Surface freedom®

Picodeon next steps in Li-ion battery material & application development

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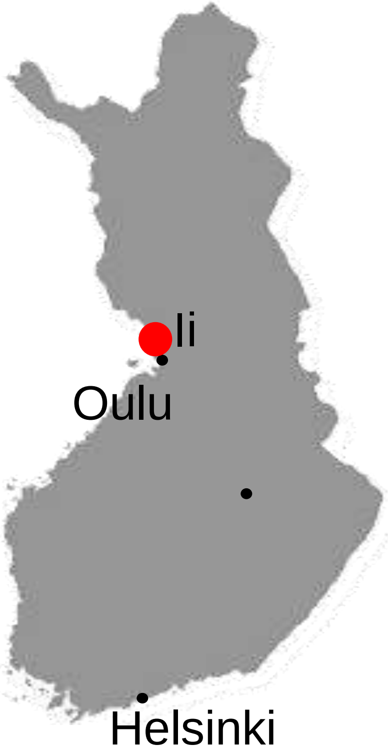
Background

- Founded 2005
- Technology and customer service center in Ii Finland, with state-of-the-art US PLD facilities
- Strong and growing IPR portfolio containing 19 patent families
- R&D supported by excellent technology and research ecosystem (e.g. universities) in Finland and Oulu region
- Multidisciplinary Ph.D., M.Sc. Technical Team



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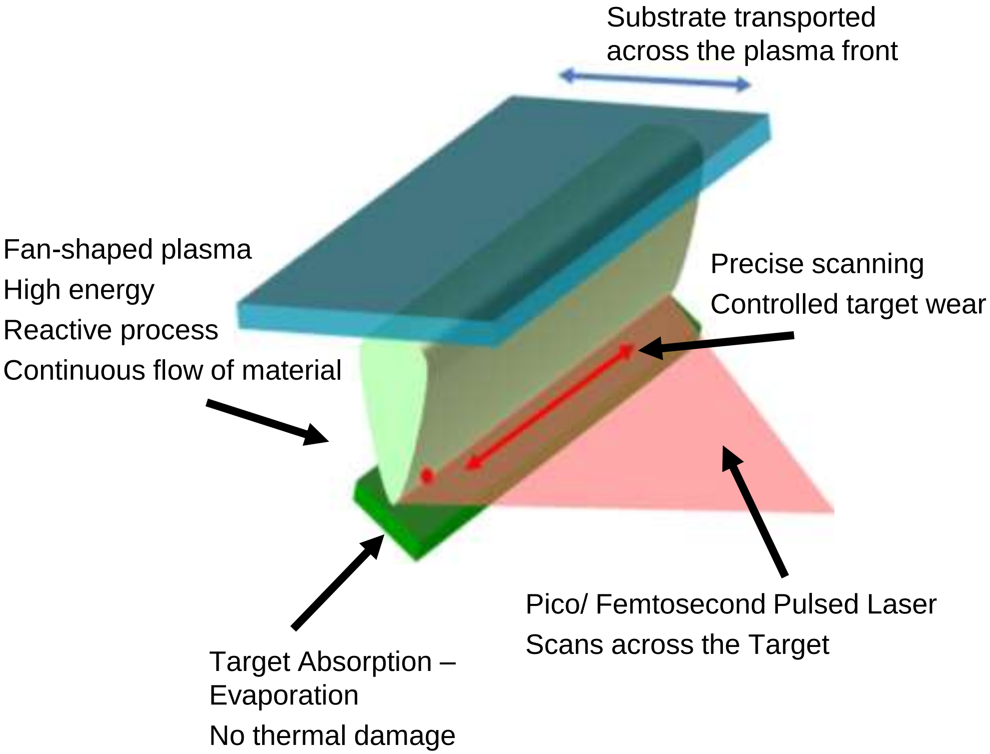
Picodeon Pulsed Laser Deposition technology

Series 4 PLD system



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Technology platform opportunities in LIBs

US PLD based technology platform
- **nanostructured & nanoparticle processing (particle size 10-1000 nm)**
- **metals, silicon, carbon, simple and complex oxides**

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Productivity concept
- **New laser energy delivery concepts**
- **Engineered targets**
- **High power laser development**

