
# Materials and Design for Sustainable development
## MACODEV

Prof. Jean-Yves Cavaillé, INSA-Lyon

**General Scope**

**Main Scientific Axis**

**Main Tools (projects of Plateformes)**

**Governance**

**Future Strategy**

RhôneAlpes

MACODEV

Cluster MAtériaux et COnception pour un DEVeloppement durable

RhôneAlpes

- Cluster MACODEV was initiated by *Région Rhône-Alpes*
- It is one of the tools to reinforce the Research activity in the field of materials science and engineering
- It is a network of expertise, involving shared large equipments
- The objective is to propose with industrials partners specific projects with laboratories they will choose within the cluster, for a limited duration (Post-Doc, Thesis, etc.)

# Materials and "sustainable development" ?

Answer to society's questions

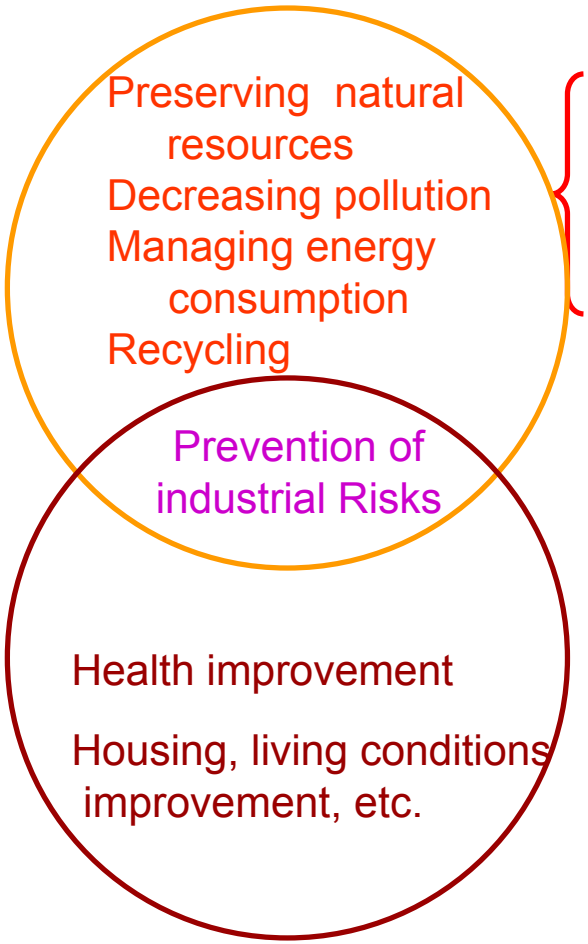
☞ Research & development and "sustainability" ?

Answering by new knowledge

Making breakthroughs

Proposing new concepts

## Ecological concern




Improving process
Lighter structures (transports)
Multi-materials
Multifunctional

"Eco-conception"

Monitoring structures life time

Biocompatible materials

Multifunctional materials

New materials ?
New systems conceptions ?
New processes ?

"nano-materials" ?

Extreme Solicitations ?

Surface with specific properties
Surfaces and interfaces effects

Monitoring *in situ* Materials and structures changes
Prediction of their evolution

Integration of ≠ "know how"

## Quality of life

About 700 researchers + 600 PhD students

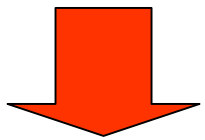
Answer to society's questions **(cont'd)**

☞ **Researchers and "sustainable development" ?**

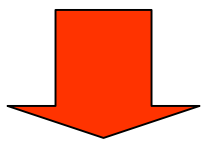
Contribution to the economic and social development ?

**Production of knowledge**

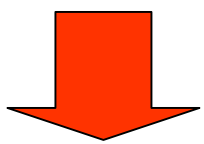
Contribution to the cultural & scientific portfolio
Concepts and methodology Transfer
Contribution to technical progress



Background training and training from research experience



High technology job - Innovation



Job development in Région Rhône-Alpes

**Main topics ?**

**Scaling effect** : strong variations of dim, T, P, $\dot{\varepsilon}$, etc.

**Compatibility** : role of interfaces

**Durability** : initial lifetime, remaining lifetime

## Keywords

lifetime
*in situ* health monitoring of materials and structures
Modeling and Prediction

New materials
New processes
New Design

"nano-materials " ?
Nano-organization (volume, surface)

Surfaces and interfaces effects
Surface with specific behavior

Biocompatible Materials

Accounting for extreme solicitations from the initial design steps

## 7 topics are considered

Materials and structures durability.

Elaboration, Processing – "Defectology".

Heterogeneous Systems and interface effects - Nano-organization.

Functional Surfaces.

Interaction inert substrate / living bodies (health, cellular adhesion, etc. ).

Materials and structures under extreme conditions.

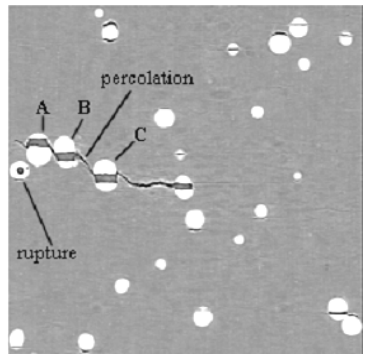
Conception and "Material by design".

