



nanomakers

Materials booster



Develops, produces & sells
silicon-based nanopowders that
disruptively improve the
properties of industrial **materials**



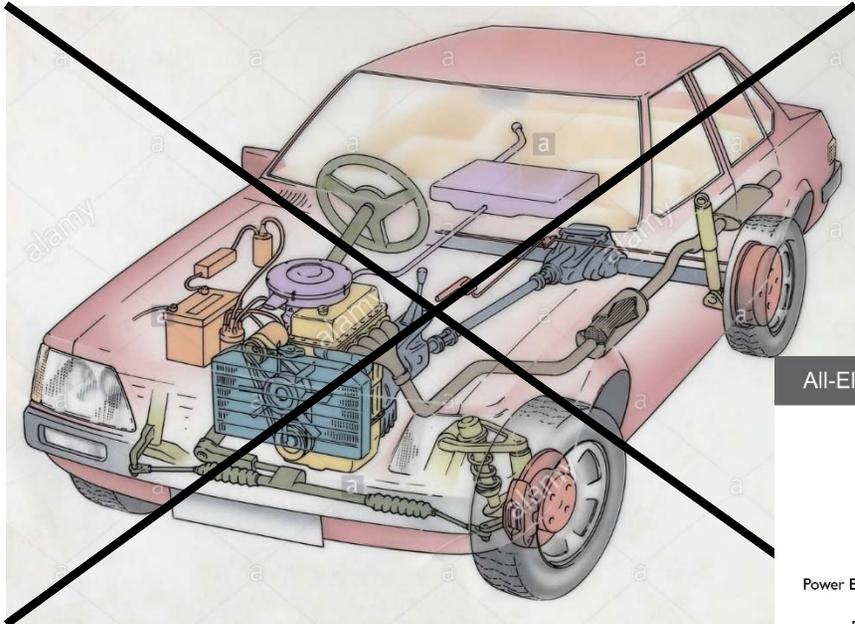
Nano silicon as a key enabling technology in the framework of the present European effort to develop a battery European industry.

Innovation, scale-up, industrial growth.

Nicolas Bécrot, Operations Director, Nanomakers (France)

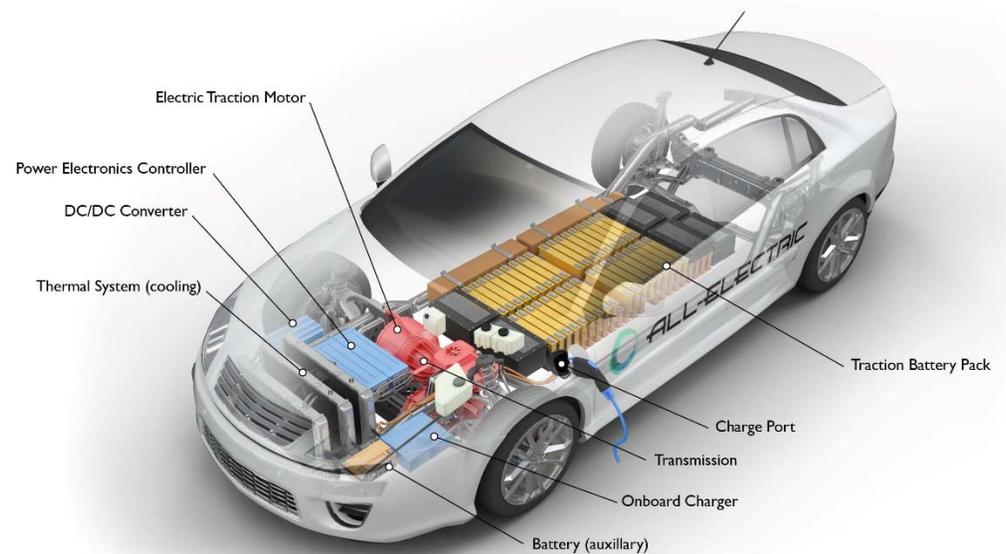
Electrical mobility challenges

- Or how do we do to get from here :



All-Electric Vehicle

- To there :



afdc.energy.gov



The industry silicon-based anode consensus

- Strong demand for innovation with major R&D efforts aiming at:
 - i. **improving density** (autonomy)
 - ii. improving **lifetime**
- Technical improvements have mainly taken place on the cathode material so far
- Industry research efforts currently cast on **improving anode capacity** using **silicon** instead of graphite, multiplying energy storage but generating **two major challenges**:

