NanoQuébec: Québec network in nanotechnologies

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Plasmas applied to micro and nanomanufacturing technologies

STAE’s second fall meeting
November 14, 2012, Toulouse

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The first 10 years of NanoQuébec

beginning of 2000's, push to develop nanotechnologies:

- Critical mass of researchers
- High quality education programs
- World class infrastructure
- Industrial sector involvement

NanoQuébec created in 2001

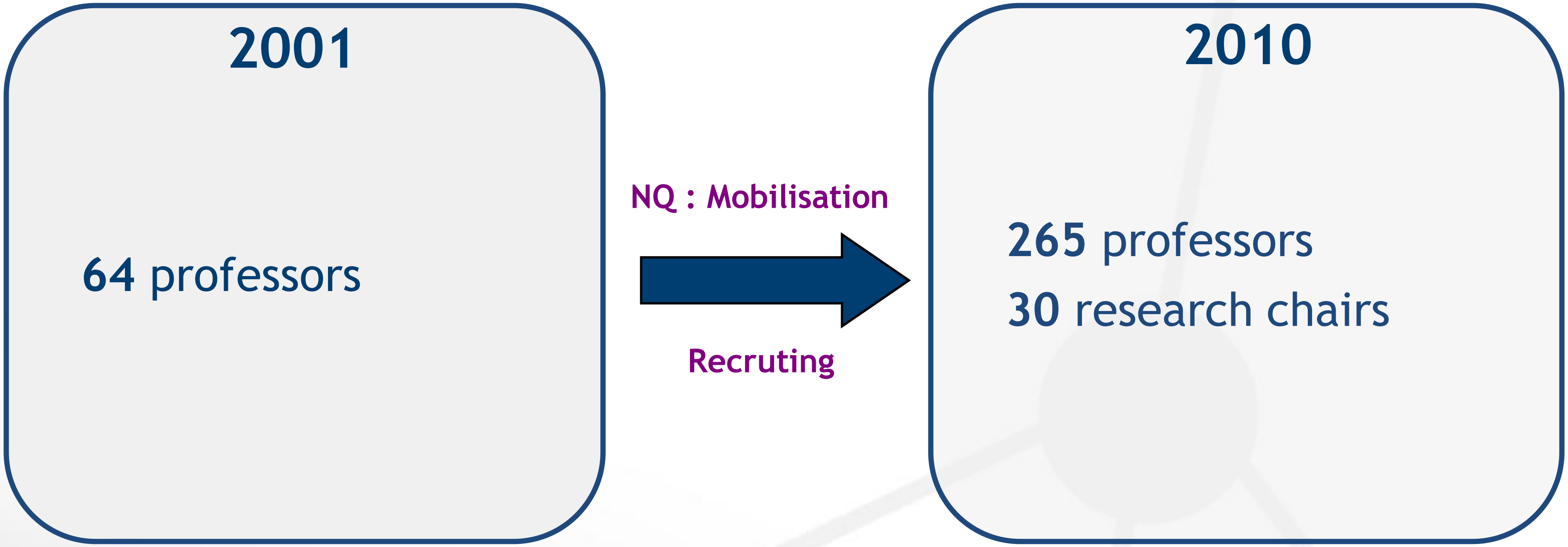
by MDEIE, Quebec's department of economic development, innovation and trade

Mission

to strengthen nanotechnology-enabled innovation with the aim of maximizing economic impact

High quality research programs

In 2001, founding universities committed to recruiting 54 additional professors in nanotechnology.



2001

64 professors

NQ : Mobilisation

Recruting

2010

265 professors

30 research chairs

High quality research infrastructure

Universities coordinated to strengthen nanotechnology infrastructure: micro/nanofabrication, synthesis and nanomaterial characterization

2001

Infrastructure not up to standards
(29 research professionals)

