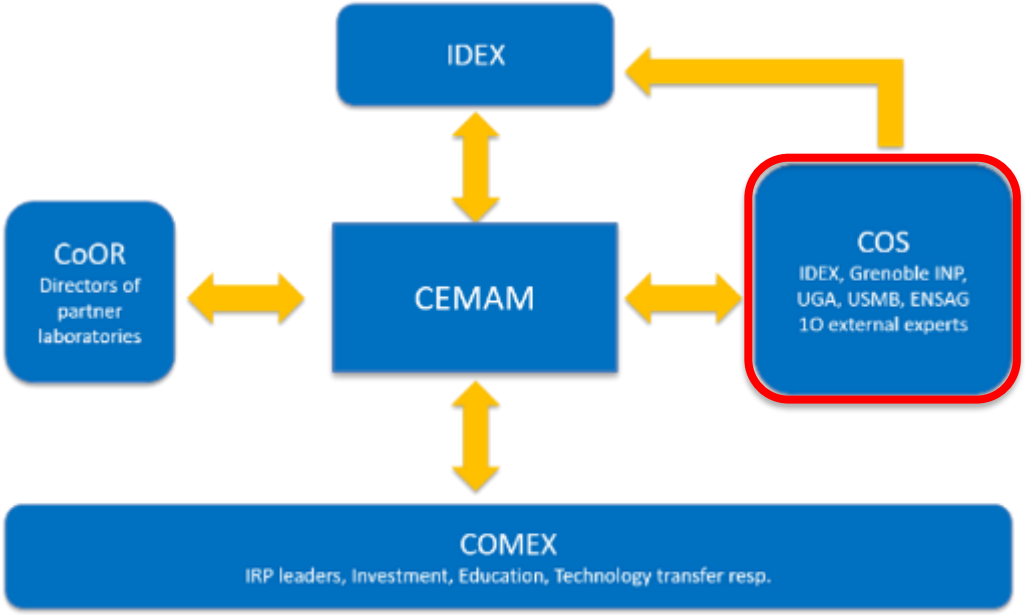
- **14 research teams**

  - 10 teams specialized in materials science and engineering (LEPMI, LMGP, SIMAP)
  - 1 team in physical biology (LiPhy)
  - 1 team in biomedical engineering (TIMC)
  - **1 new team in eco-responsible design (G-SCOP)**
  - **1 new team in urban architecture (AAU)**

  - ≈ 150 permanent members

- **Budget**
  - **3.7 M€** (≈ 0.75 M€ / year during 5 years)
  - Managing entity : **IDEX UGA**

Governance


IDEX
CoOR
Directors of partner laboratories
CEMAM
COS
IDEX, Grenoble INP, UGA, USMB, ENSAG
10 external experts
COMEX
IRP leaders, Investment, Education, Technology transfer resp.

Roadmap

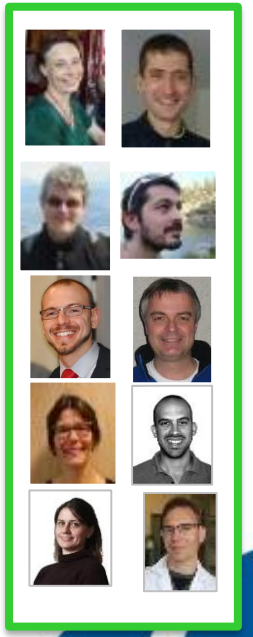
- Research
- Investments
- Education
- Technology transfer

Research

- **Updating of IRPs**

1. ~~Extreme environments~~
2. Thin Film Engineering
3. Structural Weight Saving
4. ~~Building Thermal Insulation~~
5. Electrochemical engineering
6. Biomedical Engineering

1. **<u>Ecoefficiency, second life(s), recycling</u>**
2. Thin Film Engineering
3. Weight saving engineering for structural applications
4. Biomaterials design for biomedical engineering
5. Electrochemical engineering for sustainable energy



Research / IRP 1

Isabelle BILLARD

Damien EVRARD

- **Eco-efficiency, second life(s), recycling**
  - Providing knowledge and tools to evaluate and to lower environmental impacts of architectured materials, from raw material extraction to final product and its end-of-life
    1. **Eco-efficiency** of architecturation processes
       - Life Cycle Assessment
       - Product or process eco-design
    2. **Second life(s) / recycling capacities** taken into account from the design stage
       - Finding end-of-life strategies to maintain added value created upon architecture of objects and materials
       - Procedures for dismantling architectured objects
       - Developing innovative recycling processes
       - Understanding of physical phenomena during phase separation
       - Evaluation of cost
       - …

Research / IRP 2


Raphael BOICHOT – David RIASSETTO

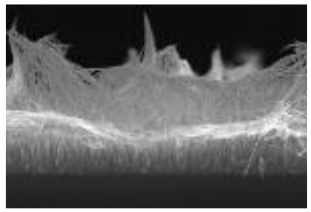
- **Thin film engineering**
  - High-performance coatings for mastering surface functionalization (at minimal energetic price and resource consumption)

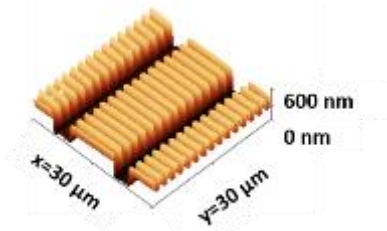
    1. **Bio-inspired nano-architectured surfaces**
       Hydrophobic surfaces (e.g. preventing bacteria adhesion)
       Water harvesting.

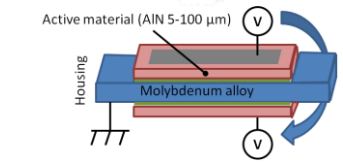
    2. **Coating on architectured materials (surface functionalization)**
       Inorganic coatings combined with bio-sourced materials
       Coating on lattice (durability increase), on ZnO networks

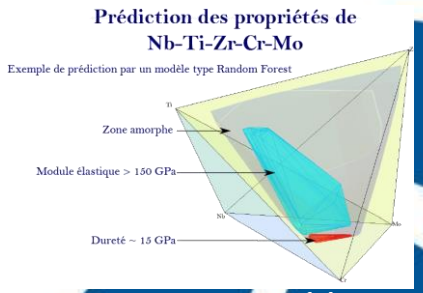
    3. **Active coatings**
       Piezoelectric coatings. Conductive materials for transparent electrodes

    4. **Combinatorial design in thin films**
       High throughput analysis (HEA, nitrides….)









