High-Rate, High-Capacity Binder-Free Electrode

Patent: PCT-09-41

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Outline

- ✓ ***What is the technology***
- ✓ ***Why it is better than other technologies***
- ✓ ***How far away from market***
- ✓ ***Technical details***
- ✓ ***Market analysis***

Outline

✓ *What is the technology*

Fast charging/discharging Lithium Ion Battery

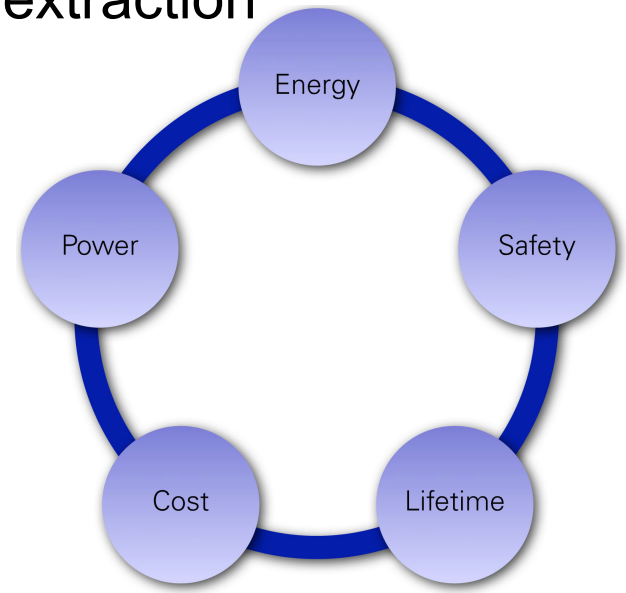
6min *charging/discharging, Both cathode and anode*

Materials:

- Reversible reaction with a higher capacity
- Endurable structure during Li^+ insertion/extraction
- Stable surface in the electrolyte

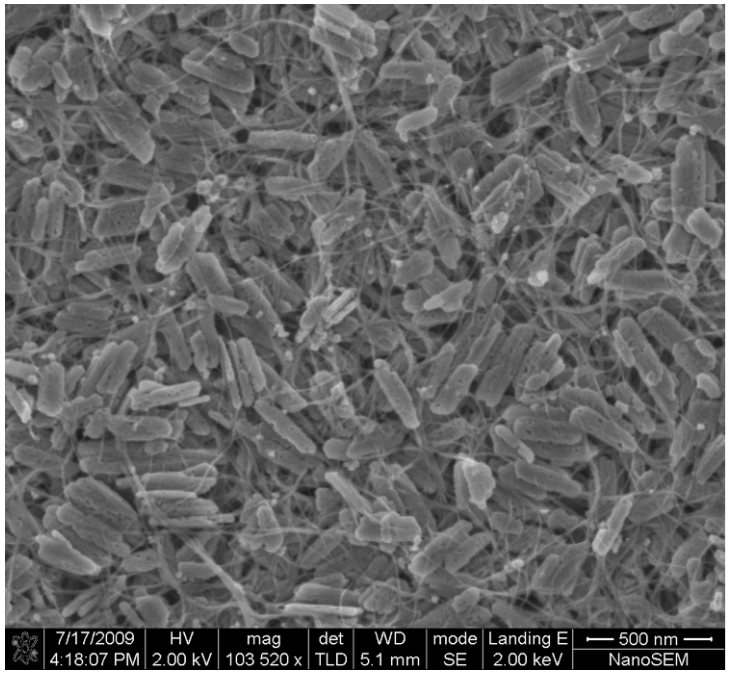
Electrodes:

