Core shell amorphous silicon-carbon nanoparticles synthesis by double stage laser pyrolysis, application to anode material

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WTE 2016

Sibali project

Introduction

Commercial anode material in Li-ion cells
372 mAh.g^{-1}
Graphitic carbon
Poor capacity
High cyclability

→ **Promising anode material**
3580 mAh.g^{-1}
Nano-Silicon
High capacity
Poor cyclability

→ Synthesis of carbon protected silicon particle with laser pyrolysis ?

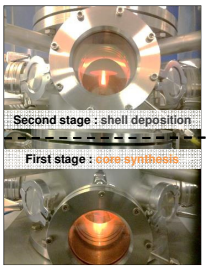
→ **Technological lock**

→ Development of a novel single step synthesis process : **double stage laser pyrolysis**

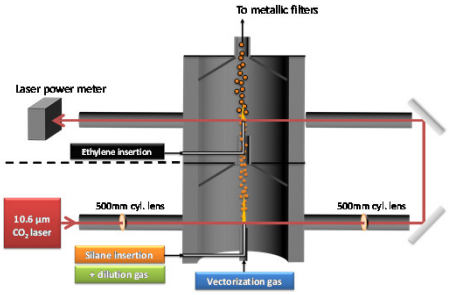
Synthesis and integration at the anode of li-ion batteries

Silicon-carbon core-shell
High capacity ?
High cyclability ?

New double stage laser pyrolysis set-up



Double stage configuration

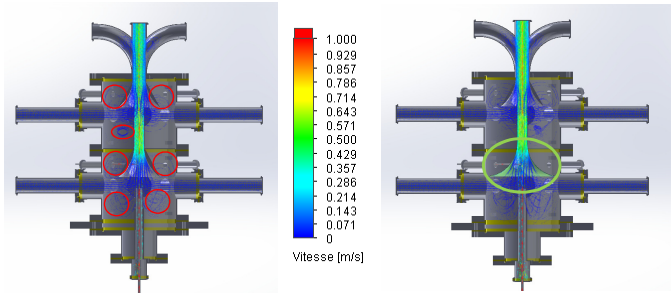


Scheme of the double stage reactor

- **Various precursors** and **no induced pollution**: wall less reaction
- **High production rate** of carbon covered silicon nanoparticles (up to 10 g.h^{-1})
- **Independent control** on both nature and structure of the core and the shell
- **Safer by design**: single step process avoiding powder manipulation

Reactor modeling to reduce turbulence

Current configuration | **Proposed upgrade**



Turbulent recirculation zones

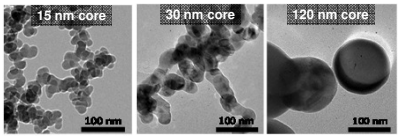
SPiCY Innovative Battery

Larger cone mitigates recirculation

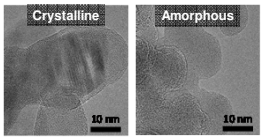
High control on core and shell properties

Silicon core (Si)

Diameter control (reactor zone residence time)

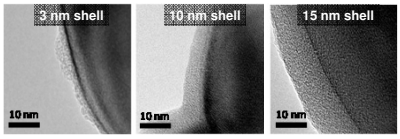


Crystallinity control (silane dilution and laser power control)

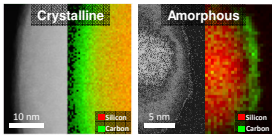


Carbon shell (Si@C)

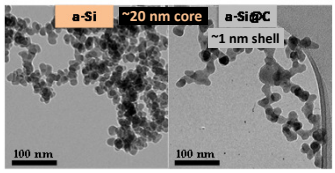
Thickness control (ethylene flow rate control)

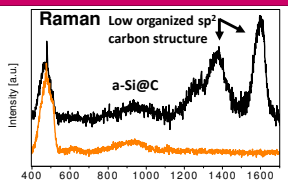


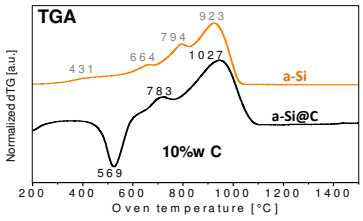
Uniform deposition of carbon

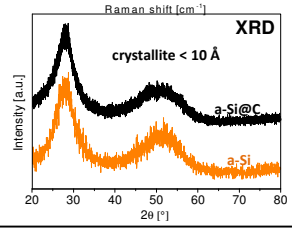


Amorphous silicon core and core shell





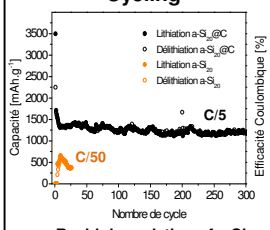




Electrochemical properties

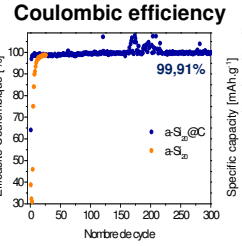
Galvanostatic cycling between 5 mV and 1 V

Cycling



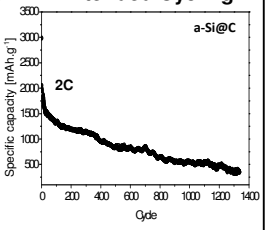
Rapid degradation of a-Si samples. Robust performance of a-Si@C samples observed with high capacity.

Coulombic efficiency



Excellent coulombic efficiency observed for a-Si@C electrodes

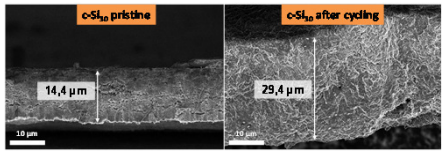
Extended Cycling



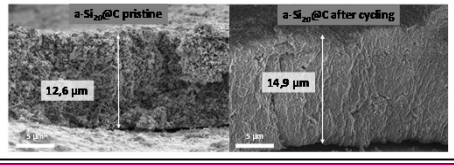
Enhanced capacity over graphite (372 mA/g) maintained over 1300 cycles

Post mortem study : microscopy

Cross section of electrodes after cycling (DMC washed)



- Porosity is filled up with SEI
- 100 % volume expansion



- Porosity remains after cycling
- 20 % volume expansion

Conclusions

- The double stage laser pyrolysis is an **up-scalable original set-up for production of core-shell materials**
- **Excellent charge/discharge properties** of the carbon covered materials and high coulombic efficiency
- The core-shell material shows improved capacity over carbon, **up to 1300 cycles at 2C**

References

Patent : WO 2014079997 A1 Dispositif pour la synthèse de nanoparticules de type cœur-coquille par pyrolyse laser et procédé associé, Y. Leconte, O. Sublemontier, N. Herlin-Boime, C. Reynaud, D. Porterat, A. Quinsac (26/11/2012)

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