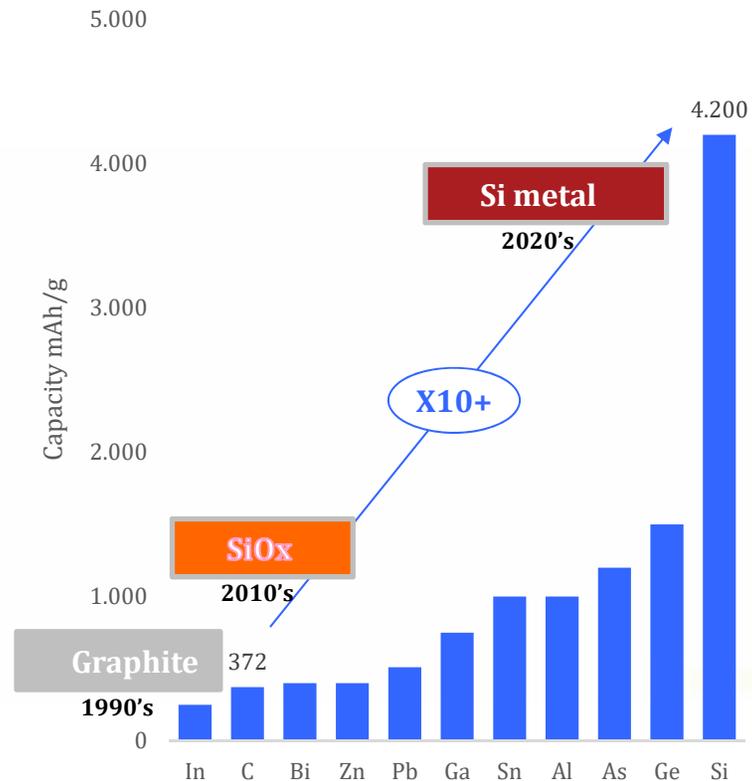


Cracking



Oxidation

Silicon performances vs. carbon

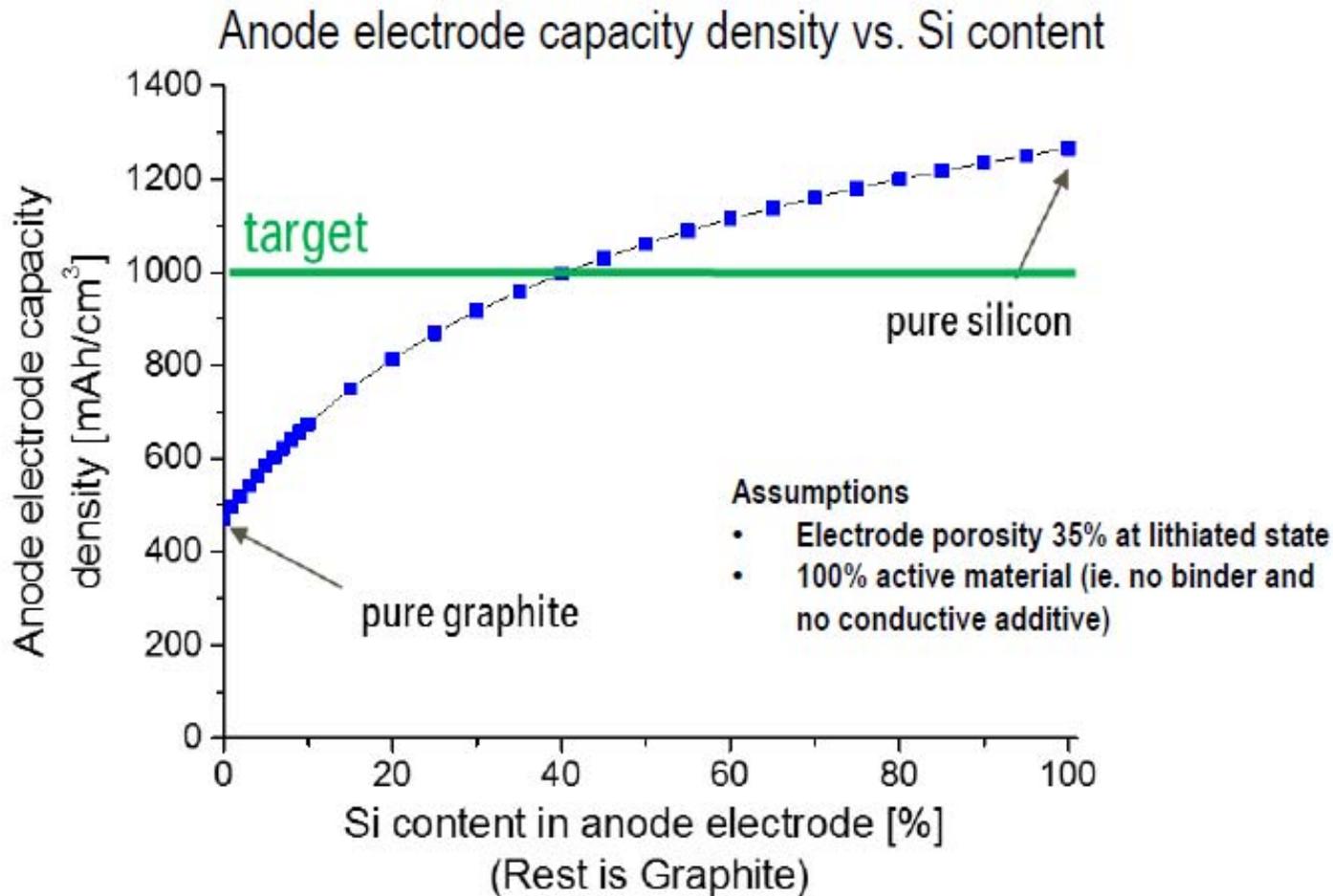


*Solving the cracking and oxidation issues are **key enablers** for the commercialization of new generation Li-ion batteries : NM SiQC*



The industry silicon-based anode consensus

OEMs Intention: **BMW** showed at Battery Japan 2018
30-50% silicon should be suitable for final target.





Market study for Li-ion Battery

Perspectives nano-Si @ 2030 (tpa)

| Forecast | 2020 | | | 2025 | | | 2030 | | |
|---------------------|----------------------|----------------------|-------------------------|----------------------|----------------------|-------------------------|----------------------|----------------------|-------------------------|
| Target markets | Anode material (ton) | Composite Si-C (ton) | % Si-C in overall power | Anode material (ton) | Composite Si-C (ton) | % Si-C in overall power | Anode material (ton) | Composite Si-C (ton) | % Si-C in overall power |
| EV | 62 468 | 1 750 | 7% | 93 701 | 7 000 | 16,6% | 109 318 | 24 500 | 37,4% |
| 3C | 40 000 | 2 000 | 5% | 55 000 | 5 500 | 10% | 64 000 | 21 120 | 33% |
| Other niche markets | 8 000 | 1200 | 15% | 12 000 | 3 000 | 25% | 14 000 | 8 400 | 60% |
| | 110 500 | 4 950 | | | | | 187 318 | 54 100 | |