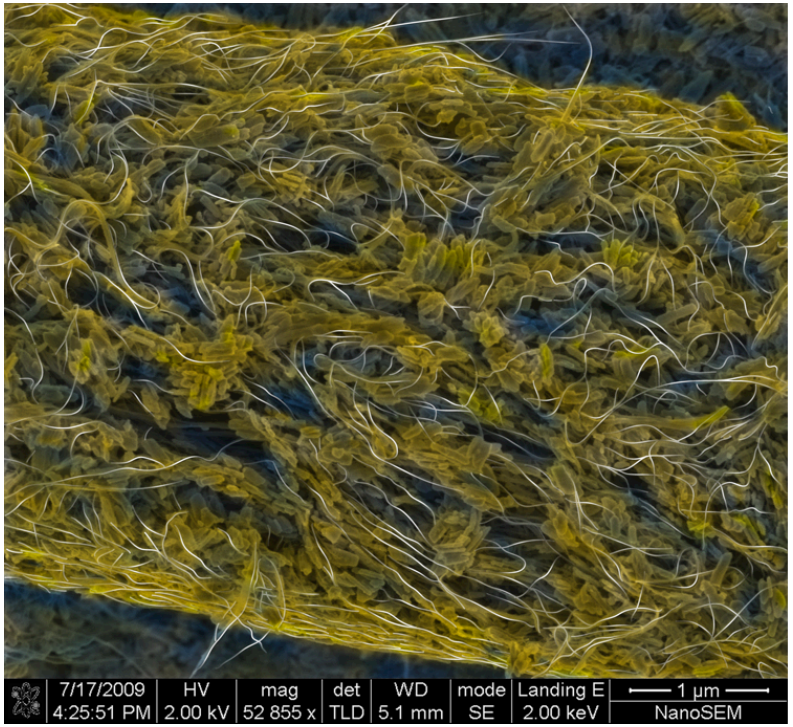
- High electrical conductivity
- Better Integrity
- Much improved Safety



Why it is better than other technologies

- Carbon Nanotubes
- Composite Materials





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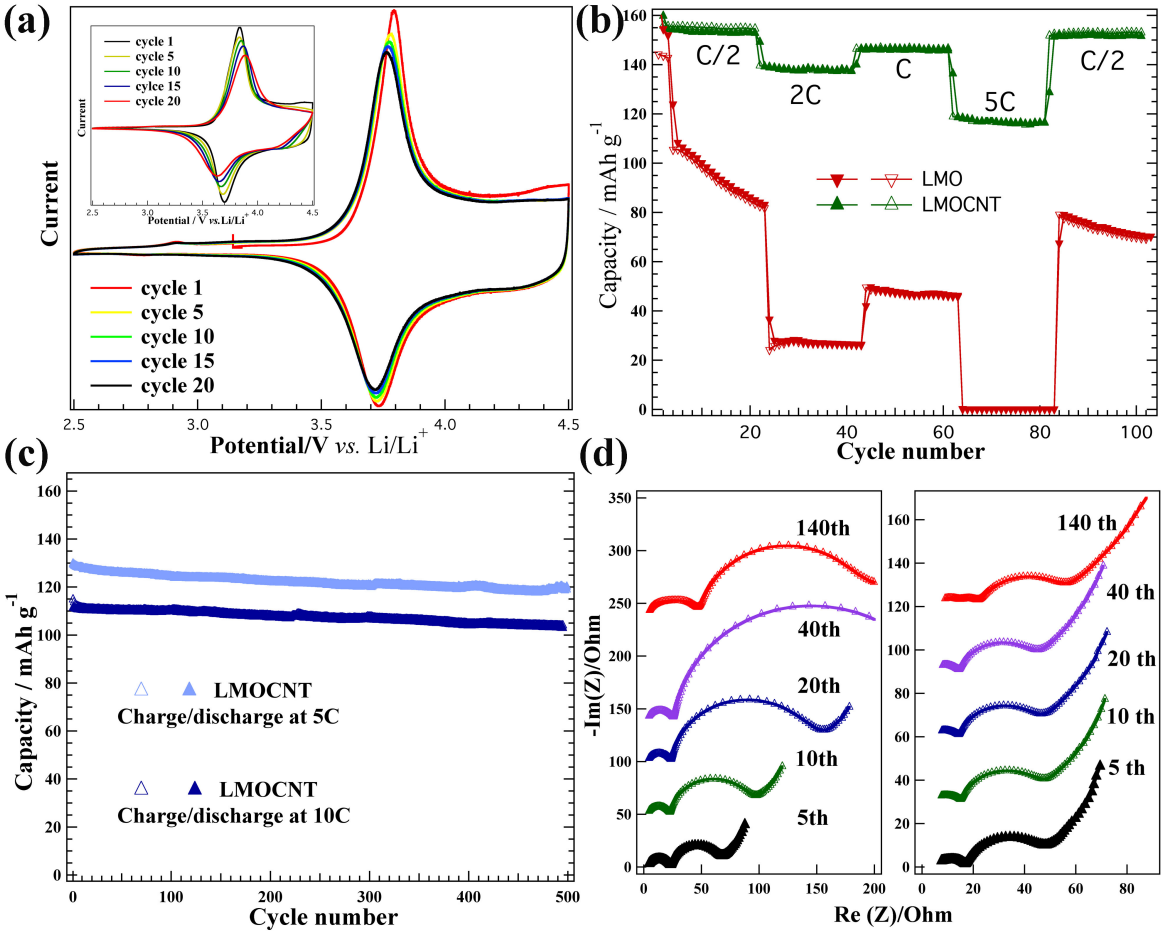
How far away from market