*Axis #1 :* **MATERIALS AND STRUCTURES DURABILITY**

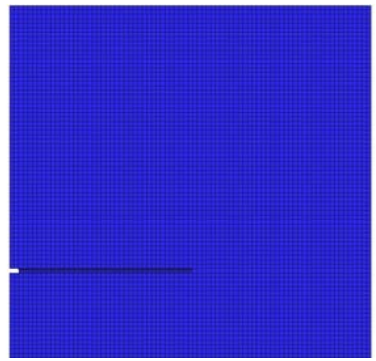
**Head of the topic: Prof. Joël COURBON (INSA) and Prof. Bernard NORMAND (INSA)**

Lifetime prediction in various systems and conditions,
Intelligent structures*

(mechanics, corrosion, etc. coupled effect)
* Collaboration Prof. Takagi Tohoku



GEMPPM

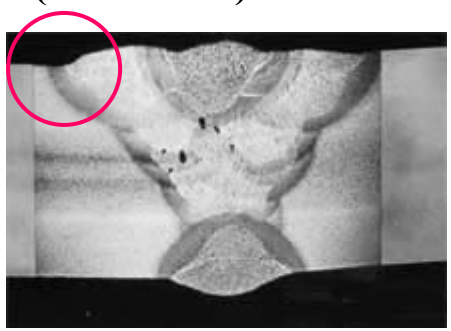

LaMCoS

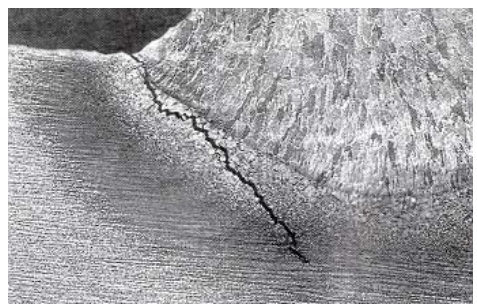
*Axis #2 :* **ELABORATION, PROCESSING – "DEFECTOLOGY"**

**Head of the topic: Dr. H. Klocker (St Etienne) et Prof. Ph. Boisse (INSA)**

High temperature crack initiation

Metals (classical and glassy), ceramics, polymers)





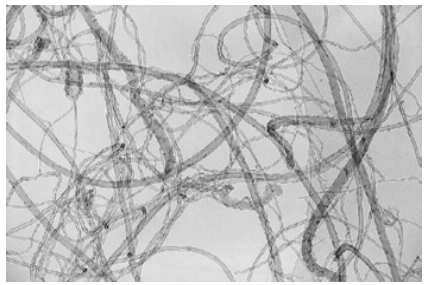
shaping defects, joining, criticality of defects, modeling of microstructure genesis, properties control via process engineering

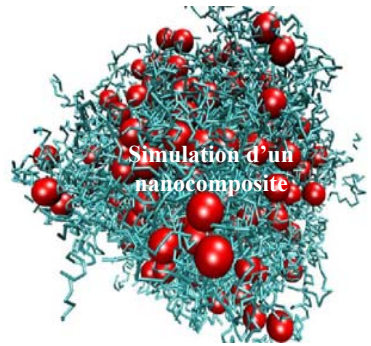
## *Axis 3 :* HETEROGENEOUS SYSTEMS AND INTERFACE EFFECTS / NANO-ORGANIZATION

**Head of the topic** **Prof. Jean-Louis BARRAT (UCB)**

nano-materials, granular materials, colloidal systems, porous materials, etc.

Molecular dynamics modeling



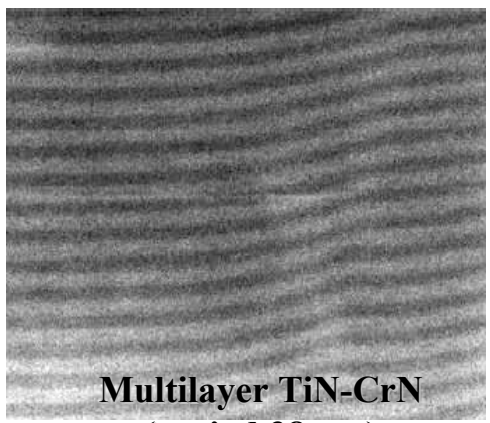



## *Axis 4 :* FUNCTIONAL SURFACES

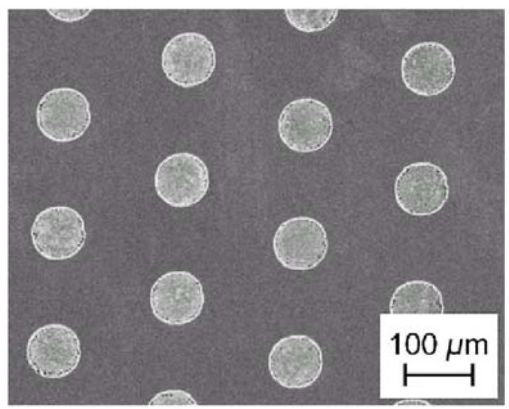
**Head of the topic :** **Prof. Denis MAZUYER (ECL)**

surface treatment, fonctionnalisation; tribology*, adhesion – wettability; durability, etc

(*Collab. Prof. Sato, Tohoku)



