

# nanomakers

**Materials booster**



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



# Continuous Innovation

---



# Continuous Innovation

- A spin off of  (2010)
- The technology is protected by several CEA patents,  
granted with exclusive rights to  nanomakers
- which pursued innovating and filed several own patents :



Patent Title	Grant dates	Filing dates
“Method for producing <b>multilayer submicron particles</b> by laser pyrolysis” : coated particles ( <b>Si<math>\Omega</math>C</b> )	Jun 2015 - Fr Sep 2017 - Eur May 2018 - Cn Jun 2018 - Jp	Jul 2012 - Fr Jul 2013 - PCT
“Submicron particles containing aluminium” : SiC $\Omega$ Al	Oct 2018 - Eur Apr 2019 - USA	Nov 2013 - Fr Nov. 2014 - PCT
“Method for producing a polymer based material” <b>nano-Si in batteries</b>		Sep 2015 - Fr Dec 2017 - Fr
“Valve and sealed container for submicron particles, and method for using same”: <b>Safe Containers</b> and NanoAirlock valves	Oct 2016 - Jp Jun 2017 - Eur/Fr	Nov 2011 PCT Nov 2012 - Fr
“Suspension system for sub-micron particles in a liquid, and method for using same”: Safe Containers external pump system		Feb 2013 - Fr



NanoReg<sup>2</sup>

Project #646221, Funded by the  
Horizon 2020  
Framework Programme of the  
European Union