- Million dollars away, see detailed market analysis towards the end of this presentation
- Carbon nanotube mass production is available
- Cathode and anode materials are readily available
- Need to build a Pilot plant

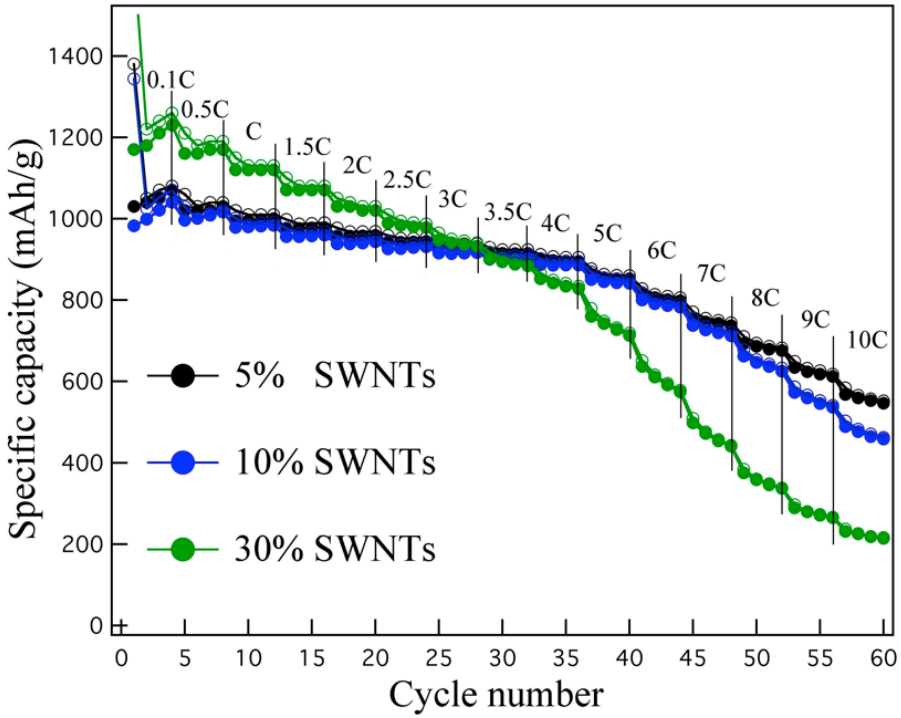
Carbon nanotube sheet, 2meter square, from Nanocomp Technology, from www.technologyreview.com