NQ : Mobilisation

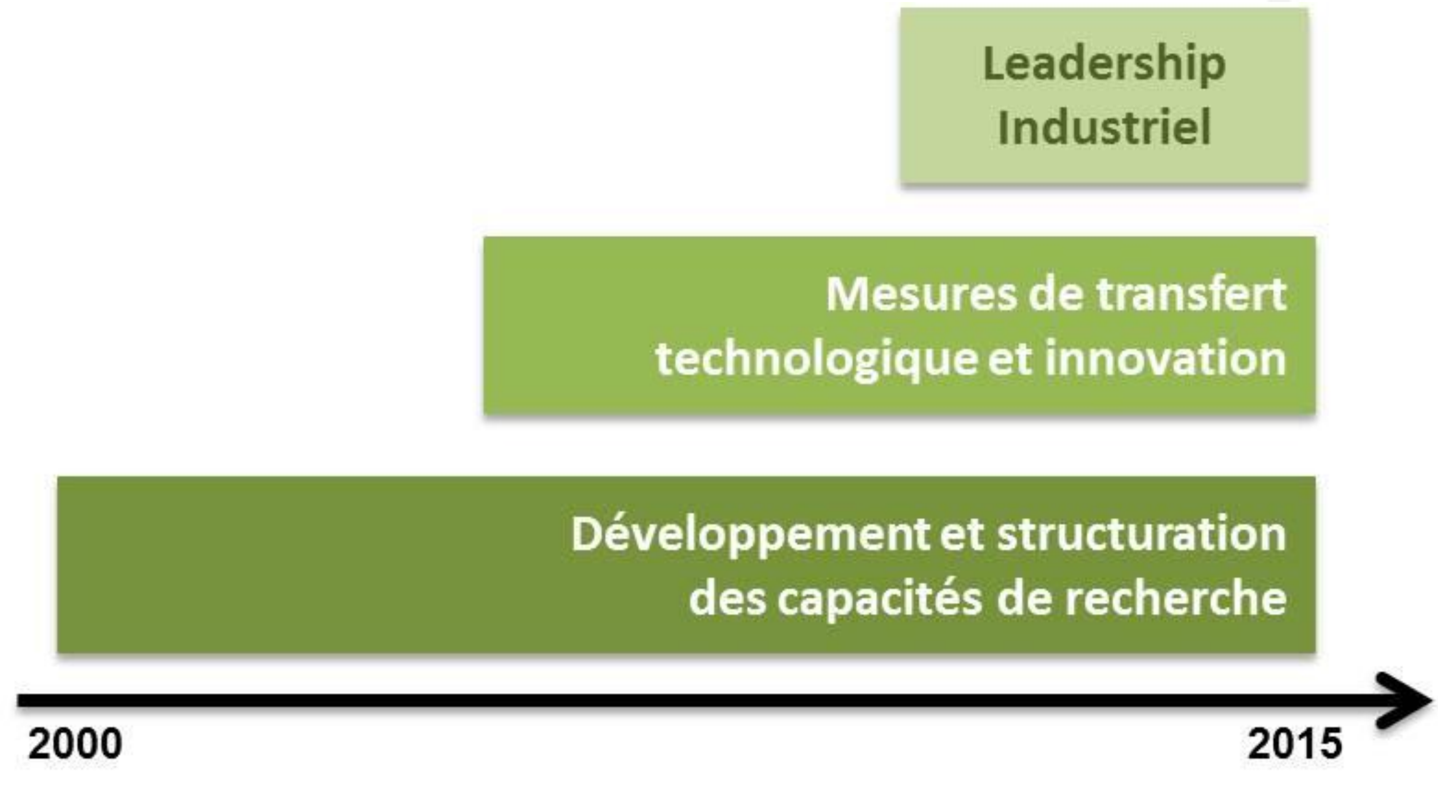
CFI awards

2010

400 M$ in equipment and a world class research infrastructure
(over 180 research professionals)

Challenge

Translating research capacity into industrial leadership



Leadership Industriel

Mesures de transfert technologique et innovation

Développement et structuration des capacités de recherche

NanoQuébec today - 2 key initiatives

The Quebec Nanotechnology Infrastructure - QNI

iNano funding program

IQN
INFRASTRUCTURE QUÉBÉCOISE EN NANOTECHNOLOGIE

iNANO

supporting university-based R&D infrastructures

fostering R&D collaborations between university and industry

Nanotechnology infrastructure in Quebec

NanoQuebec funds 11 university-based laboratories :

- 300 M$ equipment
- NanoQuébec money 2010-2013: 14 M$ total with 9 M$ to support lab operations
  - 70% is manpower, HQP to run labs

QNI regroups those 11 laboratories for a one-stop-shop

The QNI is…

- **Opened to both academic and industrial users**
- **World class in :**
  - Micro-nanofabrication
  - Nanomaterial synthesis
  - Characterization and modelling

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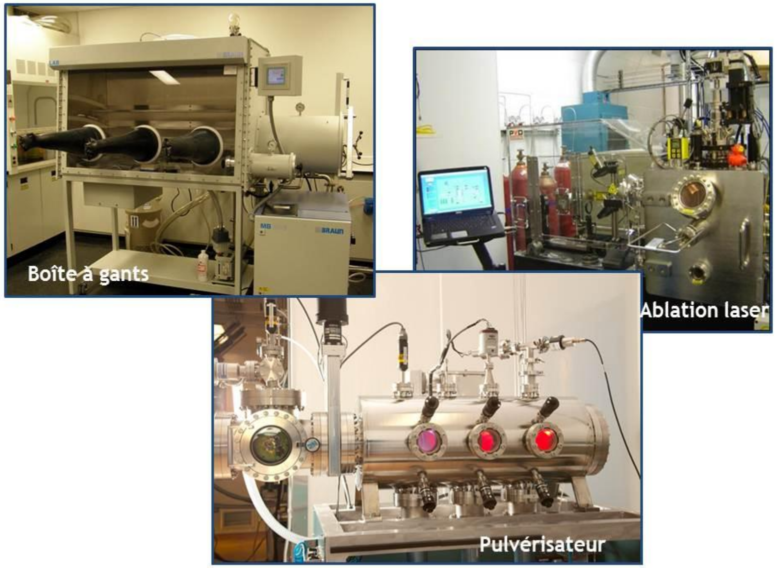
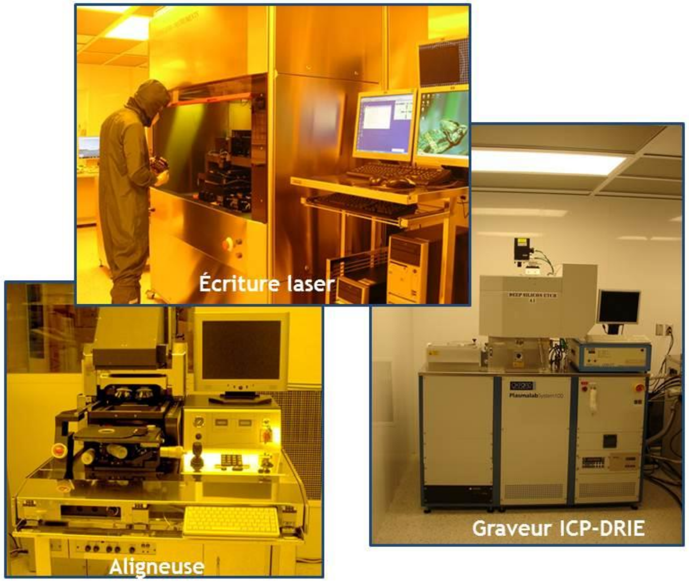
Technical offer