RawMaterials  
Connecting matters

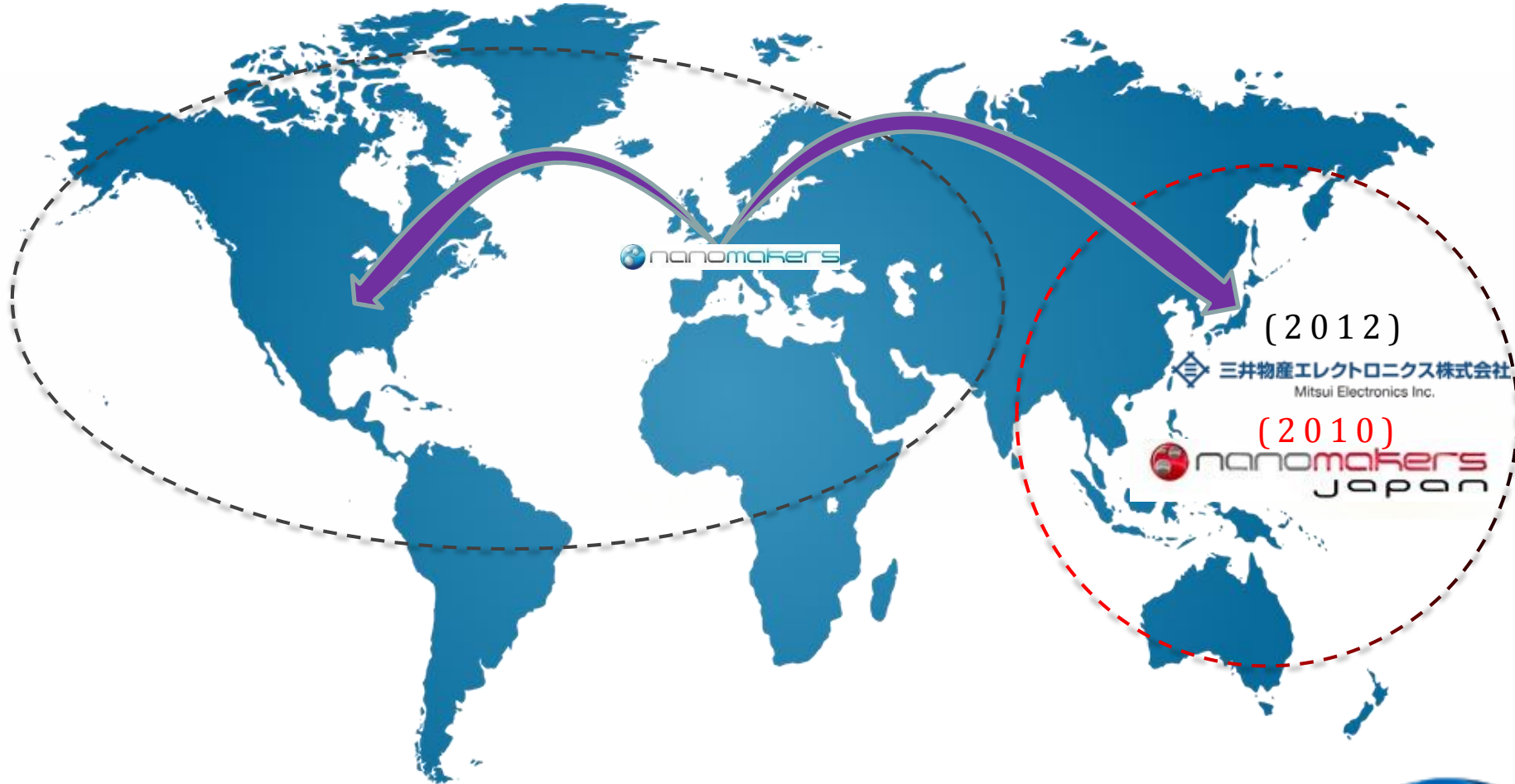




# Continuous Innovation

 nanomakers with & for global partners

*Nanomakers exports 99% of its products outside of Europe.*





Highest quality  
process & products

---



# Highest quality process & products

**+** The « nano effect » >> improving material's performance

The nano effect: material re-structured at the atom scale



Our value creation lies into dramatic improvement of material performance enabling our customers to offer outperforming products:  
lighter, stronger, more durable







# Highest quality process & products

Precise, reliable and secure technology

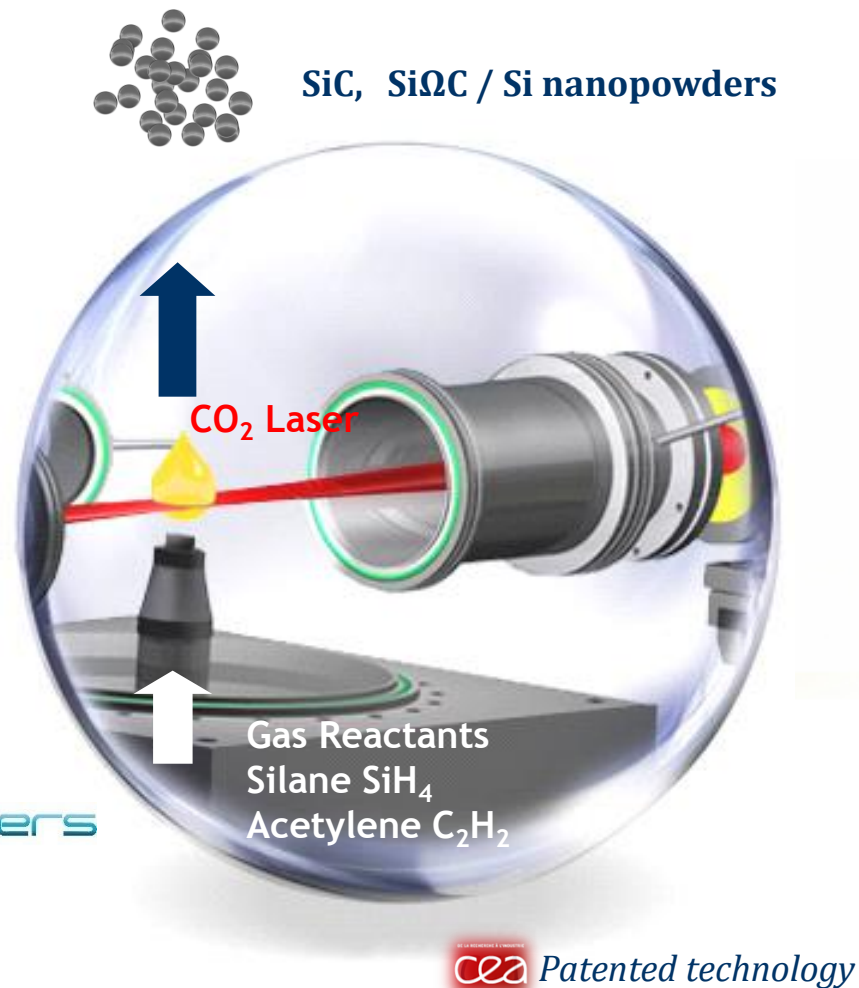
... guarantee of results

## Laser pyrolysis process:

1. The laser beam breaks the molecules of gaseous or vapor-phase precursors
2. Nanoparticles 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 





# Highest quality process & products

Laser pyrolysis  nanomakers ... 4 advantages

## ✧ Homogeneous

Low particle size deviation.