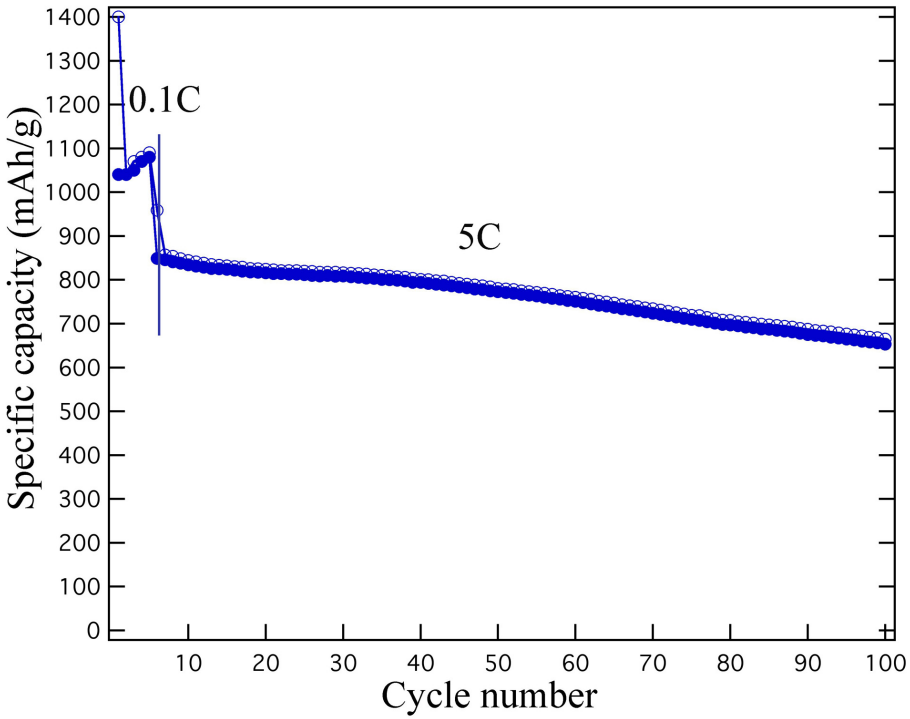
Durable High-Rate Capability



The cathode composed of layered $LiNi_{0.4}Mn_{0.4}Co_{0.2}O_2$ and SWNTs (LMOSWNT) is shown to have a capacity of ~ 130 mAh/g at 5C and nearly 120 mAh/g at 10C, both for over 500 cycles.

High Rate Fe_3O_4 / SWNT Anodes





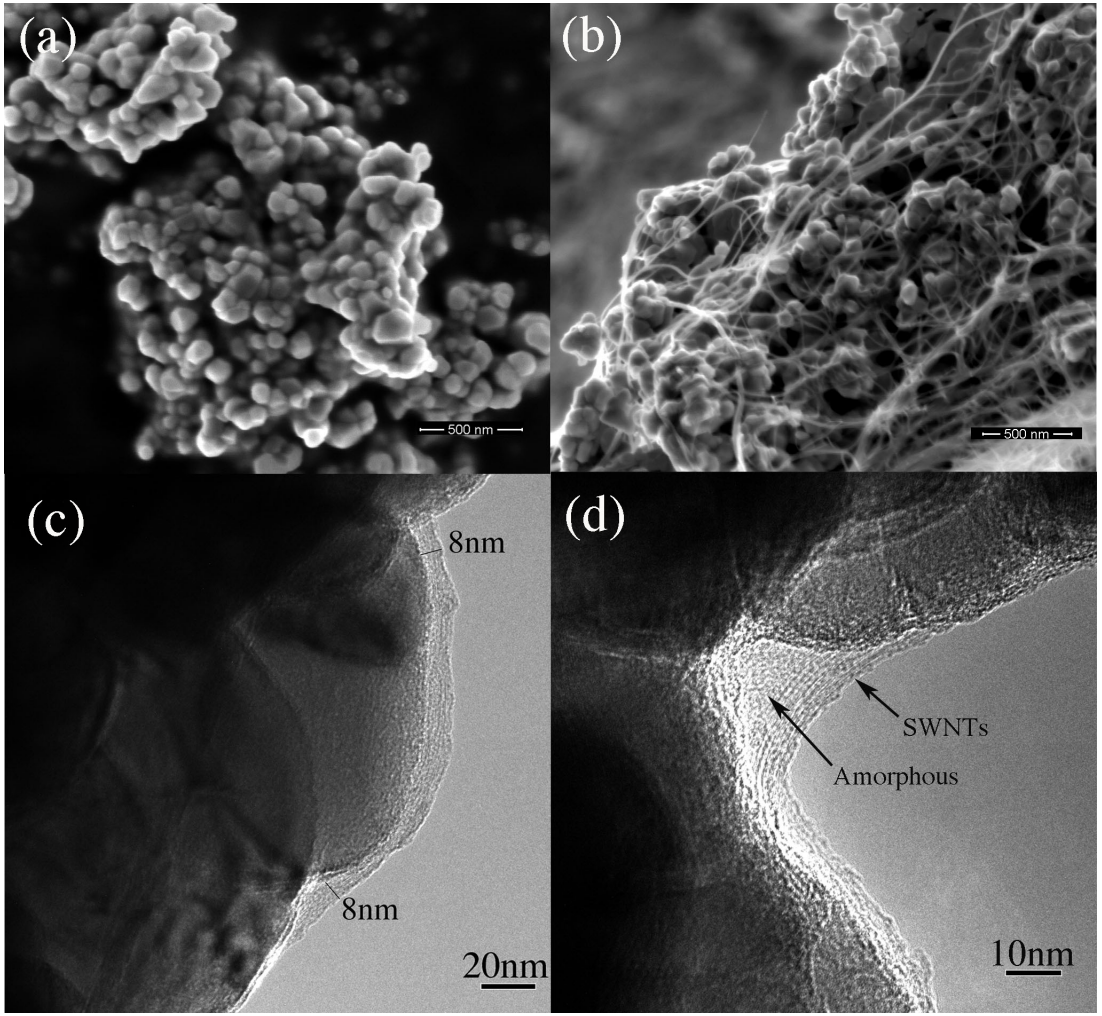
Stable capacity of over 600 mAh/g is observed at 10C (one charge/ discharge in 6 minutes).