2013-2016

LIB Separators
- **1-3 um**
- **0,5-1 um**
- **20 nm**

Sensors
- **high surface area coatings, metal doping**

Metals
- **Cu, Au, Pd,Pt,N**

Tribo
- **PTFE**

C, C-N

2017 -

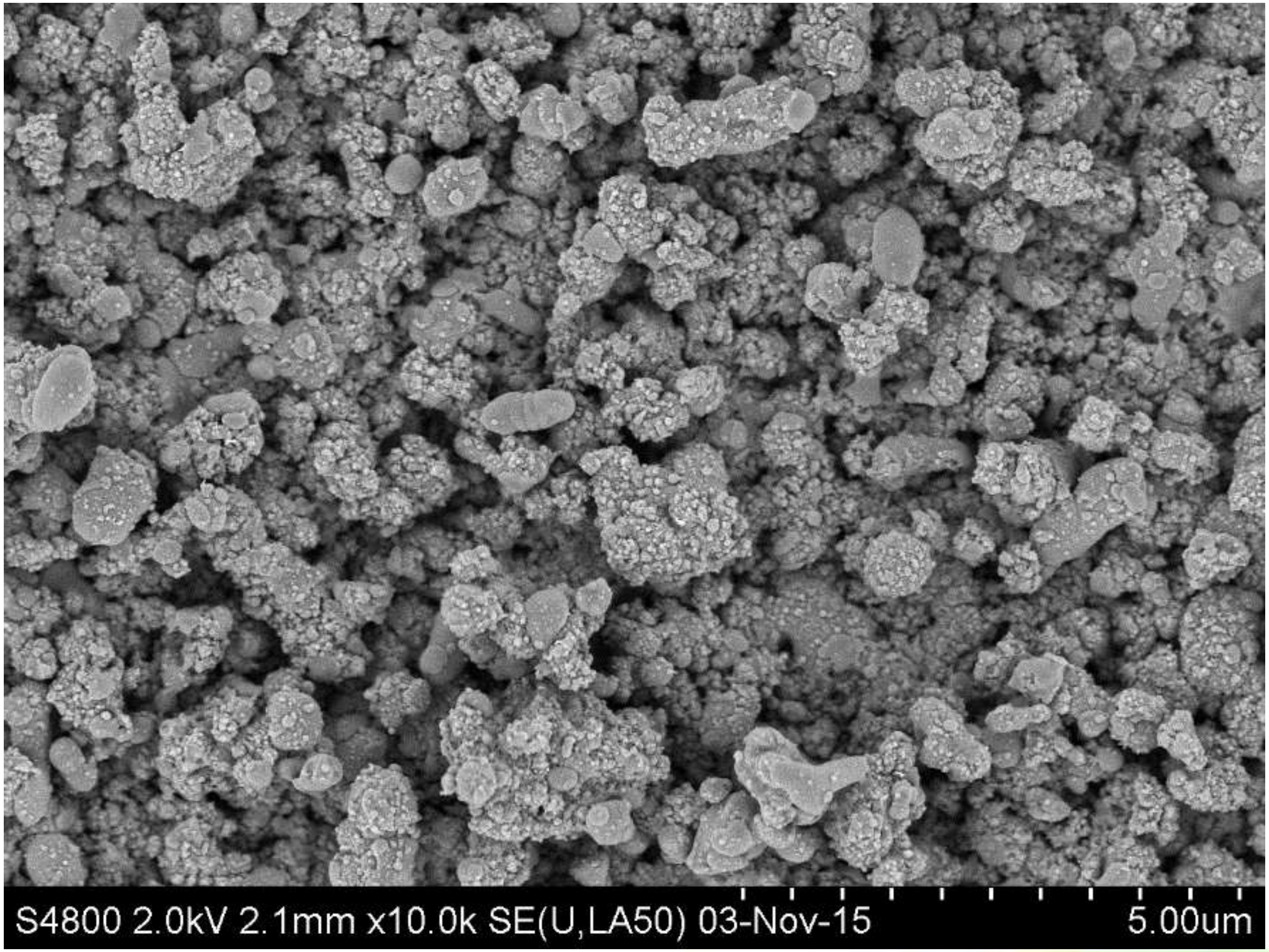