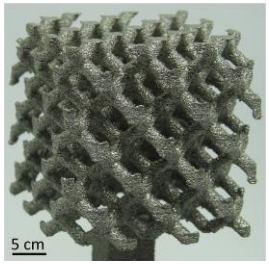
Research / IRP 3

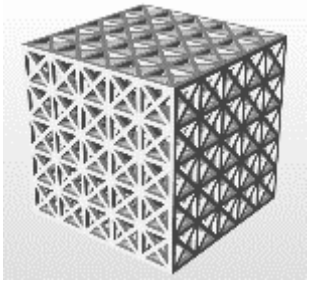
Hugo VAN LANDEGHEM

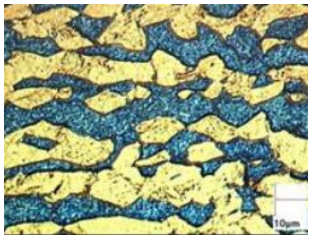
Jean-Jacques BLANDIN

- **Weight saving engineering for structural applications**
  - Promoting strategies to improve durability of architectured materials for structural applications while using the minimum quantity of material

1. **Multifunctional architectures**
   (e.g. CVD coated lattice)







2. **Damage tolerant architectures**
   (e.g. strain hardenable Ti lattice)

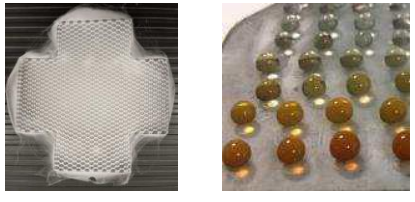
3. **Locally controlled architectures**
   (e.g. microstructures, geometries)

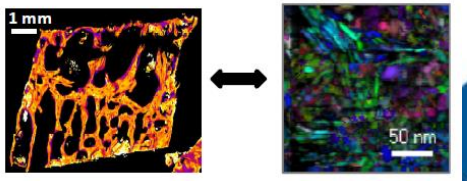
Research / IRP 4

Mariane WEIDENHAUPT – Thomas BOUDOU

- **Biomaterials design for biomedical engineering**
  - Design, fabrication and use of architectured biomaterials for biomedical engineering

1. **Tissue regeneration & medical devices**
   (e.g. biomaterials for enhancing functional recovery)
2. **Biosensors**
   (e.g. detection of biomolecules)
3. **Innovative architectured microenvironments**
   (Fundamental biology of cells and tissues)
4. **Multi-scale characterisation of tissues/organs**
   (e.g. bone characterisation)





Research / IRP 5

Cristina IOJOIU — Frédéric MAILLARD

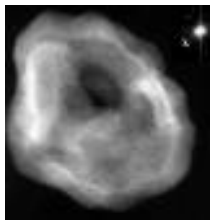
- **Electrochemical engineering for sustanaible energy**
  - Developing new electrochemical energy storage and conversion devices that can operate beyond fossil fuels

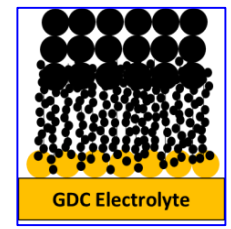
1. **Atomic-level design of nanomaterials**
   for complex electrocatalytic reactions
   (e.g. design of highly active and stable nanocatalysts)

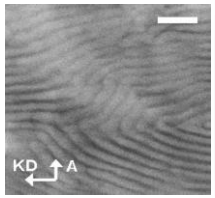
2. **Architectured electrodes**
   for energy conversion and storage (gradient-electrodes and electrodes with new ion conducting materials and/or catalysts)

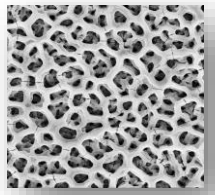
3. **Multi-functional electrolytes** for energy conversion and storage
   (more performant electrolytes and membranes and *in situ* characterisations)

4. **Architectured membrane electrodes assembly (MEA)**
   for high performance electrochemical generators
   (optimizing a cell, operando characterisation)









Research

- **Maintain of the research matrix (IRP / SF)**

Research / Call for projects

- **Every year**
  - September : Call announcement

    Scientific animation by IRP coordinators (inter IRPs, inter labs, leverage rule…)
  - December : Pre-selection of projects
  - January : Presentation of pre-selected projects to the executive committee
  - February : Selection of supported projects (Ph.D., post docs)

➢ **Key role of IRP coordinators**

Research / Budgets

- **2019** : projects were initiated (CEMAM 1st period) taking into account new CEMAM priorities

- **2020** : project call but the selected research projects could not be financially supported

Research / Budgets

- **2021 : project call → 7 selected projects** (just starting)
  - Resurrecting structurally disordered PtNi / C electrocatalysts used in PEMFC devices
    (P1, co-funding PEM Mobilité consortium Gold o'PAC)
  - Janus membrane for seawater desalination by membrane distillation
    (P1, co-funding Nanoscience Fundation UGA)
  - Elaboration and evaluation of elasto-caloric materials for refrigeration
    (P1, co-funding Labex Lanef)
  - Blistering damage mechanism of coatings and thin films
    (P2, co-funding Labex Interactifs Poitiers)
  - Single-material architectures for decoupled control of stiffness and damping
    (P2, co-funding SME Socitec)
  - Protein-Material Interactions: influence of material properties on protein adsorption and self-assembly
    (P2,, co-funding Becton Dickinson)
  - Optimization of high performance nano-architectured electrode/electrolyte bilayers for reversible Solid Oxide Cells
    (P2, co-funding Harvestore FeT Open European project)

(P1) Eco design / (P2) Durability, multifunctionality

Research / Focus on projects

- **Examples of focus on projects**

1. Extracting Pt from Membrane Electrode Assembly (P1)
2. Janus membrane for seawater desalination by membrane distillation (P1, starting in 2021)
3. Improving durability of lattice structures by adapted coatings (P2)
4. Architectured surfaces for confining cell movements (coll. ENSAG/AAU)

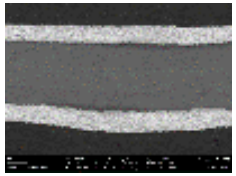
(P1) Eco design / (P2) Durability, multifunctionality

Research / Focus on projects


Isabelle BILLARD Damien EVRARD

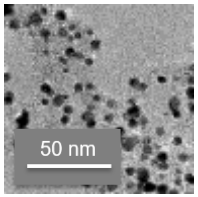
- **Extracting Pt from Membrane Electrode Assembly**