Fe_3O_4 nanorods in an SWNT net cycled at 5C (one charge/ discharge in 12 minutes).

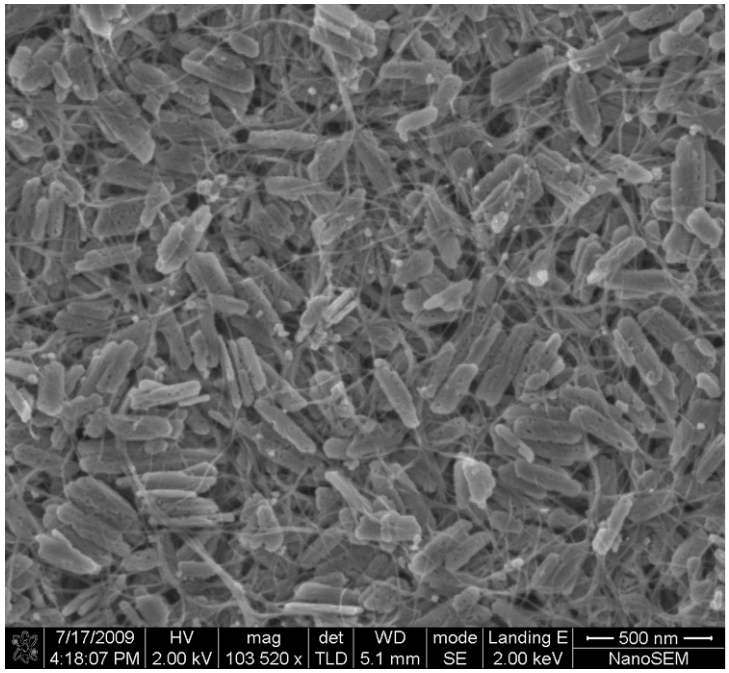
Surface Contact between SWNTs and Particles

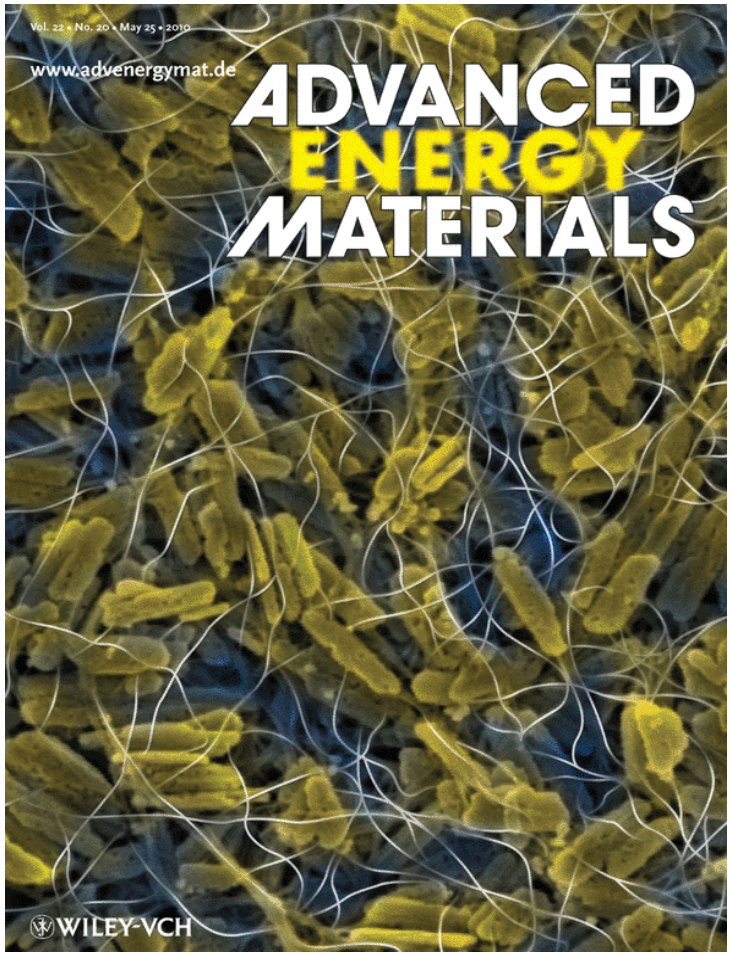
SEM images of (a)$LiNi_{0.4}Mn_{0.4}Co_{0.2}O_2$ particles. (b) $LiNi_{0.4}Mn_{0.4}Co_{0.2}O_2$ with SWNT loading, revealing that the particles are interconnected with well dispersed SWNTs.

