Catalytic Nanofabrication for Improved Energy Storage

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ABSTRACT

• We describe a new low cost method for kinetically controlled catalytic synthesis of nanocomposite anodes, cathodes and protectants for high-power Li ion batteries (LIBs).

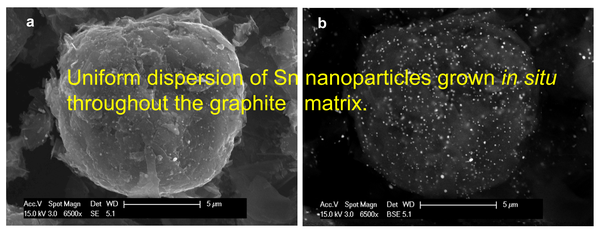
• Anodes are nanocomposites of Sn or Si nanocrystals catalytically grown *in situ* and uniformly dispersed in compliant and conductive graphite or carbon nanotube matrices. They exhibit exceptionally high power, electrochemical capacity and stable cyclability.

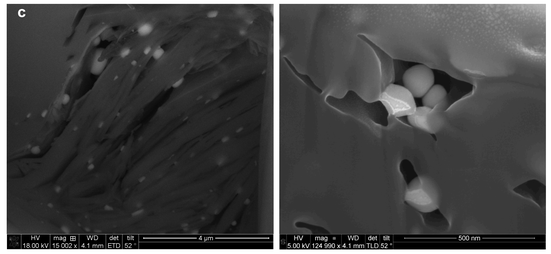
• Cathodes are catalytically synthesized as nanocomposites of nanocrystalline metal oxides in highly conductive CNT matrices. They exhibit high voltage, high power and high energy density.

• $BaTiO_3$ and $BaSrTiO_3$ nanocrystals catalytically synthesized in high yield and purity yield fine-grained nanocrystalline ceramics with strong positive thermal coefficients of resistivity (PTCR) that can be used as internal protectants against thermal runaway.

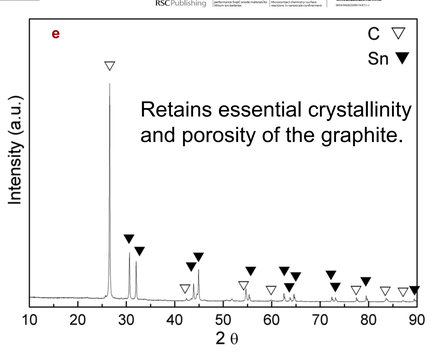
• Syntheses of the anodes, cathodes and PTCR protectant are affordably scalable.

1. HIGH-POWER NANOCOMPOSITE ANODE

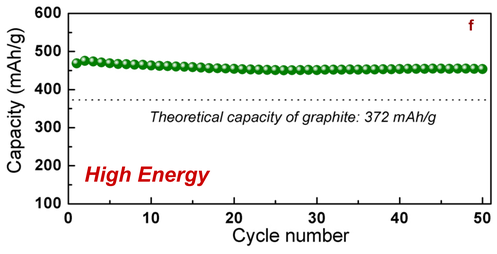


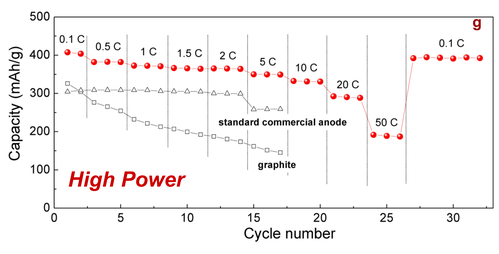


Kinetically controlled catalytic synthesis grows Sn nanocrystals *in situ*, inside the pores of the compliant, conductive carbon matrix of graphite



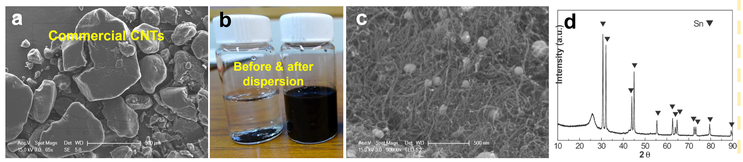
• The resilient graphite "breathes" to accommodate large volume changes accompanying each cycle of Li alloying and de-alloying on charging and discharging, yielding exceptionally high power, stability and cyclability:

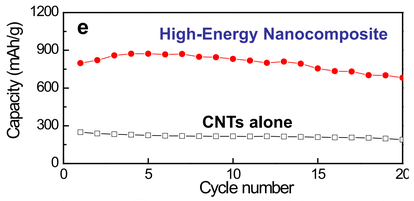




(a) SEM image of the Sn@graphite composite after surface modification; (b) Backscattered electron image of the composite showing nanocrystalline Sn; (c-d) Cross-section images of the Sn@graphite composite obtained with focused ion beam and TEM; (e) XRD pattern of the nanocomposite; (f-g) Cyclic performance and rate capability of the Sn@graphite composite, respectively.