## ✧ Pure

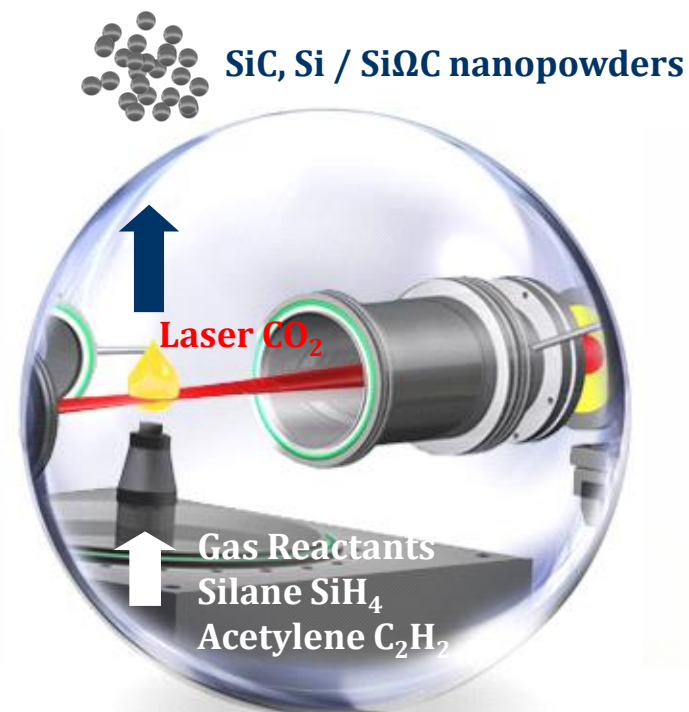
High purity batches, low O<sub>2</sub> & metallic content

## ✧ Reproducible

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

## ✧ Customizable

Size, Surface, Coating



*Our customers say* (Eck Industries, April 2014):

« First of all the **quality** of the powder received from Nanomakers was **very good**. The **particle distribution** was very **tight** and there was **no apparent chemical contamination**. From a practical aspect that means better incorporation into the melt and shorter processing times to get an acceptable particle distribution. I do not hesitate to say the **Nanomakers SiC** is the **best on the market**. »







# Highest quality process & products

Various value propositions ...

under different forms

<b>Si<math>\Omega</math>C</b>		Very High Purity (Available 40nm & 75nm) internally patented
<b>Si</b>		Very High Purity (Available 40nm & 75nm)
<hr/>		
<b>SiC</b>		Very High Purity (Available 35nm & 75nm) Mass deliveries





# Highest quality process & products

Superior **quality** recognized ... by experts

**Kazuya Shimoda** of National Institute for Materials Science (NIMS), Ibaraki and  
**Takaaki Koyanagi** of Kyoto University, Kyoto

 **nanomakers** = n°1

- IEST - Institute of Energy Science & Technology Co. Ltd., **Japan**
- Marketch International Inc., **USA**

regarding :

- Particle size distribution,
- C/Si ratio,
- Impurities and O<sub>2</sub> content,
- Industrial production capability

