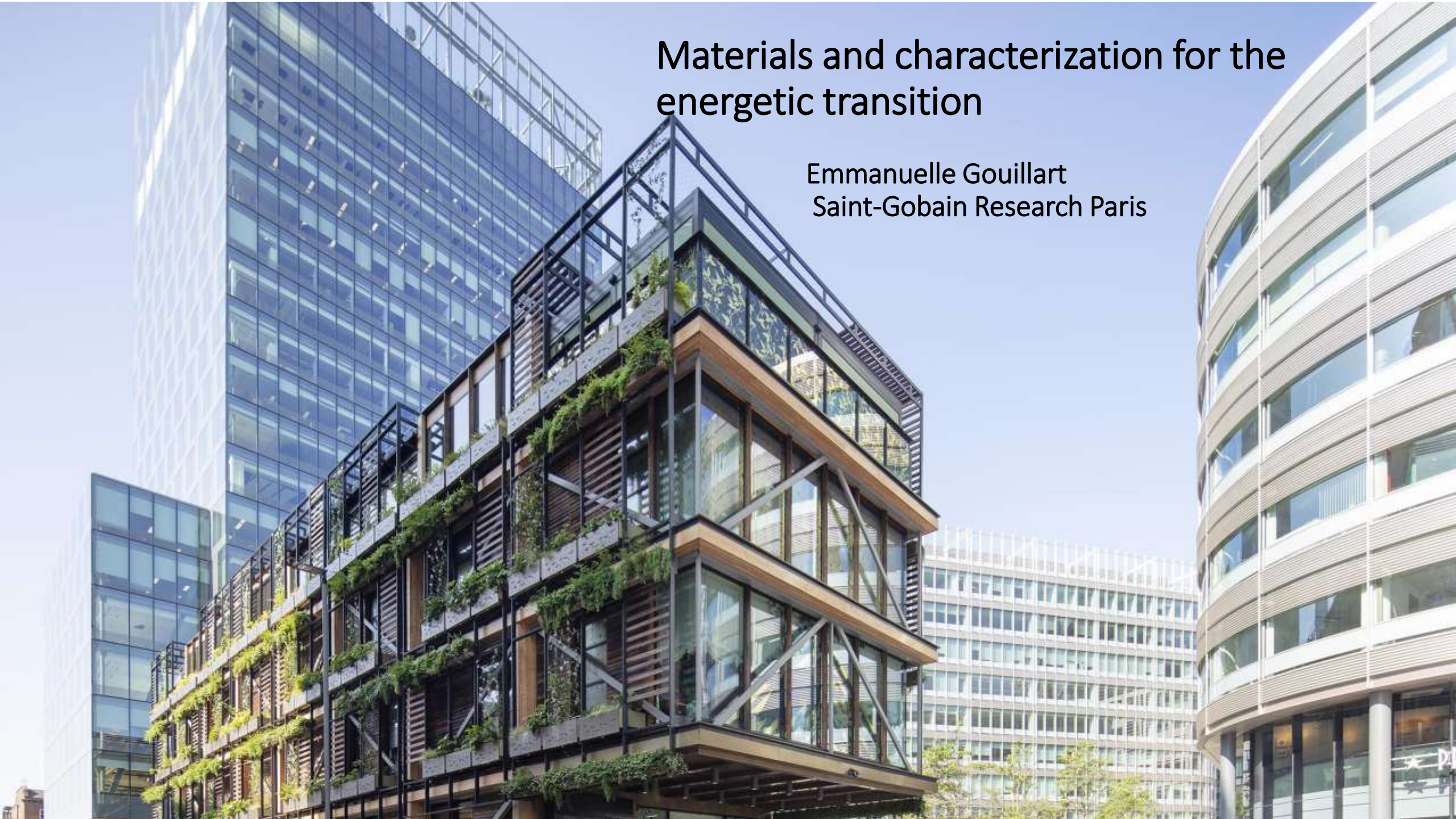


Materials and characterization for the energetic transition

Emmanuelle Gouillart
Saint-Gobain Research Paris

OUR MISSION

Saint-Gobain designs, manufactures and distributes materials and solutions for the construction, mobility, healthcare and other industrial application markets.

These materials can be found everywhere in our living places and daily life:

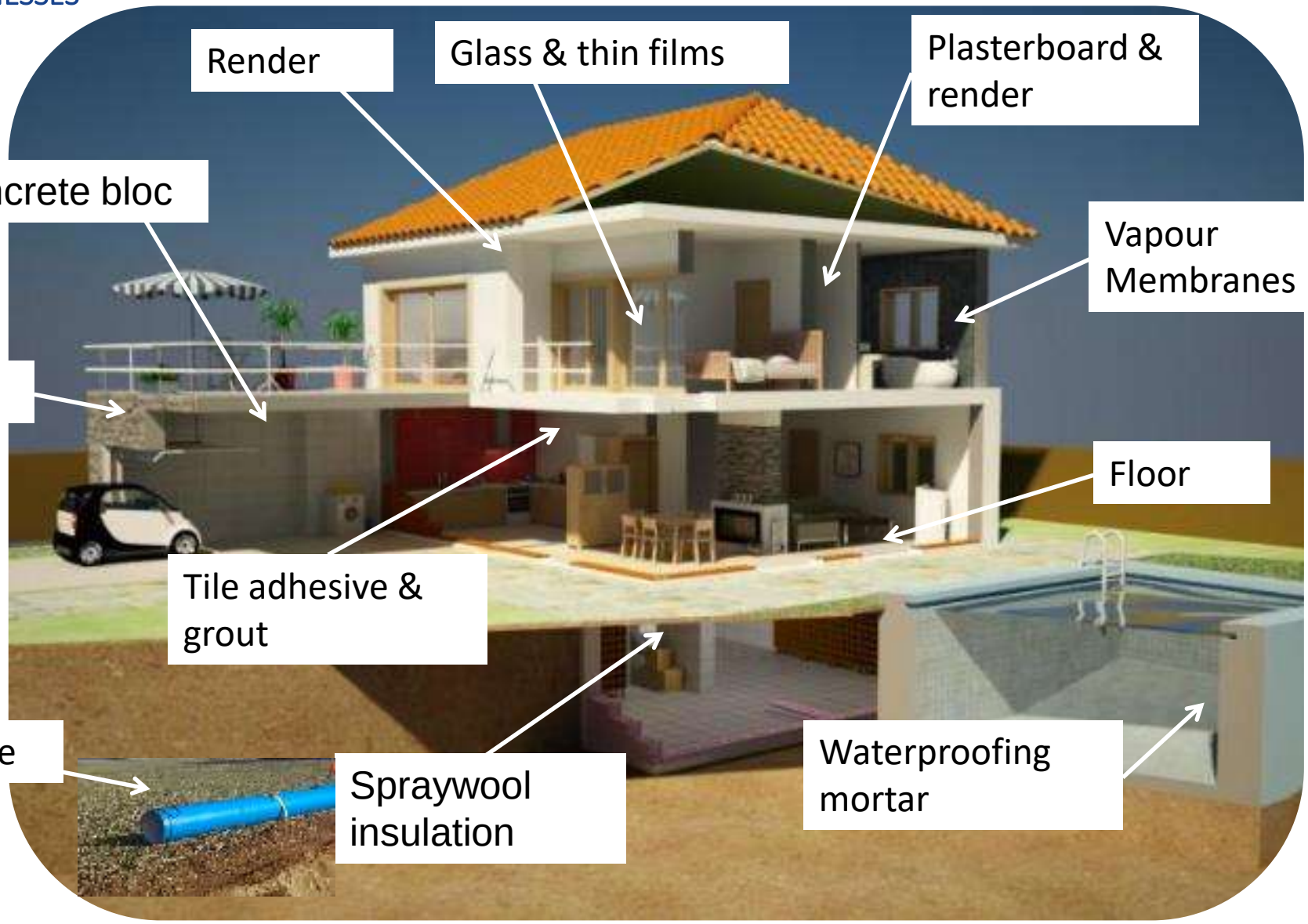
- Housing
- Transportation
- Infrastructure
- Buildings
- Healthcare
- Industrial applications

Developed through a continuous innovation process, they provide well-being, performance and safety, while addressing the challenges of sustainable construction, resource efficiency and the fight against climate change.

Commitment:
carbon neutrality in 2050

Productions and solutions for construction

PRODUCTS & BUSINESSES



OUR BRANDS & BUSINESSES

Regional businesses

- **European #1, world n°2:** flat glass
- **World #2:** plaster and plasterboard
- **World #2:** insulation (all insulating materials combined)
- **World #2:** mortars and building chemical solutions
- **A world leader** in ductile iron pipe systems
- **European #1:** distribution of building materials
- **Major player** in the heating-plumbing-sanitaryware market

Global businesses

- **Leader** in automotive glass
- **World #1:** bearings for automotive applications
- **World #1:** civilian airborne satellite communications radomes
- **Leader** in single-use tubes for the pharmaceutical industry
- **Leader** in specialty abrasive grains (zirconia-based), ceramic balls for micro-grinding, refractories for the glass industry
- **World #1:** fiberglass wall coverings

BUILD ON OUR INNOVATION CAPABILITIES

Recognized innovation capabilities

8 Saint-Gobain Research (SGR) cross-business R&D **centers**

2,100 Marketing people

1 out of 4 products sold today by Saint-Gobain did not exist 5 years ago

Over 100 development **centers**

Over 3,600 researchers

Over 400 patents filed each year

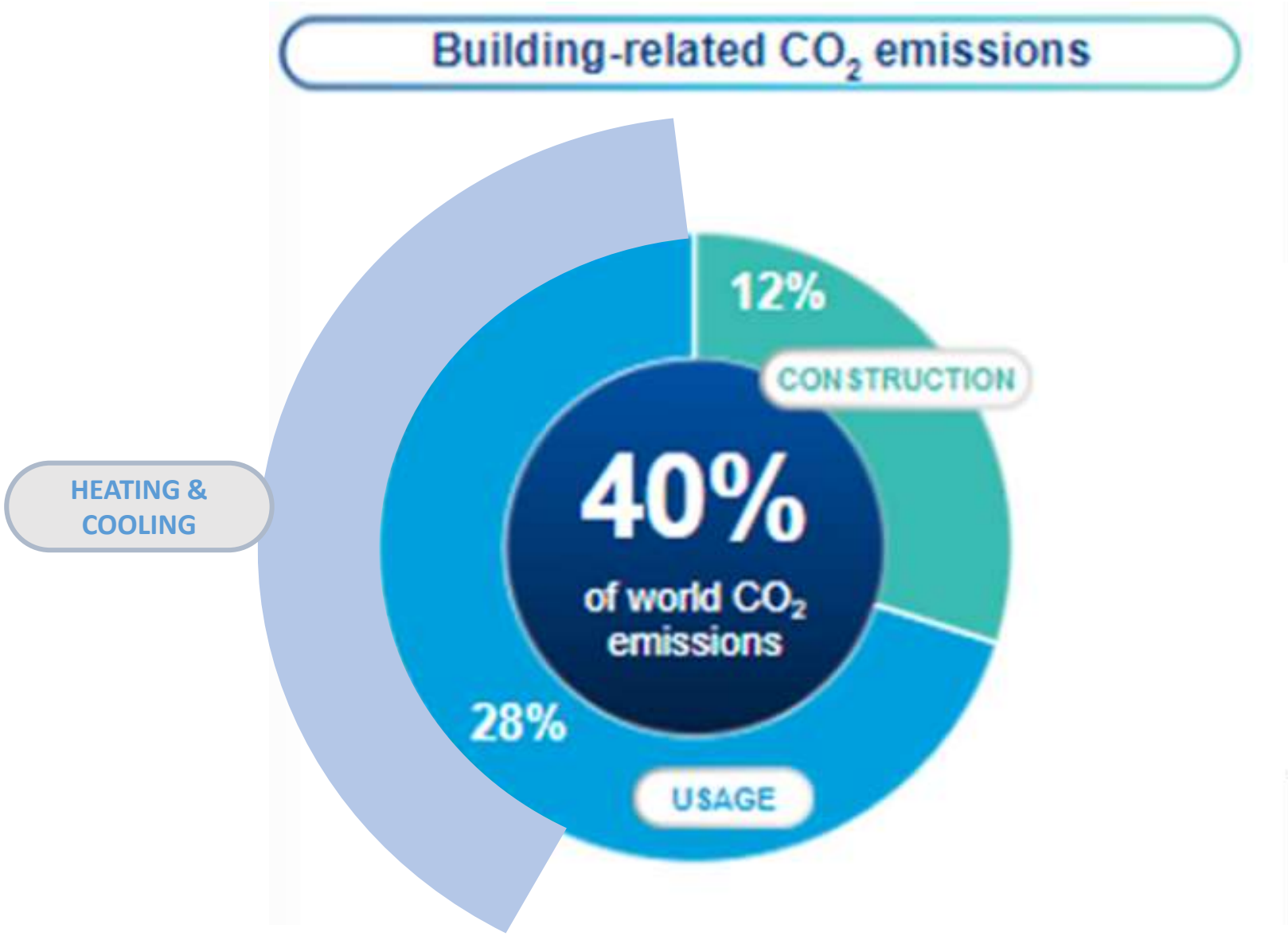
Innovate constantly

Focus our innovation efforts on customer needs

An open innovation approach: partnerships with start-ups, scientific and academic cooperation, internal venturing.