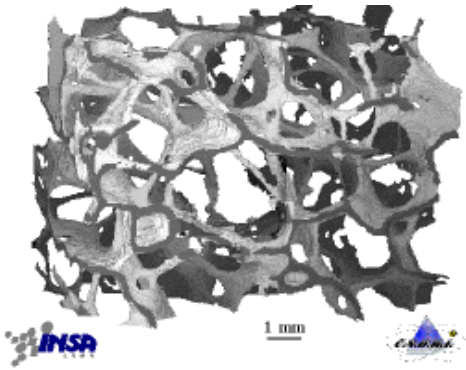
**Multilayer TiN-CrN (period 38 nm)**

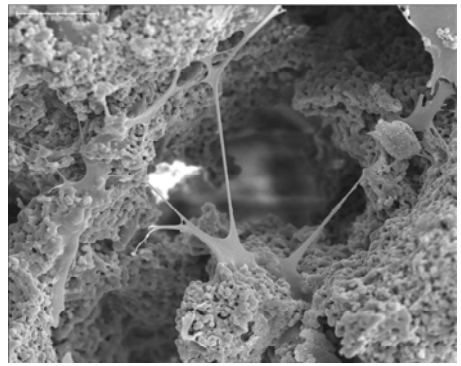


*Axis 5 :* **INTERACTION INERT SUBSTRATE/LIVING BODIES**

**Head of the topic : Prof. Jérôme CHEVALIER (INSA)**

health, bio-mimetics,
cellular adhesion,
biomechanics, fossils, etc.),

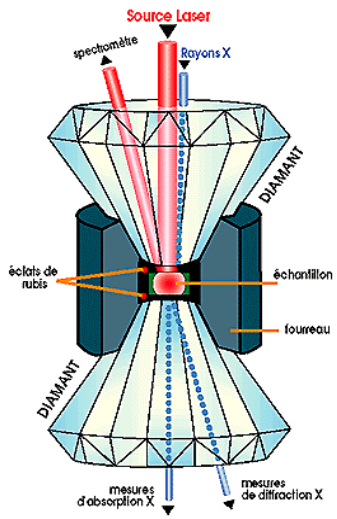


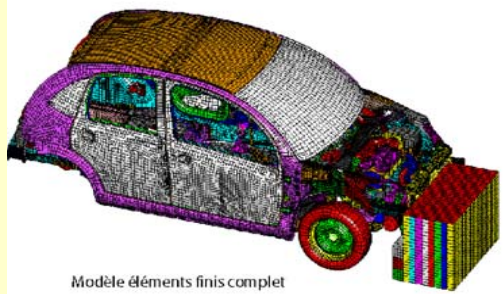



*Axis 6 :* **MATERIALS AND STRUCTURES UNDER EXTREME CONDITIONS**

**Head of the topic : Dr. Bruno REYNARD (ENS) & Prof. Alain COMBESCURE (INSA)**

geological systems,
high temperatures,
crash
Welding (classical or Friction Shear-),
severe environment, etc.



## *Axis 7 :* CONCEPTION and MATERIALS BY DESIGN

**Head of the topic : Prof. Y. Bréchet (INPG, Grenoble)**

Classical Approach →

Process

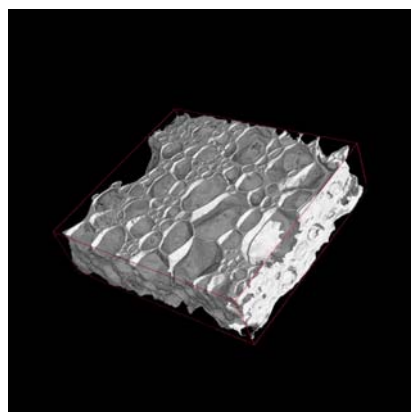
Multifunctional Materials and Structures

"sustainable development" Constraint

← "Materials by design"

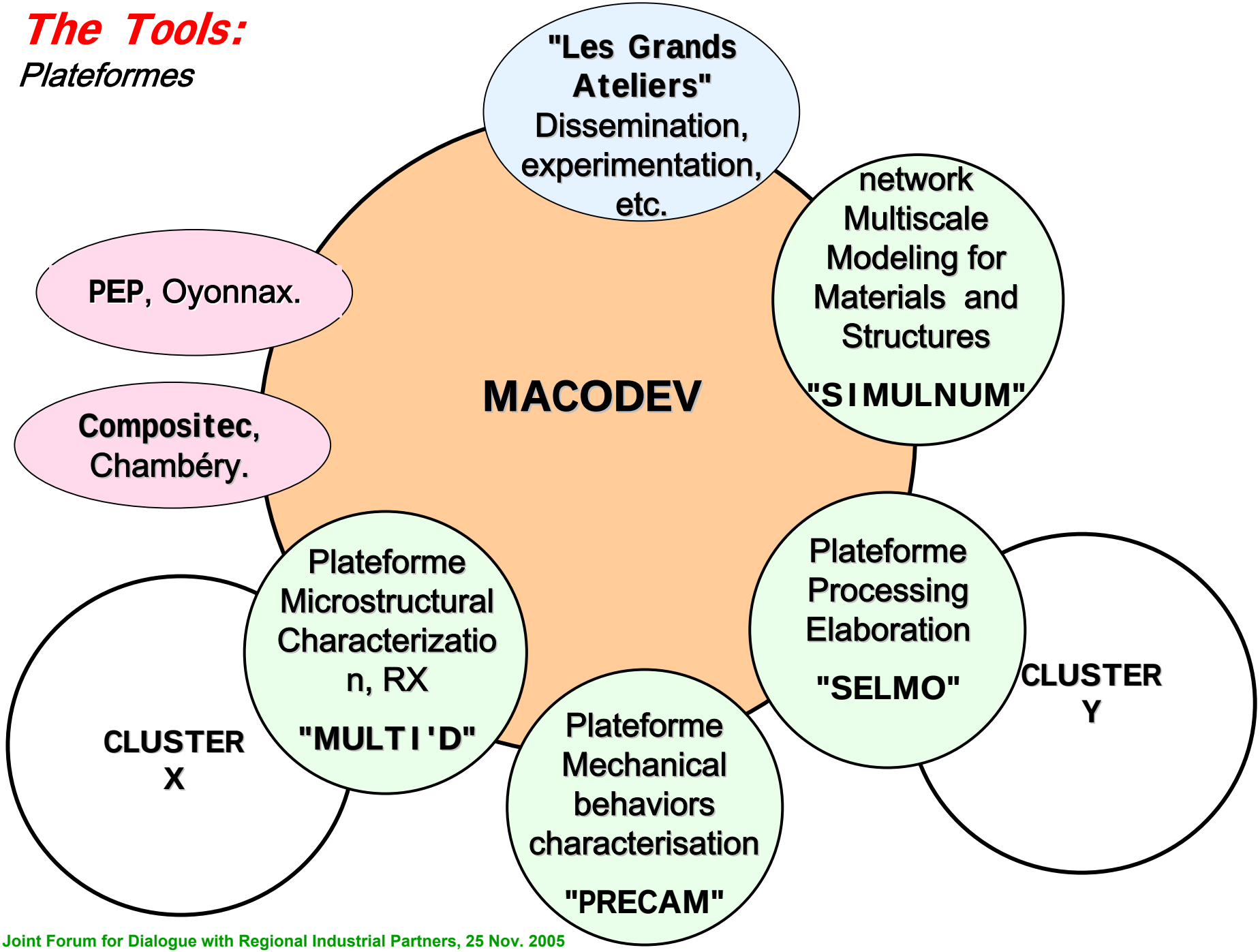
criteria for materials and processes choice,
design of materials and systems for specific (multifunctional) applications: materials with internal architecture, interface with structural and mechanical engineering, etc.