Post doc Kiran Pal SINGH



Fresh MEA with alloyed PtCo supported on carbon at the cathode side

Solution containing Pt (yellow) and Co (blue) ions



Dispersed Pt particles on carbon support

Pt Gel obtained without carbon support

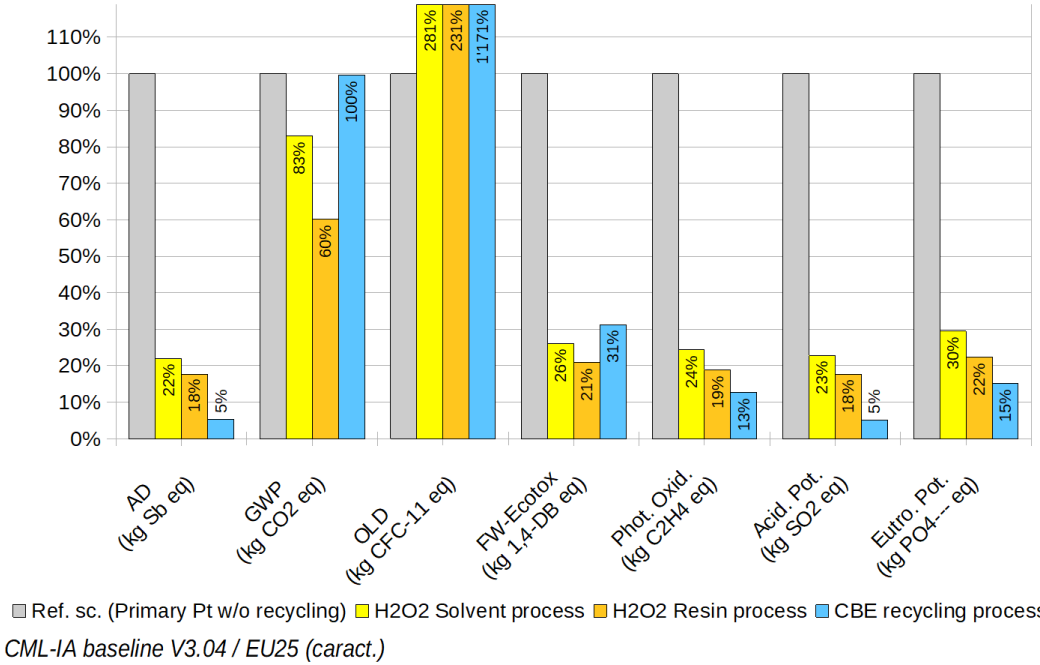
- Avoiding Co elimination before fabrication of recycled Pt particles ?
- Electrochemical activity of recycled Pt gel
- Applying these processes to aged MEA
- Life cycle analyses of recycling routes

Research / Focus on projects


Isabelle BILLARD — Damien EVRARD

- **Extracting Pt from Membrane Electrode Assembly**

Post doc Kiran Pal SINGH



CML-IA baseline V3.04 / EU25 (caract.)

Positive aspects for CBE:

- the best on 4 cat.
- better than ref. on FW-E
- same as ref. on GWP

Negative aspects for CBE:

- same as ref. on GWP
- the worst on OLD

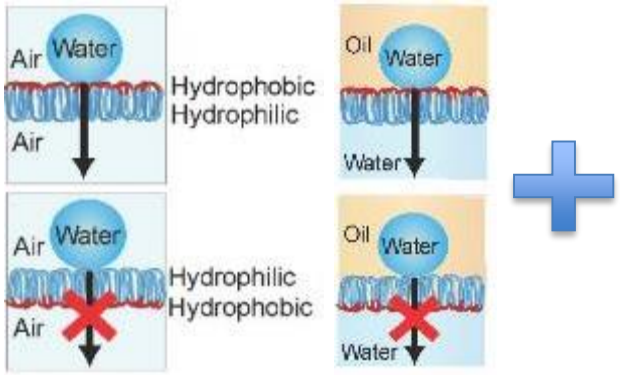
(to be relativized)

Research / Focus on some projects

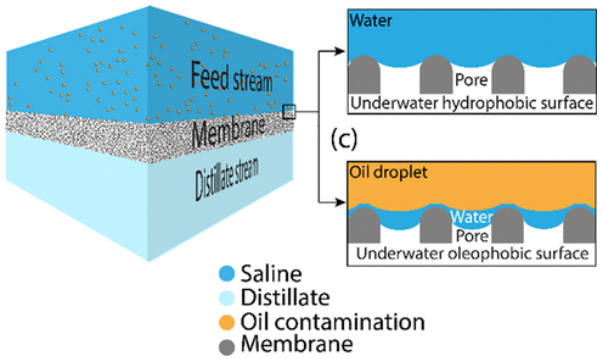
David RIASSETTO

- **Janus membrane for sea water desalination by membrane distillation**

  Post doc Sanjay CHAUDHRI



Liquid “diode”



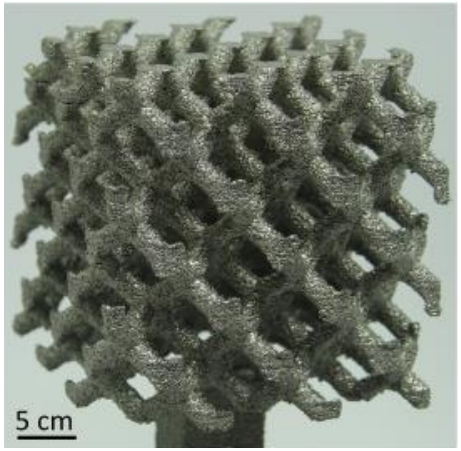
Antifouling Architecture

- Inorganic Janus membrane for water desalination
- Desalination efficiency
- Antifouling behavior
- Life cycle analyses of the membrane and the whole desalination process

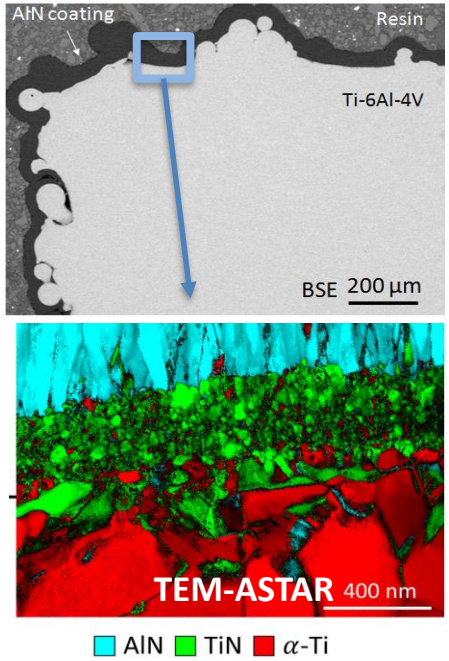
Research / Focus on some projects

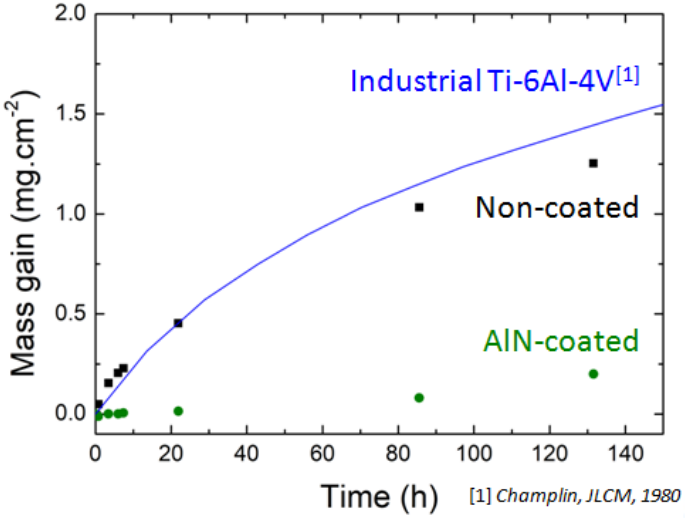
- **Improving durability of lattice structures by adapted coatings**