LIB cathode barrier layers

LIB anode materials

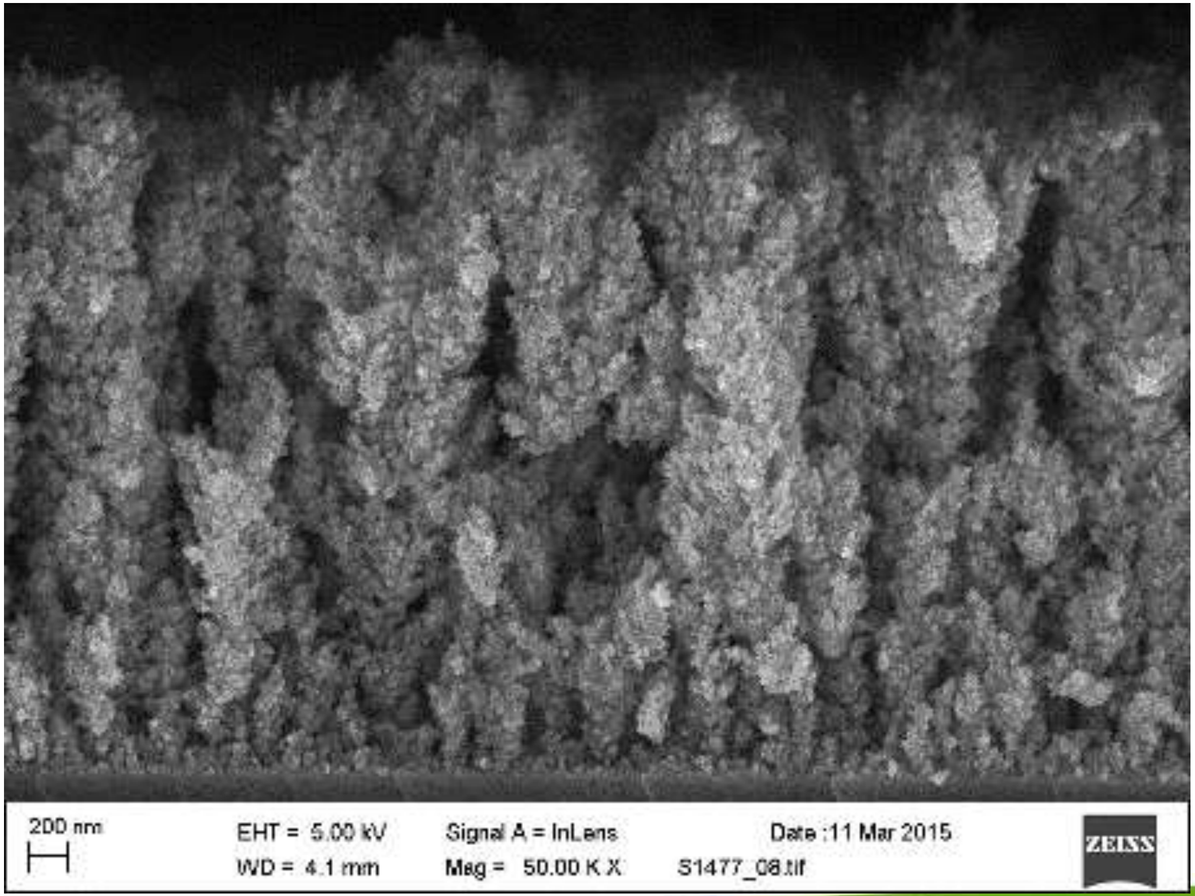
LIB cathode materials

LIB solid electrolytes

Porous 1-3 um AlOx coatings for Li-ion battery separators



WO_3 for gas sensors