• Catalytic growth of Sn nanocrystals inside the conductive and resilient matrix of dispersed multiwall carbon nanotubes:

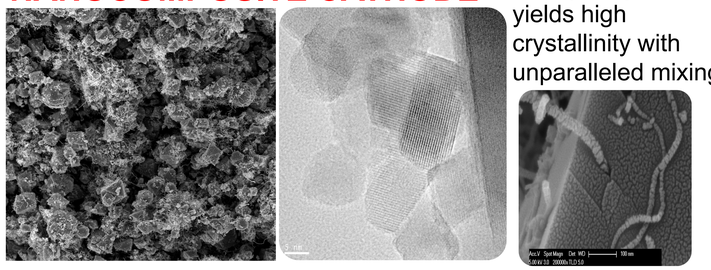




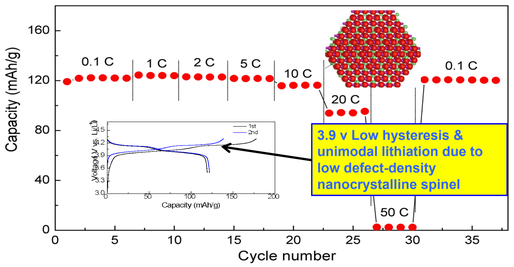
(a) SEM image of commercial multiwall CNTs; (b) Before and after dispersion of CNTs; (c-d) SEM image and XRD pattern of the nanocomposite Sn@CNTs; (e) Electrochemical performance.

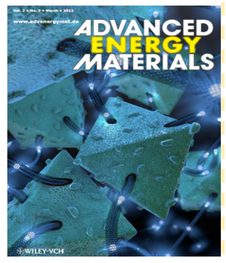
2. HIGH-POWER, HIGH VOLTAGE CNT-$LiMn_2O_4$ NANOCOMPOSITE CATHODE

Catalytic synthesis yields high crystallinity with unparalleled mixing



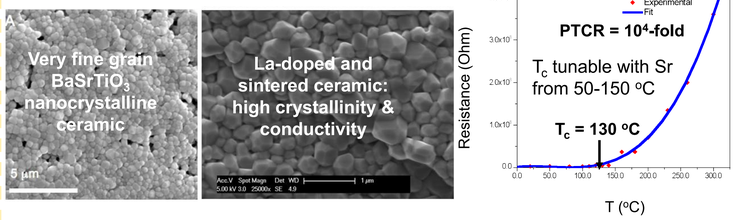
• 96% retention of original capacity after discharge at 10 C;
• >80% capacity retention at the exceptionally high rate of 20 C;
• Full recovery after complete discharge at 50C:





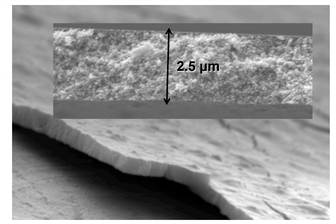
3. COLLABORATION WITH CERDEC, LIFECEL and QUALLION FOR BATTERY SAFETY: Internal PTCR Protection from Thermal Runaway

Doped $BaSrTiO_3$ nanocrystalline ceramic coatings on electrodes or current collectors to provide internal PTCR protectant against fire and explosion in rechargeable LIBs

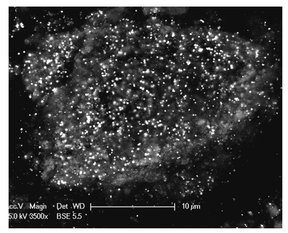


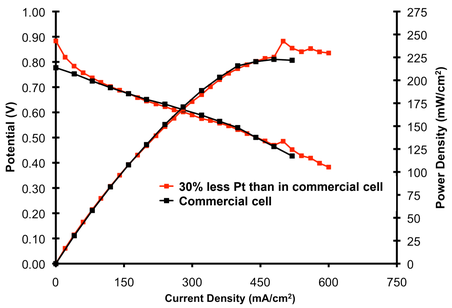
• Protection results from unique Positive Thermal Coefficient of Resistance (PTCR)

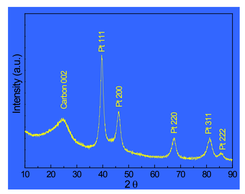
Electrophoretic deposition and double-annealing of doped $BaSrTiO_3$ nanocrystals yields smooth, uncracked films with low initial resistivity, lower T_c and strong PTCR protection.



4. FUEL CELLS



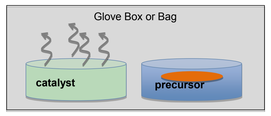




- Bio-inspired, vapor-diffusion catalytic synthesis of nanocrystalline Pt@Carbon Black nanocomposite.
- Unoptimized performance matches commercial, but with 30% less Pt.

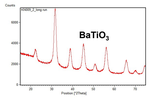
5. TECH TRANSFER: SCALE-UP SYNTHESIS

- Catalytic syntheses of Anode, Cathode and PTCR Protectant are "Chemical" (not "chip" technology); thus Readily Scalable
- Spun-out LifeCel Technology Inc. for manufacturing.



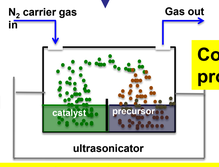
Lab Scale: 100 mg

250 g (99% yield)



Highly crystalline, 6.9 nm, Pure; Parameters unchanged with scale-up

2 kg/batch



Continuous production

Combines kinetic control and high throughput.
Proof-of-principle at 1 kg/hr for $BaTiO_3$.

Acknowledgements

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