  Post doc A. MOLL



CVD / ALD coatings on
EBM TA6V lattices





A. MOLL et *al.*, *Surface & Coatings Technology* 415 (2021) 127130

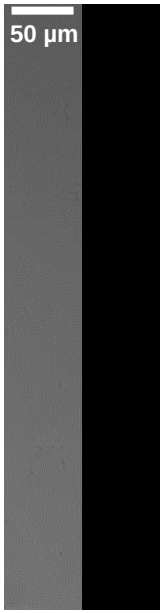
Research / Focus on some projects

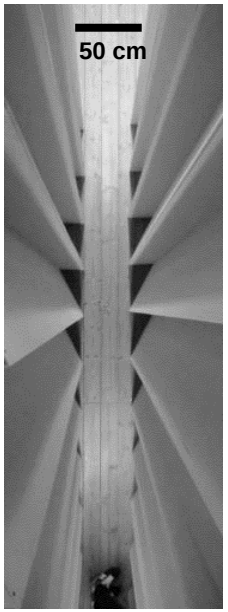
Thomas BOUDOU

- **Architectured surfaces for confining cell movements**

  PhD M. BONNEFOY, coll. ENSAG, Univ. Mons (B)

- Can architects and biophysicists learn from each other?
- How architecture impacts individual and collective movements?
- Micro- and macro-architectures prototyping
- Quantification of the trajectories of cells and humans at different scales





½ PhD CEMAM
½ PhD Ministry of Culture

⇨

Grant CNRS Interdisciplinarity
PhD UGA

Roadmap

- Research
- Investments
- Education
- Technology transfer

Investments


Patricia DONNADIEU


Laurent MANIGUET


Jean-Jacques BLANDIN

- **Strategy**
  - Characterisation, Elaboration (architecturation)
  - Consolidation of CEMAM 1st period
  - Coupling elaboration and characterisation
  - Maintain of the cost sharing policy

CEMAM support	**≈ 1 M€**
Total invested amount (**Target**)	**≥ 2 M€**

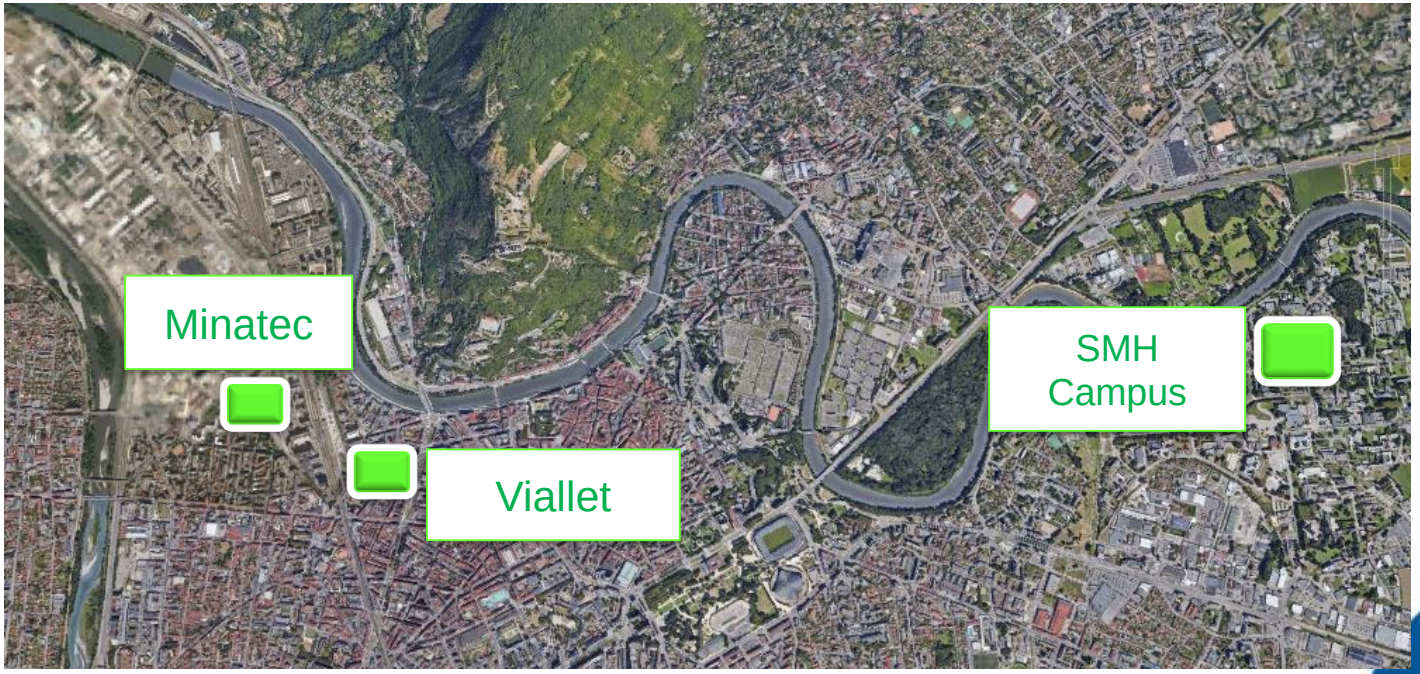
Investments

- **Roadmap**
  - **Characterisation**
    - SEM-FIB (2022, ≈ 30%)
    - In situ AFM testing (soft materials) (2021,100%)
    - In house developments for nano indentation (mechanical/electrical) (2021, 100%)
    - Multi-axis press for characterisation of micro-materials (2022, 10%, coll. TEC21 labex)
  - **Elaboration** (Architecturation)
    - Ultrasonic spray (2021, 50%)
    - Instrumented flash sintering equipment (2022, 50%)
    - Monitored laser for local TT and AM (2022, 45%)
    - Hybrid AM equipment (2023, 50%)
  - **Process oriented characterisation**
    - 2D: In situ gas analysis in CVD, calorimetry (2022-2023, 50%)
    - 3D: Element loss during metal AM, multimaterial AM (2021-2023, 50%)