“Nanotrees”, nanoparticles and nanoparticle clusters



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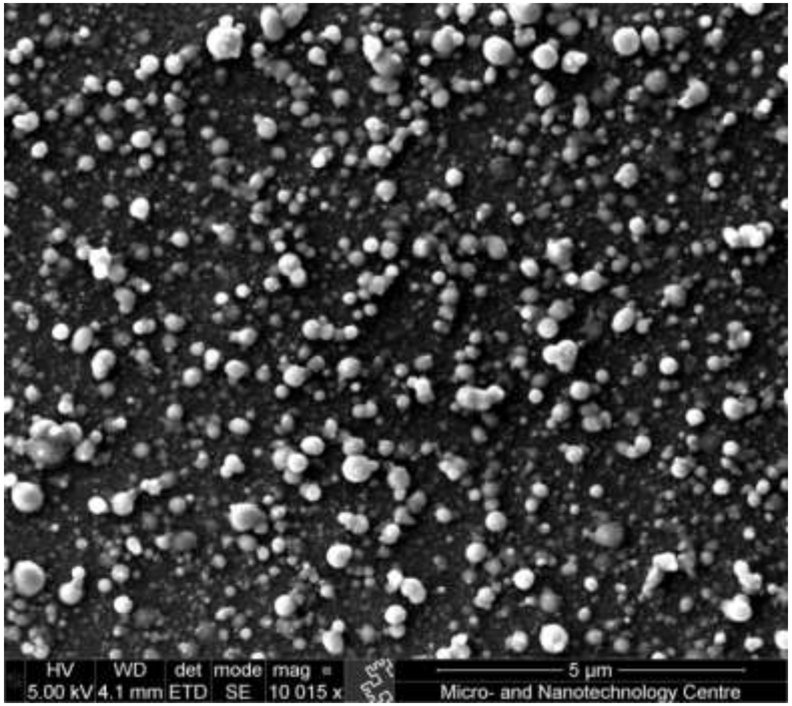
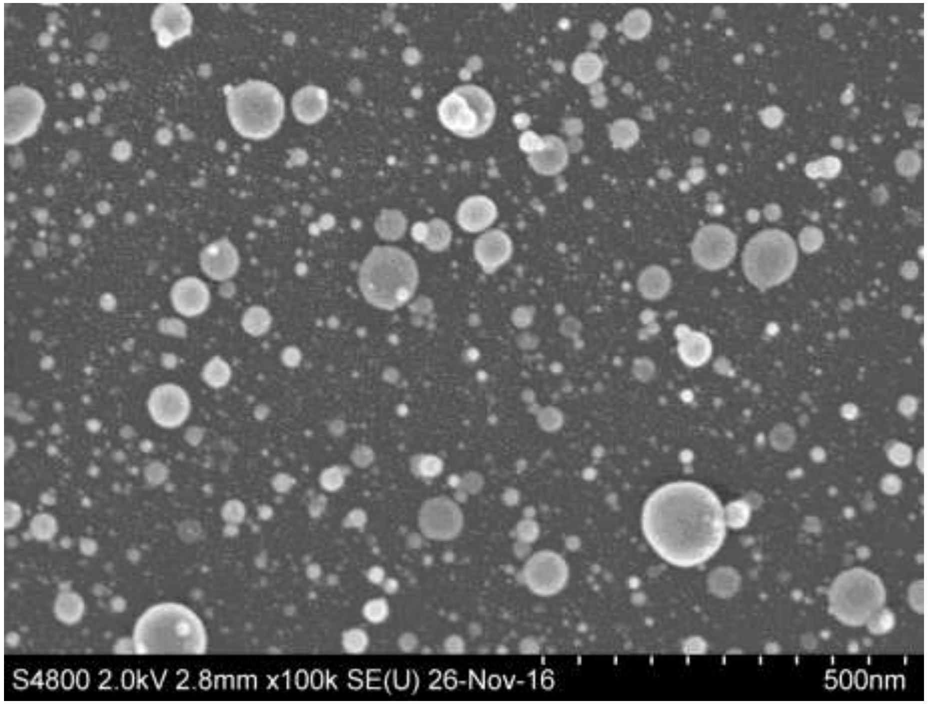
Nanoprocessing technology platform