Nanomaterial synthesis

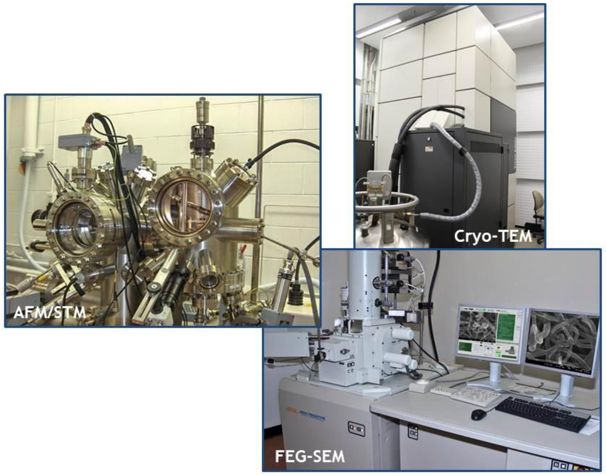


Micro-nanofabrication



One-stop-shop for access wide range of expertise

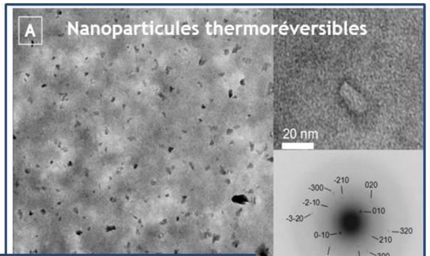
www.iqn-qni.ca

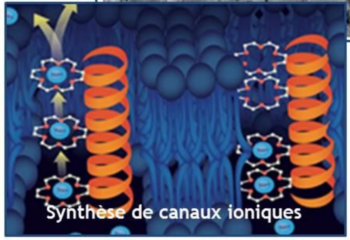


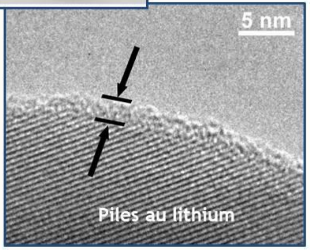
Characterization et modelling

Expertise

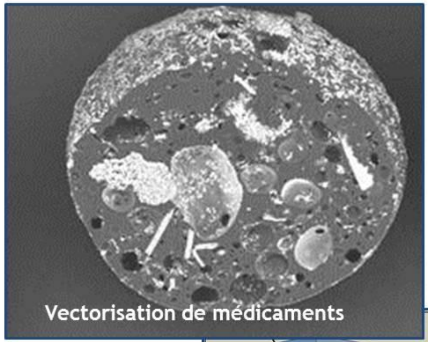
New material synthesis

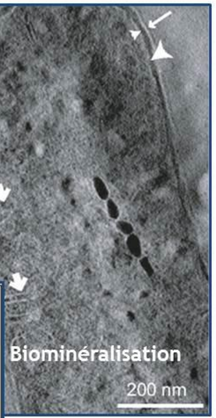

Nanoparticules thermoréversibles

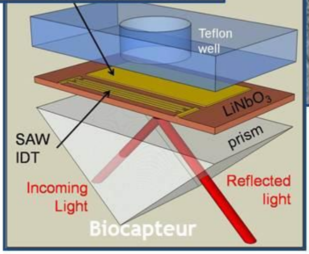

Synthèse de canaux ioniques


Piles au lithium

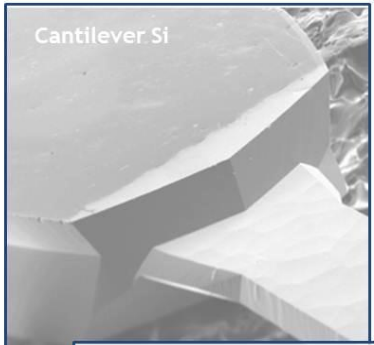
Health sciences

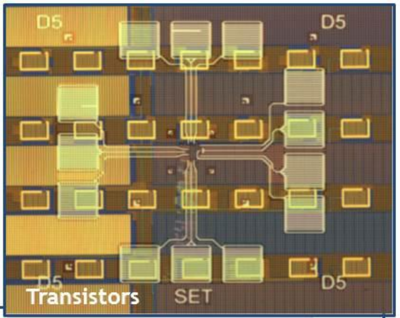

Vectorisation de médicaments

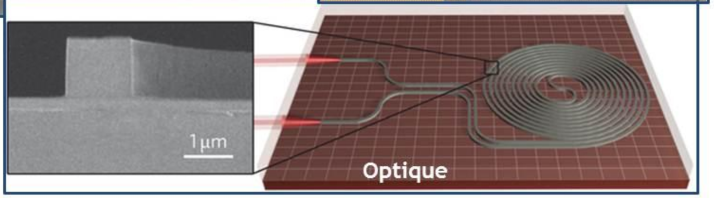

Biominéralisation


Biocapteur

Microsystems


Cantilever Si


Transistors


Optique

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INFRASTRUCTURE QUÉBÉCOISE EN NANOTECHNOLOGIE

I-Nano

- New way to promote university-industry collaborations
- Compagnies post ‘challenges’ to the research community
- Researchers suggest ‘solutions’
- Relate challenge-solution, in 4 weeks:
  - 57 challenges, 150 solutions
  - 57% of companies applying had less than 50 employees
  - 20 projects were submitted for funding (6 M$ total)
