nanomakers

Materials booster

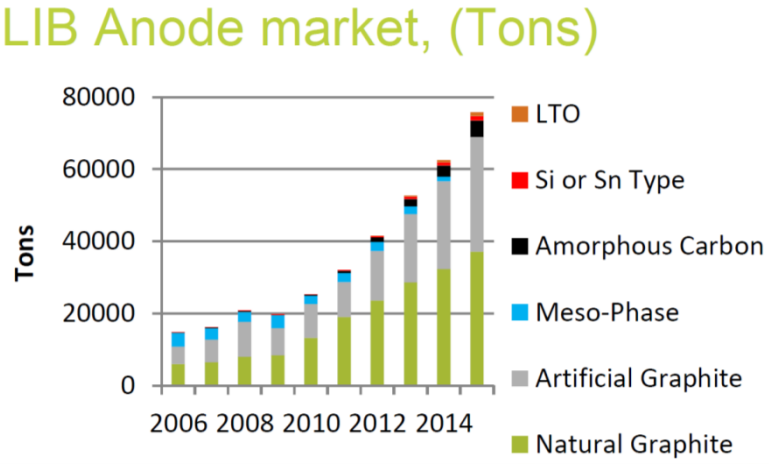
Nanomakers develops, produces & commercializes silicon-based nanopowders that disruptively improve the properties of industrial materials

Next generation Li-ion batteries

Societal Challenge → Allow the **electromobility** market **development** by addressing the **autonomy lock**

Anode market:

- 14% in value for Li-ion batteries materials
- 2020 : anode material market # 100 ktpa



Source: Avicenne 2016

Technical & Industrial Challenges:

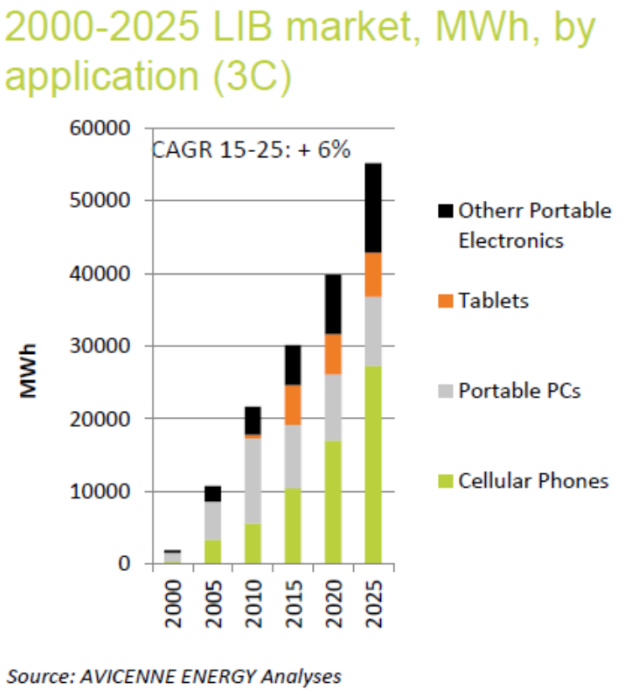
- Increase specific density vs graphite :
  → Find new materials to increase capacity
- Serve the development of the Li-ion market in the next years:
  - Mobile devices → EV

Market facts

- Anode European industry:
  - Large manufacturers of natural and artificial graphite
  - Existing nano-Si industrial production process (SiΩC)
  - Innovative materials : an opportunity for advanced materials manufacturers

➔ EU to stay in the race with Asian leaders

- European car manufacturers in good position for EV

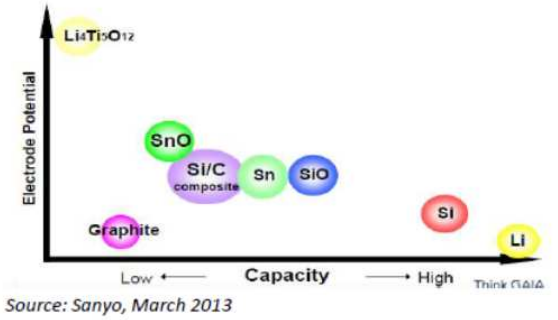


Source: AVICENNE ENERGY Analyses

Si in Li-ion batteries anodes

Si = the best compromise for battery anode capacity increase :

- available
- high intrinsic capacity
- compatible with other components of present batteries



Source: Sanyo, March 2013

Advanced developments for Si/carbone :

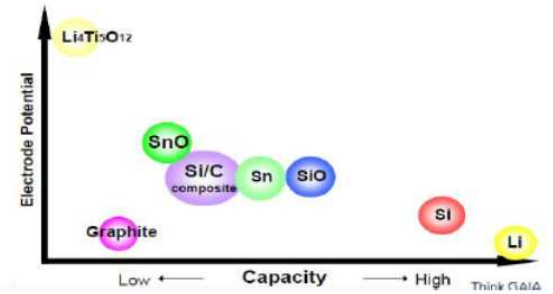
- consensus about nano-Si
  → Nano particles (<120/150 nm) avoid Si mechanical breakage during cycling
  → Nano particles show better performances (stability) vs cycling
- composite manufacturers at different stage of development