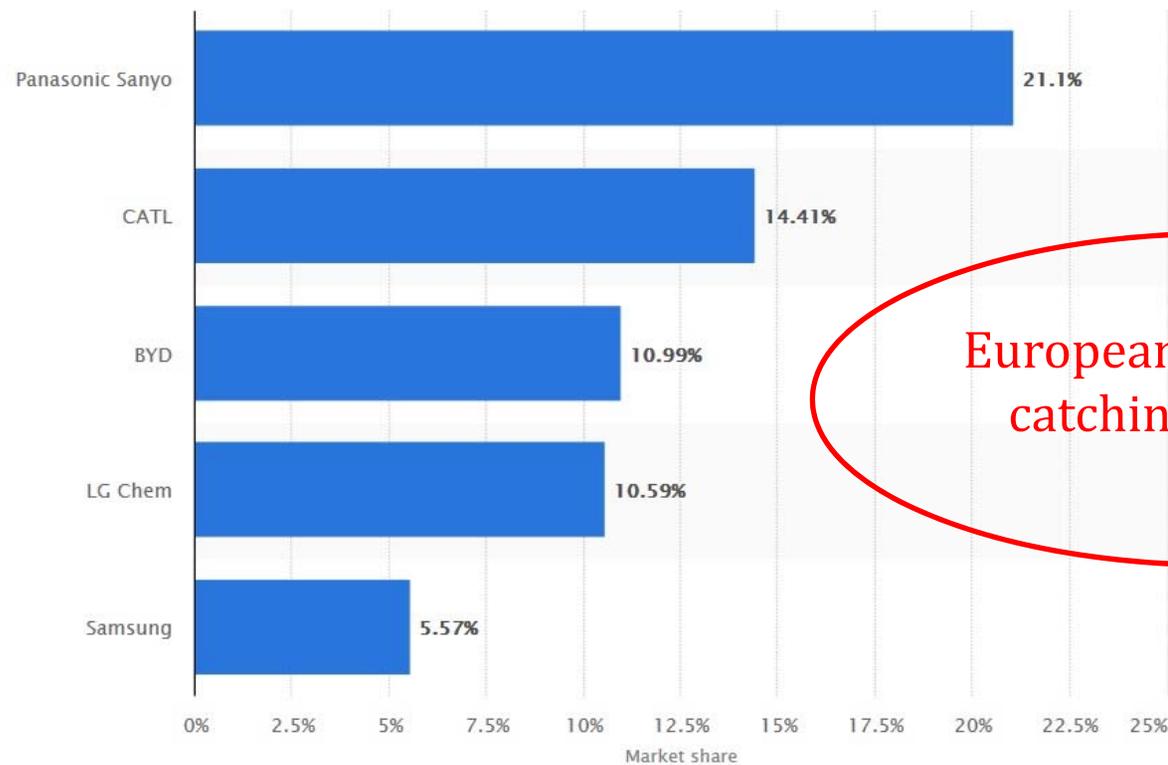
CAGR = 5,5 % (AM) / 27% (Si-C)

Tonnage calculated based on graphite with a capacity of 300 mAh/g and Si-C composite with a capacity of 800 mAh/g



Where is Europe?