Explore new business models

Marketplaces, intermediation platforms, product as a service, licensed technologies, concept sales, waste take-back and recycling services...


Building-related CO_2 emissions
12%
CONSTRUCTION
40%
of world CO_2 emissions
28%
USAGE
HEATING & COOLING

UPSTREAM COMPETENCE CENTER FOR DECARBONATED PROCESSES

Adapting **existing processes** for a reduced footprint

Work on **breakthrough processes**

PROCESS CO2 FOOTPRINT REDUCTION MATERIALS FOR BATTERIES AND H2

Link with R&D Group Initiatives

Decarbonate glass raw materials

Adapt the processes

- Silicate minerals
- More cullet
- Refractories

H2 / hybrid combustion

Adaptation of chemistry and refractories

Electrification of gypsum drying

Beyond the one-pot melting process: multi-tank, preheating, CCU, …

Beyond flames: how to bring clean energy to large glass volumes?

Electrification

Disruptive technologies: *Low-pressure glass fining, induction / plasma heating*

Combine core competencies and customer-centric approach

COMPETENCIES

EXPERIMENTS, ANALYSES, SENSORS, MODELLING, THERMAL TRANSFERS

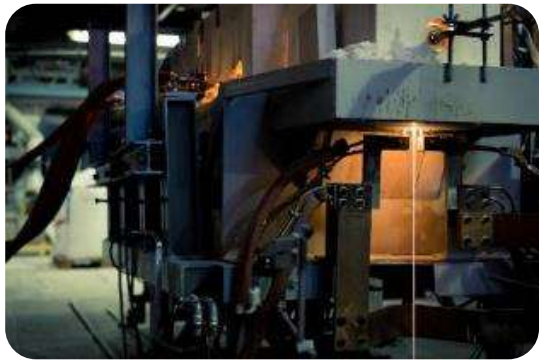
Beyond glass: **decarbonation for HPS clients**, thanks to our expertise

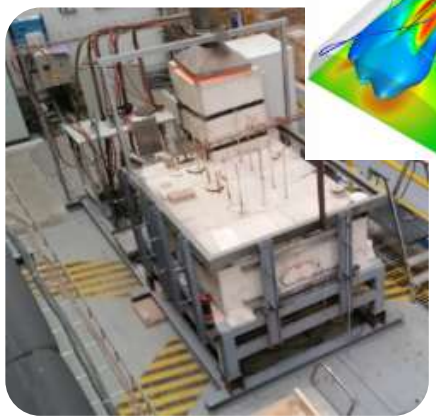

1/3

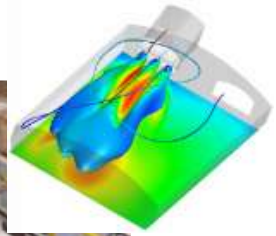

2/3

PRINCIPALES THÉMATIQUES DE R&D SUR L'ELABORATION DES VERRES

Décarbonation de nos procédés verriers







Améliorer les performances et réduire la consommation énergétique des fours verriers

Recyclage des déchets, fusibilité de matières décarbonatées

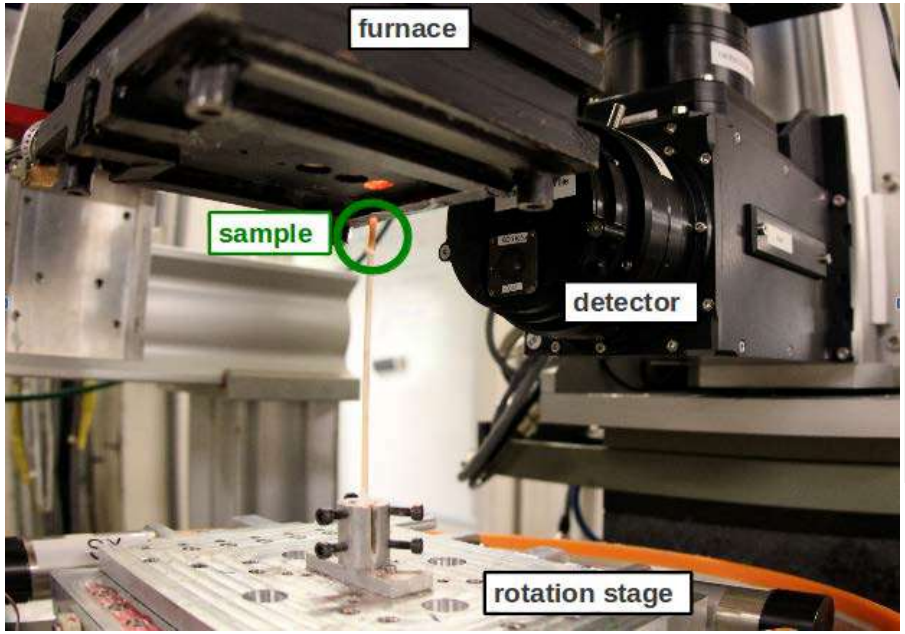
Diminuer les émissions de polluants (CO_2, CO et NOx, …)

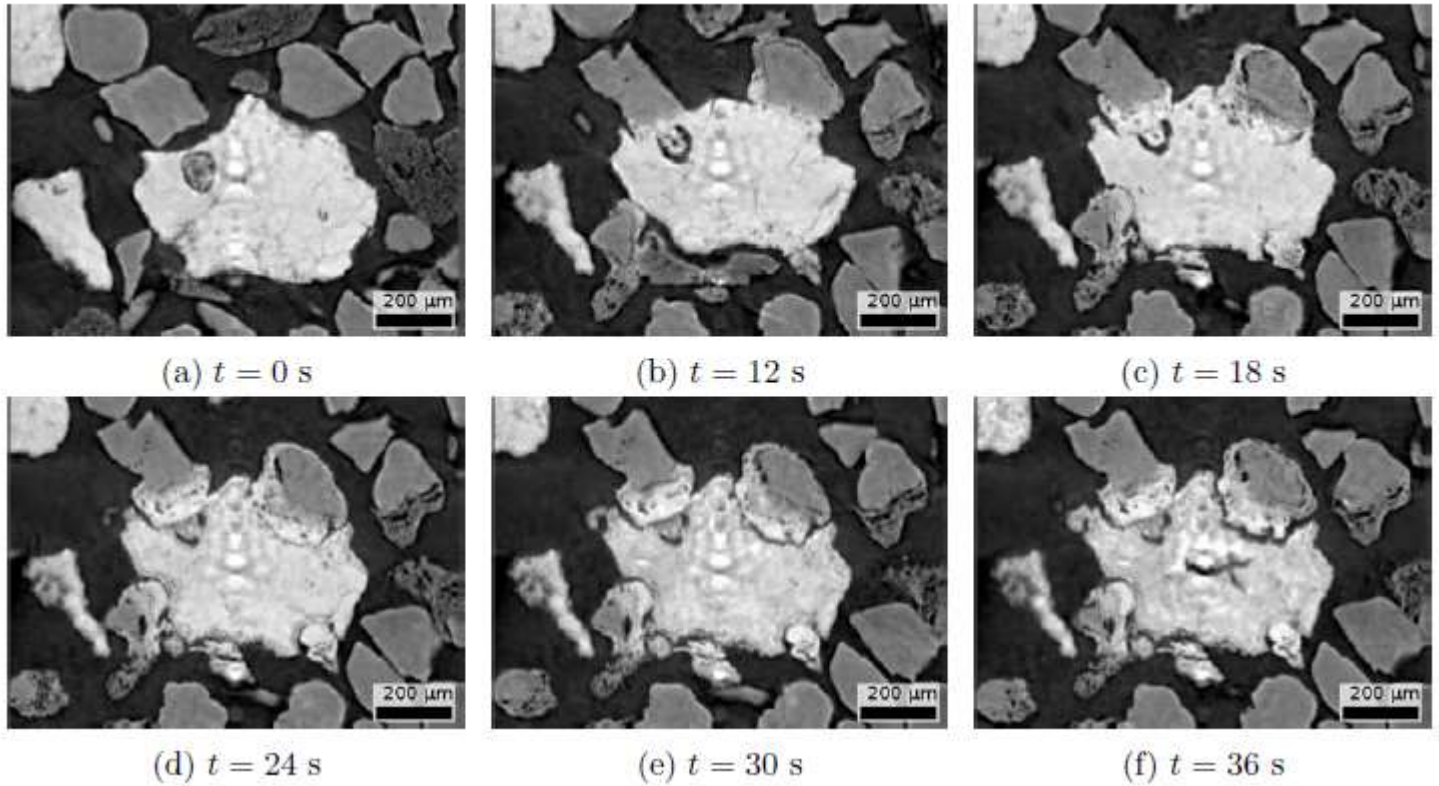
Améliorer la qualité du produit :

Réactivité de surface, défauts dans le verre, dissolution et biosolubilité des fibres…

