An Overview of Selected Diagnostic Studies of Electrode Materials for Next Generation Electric Vehicle Batteries

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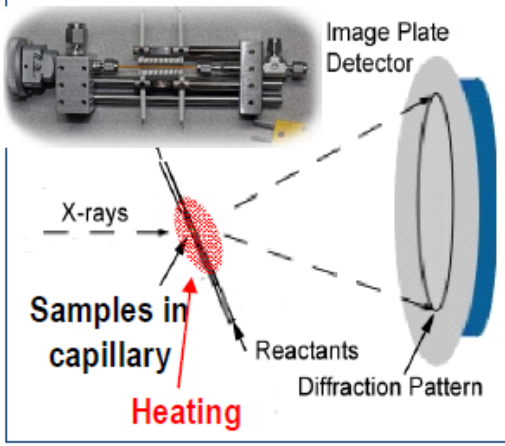
NSLS II (under construction)

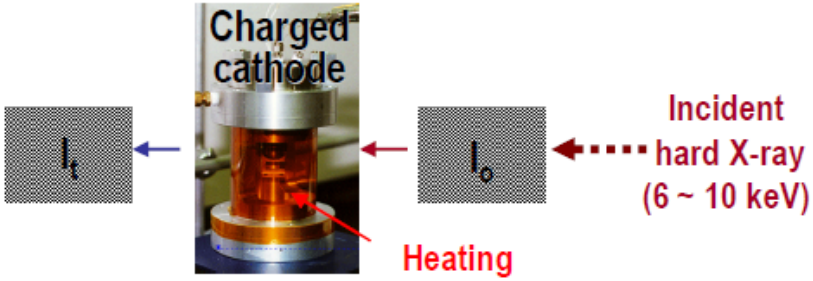
Approach I: *In situ* TR-XRD, XAS and TEM during heating of charged cathode (thermal stability study)

1. *Time-resolved XRD* of charged cathode



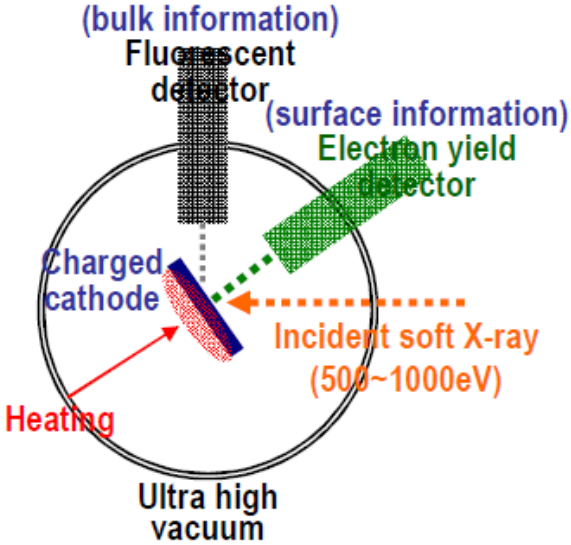
- Average structural information (long range order)

2. *In situ Hard XAS* of charged cathode



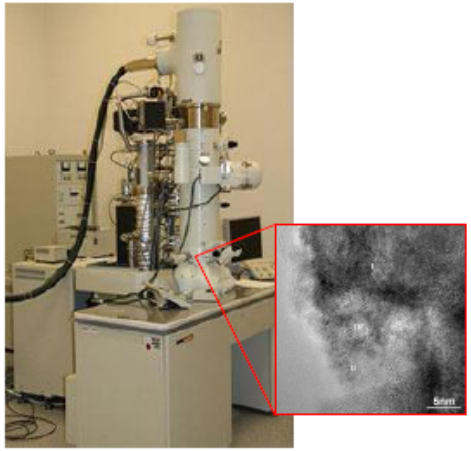
- Local electronic and structural information (bulk) in elemental-selective way

3. *In situ Soft XAS* of charged cathode



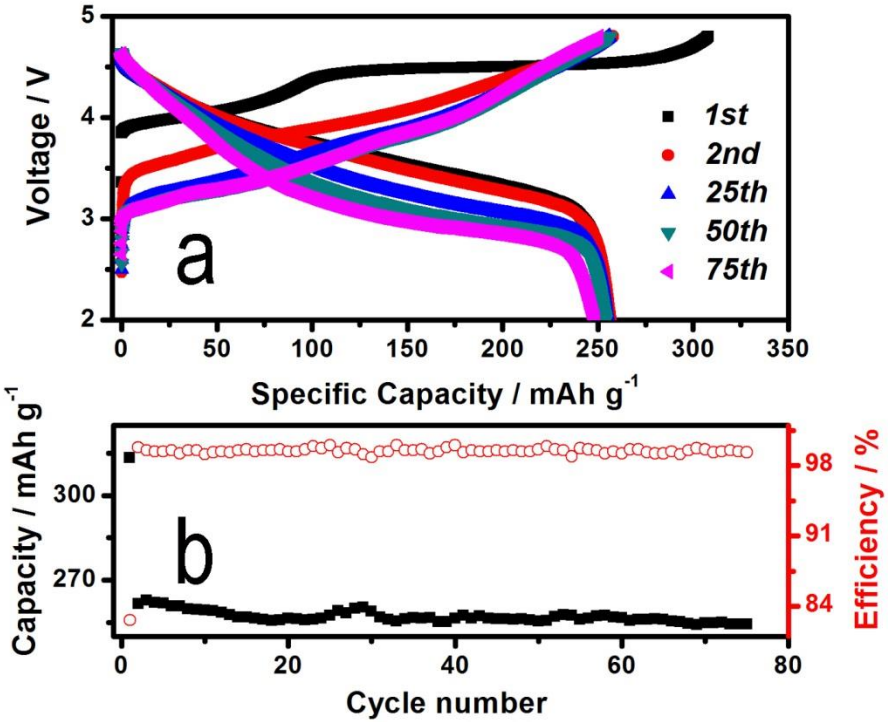
- Electronic structural information at the surface (~ 50Å) and in the bulk (~ 3000Å) in elemental-selective way