  - 40% NQ - 30% NSERC-DRC - 30% company (15% inkind)

Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada

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www.nanoquebec.ca / I-Nano

I-Nano – some examples of challenges

1. New polymers for advanced photolithography
2. Nanoscale electronic structures adapted to textile and garment integration
3. Transparent electrodes for photovoltaics applications
4. Integration of Nanostructured Synthesized Elements for high efficient Sensors
5. Synthesis and development of UltraNanoCrystalline Diamond for sensing applications
6. Modeling of high power batteries/capacitors for energy recovery
7. Impact of nanomaterials on health and environment
8. Volume Production of Optical MEMS Devices
9. Development of cGMP production processes and QC analytical procedures for chitosan/nucleic acid nanoparticles
10. Color maintenance in textile
11. Self-repair paints
12. Surface protection against ice and graffiti
13. Development of an intelligent fiber that has the capabilities to detect the presence of blood in a wounded person
14. Improving performance of epoxy based semiconductor packaging

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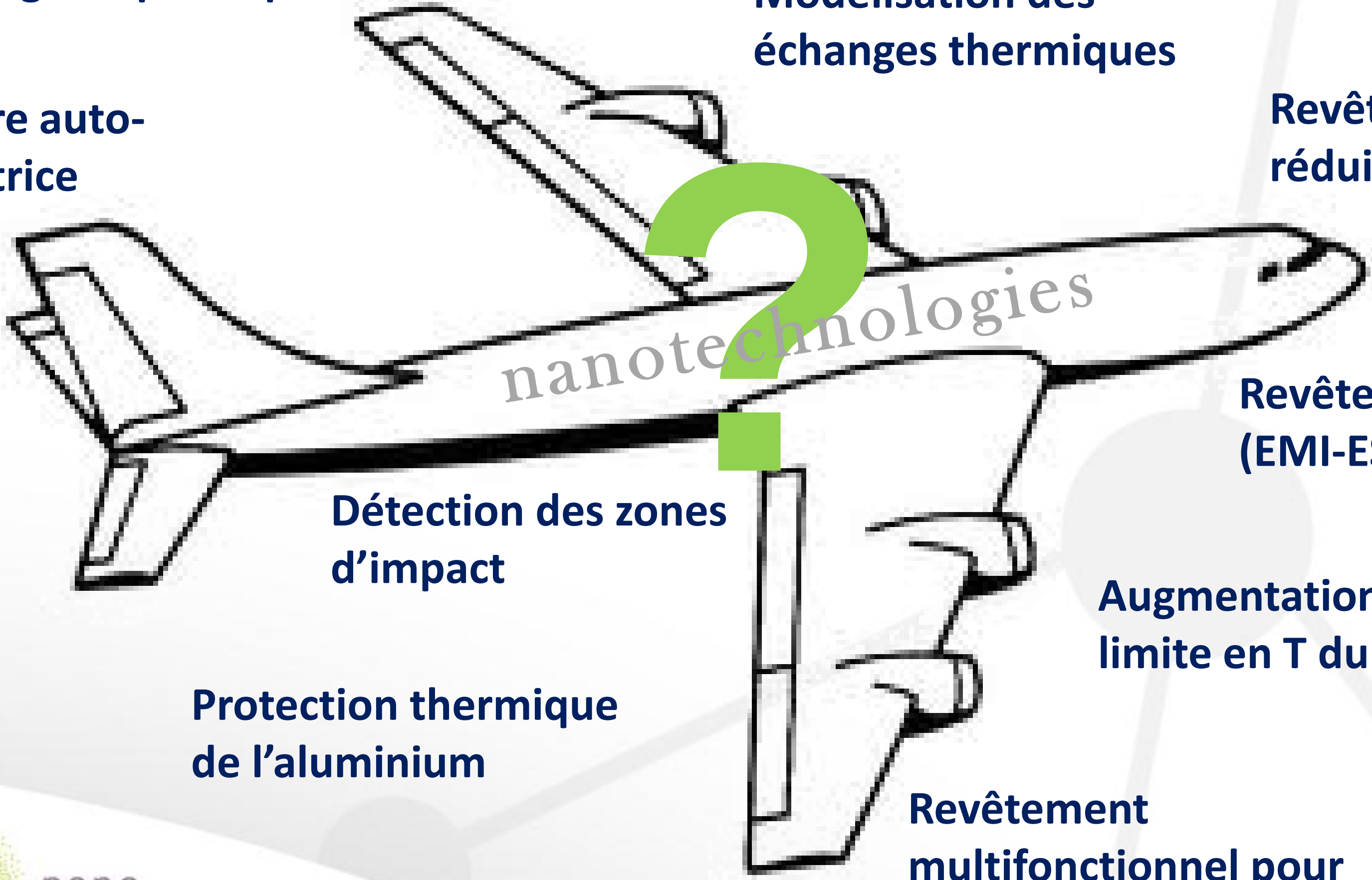
10 défis provenant du secteur aéronautique