Développer de nouvelles formulations

GEOMETRY AND HETEROGENEITY OF REACTION PATHS IN GLASS BATCH MELTING



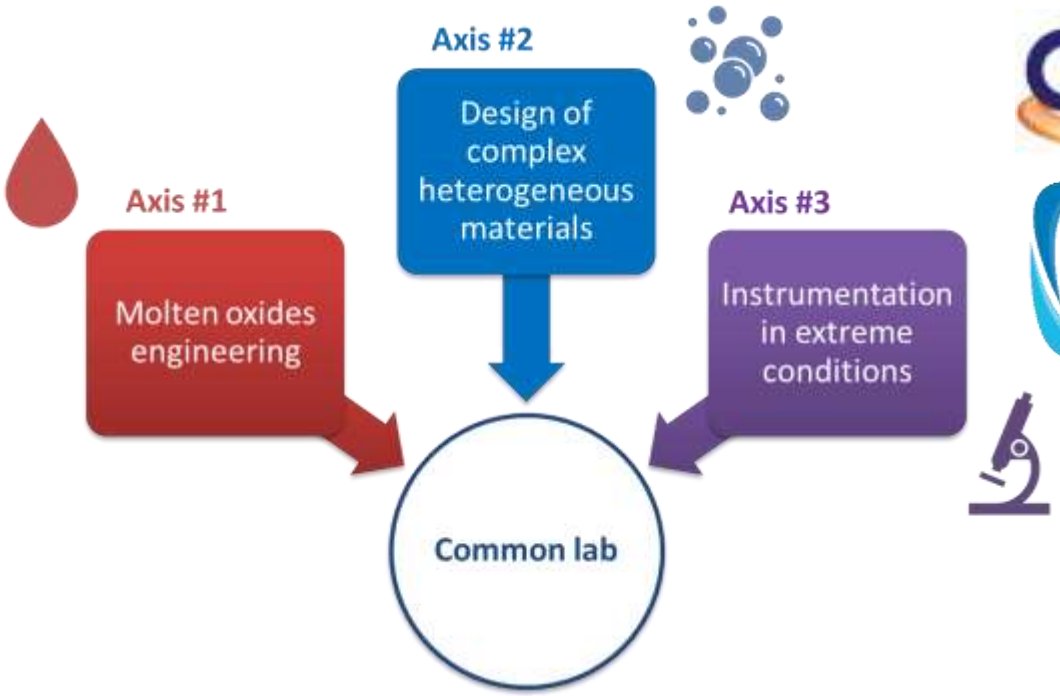


In situ microtomography experiments at ID19, ESRF

Coll. L. Salvo, P. Lhuissier Simap

PhD of W. Woelffel, coll. M. Toplis, MH Chopinet

CANOPEE, A JOINT LABORATORY SG, CNRS & UNIVERSITY OF LORRAINE



Workshop July 1st, 2019 @ SGR Paris

Post-doc fellowship at LEMTA (axis #2) “Characterization of thermal properties of complex heterogeneous solid materials at high temperature” – Léa PENAZZI 2021-2022 (18 months)

PhD at LEMTA (axis #3) “Measurement of temperatures and heat fluxes on semi-transparent materials at high temperature by multi-spectral methods” – Kamal ENNASS 2021-2024 (36 months)

GLASS WOOL

Cotton candy at 1000°C, 2000 rpm,
30 tons/day!

UPSTREAM COMPETENCE CENTER FOR CONSTRUCTION IN A SUSTAINABLE FUTURE

COMPETENCIES

CHEMISTRY, FORMULATION, THIN FILMS
CHARACTERIZATION, MECHANICS, OPTICS
THERMICS, ACOUSTICS, DESIGN, SOCIOLOGY
ECO-CONCEPTION, SENSORS, DATA SCIENCE
MICROBIOLOGY
…

ALL OUR COMPETENCIES

MECHANICAL TESTING
DESIGN
OFFSITE &MODULAR CONSTRUCTION
GREEN CHEMISTRY
ADHESION

Link with R&D Group Initiatives

Design of low C solutions

New alternative materials (raw earth, wood)