(c) TEM image of the electrode showing that single-wall carbon nanotubes seamlessly stick on the particle surface.



(d) TEM image of the electrode showing that the nanotubes also encapsulate an amorphous pocket of Li_2CO_3.





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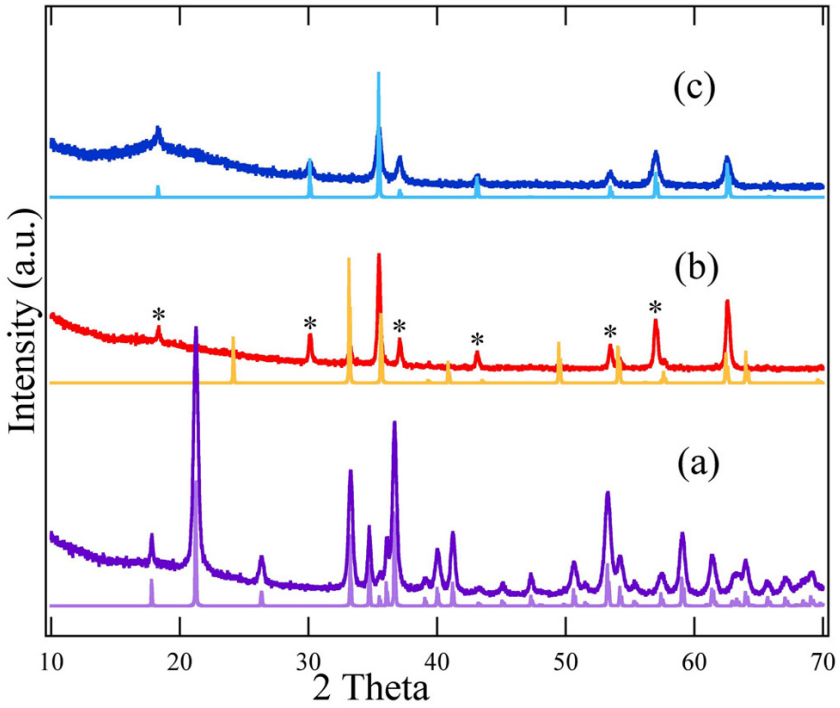
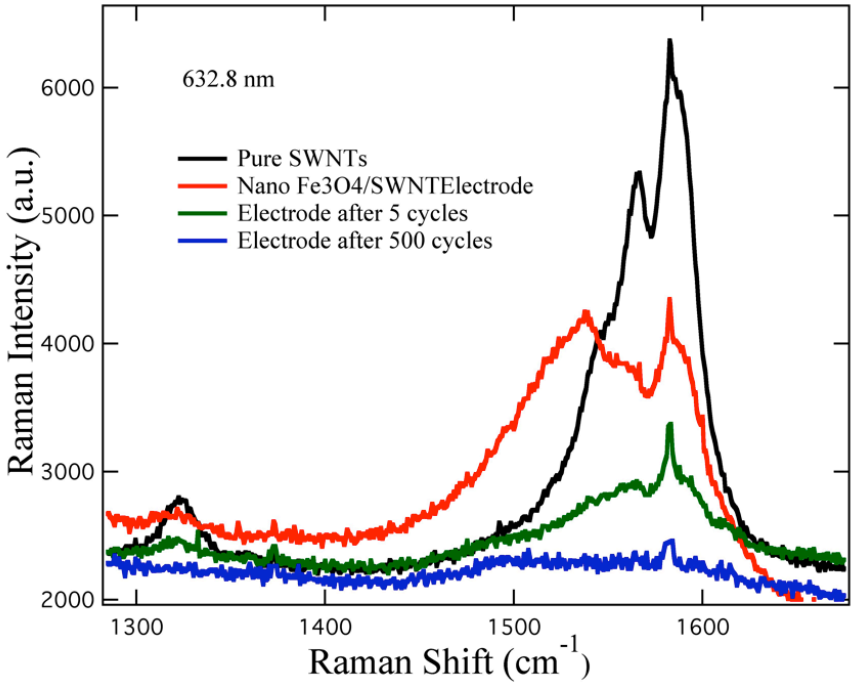
Stable New Chemistry Enable to Improve