- Li Ion batteries manufacturers / Q1 2018



European battery alliance
catching up too slowly

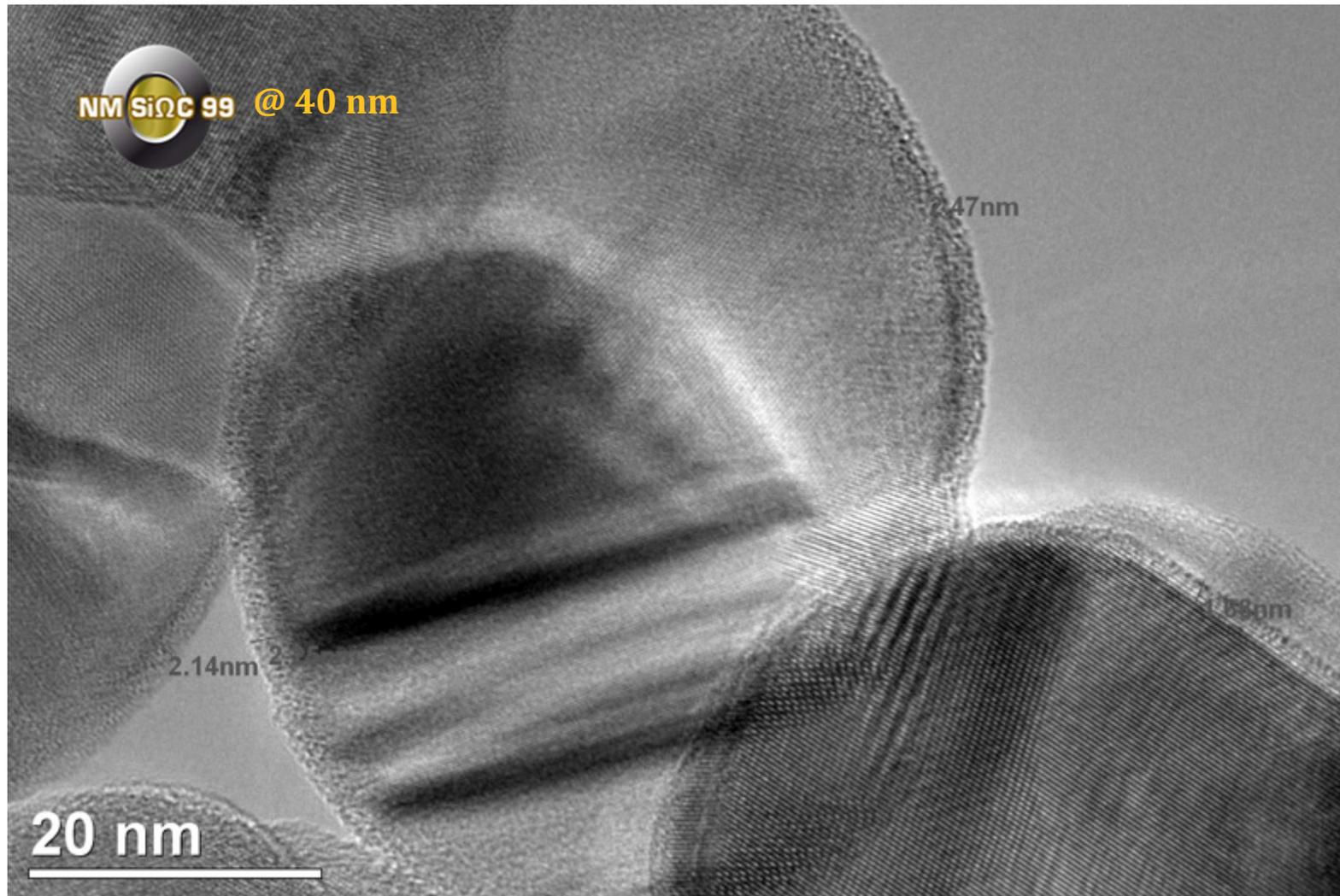


**EuroNanoForum
2019**

The key technology : carbon coated silicon
nanomaterial.



NM Si Ω C for high density batteries





NM Si Ω C for high density batteries

NM Si Ω C99 Product Advantages:

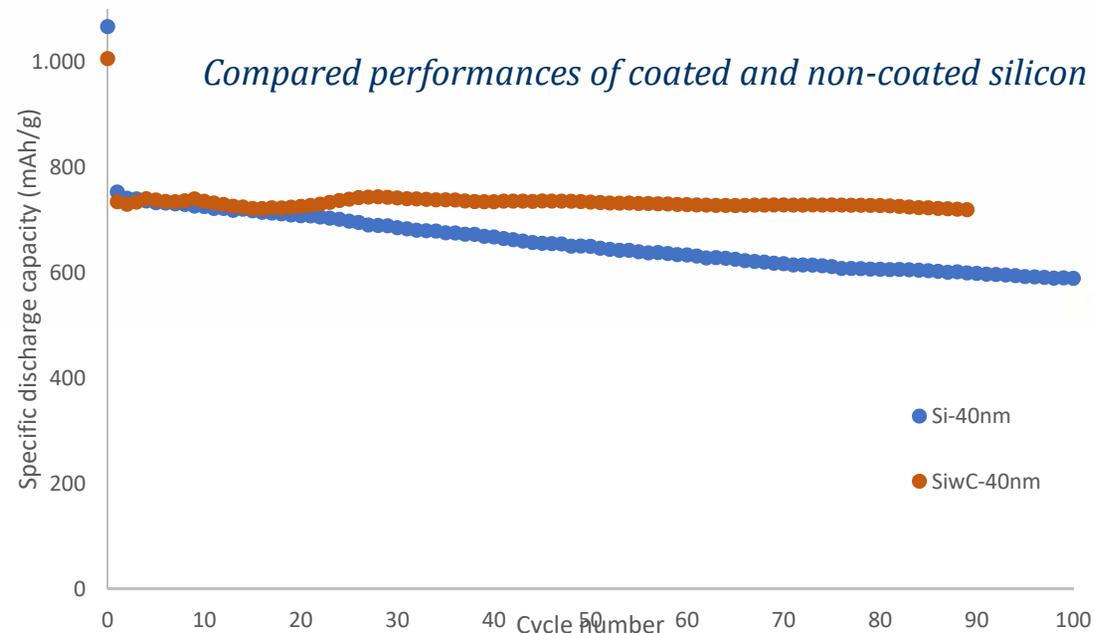
- Our novel nanocomposite **Si Ω C** overcomes the **limitations** of
 - pure or non nano Si (**cracking** and **oxidation**)
- **Silicon-based particle**
 1. **Homogeneous** particle **size distribution**
 2. **Small** size (**40** nm)
 3. **Low oxygen** content (< **2%** wt.), purity in the range of SemiCon
- **Carbon shell**
 1. **protects Si** from direct **electrolyte** exposure,
 2. **favors** the creation of a **stable SEI** layer, and
 3. improves the **affinity of Si** with most **graphites** and **binders** (CMC, PVDF...).
- **Chain like** structure enables **high conductivity** of Si Ω C