CMC quasi-isotrope à haute résistance

Revêtement glaciophobique

Modélisation des échanges thermiques

Peinture auto-réparatrice

Revêtement réduisant la trainée

Revêtement conducteur (EMI-ESD)

Détection des zones d’impact

Augmentation de la limite en T du titane

Protection thermique de l’aluminium

Revêtement multifonctionnel pour titane

R&D 2011

Creation of spin offs from university research

Canétique from INRS-ÉMT

Research into fuel cells by Prof. JP Dodelet

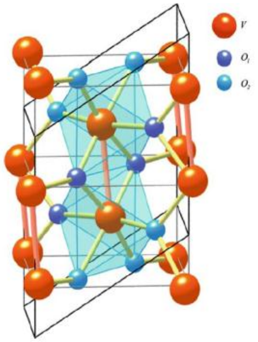
Following breakthgoughs published in **Science** in 2009 and **Nature Comm** in 2011:

- M. Lefèvre, *et al.*, Iron-based catalysts with improved oxygen reduction activity in polymer electrolyte fuel cells, **Science**, 324, 71-71 (2009)
- E. Proietti, *et al.*, Iron-based cathode catalyst with enhanced power density in polymer electrolyte membrane fuel cells, **Nature Communications**, 2 : 416, DOI :10.1038 /ncomms1427.

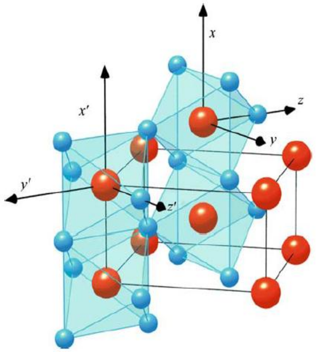
Vanadium dioxide VO_2

Monoclinic

a = 5,7517 Å
b = 4,5378 Å
c = 5,3825 Å
β = 122,646°



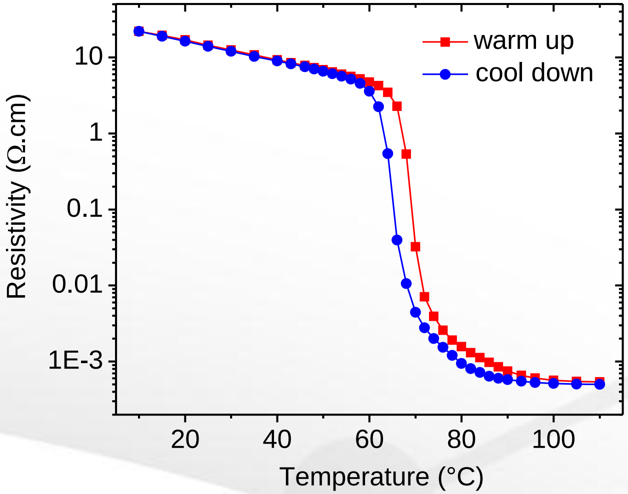
Temperature ↑

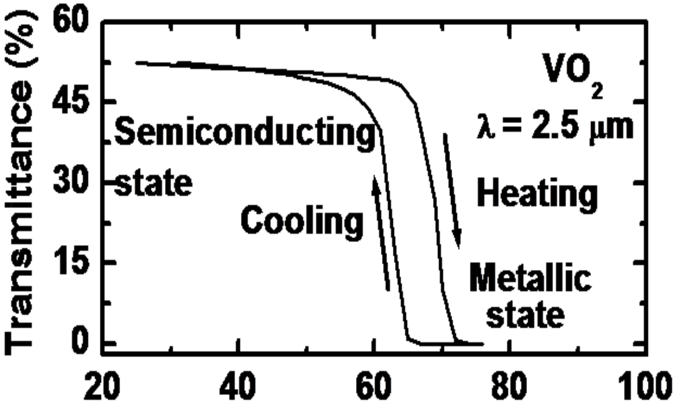


Tetragonal

a = 4,5546 Å
c = 2,8514 Å

- ➢ Large variation in the electrical and optical properties due to the metal-to-insulator transition.
- ➢ Transition temperature (T_{MIT}) close to room temperature.
- ➢ The transition temperature can be modified through doping.