Decarbonated raw materials

Lightweight & mechanical properties

Positive impact of our materials

Insulation solutions

Textured glass – matte façades

Switchable glass roofs

New construction modes and techniques

Ease of installation /dismounting

3D Printing Digitalisation

Social and Human sciences & testing capabilities

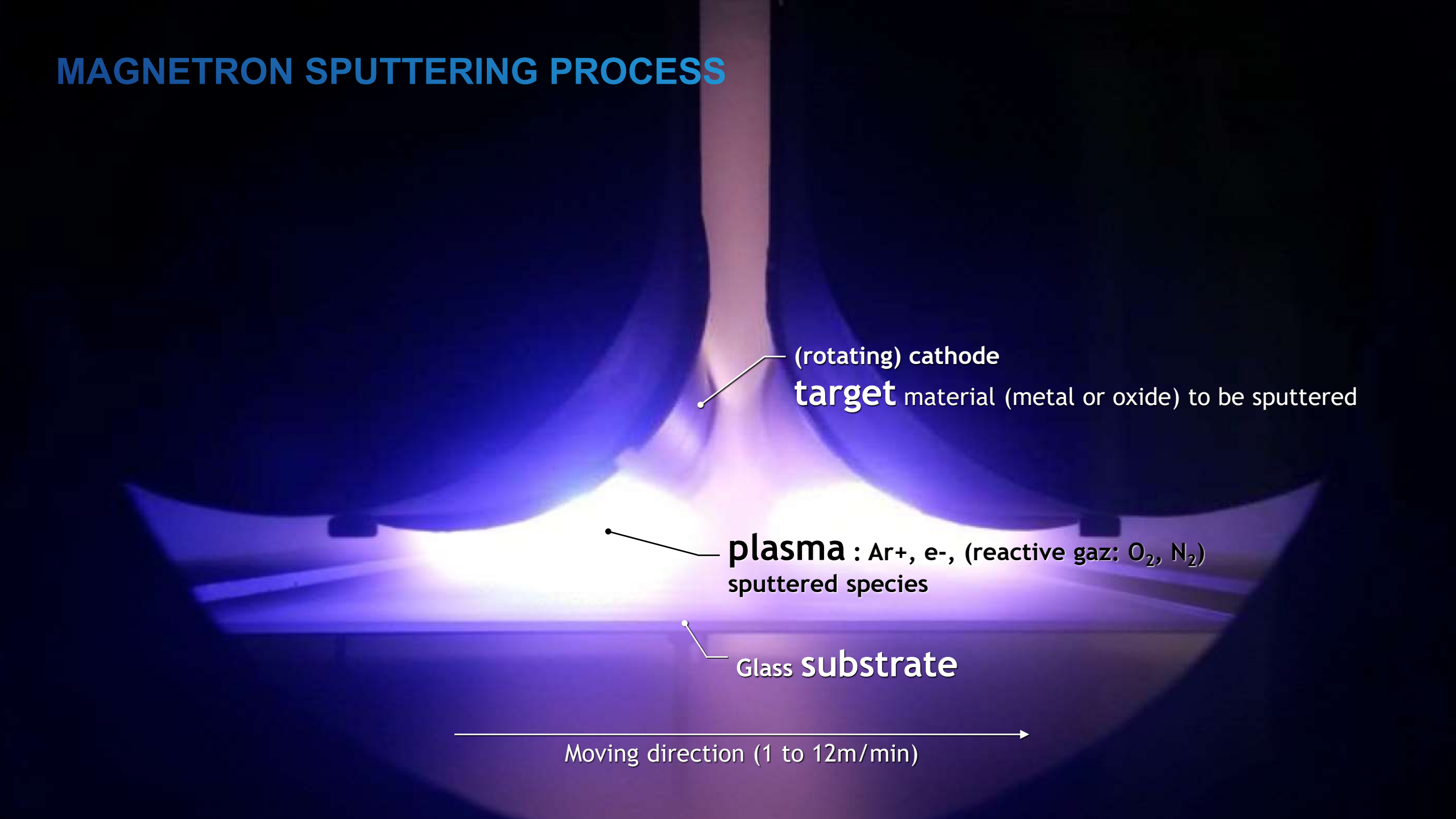
Material to be repaired or recycled

Assembly / disassembly

Study the potential of biological processes of separation

New Industrial processes

MAGNETRON SPUTTERING PROCESS



Si_3N_4 - 40 nm

ZnO - 54 nm

Ag - 10 nm

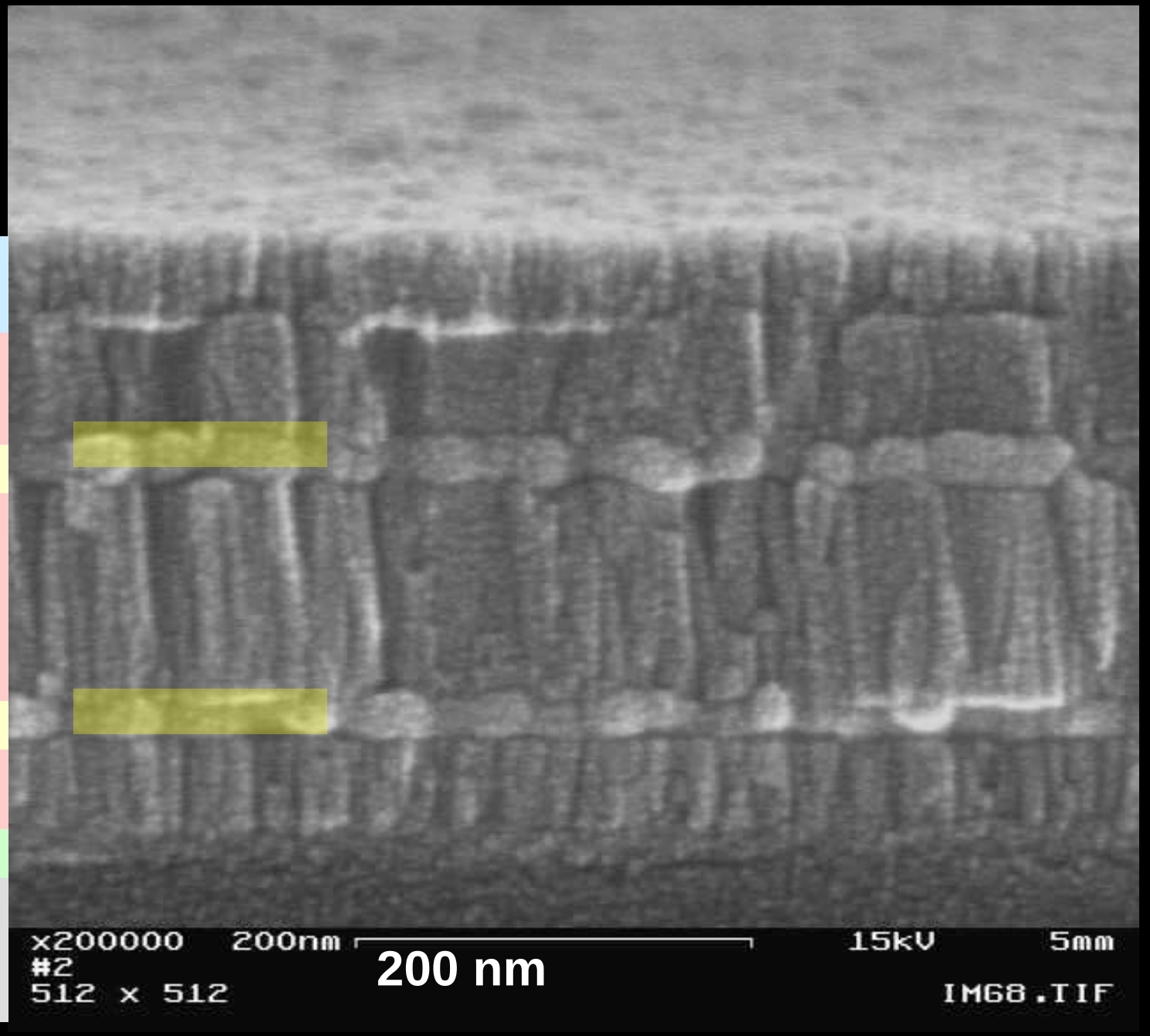
ZnO - 100 nm

Ag - 11 nm

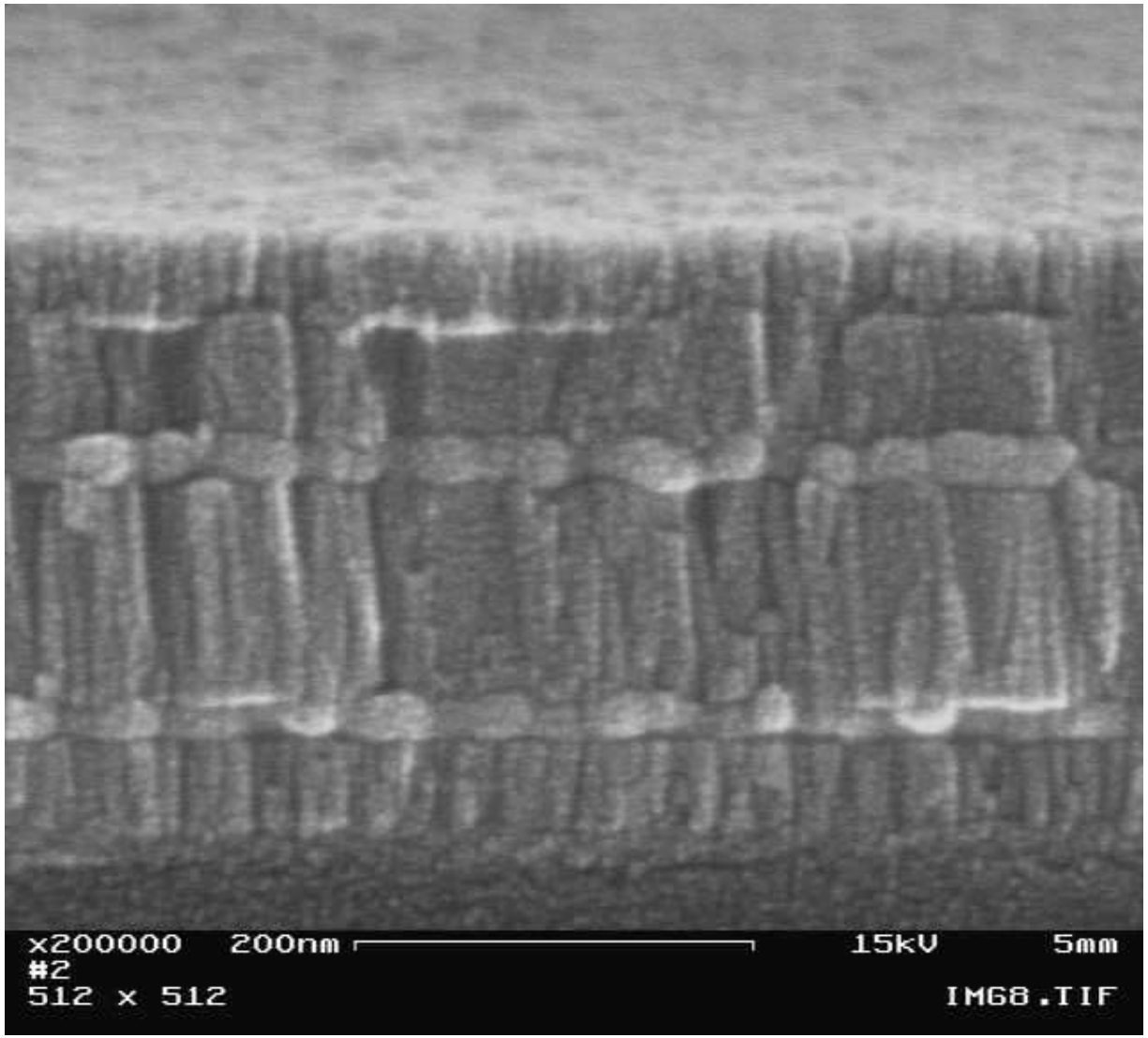
ZnO - 54 nm

SnO_2 - 16 nm

Glass Substrate



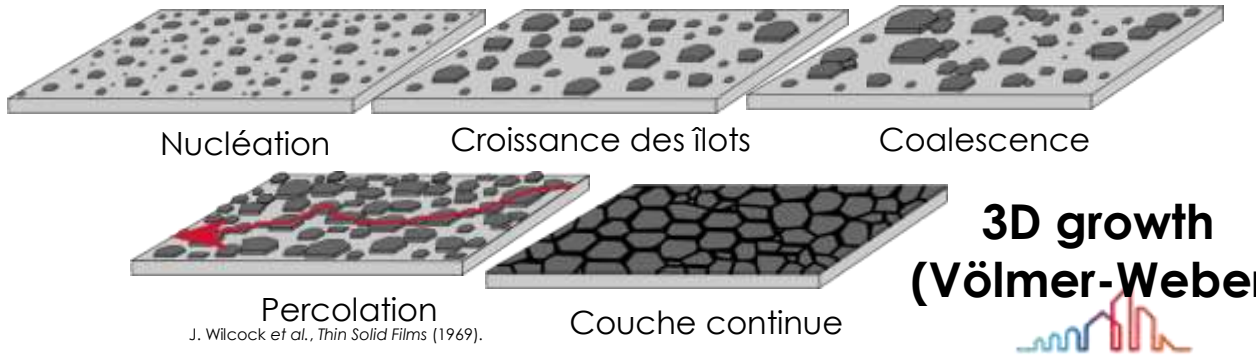
SILVER-BASED STACKS: ONGOING CHALLENGES



Product: optimize selectivity, mechanical resistance, ….

Materials:

- How to optimize silver quality? Role of underlayer and process parameters.
- How to control diffusion during heat treatment?



J. Wilcock *et al.*, *Thin Solid Films* (1969).

C. Thompson, *Annual Review* (2000).

3D growth (Völmer-Weber)

Product development at SGR Paris

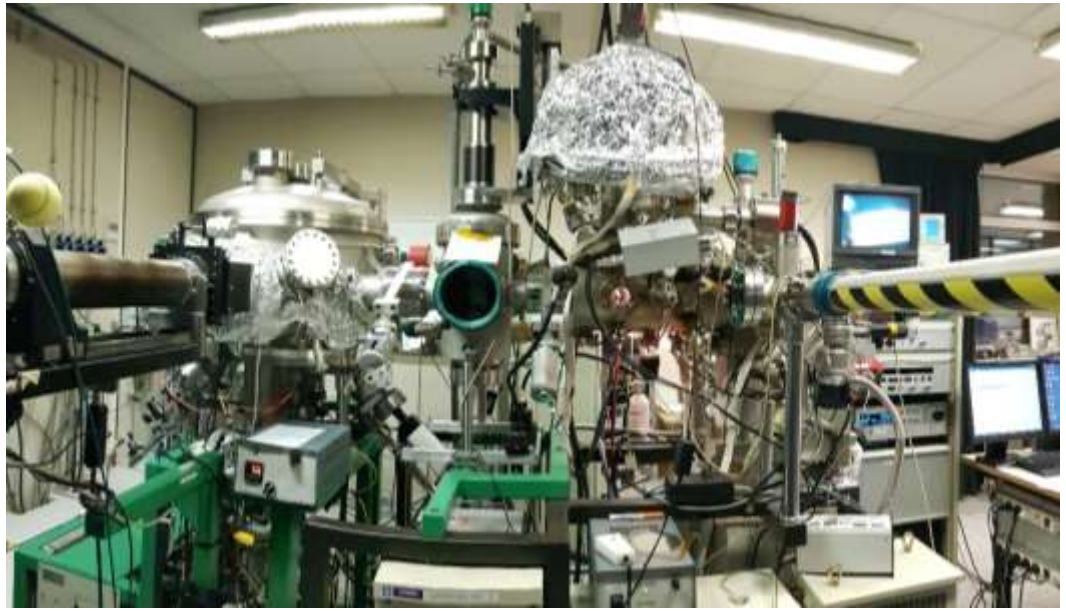
10-20 layers

Continuous deposition with in-line cathodes

R&D set-ups and tests on industrial coaters

Also numerical models for optics and materials

Academic research in joint unit SVI



Research set-ups

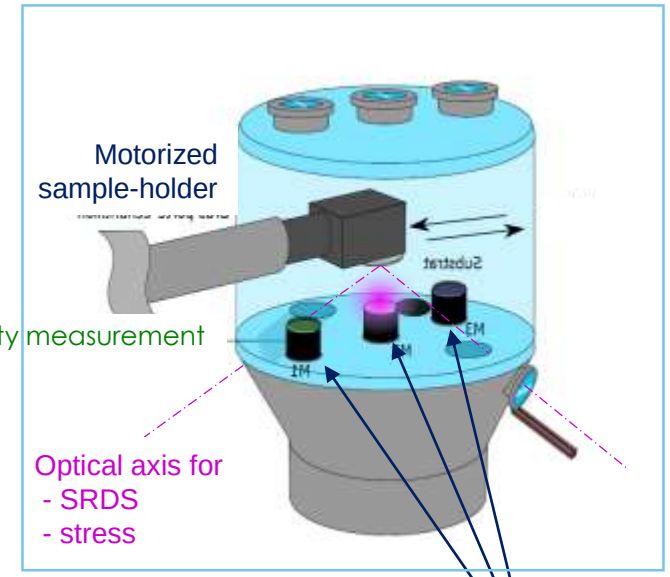
Very simplified stacks (1-3 layers)

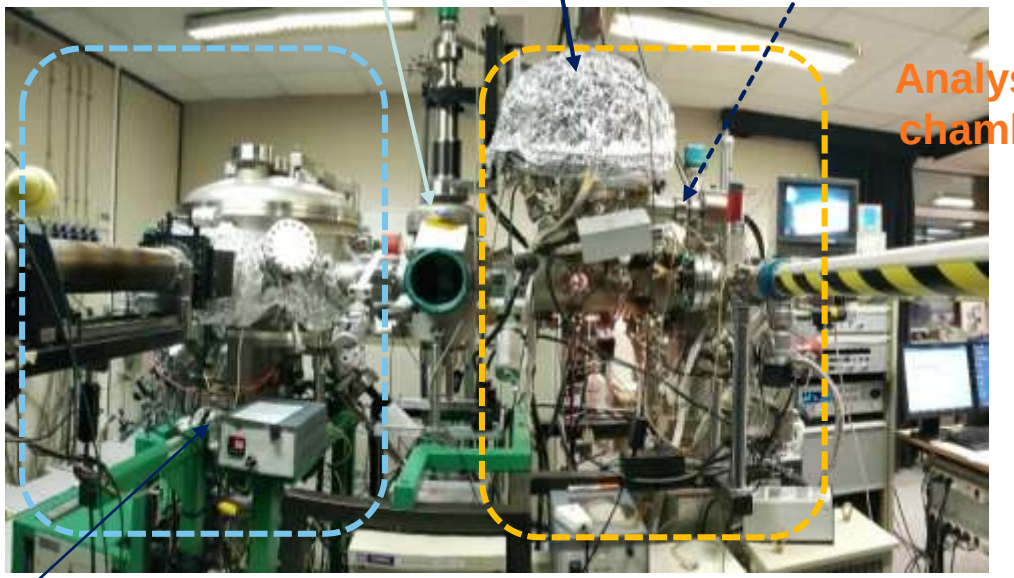
Instrumentation for in-situ advanced characterization

EXPERIMENTAL: SVI SET-UP FOR SPUTTERING & CHARACTERIZATION

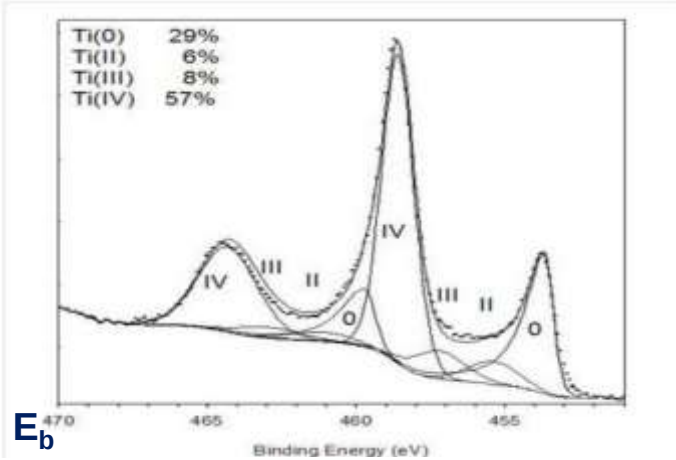
H. Montigaud
S. Grachev
Coll. R. Lazzari
INSP

Deposition config.