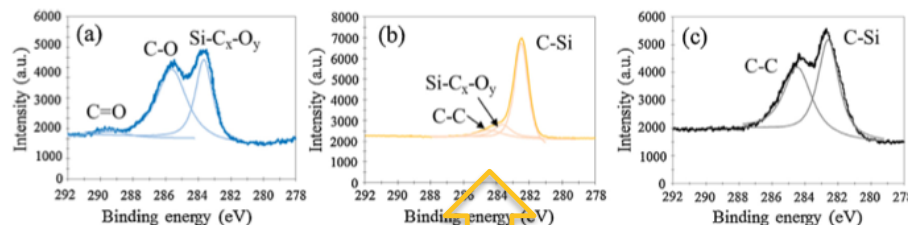
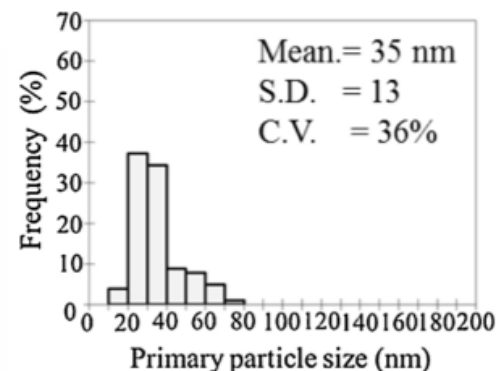


Fig. 7. XPS spectra of C 1s peak for (a) SiCN-1, (b) SiCN-2, and (c) SiCN-3.



In :

« Surface properties and dispersion behaviors of **SiC nanopowders** »,  
in Colloids and Surfaces A: Physicochem. Eng. Aspects 463 (Sept. 2014) 93



# An Industrial Company

---



# An industrial company

Industrial production facility in Rambouillet

... since 2012

## ➤ 10-20 Ton/year

- Storage & distribution  AIR LIQUIDE for 200+ ton/year

## ➤ Quality controls

- Procedures, Material Certificate
- Internal laboratory of controls
- ISO 9001

## ➤ Strategy « 0 contact »

For small and big quantities





Creating value for  
our customers

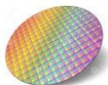







---



# Creating value for our customers

## Applications examples :

- mechanical & chemical **reinforcements**, **batteries density** etc.

	 Semiconductors	 Energy Storage	 Aerospace	 Automotive	Other applications ...	
Targeted end products	<b>Elastomers</b> (e.g. FFKM/FKM) for <b>high performance seals</b> 	<b>Anode material</b> for Li-ion batteries 	<b>Aluminium alloys</b> <b>Nano composite powders for Additive Manufacturing</b>		<b>Armouring</b> 	<b>Plating</b> 
	<b>Longer seals lifetime &amp; Lower cost of ownership</b>	<b>Doubled energy density of anode batteries</b>	<b>Lightweight structures &amp; parts</b>		<b>Lighter protection devices</b>	<b>Increased abrasion resistance</b>







# Creating value for our customers

FFKM seals for semiconductor applications

---

## Semiconductors applications ... High cleanliness seals

### Market Drivers

- Semiconductors: industry needs for higher performance and improved cleanliness (plasma etching and CVD).
- Increasing production of below 28 nm transistors creates a demand for improved cleanliness using well distributed fillers.
- Usage of aggressive plasmas create a need for improved chemical resistance of elastomeric seals and reduced contamination.
- Semiconductors: Plasma etching and CVD applications

Seals used in semiconductor applications have to face four important issues:

1. Plasma resistance
2. Particle contamination
3. Metallic contamination
4. Outgassing

Semiconductors applications ... High cleanliness seals

## Market Drivers

### 1. Plasma resistance

- Fluorine plasma
- Oxygen plasma
- Plasma resistance of elastomers can vary widely depending upon the plasma chemistry

### 2. Particle contamination

- *Carbon black: metal contamination, poor particle size homogeneity, high loading needed for reinforcement.*
- *Silica: metal oxides contamination, batch to batch variation, high loading needed for reinforcement.*
- Organic Fillers: poor mechanical and plasma resistance.