Vanadium dioxide VO_2

Transition control methods

- Temperature
- Photo-excitation
- Electric field
- Pressure

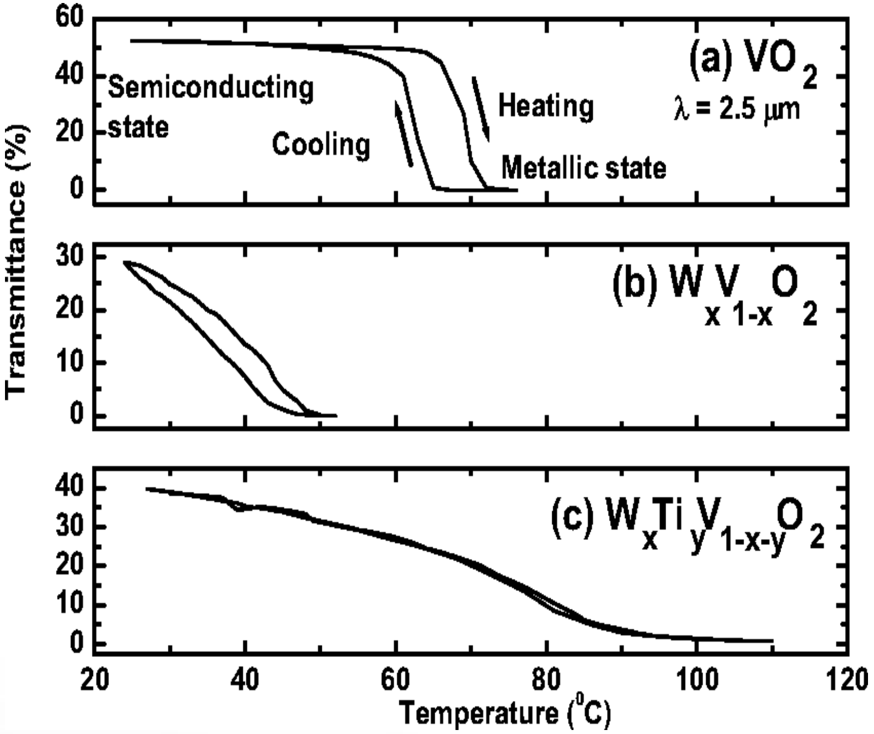
Control of the transition temperature

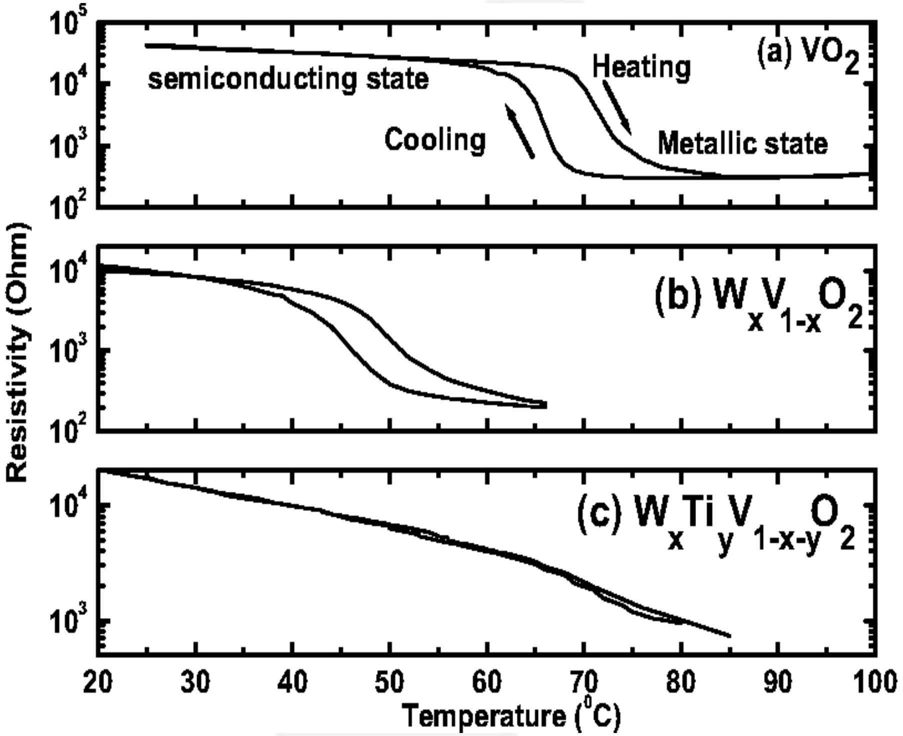
- Donorlike or acceptorlike centers:
- W, Ti, Al,…etc