Metals, silicon, carbon, simple and complex oxides, PTFE



Si nanoparticles, amorphous, size 20-200 nm



Pd nanoparticles, amorphous, size 10-100 nm

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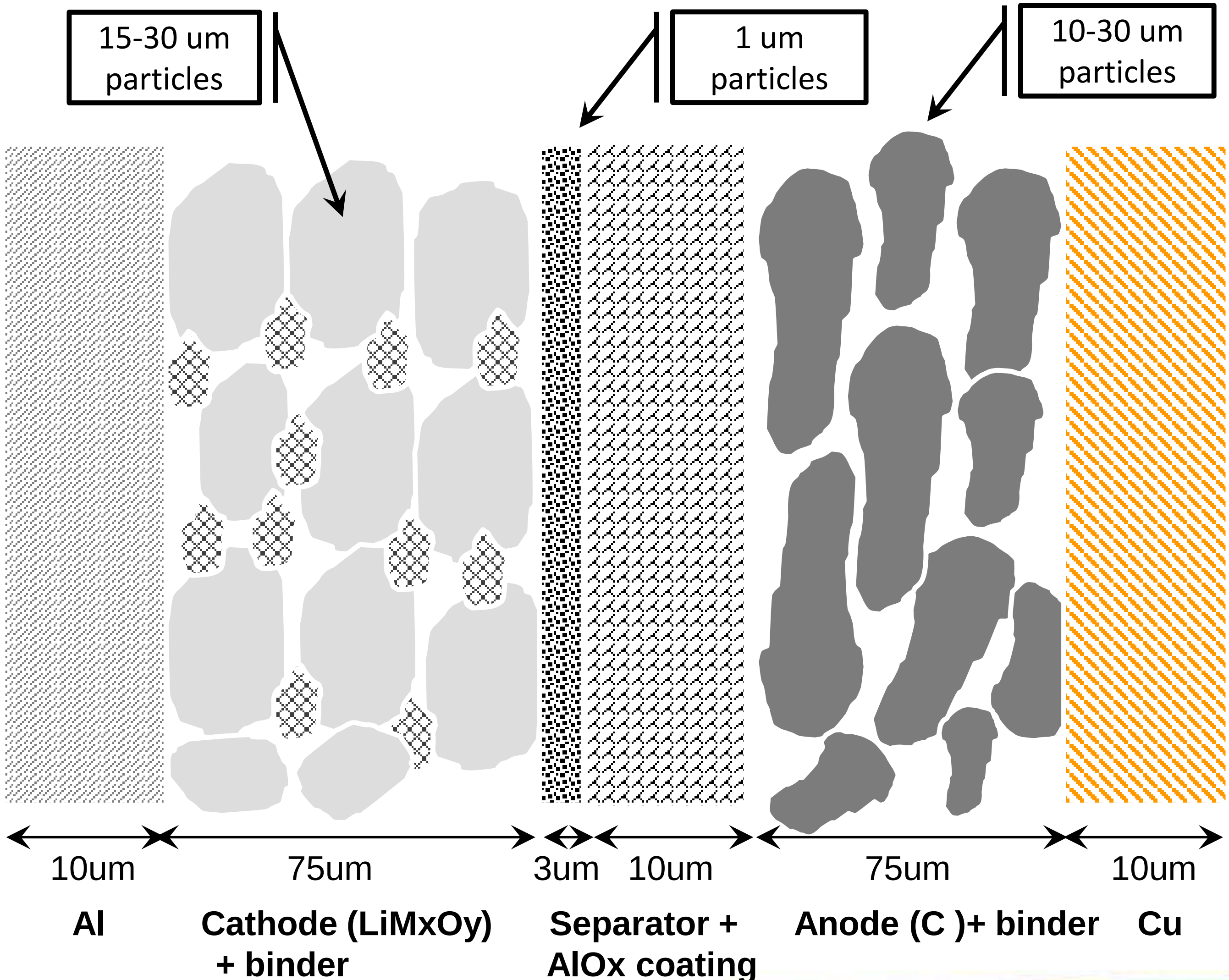
Key performance requirements for LIBs

Capacity	Rate-capability	Life time
• Lithiation capacity i.e. capability to absorp & store Li • Si 10x as compared to most commonly used graphite	• Smaller particle size (nanoscale) reduces diffusion distances for ions and electrons • Selected metallic dopants promotes electronic conductivity	• Aging of electrolyte • Microscopic damages of particles, microcracking and loss of adhesion • Corrosion and oxidation • SEI growth
Range of driving	**Charging speed**	**Battery lifecycle cost**