Example : materials with specific mechanical / thermal / acoustic properties



# *The Tools:*

*Plateformes*



# Plateforme: Microstructural Characterization MULTI'D

INSA
TEM
EBSD
AFM

UCB
HRTEM
AFM, STM
Confocal
Raman

ECL
low angle RX
EFTEM

ENS
ECP
Raman

## In Lab Units

ESEM-Tomo
RX Tomography
FIB-Cryo.
TEM/Tomo/Env.
STM (Vide)
µRaman
ToF-SIMS
Image Anal.

HRTEM-
"GIF"

## Specific centers

ESRF
Lines X

INPG/UJF
TEM in situ
µprobe
HRSEM

ENSM.SE
TEM
HR EBSD
AFM

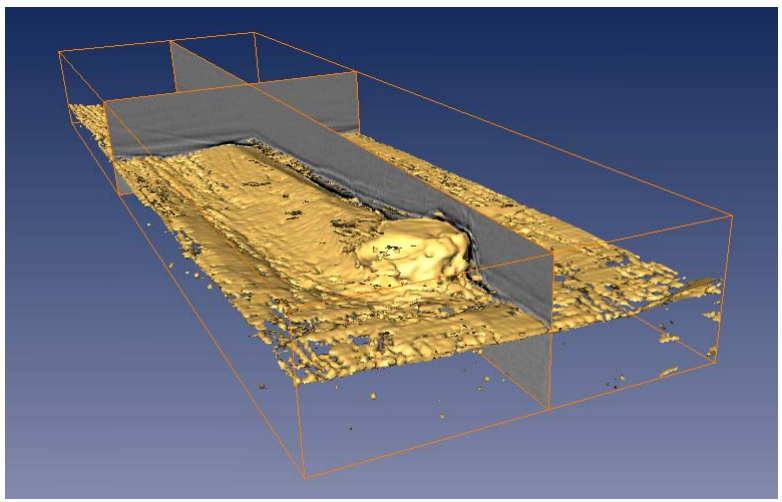
*under construction*

***Staff***

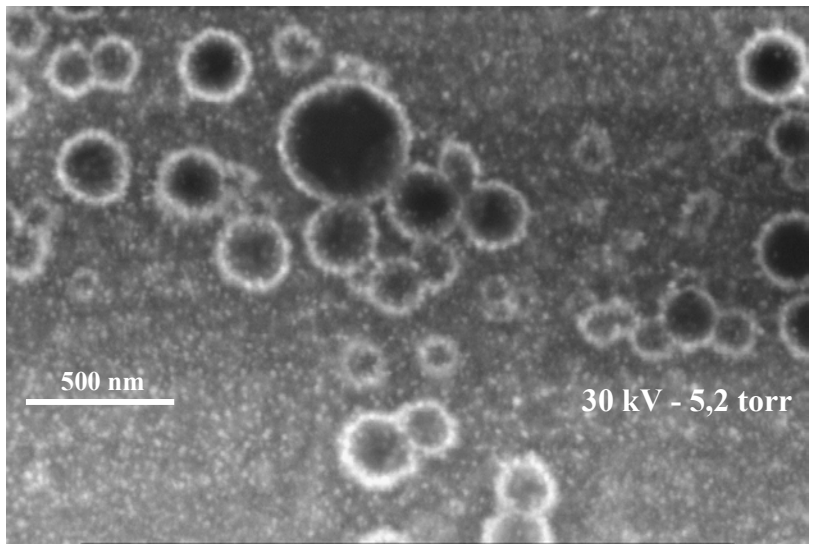
*Head*: Daniel Araujo / Claude Esnouf

TEM-Anal.- Thierry Epicier
SEM - ESEM - Gilbert Thollet
Tomography - Eric Maire
low angled RX - Fabrice Dassenoy et Bernard Beaugiraud
ToF-SIMS - Didier Léonard
Images Analyses - Jean-Michel Letang
AFM - Georges Brémond
FIB-Cryo - (Daniel Araujo)
µRaman - (Bruno Reynard)