Applications of VO_2

- IR uncooled bolometer
- Field effect transistors
- Ultrafast infrared shutters
- Modulators
- Holographic storage system
- Microwave switching applications
- Smart windows
- Smart Radiator Devices (SRD) for spacecraft
- Sensors
- …

Effects of W and Ti-W codoping on VO_2 phase transition





- The transition temperature (Tt) is about 36 ºC for W-doped VO_2 as compared to 68 ºC for VO_2 films, T_t is then lowered by about 23ºC per one at. % of W dopant ions added
- T_t is about 60 ºC for Ti-W codoped VO_2 films,
- The optical hysteresis is completely suppressed in Ti-W-codoped VO_2 films.

VO_2 : smart radiator device

- Spacecrafts are subjected to large external temperature swings (–150/ +150°C)
- Internal temperature must be regulated over -10 to 30°C
- Efficient thermal control of spacecraft is crucial for spacecraft missions to succeed.

Problems associated with the current thermal-control systems:

- Cost, complexity, size, weight, and the risk of damage of the mechanic and/or the power supply systems.

New approach for the thermal-control systems: Smart radiator device (SRD)

- Development of VO_2-based variable emittance coatings

Advantages of the smart radiator device:

- Cost-effective, simple, lightweight, and can be directly integrated onto the spacecraft parts
- Passive

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VO_2 : smart radiator device

SRD requirements:

- High temperature Emissivity (ε-high) > 0.7
- Low temperature Emissivity (ε-low) $\leq$0.5
- Tunability (Delta Emissivity, $\Delta\varepsilon$) $\geq$ 0.35
- Switching temperature around 20°C
- Solar absorbance EOF (α-EOF) <0.3
- The optimal performance of SRD should be obtained over a large surface area (>3” in diameter)

Methodology

- Optimization of the VO_2 properties
- Simulation
- Fabrication
- Emittance characterization (from FTIR reflectance measurements)

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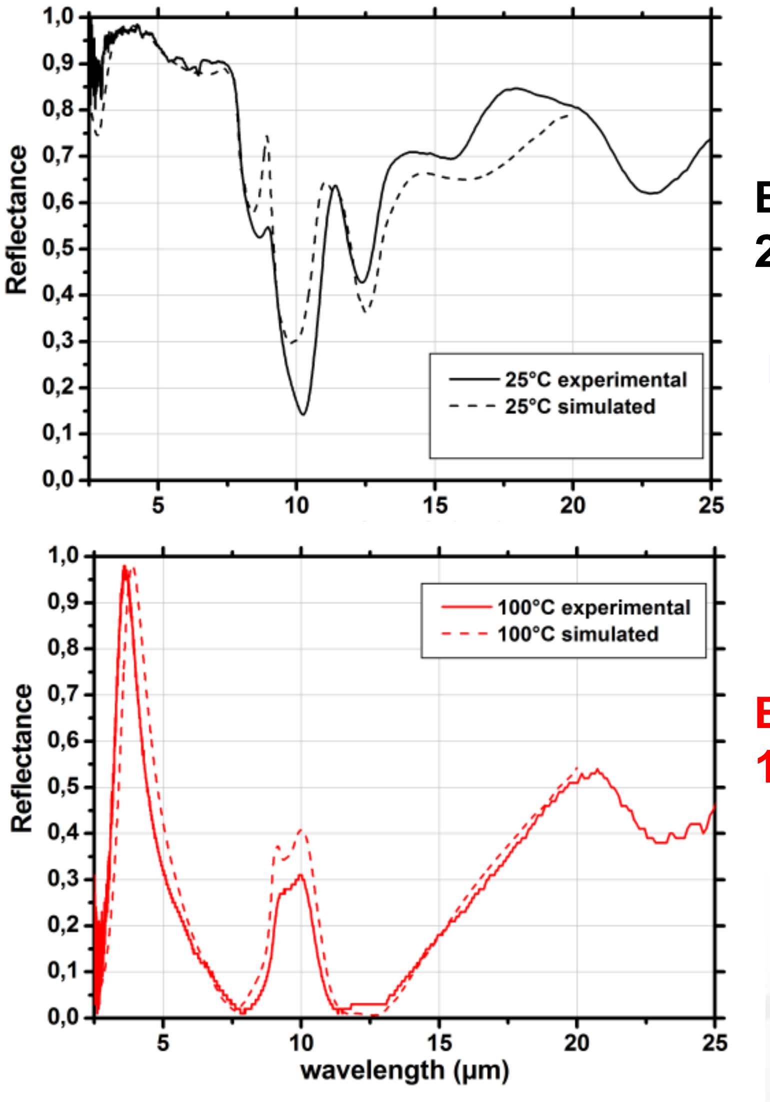
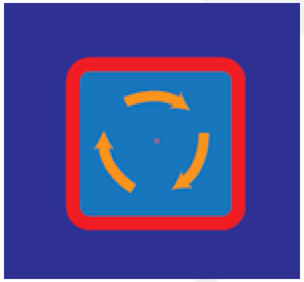
VO_2 : smart radiator device