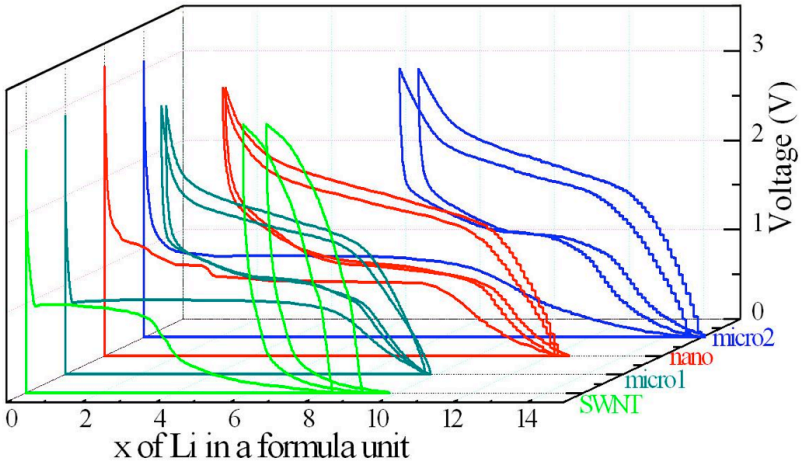


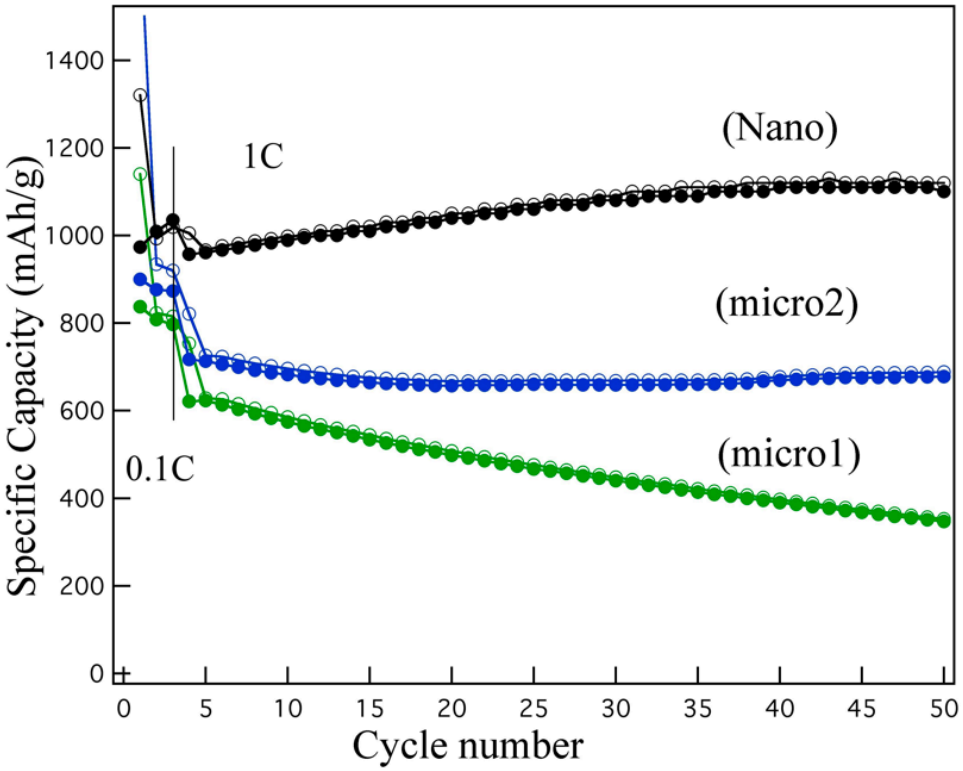


Initial particles change from tetragonal α-FeOOH (a) to a mixture of Fe_2O_3 (hematite) and Fe_3O_4 (magnetite) when heated at 450 ˚C in Ar but are completely reduced to Fe_3O_4 when heated with SWNTs

Decrease in D-band upon heat treatment is consistent with oxidation of residual carbon impurities. Large shift in G-band indicates charge transfer/perhaps binding. Quenching is consistent with irreversible intercalation.

Commercial Fe_3O_4 material works too!