Li-ion battery material layers



NOTE: Layer thicknesses vary, these dimensions from Samsung Galaxy Note 7

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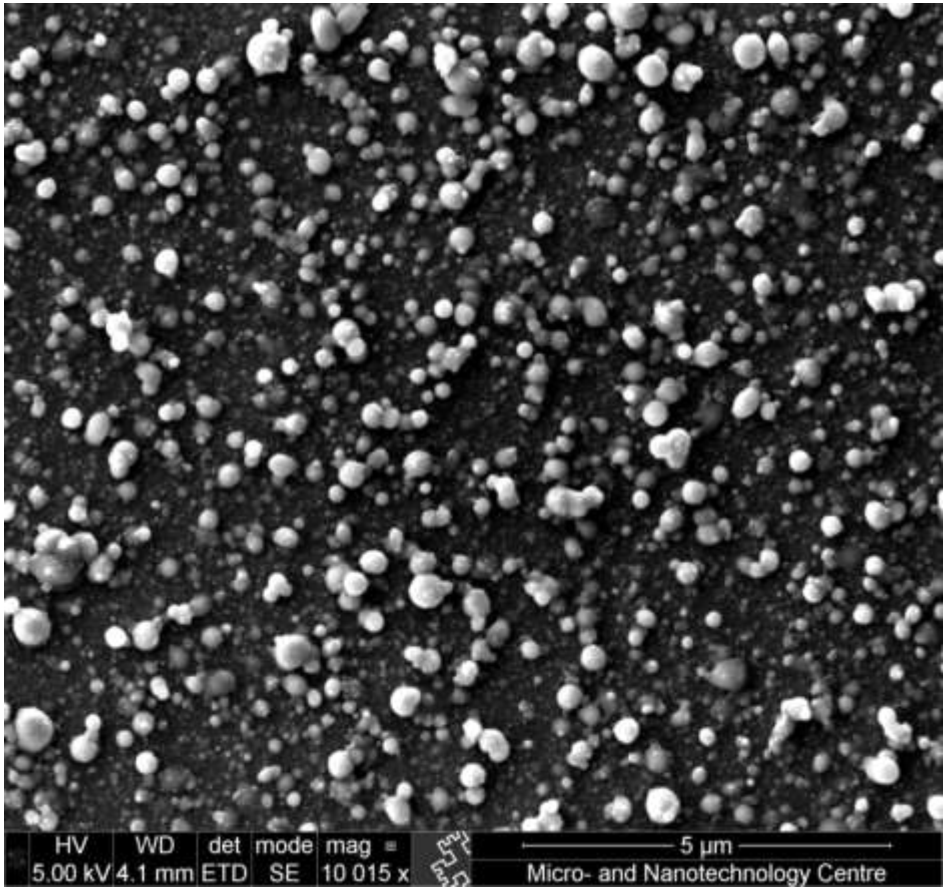
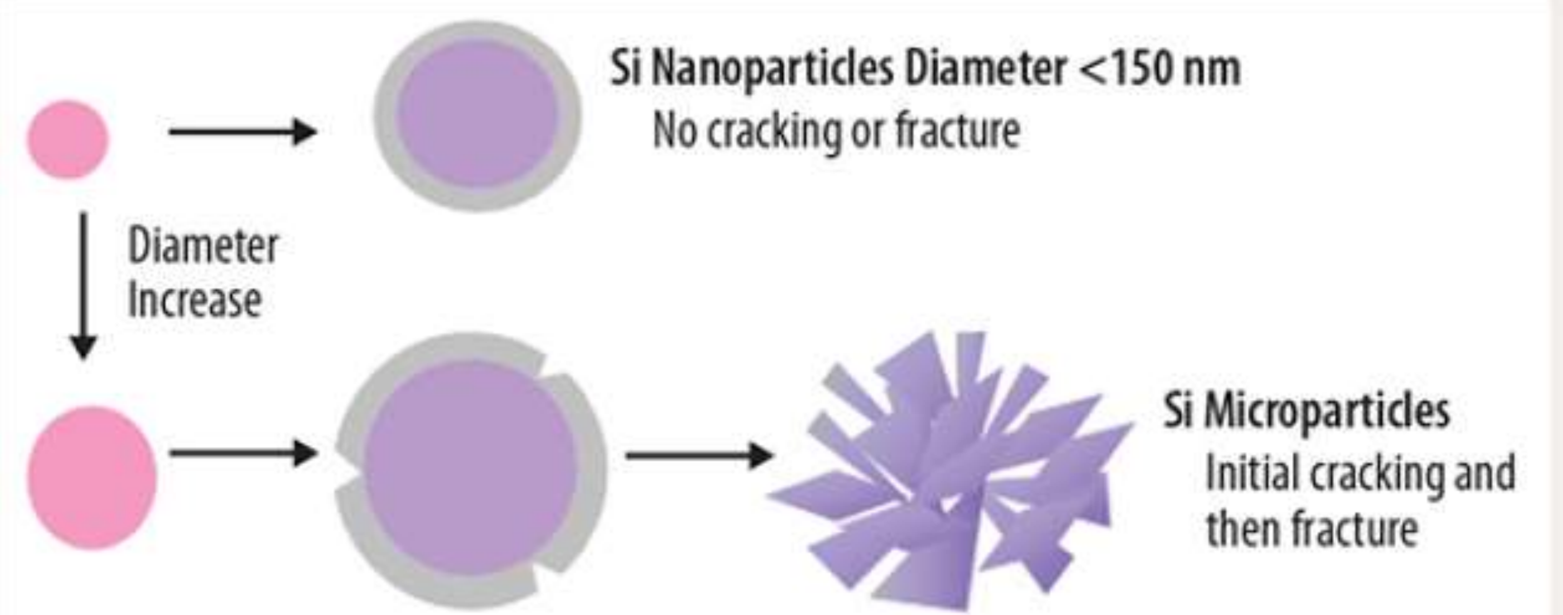
Picodeon LIB anode material development