# Examples of actual activity of MULTI'D



*X-ray tomography*



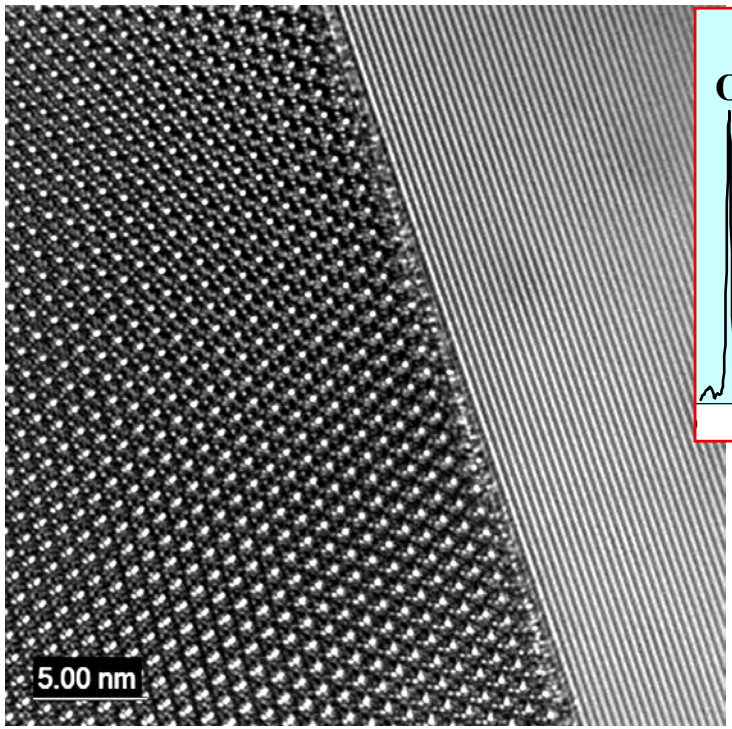

*natural latex grafted with PMMA*

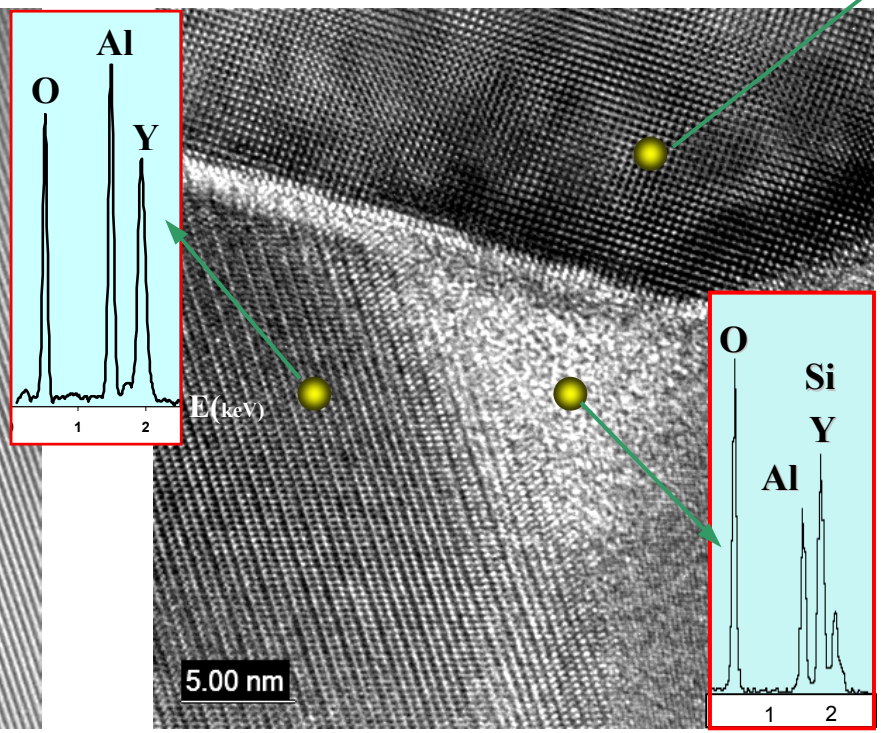
plus "classical" observation and analysis (high resolution, EDX, EELS, etc.)

# POSSIBILITES INSTRUMENTALES au travers d'exemples d'études :

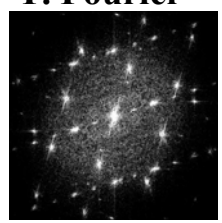
**MET Jeol 2010F :** Emission de champ - $C_S$ = 0,5 mm - Résolution 0,19 nm - Taille de sonde mini 0,5 nm

## CONTEXTE : Matériaux Céramiques 'nanométriques'



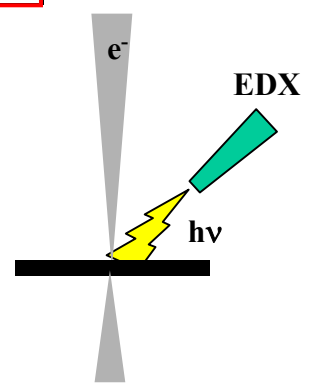




T. Fourier



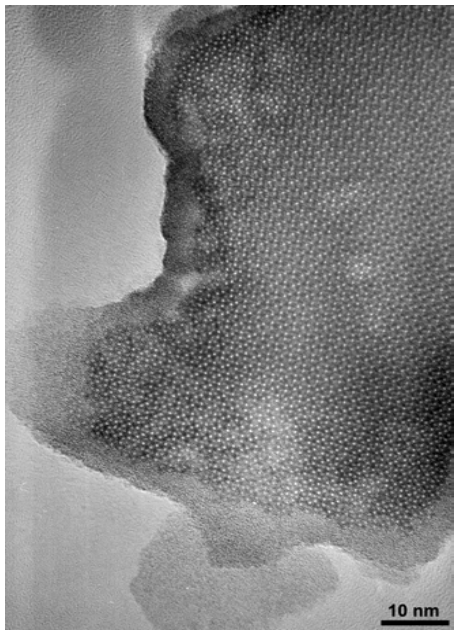
**Joint hétérophase $Al_2O_3$-YAG 50-50**
(Voie sol-gel + traitement thermique + compactage + frittage)