X-ray Photoelectron Spectrocopy

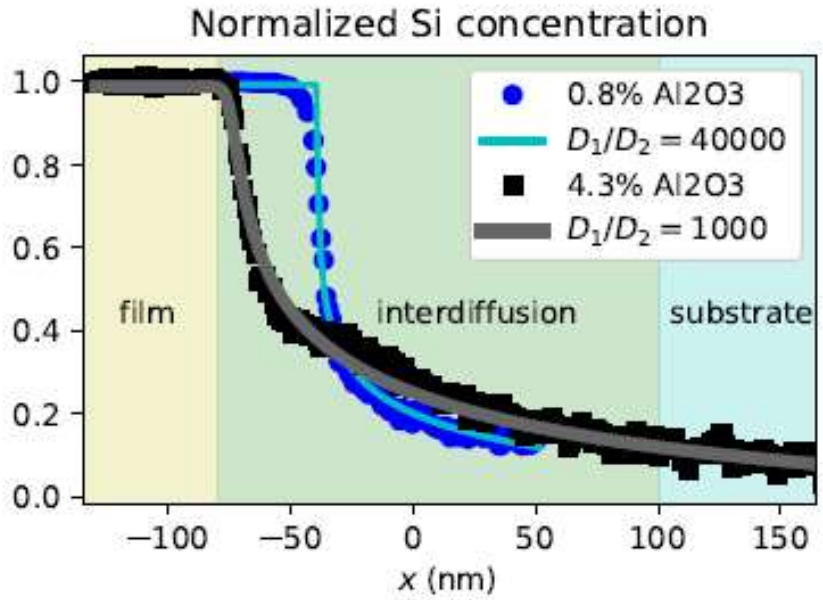


Example of Ti 2p spectra

- ***In situ* characterization**
  - during the process (layer conductivity, intrinsic stress, optical properties)
  - on the final coating without atmospheric contamination (composition, structure)

M Biesinger, XPSFitting,com

Diffusive dissolution of thin film and multicomponent effects



$$\frac{\partial C}{\partial t} = \nabla \cdot (D \nabla C)$$

D often considered constant, but sometimes this approximation cannot be used

silica thin film	soda-lime glass
smaller D	larger D

High Si diffusivity (& viscosity) ratio between substrate and film

Using Crank's model to fit profiles :

$$D_{Si} = D_0 \exp(-\beta C_{Si})$$

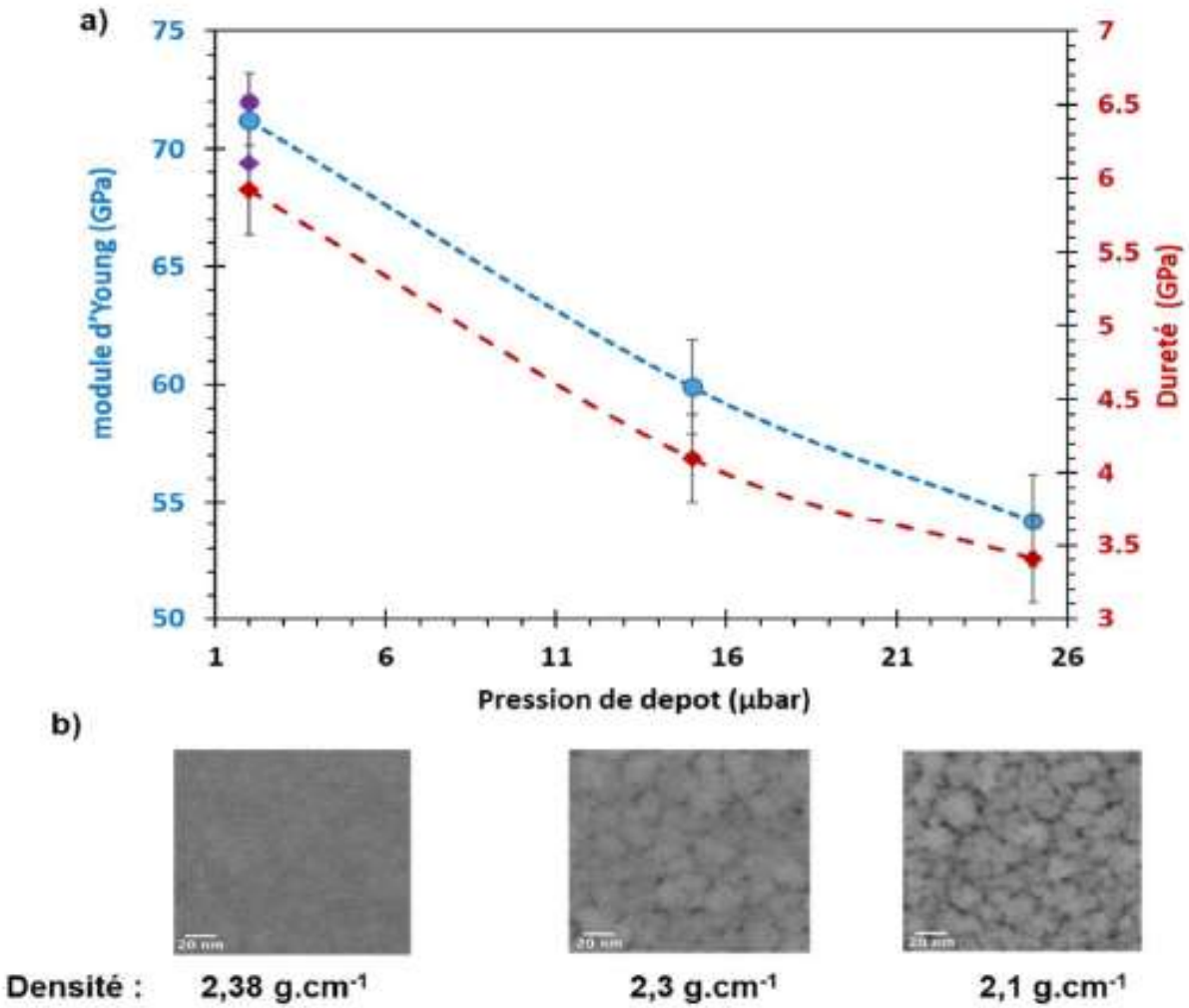
Fitted values of β consistent with Eyring's law and viscosity model

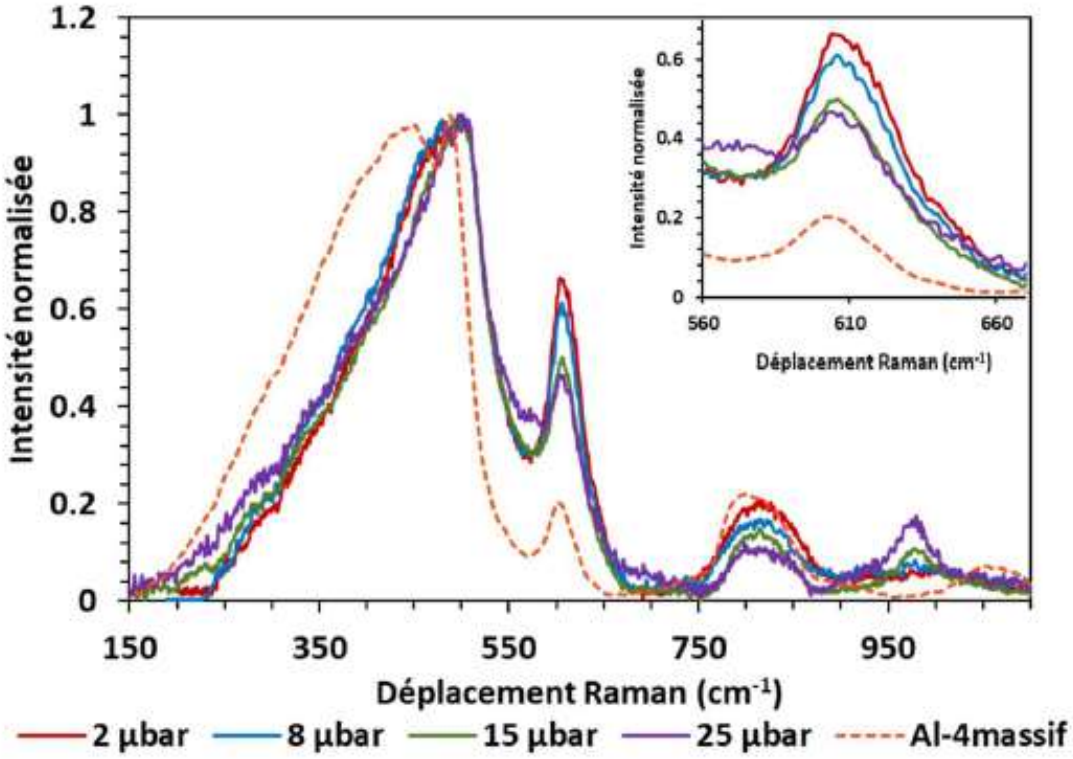
Use bulk eigenvectors to fit profiles

PhD JT Fonné ; Fonné et al., JACS 2017, JACS2018
PhD S. Ben Khemis, coll. L Cormier