Nanoparticles, amorphous Si, 20 – 200 nm

Nanoparticle size active materials	Control & reduction of microcrcking
	Larger interfacial area with electrolytes
	Stable SEI
	Ionic and electron conductivity
Hybrid materials	Control & reduction of microcracking
Doping	Improved electron conductivity
No binders	Stable chemistry
Good adhesion	Reliability
Amorphous structure	Less tendency for microcracking

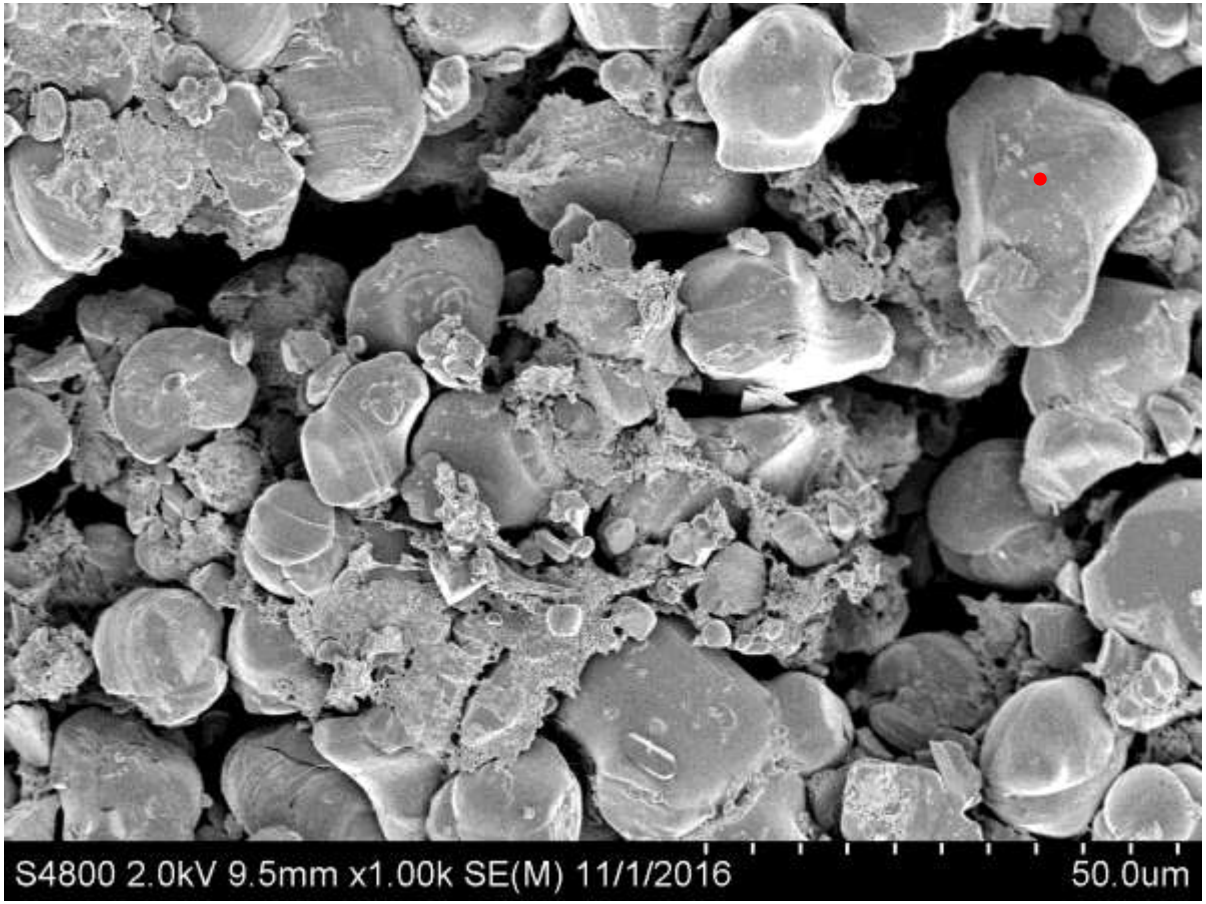
Anode material particle size change
Nanoparticle size (<1 um) to allow Si volume change accommondation



Liu, X. H.; Zhong, L.; Huang, S.; Mao, S. X.; Zhu, T.; Huang, J. Y., *ACS NANO*, **2012**, *6*, 1522.