NM Si Ω C for high density batteries

NM Si Ω C99 Product Advantages (used in composite) :

- Anode performance is improved when using a **structured Graphite/n-Si Ω C composite**, which offers significant improvements in both the **gravimetric** and the **volumetric energy density** over commercially used graphite.
- Such composites show a **high initial coulombic efficiency** and an **excellent cycling performance**.





NM Si Ω C for high density batteries

NM Si Ω C99 Product applications:

2 approaches for Lithium-ion Battery application:

- 1. Horizon 2020, Liquid type LiB :** Adding NM Si Ω C99 to anode materials (SiO_x, graphite, etc.) to improve the current anode energy density
 - Mixing nano Si Ω C with anode materials,
 - Introducing into existing anode manufacturing process,
 - Improving LiB performances by increasing anode specific capacity
- 2. Horizon 2030/40, All Solid State :** Using NM Si Ω C99 as main anode material combining with solid electrolyte and solid cathode to make All Solid-State Battery.
 - Multiplying specific capacity of anode by 2-3 (compared with liquid type LiB)
 - Controlled silicon volume expansion: simpler battery design compared to Li metal
 - Providing a safer system for LiB: no dendrite formation, no inflammation if punctured
 - No “dead Li”
 - Si anode compatible with LiS battery



Highest quality process & products

Precise, reliable and secure technology

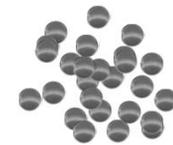
... guarantee of results

Laser pyrolysis process:

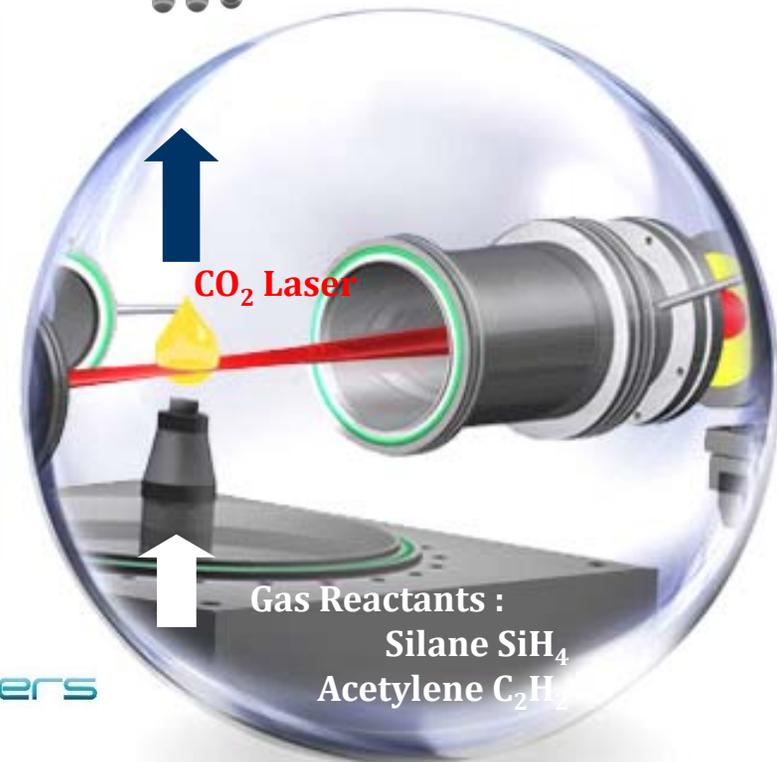
1. The **laser beam breaks** the **molecules** of gaseous or vapor-phase precursors
2. **crystals** start **building up** abruptly
3. Particle **size is controlled** by a fast **quenching** which stops the particle growth

Experience and expertise:

- 33 years of  know how
- +7 years at pilot scale 
- +7 years industrial scale  nanomakers



SiC, Si Ω C / Si nanopowders



 Patented technology



Highest quality process & products

Laser pyrolysis  nanomakers ... 4 advantages

Homogeneous :

Low particle **size** deviation.