**Nœud triple $Al_2O_3$-YAG 50-50**
(Voie sol-gel + traitement thermique + compactage + frittage)

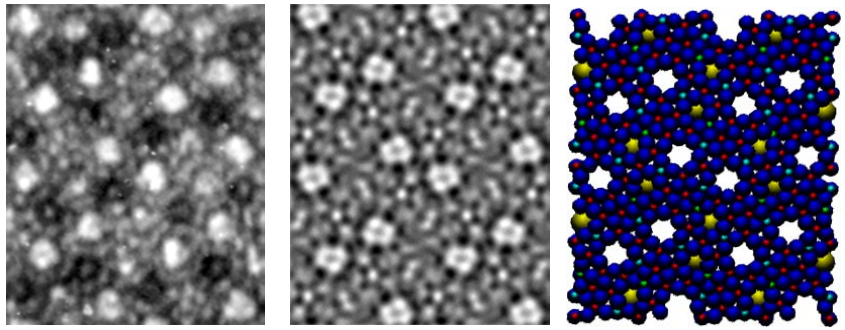



***Haute résolution et Nanoanalyse X***

# CONTEXTE : Catalyse d'oxydation de propane en acide acrylique : phase $MoTeNbVO_x$ (1)




Expérimental | Simulé (EMS) | Modèle



*(1) : AOUINE M, DUBOIS J L, MILLET J M M, Chem. Commun., 2001, 1180-1181.*

*(2) : LUNDBERG M. et all, Ultramicroscopy, 52, (1993), 429-435*

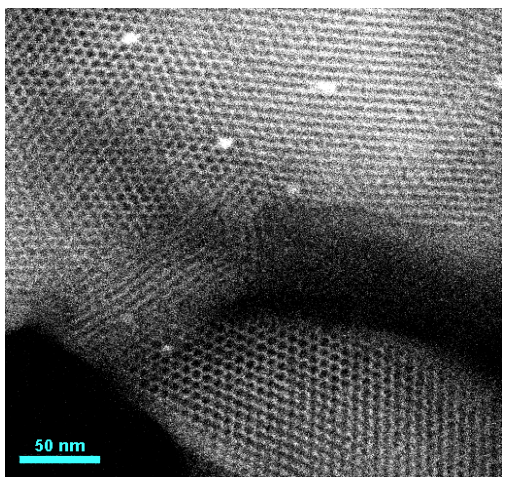
***Imagerie de structure***

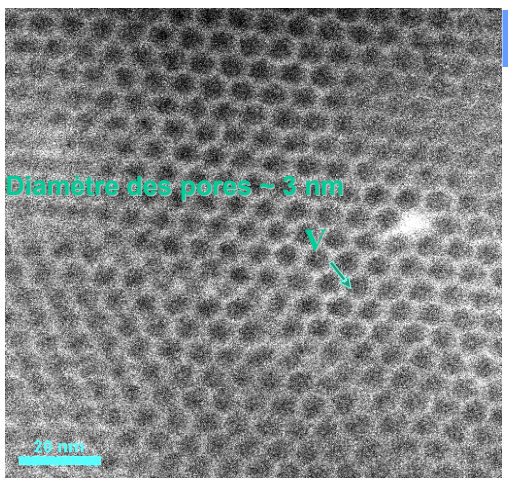
MoTeNbV

- Les paramètres de mailles (a = 2.12 nm, b = 2.68 nm, c = 0.40 nm) déterminés par diffraction des électrons et diffraction des rayons X.
- Les canaux heptagonaux vides.
- Les canaux hexagonaux occupés par le tellure.
- Les canaux pentagonaux occupés par le niobium.

***La meilleure simulation***

# CONTEXTE : Catalyse pour la déshydrogénation oxydante du propane




**MCM-41 dopée au vanadium**

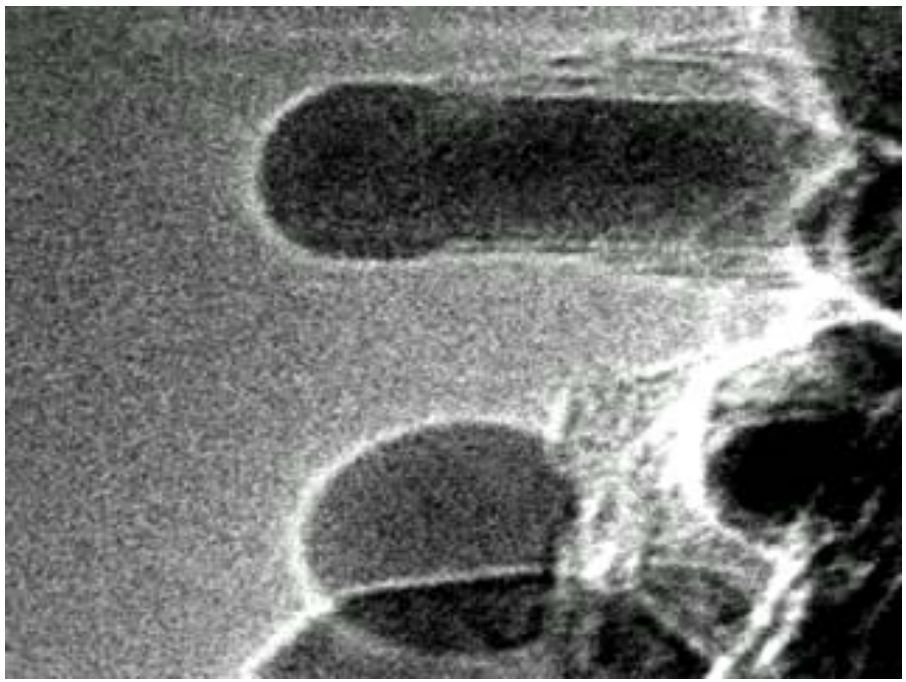
**Imagerie HAADF (High Angular Annular Dark Field) : les parties claires indiquent la présence d'atomes lourds.**