→ Time to market: 2018 for the first ones (→ 2020)
→ Present TRL = 5 / 7

Si in Li-ion batteries anodes

Challenges to overcome:

- Increase the stability of discharge capacity during cycling
- Adapt the other components of the battery to Si-based anode and higher density



Source: Sanyo, March 2013

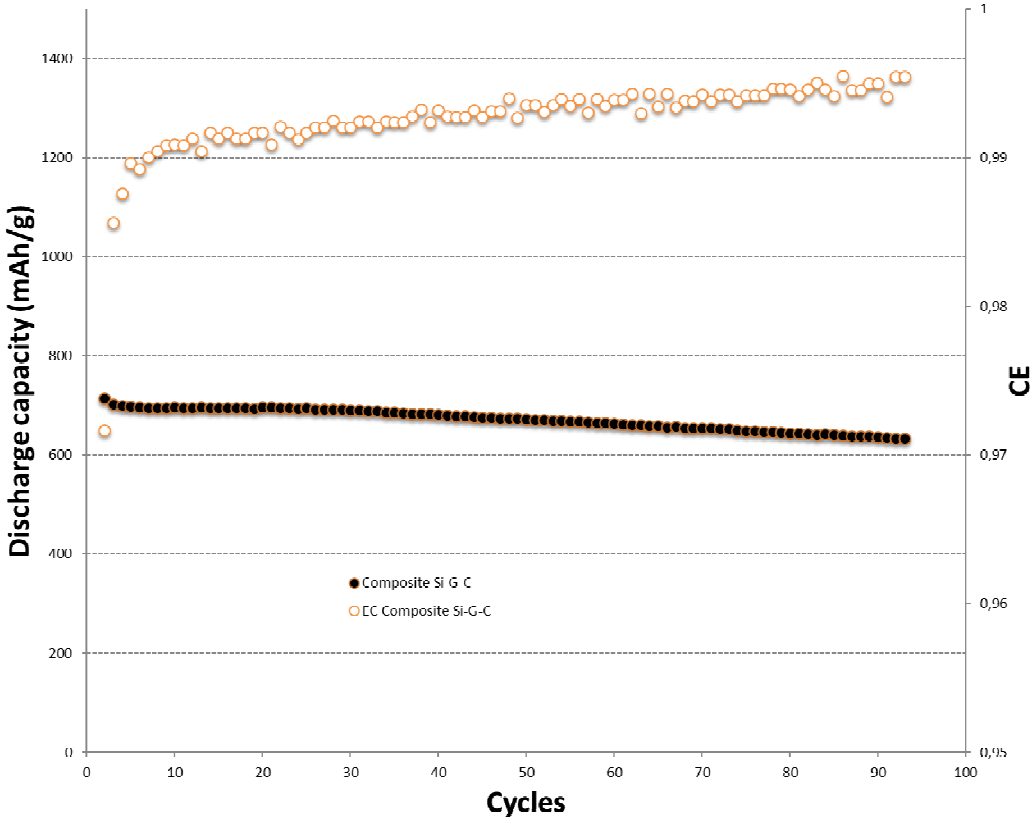
Key Success Factor for EV battery industry in Europe:

- Build alliances between i) car manufacturers and ii) electrochemistry industry to benefit from :
  - i) mobility market knowledge & mass production ability
  - ii) advanced materials expertise
- Around a jointly developed technology

Creating value for our customers

Starting point : TRL 5 result *(NMKS internal results)*

- high performances of the batteries at 700 mAh/g
- 92% capacity retention between cycles 2-80



Li metal button cell
Formulation 80 SCN01 / 10 CMC / 10 Super P
~ 2 mg/cm²; Electrolyte EC:DEC 1:1 +
2wt%VC + 10%wt FEC + 1M LiPF6
Lithiation CCCV till 10 mV
Delithiation CC 1 V
Cycling : C/5 (1rst cycle C/20)

SIRIUS project : new Li-ion batteries anodes

SIRIUS (SIlicon nanopaRticles based composItes UpScaling) =

an **EIT Raw Materials** 2017

"Upscaling" project

.