Committed amounts	
CEMAM	**540 k€**
Total	≈ 1700 k€

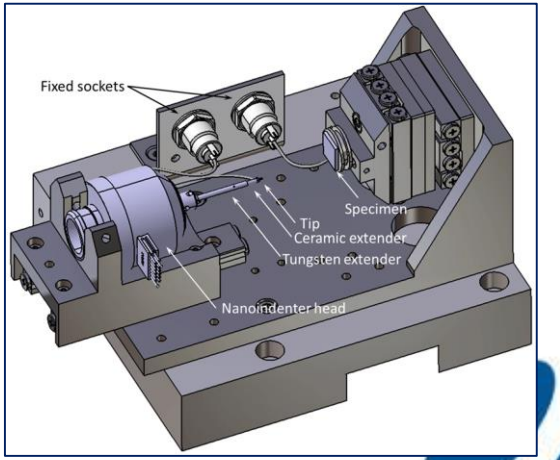
Investments / CEMAM platforms

- **3 sites**



Investments / Characterisation platforms

- **Characterisation of architectured materials**
  - X-ray micro tomography [M. Suard et *al*., *Adv. Eng. Mater*. 2020, 2000315]
  - In situ SEM [T. Dessolier et *al*., *Mater. Sc. Eng*. A 775 (2020) 138957]
  - Resistive nano indentation [F. Volpi et *al*., *Rev. Sci. Instrum*. 92, 035102 (2021)]

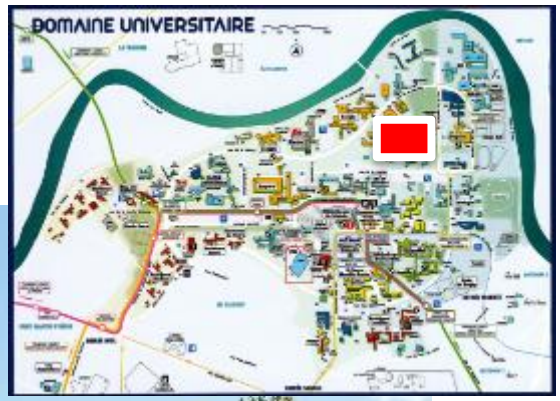


Investments / Architecturation platforms

- **Available equipments**
  - **Coating**
    - CVD and MO-CVD reactors
    - Spatial ALD, Plasma Enhanced ALD
    - PVD
    - Electro Spray Deposition (including US)
    - In situ photo patterning of proteins and hydrogels
  - **Sintering**
    - Traditional sintering (including optical dilatometer)
    - Flash sintering
    - Microwave
  - **Additive Manufacturing**
    - Electron Beam Melting
    - Wire Arc Additive Manufacturing
    - Wire Laser Manufacturing
    - Indirect technology assisted sintering
    - High resolution 3D maskless lithography

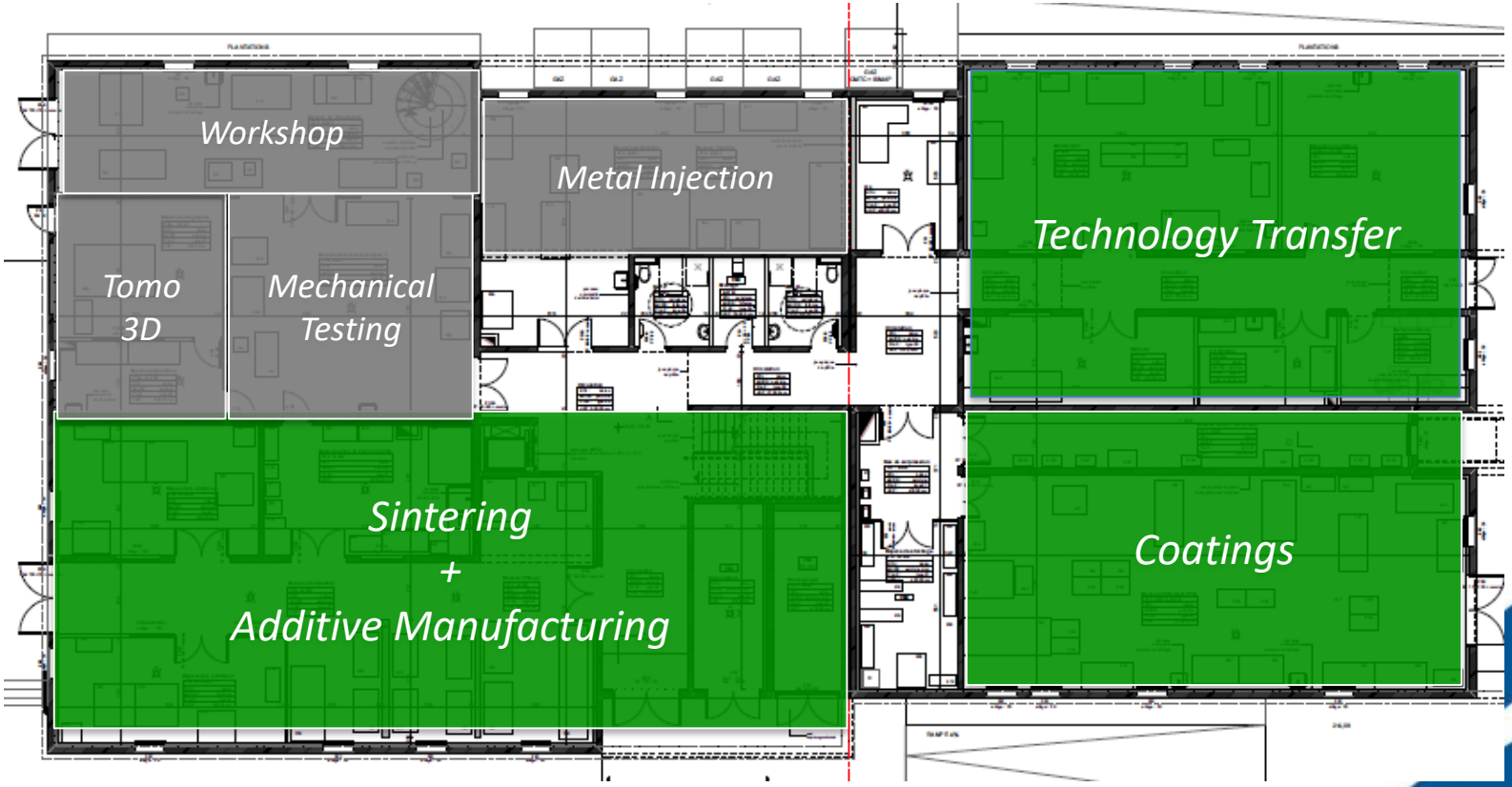
Investments / Architecturation platforms