Strict crystal growth & size control

Pure :

High **purity** batches, **low O₂** & metallic content

Bottom-up process

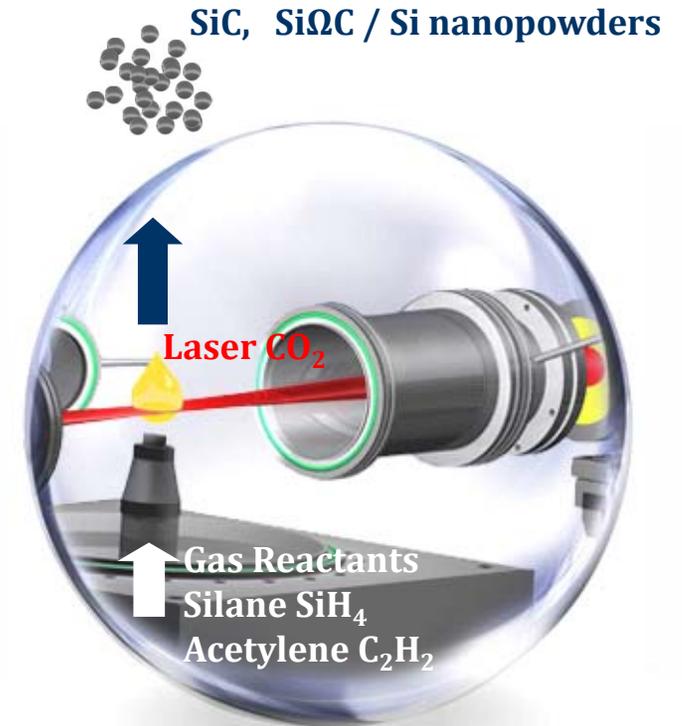
Reproducible :

Similar particle size distribution, chemical composition from **one lot to another**.

Unique industrial practice

Customizable:

Size, Surface, Coating





Innovation, scale-up, industrial growth :
A lot of challenges to solve.



The pillars to enable a safe growth

- **Safety first**
 - Safe by design
 - Safe operations
 - Occupational health and safety
- **Quality matters**
 - Reproducibility and narrowed specifications are tremendous competitive advantages
 - Industrial standards are relevant : ISO, TS, Copy Exact, ...
- **Environmental responsibility**
 - Anticipate national and European regulations
 - Integrate environmental constraints by anticipating plant layout
 - Have a risk management approach from the very beginning



An industrial company

Industrial production facility in Rambouillet
(50 km *Paris*)

... since 2012

- **40 t/year** capacity
- Storage & distribution  **AIR LIQUIDE** for 200+ t/year



- **Quality control**
 - Procedures, Certificate of Analysis
 - Own quality control lab
 - ISO 9001

| nanomakers | | PRODUCT DATA SHEET |
|------------------------|--|--------------------|
| Product Name | | |
| Product Code | | |
| Product Description | | |
| Product Type | | |
| Product Category | | |
| Product Group | | |
| Product Subgroup | | |
| Product Family | | |
| Product Line | | |
| Product Series | | |
| Product Model | | |
| Product Variant | | |
| Product Specification | | |
| Product Dimensions | | |
| Product Weight | | |
| Product Volume | | |
| Product Density | | |
| Product Composition | | |
| Product Analysis | | |
| Product Testing | | |
| Product Certification | | |
| Product Compliance | | |
| Product Safety | | |
| Product Environmental | | |
| Product Sustainability | | |
| Product Innovation | | |
| Product Research | | |
| Product Development | | |
| Product Manufacturing | | |
| Product Distribution | | |
| Product Sales | | |
| Product Support | | |
| Product Training | | |
| Product Documentation | | |
| Product Information | | |
| Product Contact | | |
| Product Feedback | | |
| Product Improvement | | |
| Product Evolution | | |
| Product Future | | |



- **« no contact » Strategy**
 - for small and larger quantities
 - “safe by design”





Opportunities for Europe ?

- **Take the technical lead : we have key enabling technology in a very competitive environment**
- **Integrate the value chain inside European borders : battery production is a long process**
- **Compete for the next revolution**



Questions?

Thank you all for your attention!



nanomakers



When small makes a difference :
the « **Nano effect** »