Diffusion and structure of thin films, PhD Sirine Ben Khemis

Silica thin films with different sputtering conditions

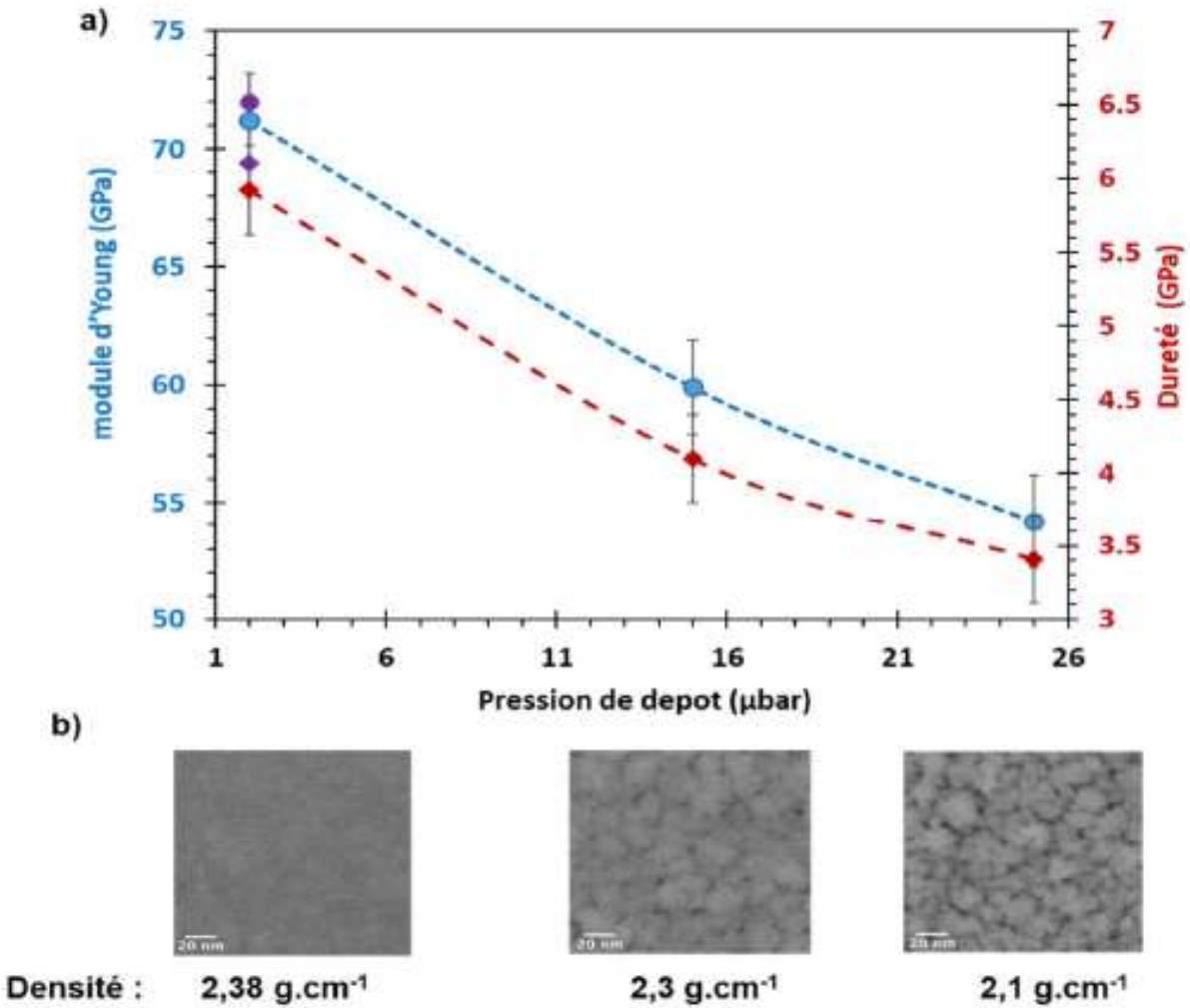


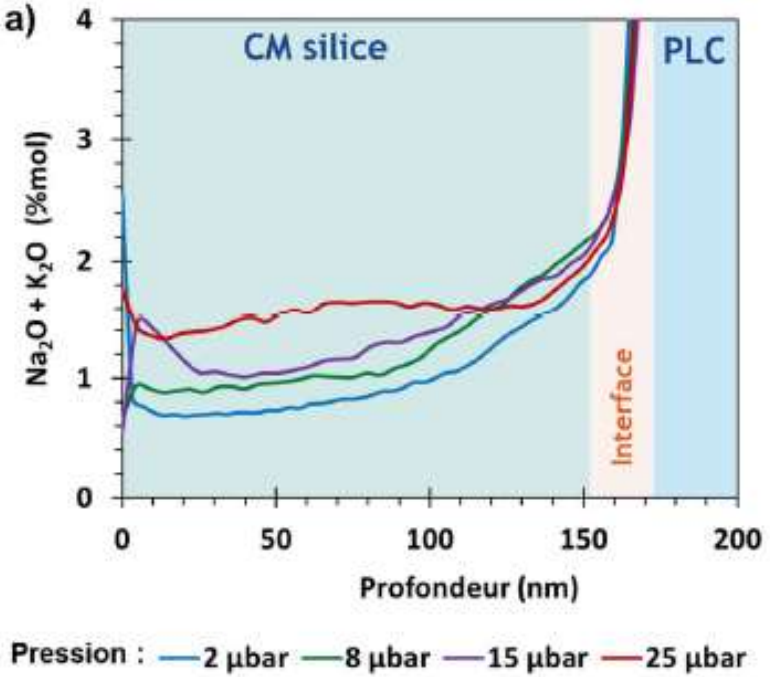


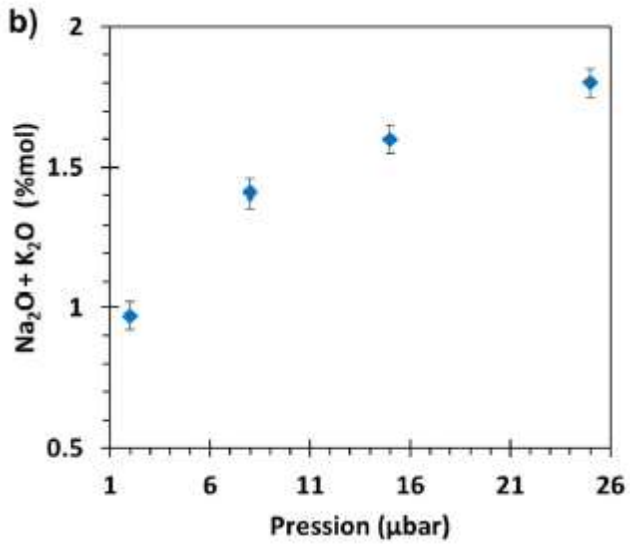
MAGI project, L. Cormier (IMPMC), E. Burov (SVI)

Diffusion and structure of thin films, PhD Sirine Ben Khemis

Silica thin films with different sputtering conditions



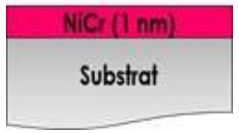




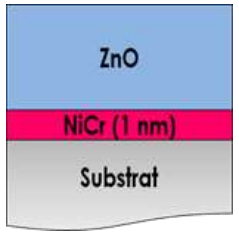
thermodynamics + kinetics

MAGI project, L. Cormier (IMPMC), E. Burov (SVI)

NiCr thin layer structure

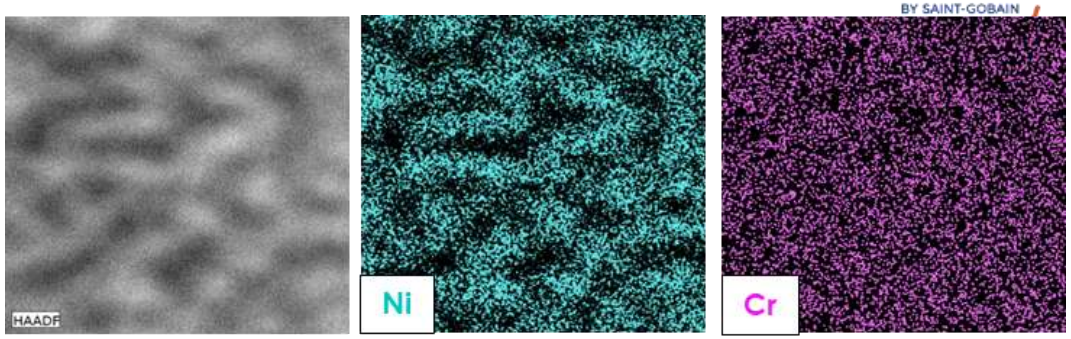


- **Spinodal-type morphology**
- Consequence of substrate (oxide) surface tension

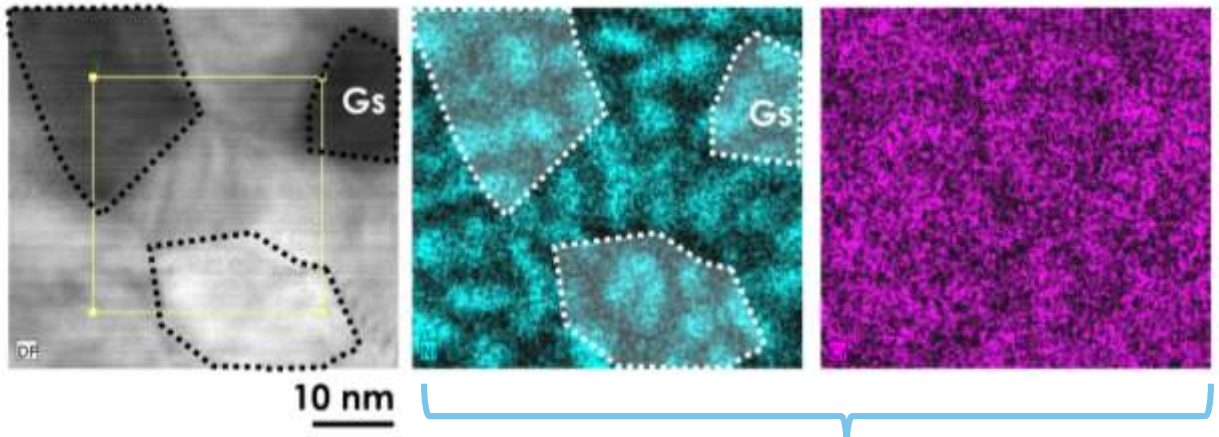


- **Spinodal-type morphology**
- No impact of the sputtering deposition of zinc oxide

  (rf/ZnO deposition example)

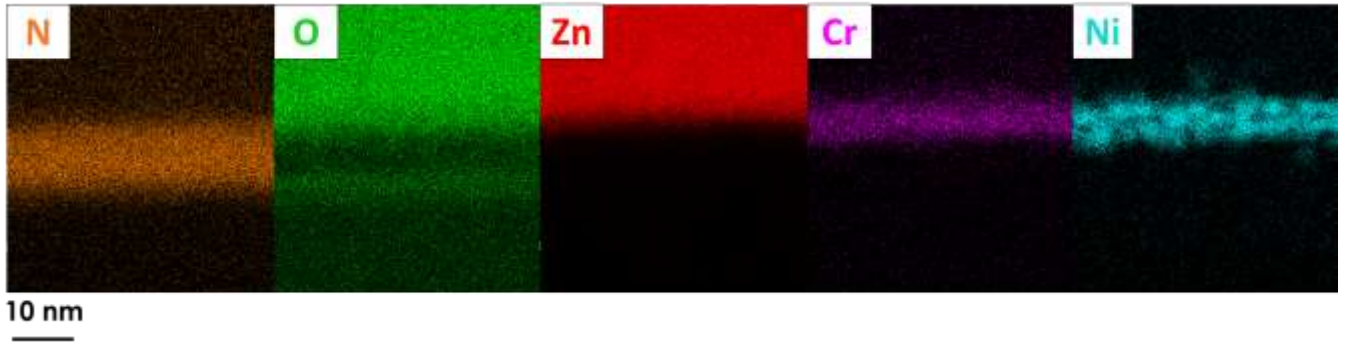


STEM-HAADF



STEM-EDS **plan-view**

cross section

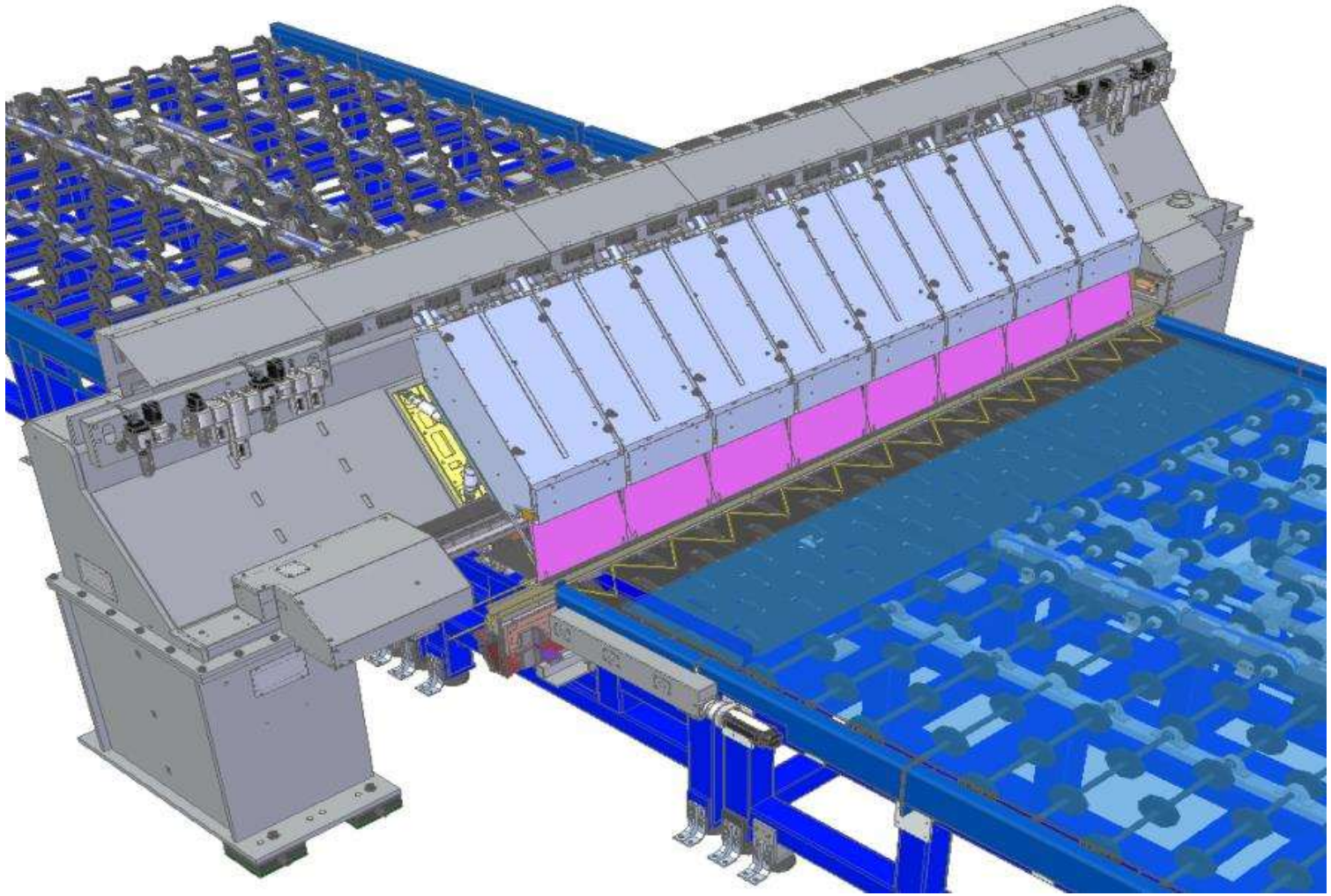


Composition (EPMA)