- **New ECOMARCH building** / 8 M€, opened in 2020



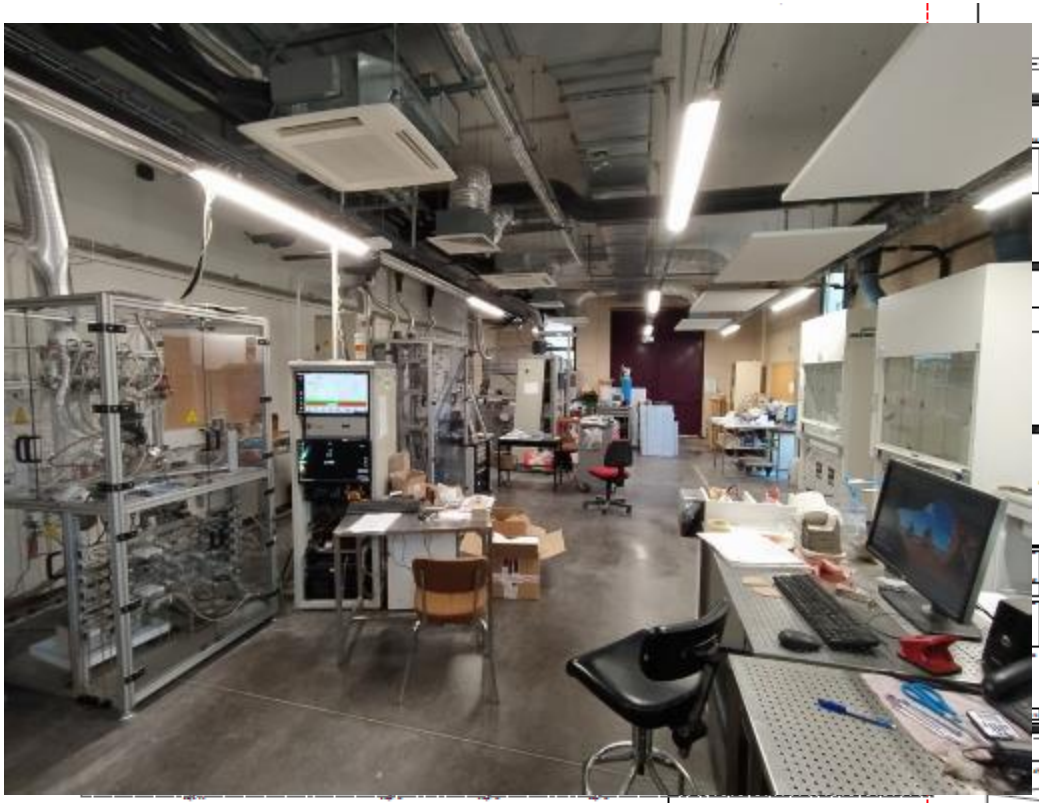
Investments / Architecturation platforms

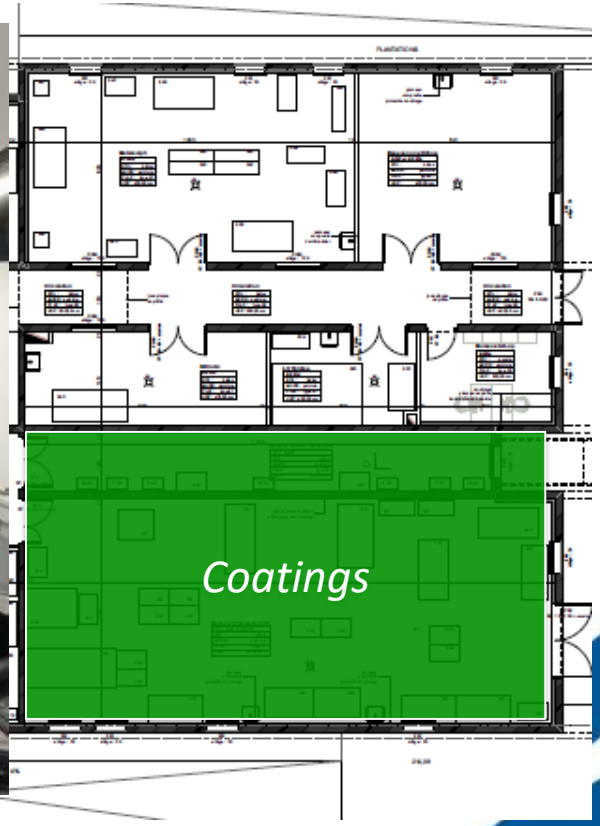
- **New ECOMARCH building** / Architecturation platforms



Investments / Architecturation platforms

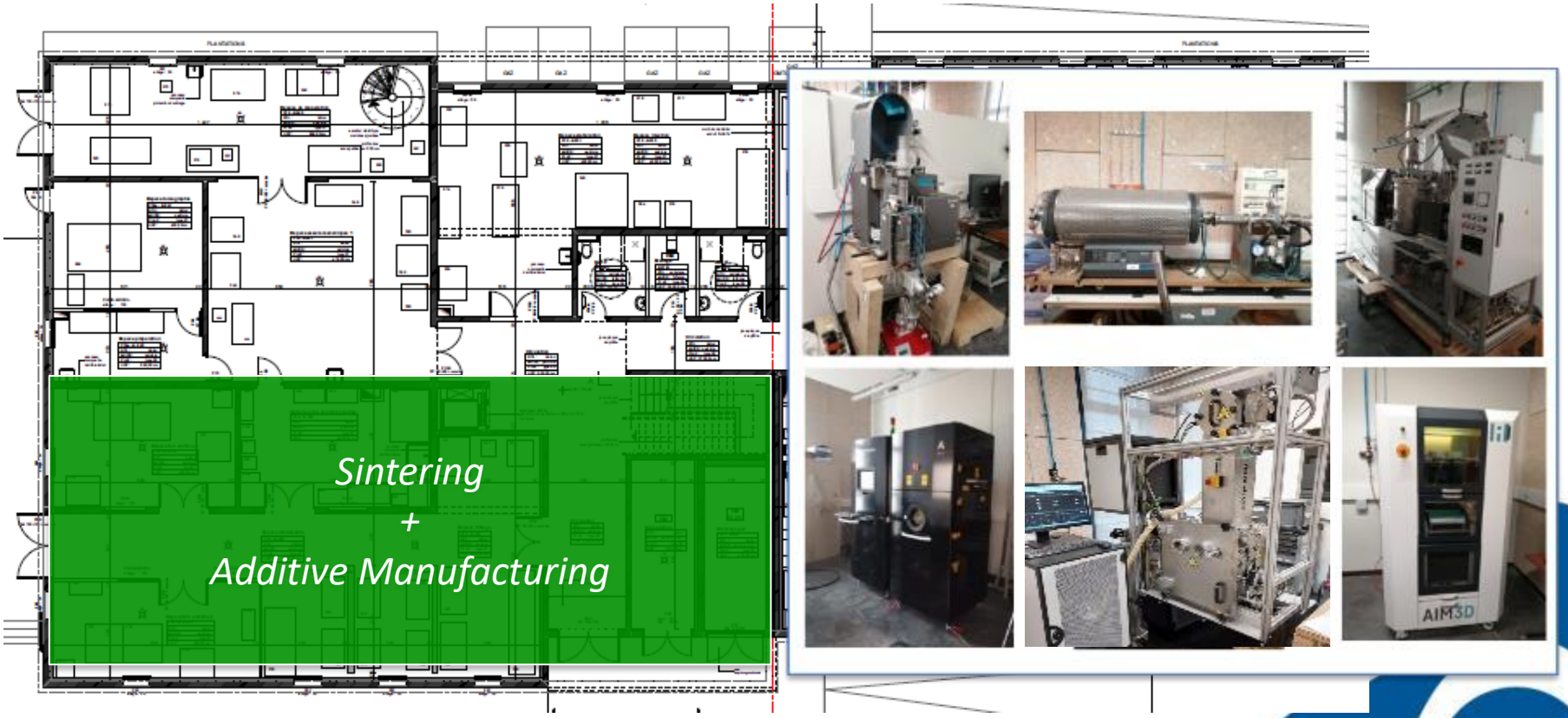
- **New ECOMARCH building** / Architecturation platforms