Emittance at 25˚C

ε = 0.35



Emittance at 100˚C

ε = 0.81

Δε = 0.46

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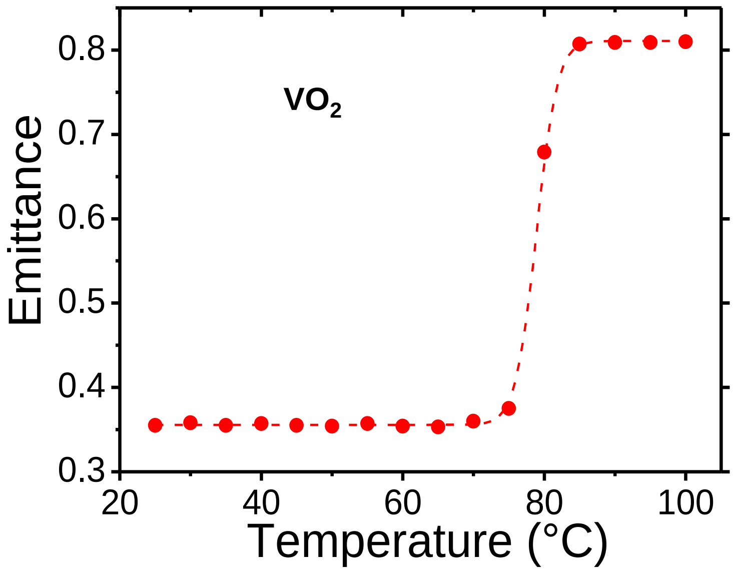
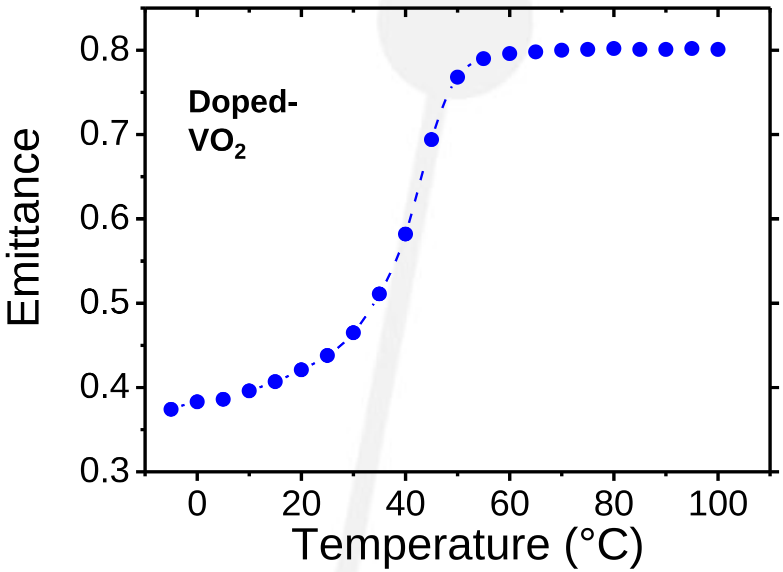
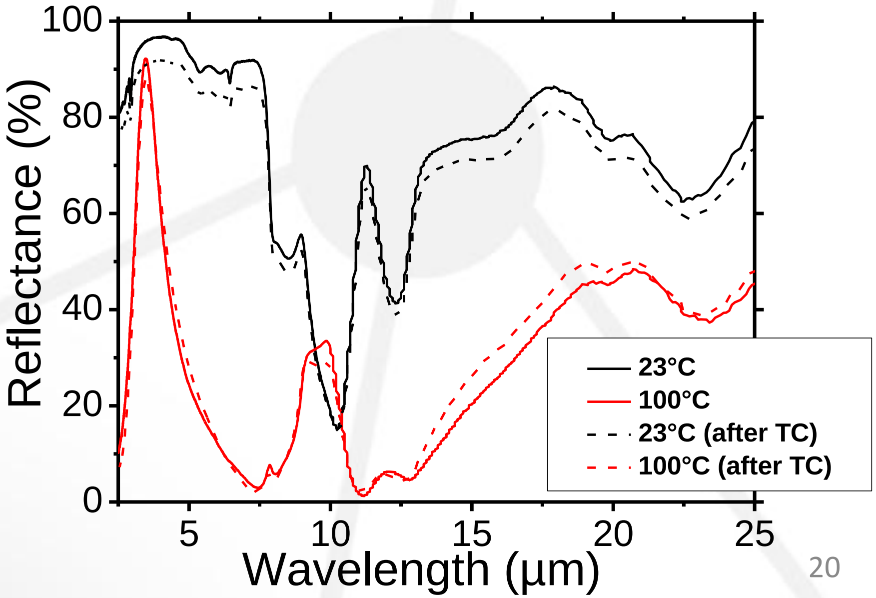
VO_2 : smart radiator device



Emittance versus Temperature



Stability of the radiator performance after thermal cycling tests (250 cycles between -20˚C and 100˚C)



Conclusion

Many cooperation opportunities

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Merci

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