Element	Ni	Cr
% at.	77.0 ± 0.2	23.0 ± 0.1

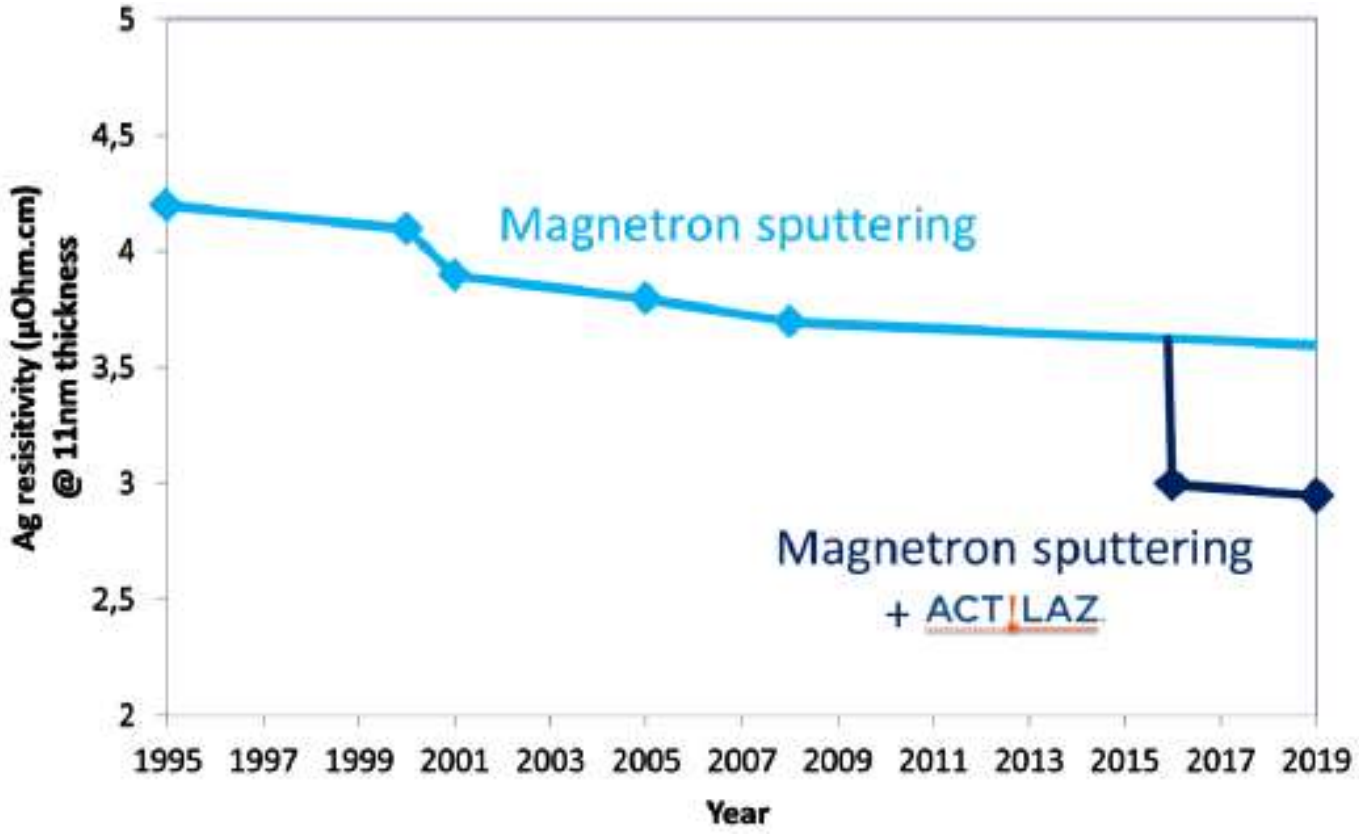
Saint-Gobain confidential &

LASER ANNEALING OF THIN FILM COATINGS ON LARGE AREA GLASS SUBSTRATES



Developed in collaboration with Trumpf and Manz

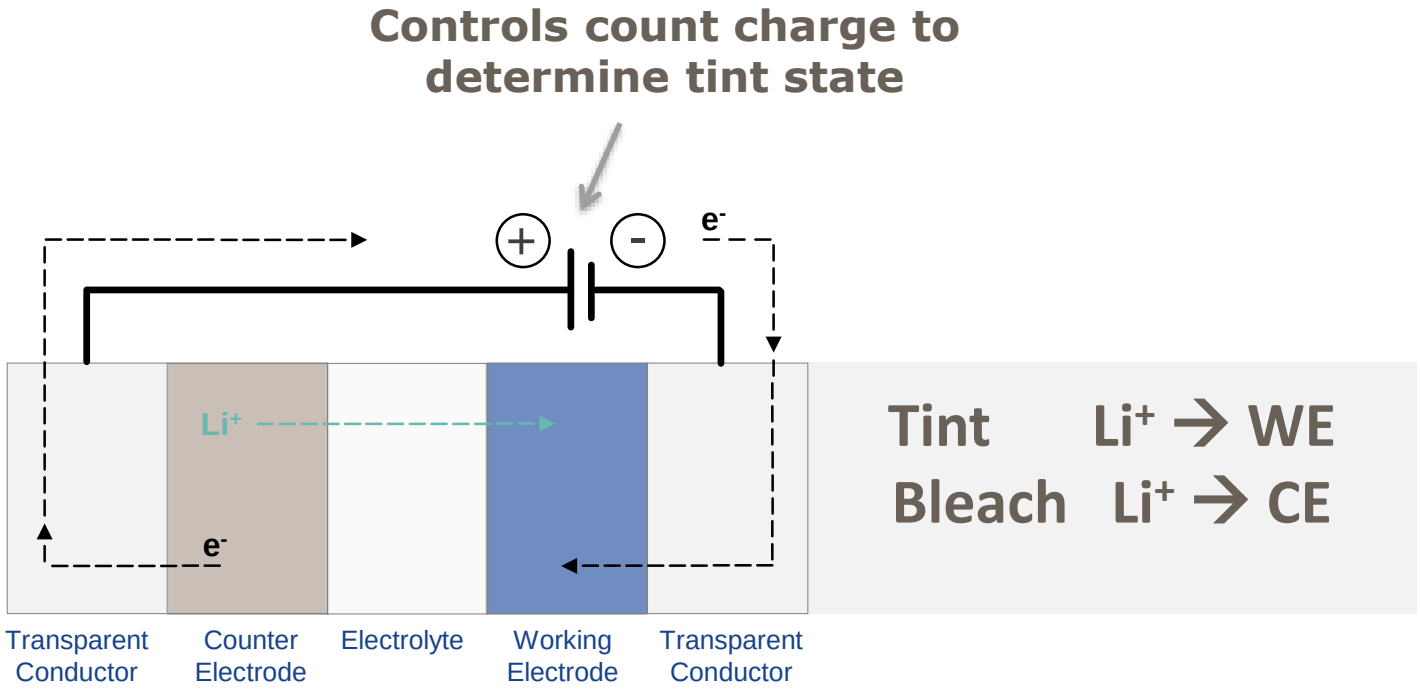
LASER ANNEALING OF THIN FILM COATINGS ON LARGE AREA GLASS SUBSTRATES

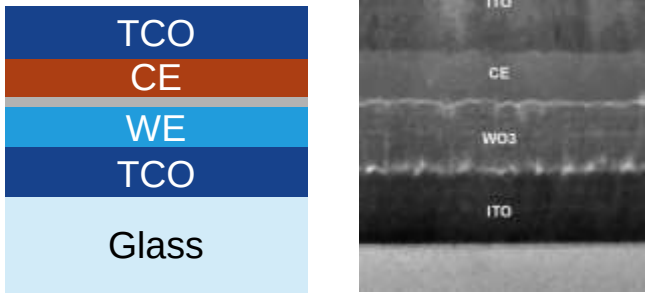


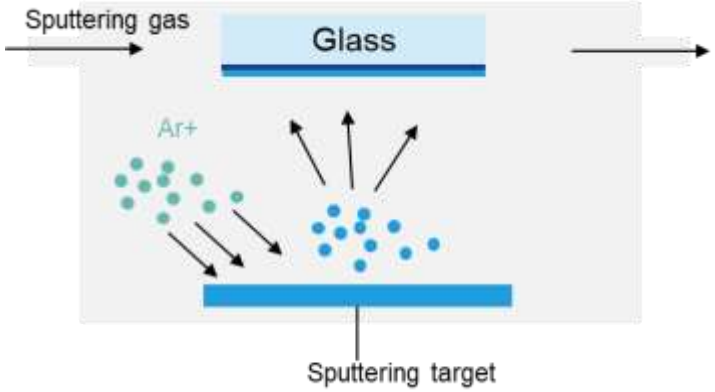

SageGlass®

PHYSICS OF EC TECHNOLOGY

Thin film Deposition and Electrochemical reactions involved

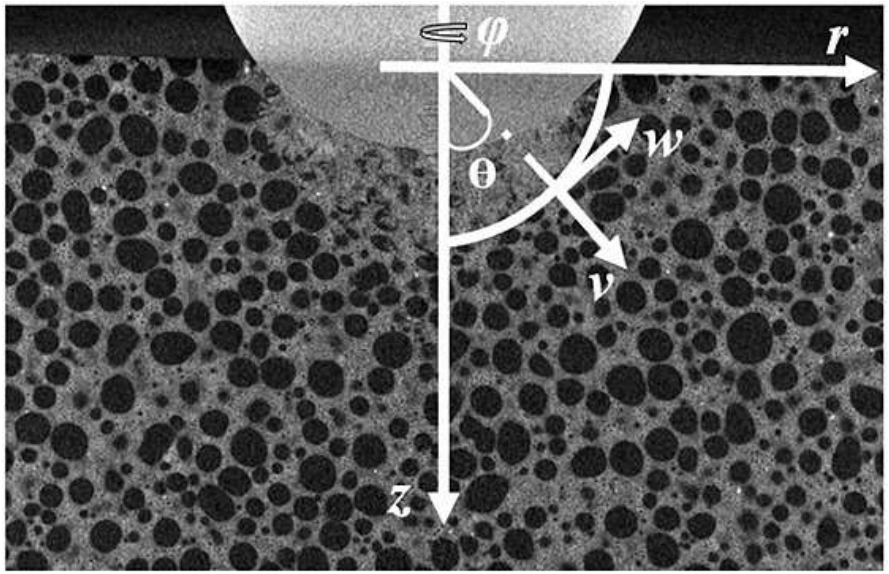




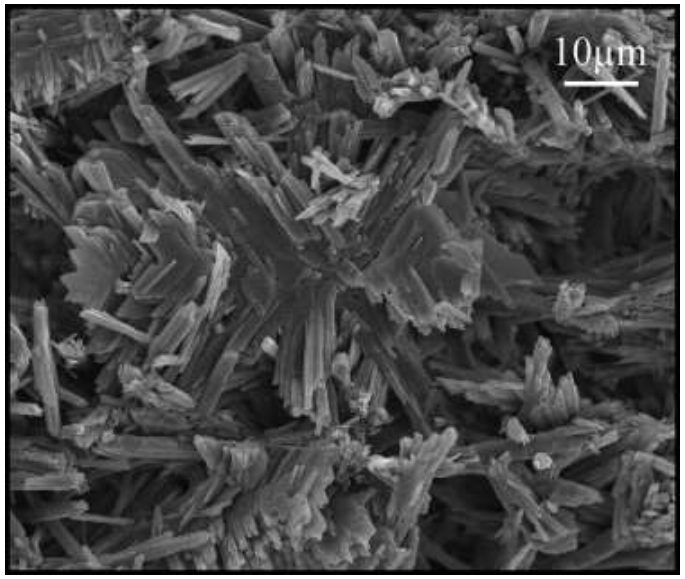


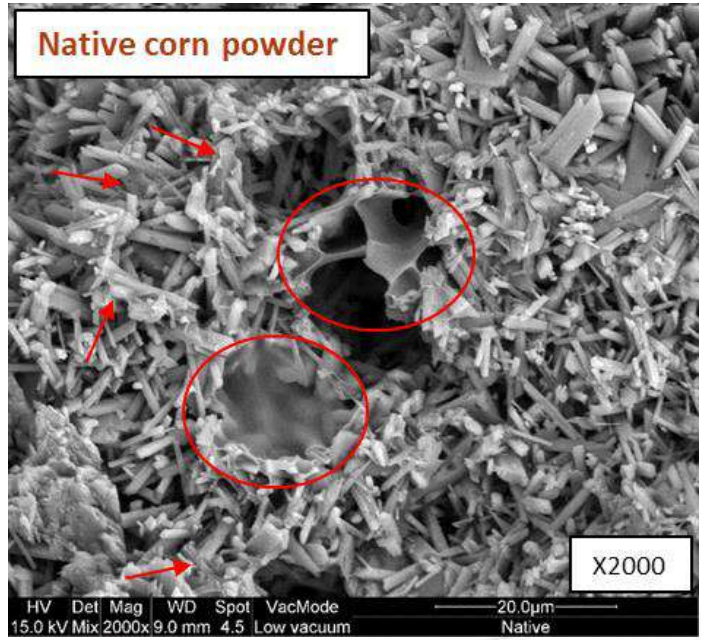
Electrochromic glass act as a **lithium ion battery made out of transparent thin coatings on Glass**

GYPSUM BOARDS: MULTISCALE MATERIALS



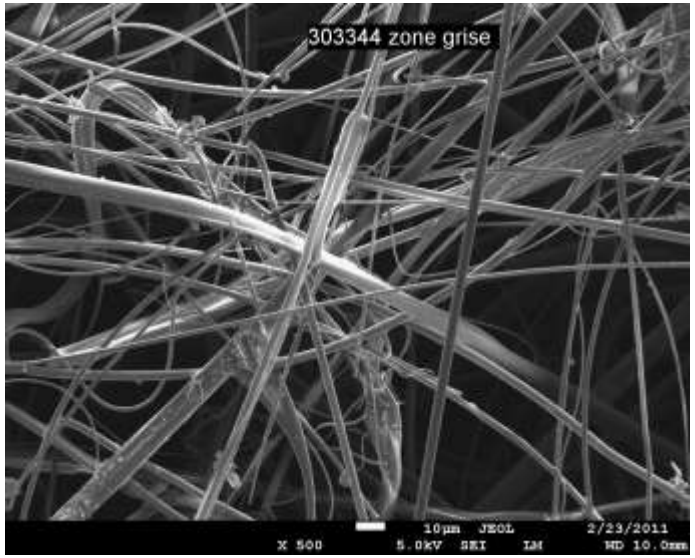
Bouterf, Amine, et al. *Strain* 50.5 (2014): 444-453.
In situ X-ray tomography and DIC, coll. S. Roux (LMT)





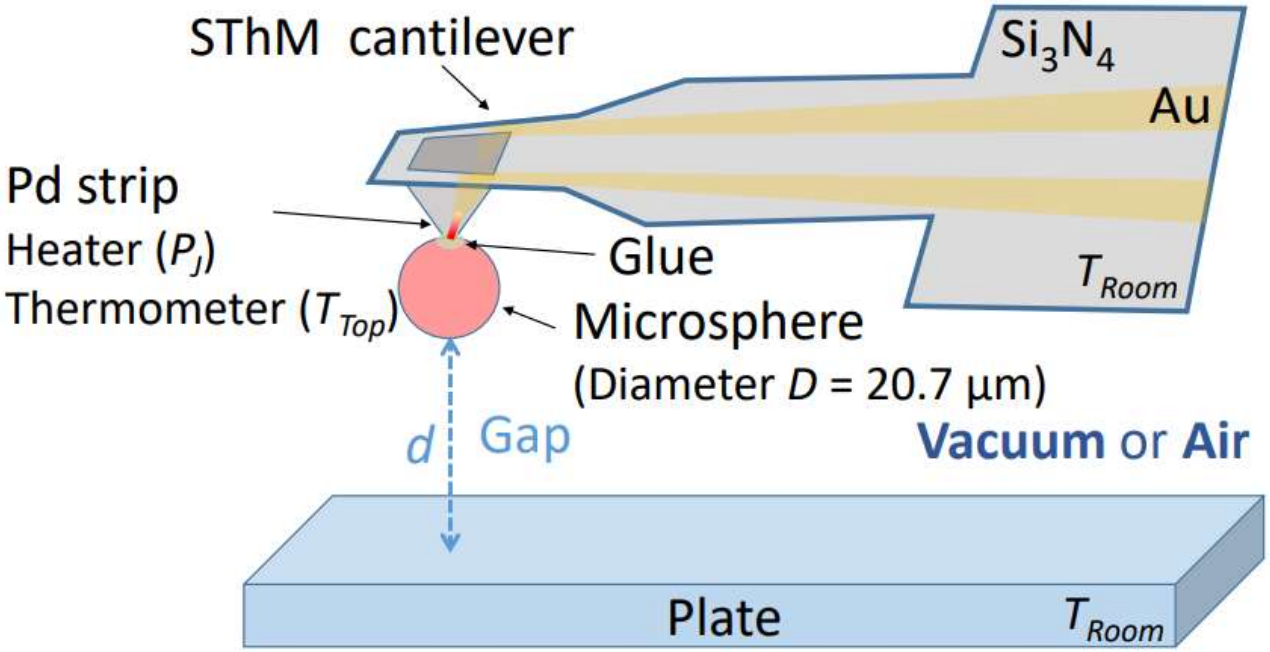
H. Jaffel, PhD thesis, 2006; S. Moro