Investments / Architecturation platforms

- **New ECOMARCH building** / Architecturation platforms



Roadmap

- Research
- Investments
- Education
- Technology transfer

Education

Rémy DENDIEVEL

Arnaud MANTOUX

- **L2, L3**
  - **“Merit grants”** to discover research in labs or industry for short periods (typically 1 to 3 months)
  - **Innovative Materials Day**
    (40 students every year, visit of CEMAM platforms, discussions with CEMAM staff)

- **M1, M2**
  - Support to **European exchanges** (e.g. Kic Inno Energy, TeachHy)
  - Consolidation of **Integrated Projects**

Education

- **Consolidation of integrated projects**
  - Master 1 (4 months full time industrial project) + Master 2 (5 months half time, academic projects dedicated to industrial subjects + final internship)
  - Materials Training Platform : investments of INP Phelma
    (important refurbishment work, new equipments : Metal AM, X-ray tomography…)

Education

- **Seminars, workshops, summer schools…**
  - « Chimie à Grenoble » Day, 21/03/**2019**, co-organised with Arcane, Tec21, Carnot Polynat & Energie du Futur
  - “Student day”, 26/11/**2019** : Scientific presentations PHD post docs, Technology transfer presentations
  - 1st Summer School “Additive Manufacturing”
    - Autrans, cancelled may 2020 → may **2021** (remote)
    - > 180 persons. 26 pre-recorded lectures + live sessions
    - 100 % satisfied or very satisfied participants

  - RAFALD 2021 workshop
    - Workshop on Atomic Layer Deposition
    - Marseille, 3-5 Nov. **2021**

Roadmap

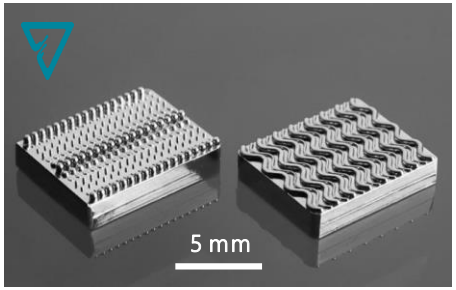
- Research
- Investments
- Education
- Technology transfer

Technology transfer

- **Partnerships with networks**
  - **Institut Carnot “Energies du Futur”**
    (e.g. materials and processes for energy” and “life cycle”)
  - **RAFALD network**
    Network of the French actors in Atomic Layer Deposition
  - **CIMES competitiveness cluster**
    Renewal of CEMAM as reference labex on Advanced Manufacturing Processes
  - **INITIATIVE 3D network**
    Auvergne Rhône Alpes network on Additive Manufacturing

Technology transfer

- VULKAM amorphous metal
  - Micro-technical parts in amorphous metallic alloys



2016 | **2017** | **2018** | **2019** | **2020** | **2021**

Support **CEMAM**

Linksium Maturation Incubation

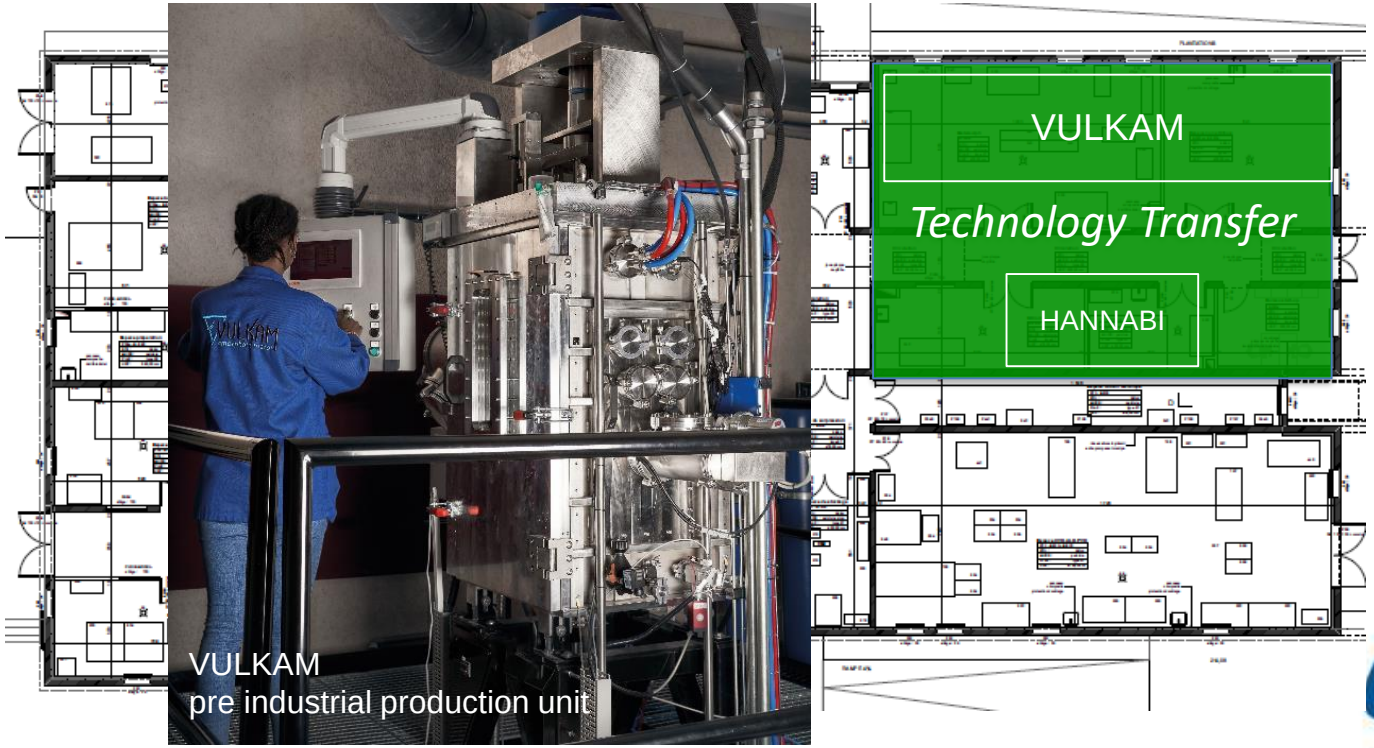
Awards:
- Best industrial innovation 2019 (CCI Grenoble)
- Winner I-lab competition,
- Winner « µ d'or » (Micronora exhibition)
- Start up labelled Deep Tech (BPI)