Objective:

- Develop high capacity Si–C nanocomposite anodes for Li-ion batteries
  → high performances battery prototype (TRL 7)
- to support the industry with high added value

Targets:

- High energy density applications (> 300 Wh/kg & > 700 Wh/L)
- Specific capacity : 1000 mAh/g
- Initial irreversible capacity : > 85%
- Intermediate capacity retention et cycle life : 70% @ >500 cycles

Budget :

- 1.6 M€

SIRIUS project : new Li-ion batteries anodes

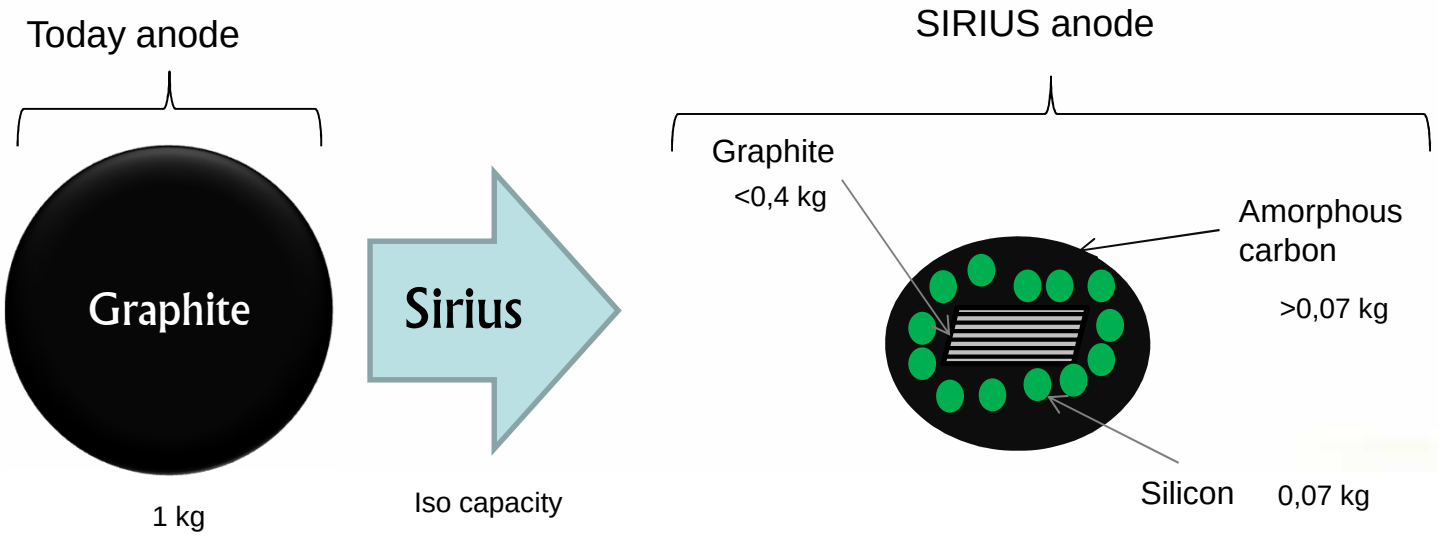
Partners :

- Nanomakers : nano-SiΩC design & production → Associate partner, Project leader
- CEA : French Atomic Energy research center → Core partner
- SGL Carbon : leader in carbon products → Task partner
- Varta Micro Innovation → Task partner
- Uppsala University → Core partner

SIRIUS project : new Li-ion batteries anodes

EIT Raw Materials „Substitution“ theme :

- Replace natural graphite (strategic material) in anode by Si-carbon material with higher capacity (Si 4200 mAh/g vs Graphite <400 mAh/g)
- Higher capacities = lower material quantities for similar energy capacity



- Si nanoparticles usually made from SiH_4 from Mg_2Si or FeSi alloys (strategic Si metal not necessary)

SIRIUS project : new Li-ion batteries anodes

Tasks : To start April 1st, 2017 + 30 months

Activity	Leader	Participants
WP0 Feasibility study	NMKS	
0.1 Business plan		All
WP1 Project Management	NMKS	
1.1 Management		NMKS, CEA
1.2 Dissemination		All
WP2 : Active Material Synthesis Optimization	CEA	
2.1 Nanoparticules synthesis and process optimization		NMKS, CEA
2.2 Composites synthesis and tests		CEA
WP3 : Active Materials Synthesis and Upscaling	SGL Carbon	
3.1: Preparation, characterization, safety evaluation and delivery of first generation nano-Si		NMKS
3.2: Preparation, initial characterization and delivery of first generation C-Si anode material		SGL carbon
3.3: Upscaling of the silicon / carbon core shell nanoparticle synthesis process		NMKS
3.4: Preparation, characterization, safety evaluation and delivery of second generation nano-Si		NMKS
3.5: Preparation, initial characterization and delivery of second generation C-Si anode material		SGL carbon
WP4 : Cell manufacturing and evaluation	Varta MI	
41: Electrode processing with advanced Si/C-composite material		CEA, Varta MI
4.2: Cell manufacturing and electrochemical characterization		Varta MI
WP5 : Cell Characterization and ageing investigation	Uppsala	
5.2 Electrode characterizations		Uppsala, CEA
5.3 Post mortem cell characterizations		Uppsala, CEA