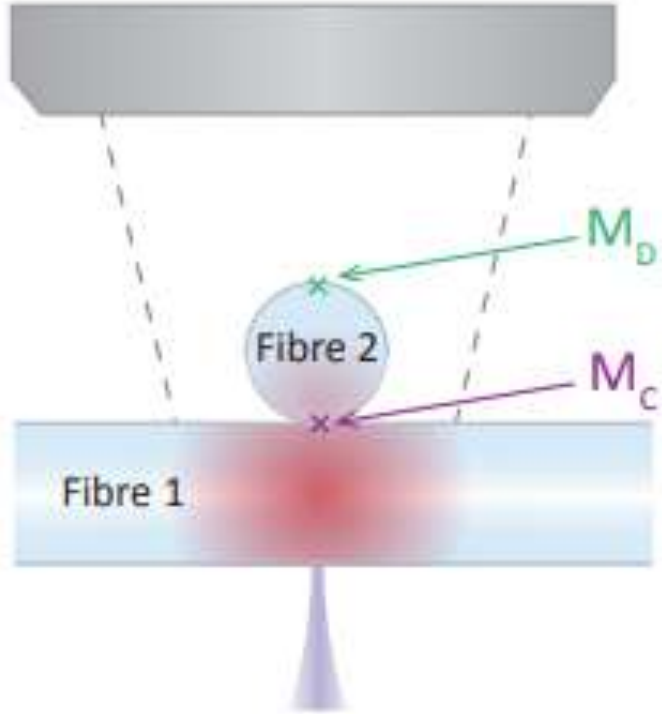
GLASS WOOL: OPTIMIZING FIBRE ARRANGEMENT FOR THERMAL INSULATION



MEASURE OF THERMAL CONTACT RESISTANCE

COLL. Y. DE WILDE, R. CARMINATI (LANGEVIN), PHDS E. PERROS, J. DOUMOURO





Doumouro, Joris, et al. "Quantitative measurement of the thermal contact resistance between a glass microsphere and a plate." *Physical Review Applied* 15.1 (2021): 014063.

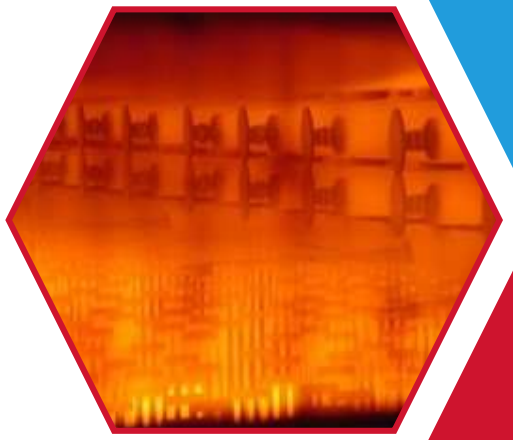
UPSTREAM COMPETENCE CENTER FOR DIGITAL & MODELLING TOOLS

COMPETENCIES

SENSORS & METROLOGY,
DATA SCIENCE,
BUILDING SCIENCE,
NUMERICAL MODELLING

NUMERICAL MODELING,
ROBOTICS AND
AUTOMATION,
DIGITAL RENDERING,
VR/AR

Link with R&D
Group
Initiatives

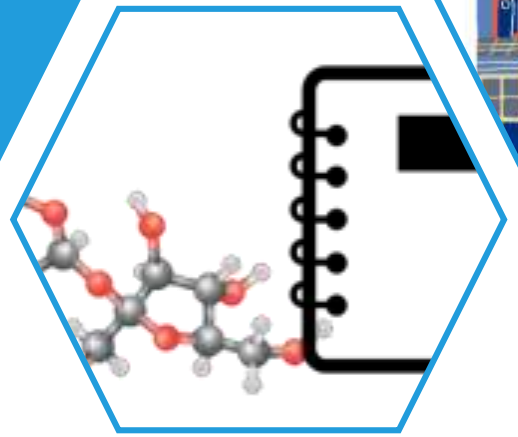


4.0 industry
Reinforcement learning
Control; Sensors

Experimental databases and materials design *LIMS, NLP databases*

Building science
Visualisation
immersion

Advanced methods for process modelling
Hybrid models
Model reduction
Smart interpolation



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