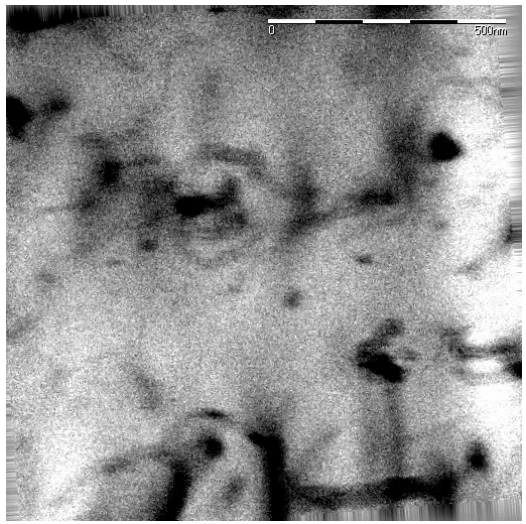
**Le vanadium est localisé dans les pores de la MCM.**

***Imagerie HAADF***

*Image AOUINE M, IRC (en collaboration avec B. KILOS et J.C. VOLTA)*

# Among the projects of the plateforme MULTI'D:

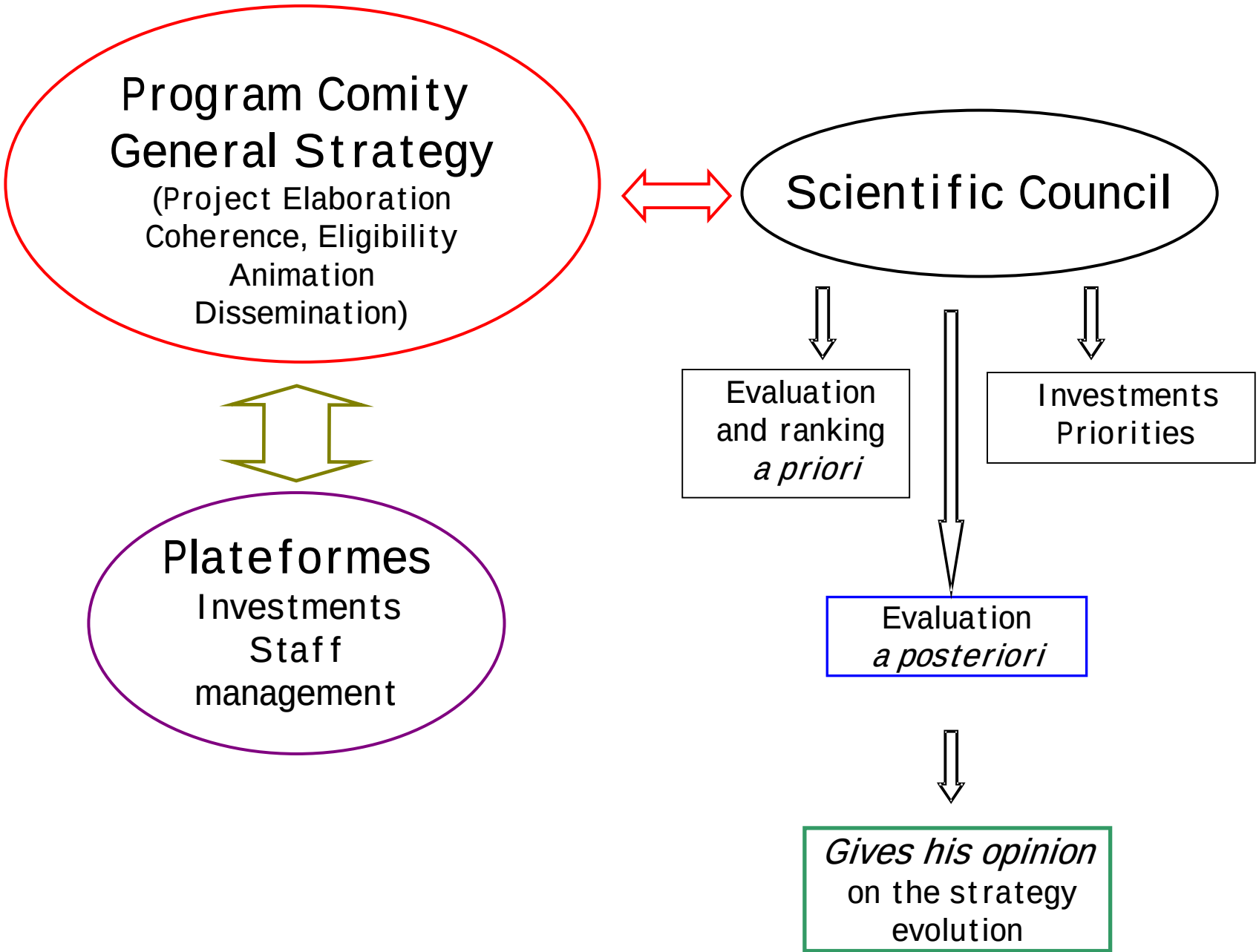





Environmental transmission microscopy

Electron tomography

# *Governance of MACODEV*



# Relationship with industrial research tools

Research Activity promoted by industrial problems

MACODEV Scientific Strategy


Plastipolis

ViaMéca

MACODEV

**National Industrial Clusters**

**Research cluster**


# Strategy for 2006 – 2007 ?

## Examples of Propositions for Priorities for 2006 – 2007

1. Multifunctional MultiMaterials (3MF)
2. Comportment and break of materials and structures under extremes solicitations: temperatures, friction, fracture, chocks…
3. Materials and surfaces for a better bio-integration
4. Materials at low environmental impact (MATIERE)
5. Structuration of surfaces and interfaces
6. Field measurements for the optimization of materials and structures proprieties
7. Powder Materials: elaboration, control, processing
8. ….

MACODEV
Cluster MAtériaux et COnception pour un DEVeloppement durable
RhôneAlpes

## Strategy for 2006 – 2007 ?, cont'd

**focus on 3 priorities /an**

***2 thesis supported by Région RA***
***+ 2 thesis industrial partners***
***+ 2 thesis provided by the laboratories***
***>>>>> for each priority***

**Criteria of eligibility of a thesis project**

- ***at least 2 laboratories involved in the in the project***
- ***partly supported by industrial partners***

***or / and***

- ***strong international collaboration***


# Conclusion

*Japanese and French people have in common, extremely refined food and love of beauty… so that why not going on strongly on research and higher education !*

Regional network of industrial and academic partners

☺ Interaction with other similar network in Sendaï ?

☺ Improvement of scientific collaborations in the Material Science and Engineering fields covered by Tohoku University and the main laboratories, skeleton of MACODEV

## Scientific contacts : jean-yves.cavaille@insa-lyon.fr

1 - Materials and structures durability: (lifetime prediction in various systems and conditions), *Joël Courbon, Bernard Normand, Alexis Deschamps, Luc Salvo, David Delafosse*

2 - Elaboration, Processing – "Defectology": (shaping defects, joining, criticality of defects, modeling of microstructure genesis, properties control via process engineering), *Jean-Pierre Pascault, Michel Brunet, Jean-Jacques Blandin, Helmut Klöcker*

3 - Heterogeneous Systems and interface effects:

- (nano-materials, granular materials, colloidal systems, etc.), *Jean-Louis Barrat, Sandrine Bec, Rémy Dendievel, Anna Fraczkiewicz*
- Nano-organization (surface and volume) : (nano-materials, porous materials, etc.), *Georges Brémond, Jean François Gérard, Edgar Rauch, Christophe Pijolat*

4 - Functional Surfaces: (surface treatment, fonctionnalisation ; tribology, adhesion – wettability ; durability, etc), *Denis Mazuyer, Jean-Claude Viala, Didier Léonard, Michel Langlet, Patrick Benaben, Philippe Vergne*

5 - Interaction inert substrate/living bodies (health, cellular adhesion, etc.): (Biomimetics. cellular adhesion, biomechanics, fossils, ….), *Jérôme Chevalier, Philippe Oger, Didier Delabouglise, Franz Bruckert, Bernard Guilhot, René Guyonnet*

6 - Materials and structures under extreme conditions: (geological systems, high temperatures, welding, severe environment, etc.) *Bruno Reynard, Alain Combescure, Christian Chatillon, Krzysztof Wolski*

7- Conception and "Material by design": (criteria for materials and processes choice, design of materials and systems for specific (multifunctional) applications: materials with internal architecture, interface with structural and mechanical engineering, etc.), *Jean-François Jullien, Eric Maire, Cécile Langlade, Yves Bréchet, Patrice Goeuriot*

# Local contacts for each topic

**Lyon / Grenoble / St Etienne**

| | |
|---|---|
| Materials and structures durability | Lyon : joel.courbon@insa-lyon.fr<br>Grenoble : alexis.deschamps@ltpcm.inpg.fr<br>St Etienne : david.delafosse@emse.fr |
| Elaboration, Processing – "Defectology". | Lyon : philippe.boisse@insa-lyon.fr<br>Grenoble : jean-jacques.blandin@gpm2.inpg.fr<br>St Etienne : helmut.klocker@emse.fr |
| Heterogeneous Systems and interface effects<br>- Nano-organization | Lyon : jean-louis.barrat@ens-lyon.fr<br>Grenoble : remy.dendievel@gpm2.inpg.fr<br>St Etienne : anna.fraczkievicz@emse.fr |
| Functional Surfaces | Lyon : denis.mazuyer@ec-lyon.fr<br>Grenoble : michel.langlet@inpg.fr<br>St Etienne : patrick.benaben@emse.fr |
| Interaction inert substrate /living bodies (health, cellular adhesion, etc.) | Lyon : jerome.chevalier@insa-lyon.fr<br>Grenoble : didier.delabouglise@lepmi.inpg.fr<br>St Etienne : rene.guyonnet@emse.fr |
| Materials and structures under extreme conditions | Lyon : bruno.reynard@ens-lyon.fr<br>Grenoble : christian.chatillon@ltpcm.inpg.fr<br>St Etienne : krzysztof.volski@emse.fr |
| Conception and "Material by design"<br>Multifunctional, multimaterials | Lyon : jean-francois.jullien@insa-lyon.fr<br>Grenoble : yves.brechet@ltpcm.inpg.fr<br>St Etienne : patrice.goeuriot@emse.fr |