Major fundraising

Today, staff > 20 persons

Technology transfer

- → **Technology Transfer Platform of ECOMARCH**



Technology transfer

- **New start up : HANNABI**
  - Ceramic coatings
    on bio sourced materials

2018 | **2019** | **2020** | **2021** | **2022** | **2023**

CEMAM Laboratoire d'excellence

Support **CEMAM**
Post-doc
E. GICQUEL
(May 2018 - 2019)

CHALLENGE Out of labs — Maturation

Linksium technology transfer & startup building Grenoble Alpes — Incubation

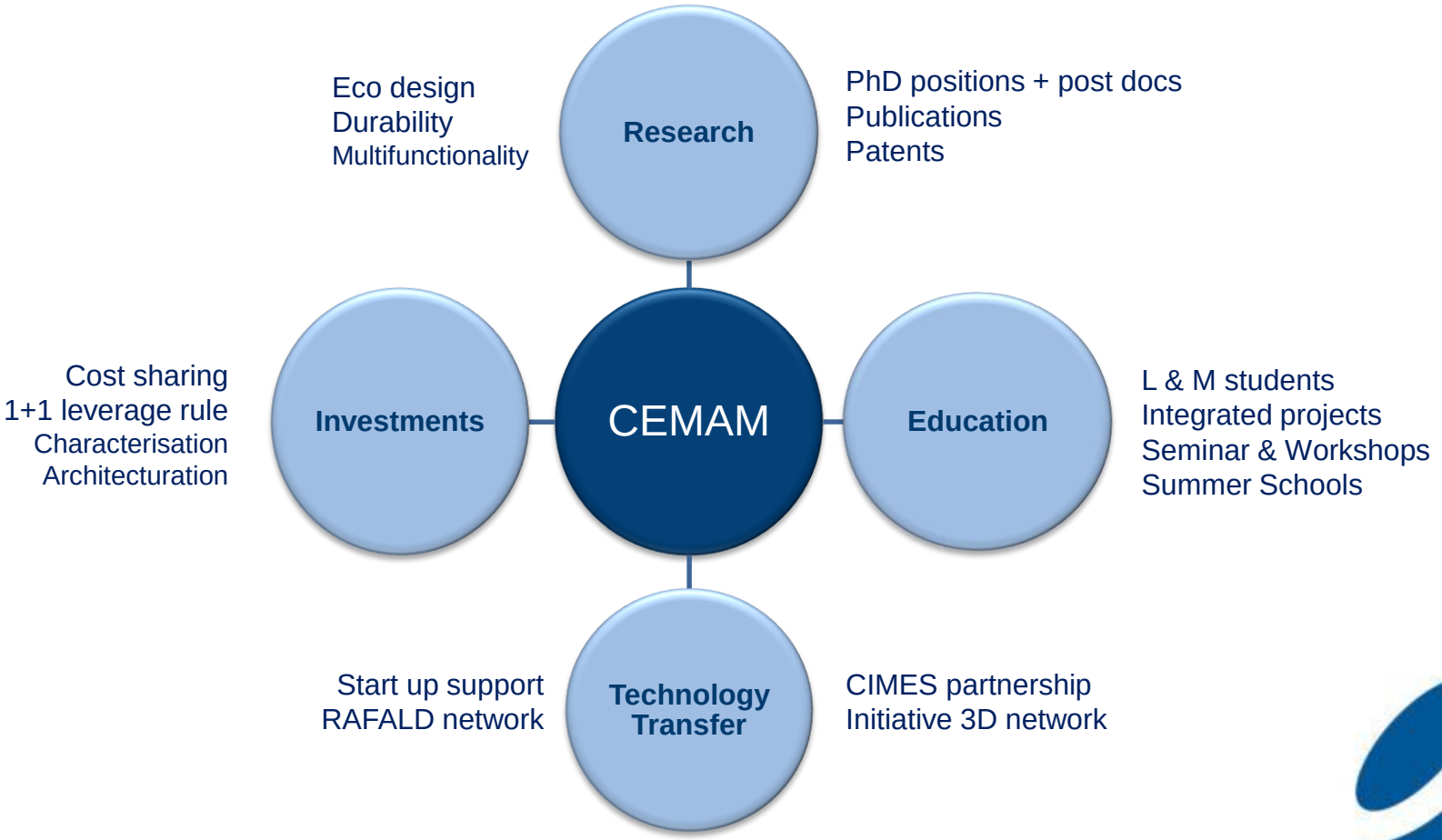
CEMAM Laboratoire d'excellence

tec21 the engineering of complexity

« Starting »
Start up

CEMAM is a « Laboratoire d'Excellence ». More information on www.cemam.fr

Summary


Eco design
Durability
Multifunctionality
Research
PhD positions + post docs
Publications
Patents
Cost sharing
1+1 leverage rule
Characterisation
Architecturation
Investments
CEMAM
Education
L & M students
Integrated projects
Seminar & Workshops
Summer Schools
Start up support
RAFALD network
Technology Transfer
CIMES partnership
Initiative 3D network

Additional actions in 2022

- **Adaptation to updated environments**
  - **IDEX management**
    - Physics, Electronics, Materials (PEM) research department
    - Links with other labex (e.g. TEC21)
  - **PEPR**
    - **DIADEM (**DIscovery Acceleration for the Deployment of Emerging Materials)
      Demonstrator ADAM (Accelerated Development of Architectured Materials)
      Other demonstrators, project calls…
    - Other PEPR (Hydrogen, Batteries…)

Scientific Committee Labex CEMAM

Center of Excellence on Multifunctional Architectured Materials

Centre d'Excellence sur les Matériaux Architecturés Multifonctionnels

2020-2024

16/11/2021