### 3. Metallic contamination

- Iron, Chromium, Nickel, Copper, Titanium, Magnesium, are a concern in plasma processes.
- *Carbon black and silica fillers are not clean enough to avoid metallic impurities.*

### 4. Outgassing

Low level of contamination ... high purity

 typical grade for semicon industry is:

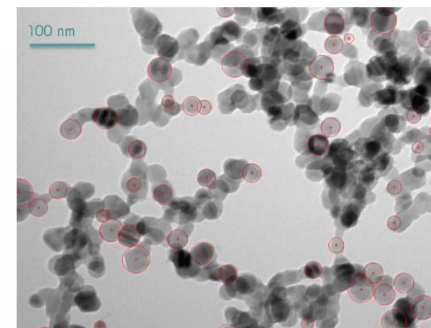


**NM SiC99 @ 35nm**

Purity above 99%

## Specifications:

- SSA: 50 – 60 g/m<sup>2</sup>
- APS: 32 – 38 nm
- Density: 3.1 – 3.2 g/cm<sup>3</sup>
- Metal impurity: on demand
- Oxygen < 1%
- Moisture content < 1%



Low level of contamination ... Few metallic impurities

## NM SiC 99 @ 35nm

Determination of trace elements by ICP-MS analysis method

Some analysis results form our last batches

Component	Units	Detection Limit	Result Value
<b>L0115-SAR-P-R Priority Quantitative Analysis by Laser Ablation ICP-MS</b>			
Chromium (Cr)	ppm (µg/g)	0.05	1.7
Iron (Fe)	ppm (µg/g)	0.05	5.3
Nickel (Ni)	ppm (µg/g)	0.05	0.52

Oxygen 0,4%

Component	Units	Detection Limit	Result Value
<b>L0115-SAR-P-R Priority Quantitative Analysis by Laser Ablation ICP-MS</b>			
Chromium (Cr)	ppm (µg/g)	0.05	0.94
Iron (Fe)	ppm (µg/g)	0.05	4.1
Nickel (Ni)	ppm (µg/g)	0.05	0.35

Oxygen 0,4%

PerFluoroelastomers are often compounded with nearly “inactive” fillers (MT N-990, Austin Black)

**Replacing CB and Silica with nano SiC allows:**

- SiC has **high thermal conductivity** => improve life time of the seal
- **No defects** during semiconductor manufacturing (nano size SiC as filler avoids release and deposit from FFKM compound on silicon wafer)
- **Inhibiting generation of foreign matters** (particles) during plasma treatments thanks to purity of nano SiC.
- Optimum nano effect reinforcement, **low loading** resulting in **shorter processing time, weight reduction**.
- Opportunity of surface chemistry (limited surface oxidation allows coupling agent opportunity) : **improve dispersion** into the FFKM.



## Nanomakers SiC Nano @35nm Value Proposition for FFKM seals

- **High plasma resistance:**
  - Reduce usage of carbon black and improve cleanliness of compound when used in plasma process >>> **Improve yield factor in semicon operation**
  - Increase temperature and chemical resistance >>> Reduce down time on machinery for seal replacement / Extend mean time between seal replacement >>> **Improve productivity and Lower cost of ownership**

## Nanomakers SiC Nano @35nm Value Proposition for FFKM seals

- **High mechanical performances:**

SiC content (phr)	Hardness (Shore A)	Compression set - DRC, 70h (%)	Tensile stress at break (MPa)	Elongation at break (%)	Tensile stress at 100% elongation (MPa)	Tensile stress at 300% elongation (MPa)
4	50-55	15-20 (200°C)	10-12	320-350	1,5-2	9-12
15	70-75	35-50 (300°C)	-	-	-	-

Good mechanical properties of nano-SiC reinforced FFKM even at low filler content



# Creating value for our customers

Silicone thermal behaviour enhancement: TIM

---



## Silicone rubbers

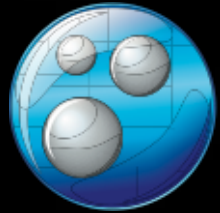
Silicone is an elastomer made of silicon, oxygen & hydrogen. It resists to temperature change, UV radiation and certain solvents and chemicals.

## Silicon carbide (SiC) has high thermal performance

- Excellent property in term of heat dissipation (170 W/m.K for the bulk)
- Good electrical insulating material, mechanical performances in term of durability & lightness

## Main benefits of using nano SiC of Nanomakers

- Nano size: good to avoid the holes at the interface of the TIM and substrate
- Low thermal expansion (4,7 ppm/K) which can compensate the one of the silicone rubber



# nanomakers



When infinitely small makes a  
difference :

the « **Nano effect** »