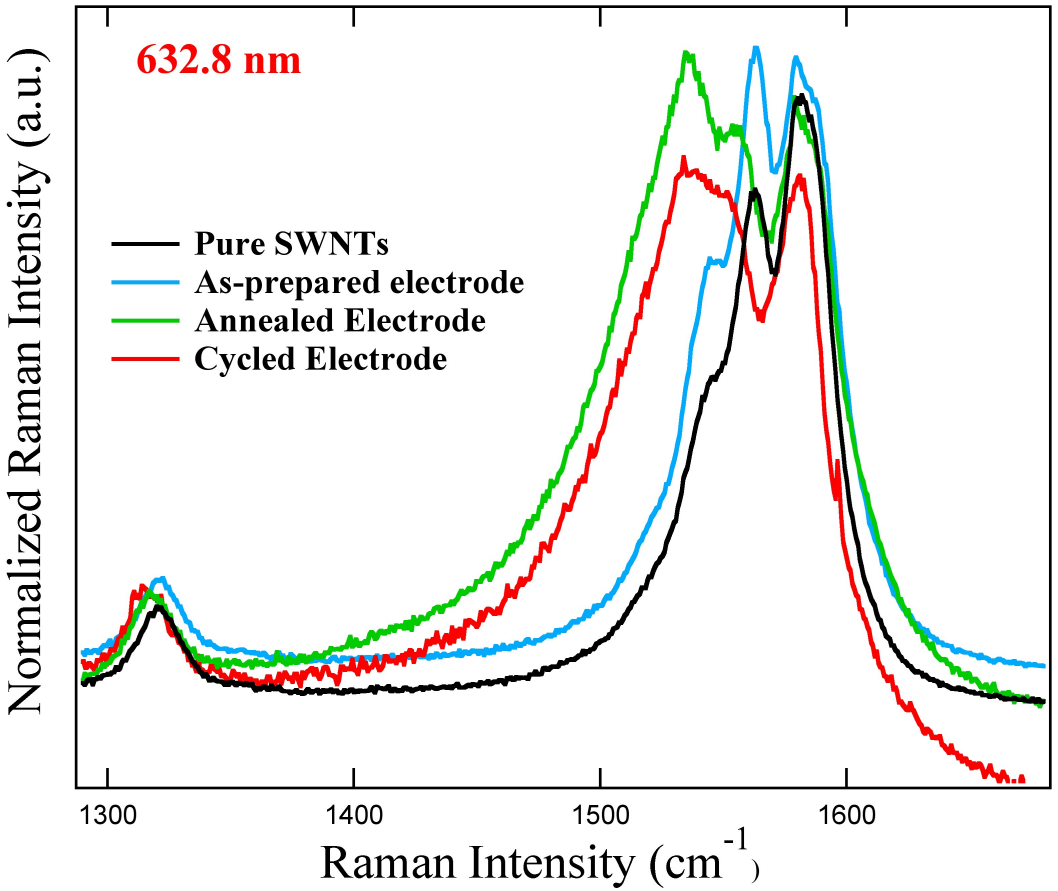


- Voltage profiles and cycling performance of Fe_3O_4/SWNT (nano) compared to micron-sized Fe_3O_4/SWNT (micro2) and μm-sized Fe_3O_4 with PVDF binder / acetylene black (micro1).

- This suggests that this process could be employed for any high-volume expansion material.

- Volumetric capacity at 1C is 2000 mAh/cm^3 (3 x graphite).

Surface Stabilization by SWNTs



A significant shift in the Raman lines is observed in the electrode after annealing(cathode). This indicates that significant charge transfer occurs and that perhaps even a chemical bond is formed.

Conclusions

- ✓ Fast Charging/Discharging Technology has been demonstrated and accepted by the science community, both in anode and cathode
- ✓ Materials (cathode/anode/SWNT) are available
- ✓ Markets are huge
- ✓ NREL is dedicated to help, through CRADA

Goal:

Development of cost effective, long lasting, and abuse tolerant Li-ion batteries

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Why choose this team

Dr. Chunmei Ban is a leading expert in Li-ion battery development and has more than 10 years of experiences in materials synthesis via both physical and chemical procedures. *Her expertise in study of nanostructured materials has been instrumental in the successful implementation of the DOE funded projects including Nanostructured Metal Oxide Anodes and High-capacity anode work.*

Dr. Zhuangchun Wu has 9 years of experiences working on carbon nanotubes (CNT) applications. He has 4 US patent applications all related to CNT, One granted. 14 publications in CNT related applications, including *Science, Nano Letters, Advanced Materials* etc with more than 1200 citations.

NREL's CRADA program is specifically designed for promoting technology transfer to market place, especially helping start-ups to license patents and allow NREL to provide technical support. More info, please see:

http://www.nrel.gov/technologytransfer/cradas.html