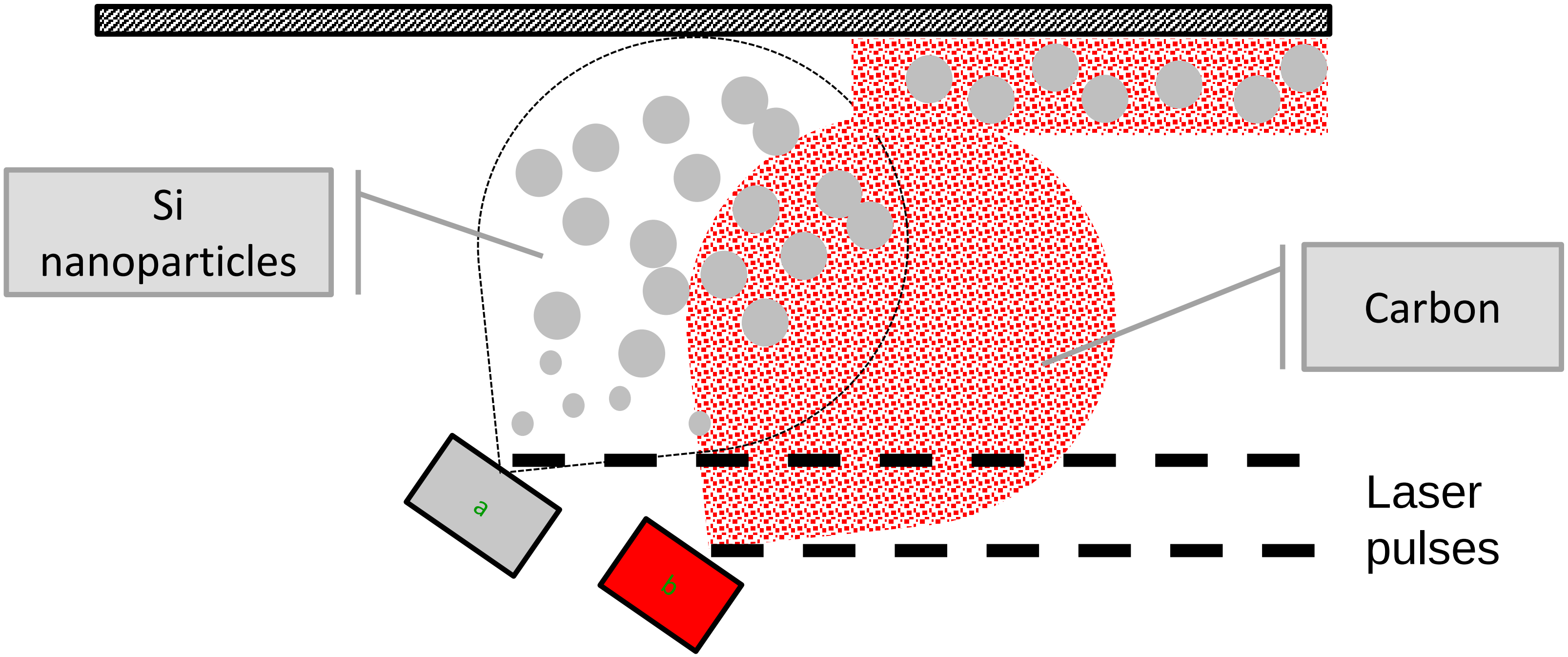
NOTE: For crystalline Si nanoparticles 150 nm is a limit to minimize microfractures, for amorphous Si nanoparticles limit is close to 1 um

LCO cathode materials based on conventional processing



- Nanoparticle (1 um)

Example of possible deposition arrangement



Direct manufacture of high capacity, microcomposite anode layer from target materials based on RtR arrangement, individual tailoring of both plumes

Near future plans (Q1_2017) for new areas

Submicron porous AlOx coating on separators

- Reduced amount of passive material in LIB

10-20 nm cathode barrier coatings

- Cathode material electrochemical & chemical stability

Nanoparticle Si doped anode coating

- Significant increase of battery energy density with good cycling performance