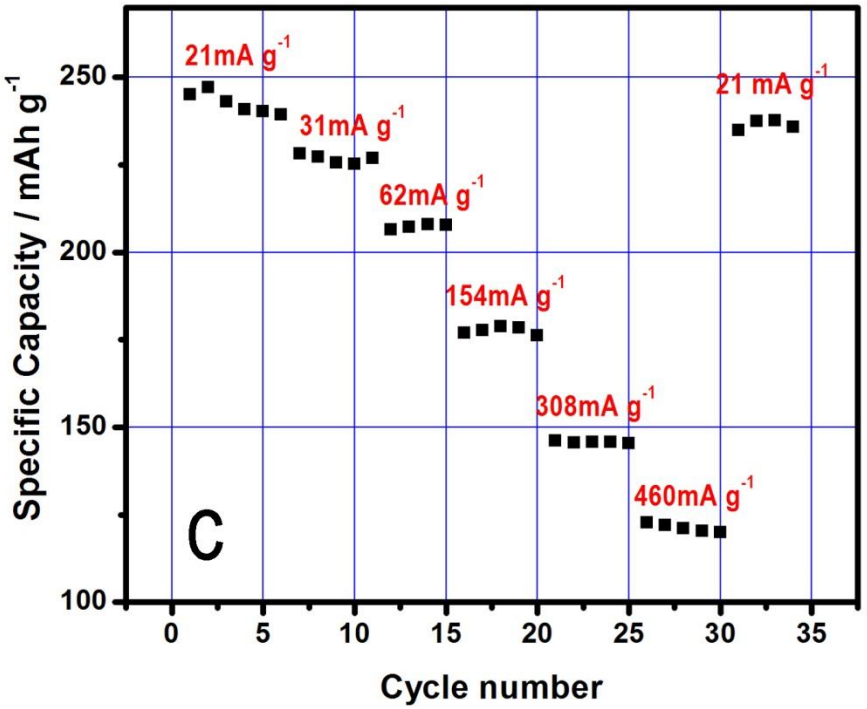
4. *In situ* TEM of charged cathode



- Where and how the new structure nucleated and propagated with high location specification and spatial resolution (~ nm range)

Electrochemical performance of $Li_{1.2}Ni_{0.15}Co_{0.1}Mn_{0.55}O_2$ Sample





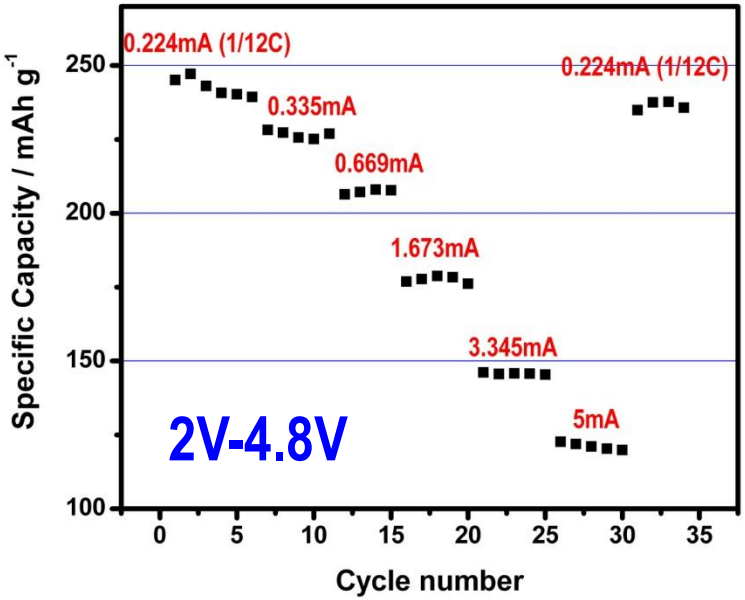
Electrochemical performance of $Li_{1.2}Ni_{0.15}Co_{0.1}Mn_{0.55}O_2$ Sample:

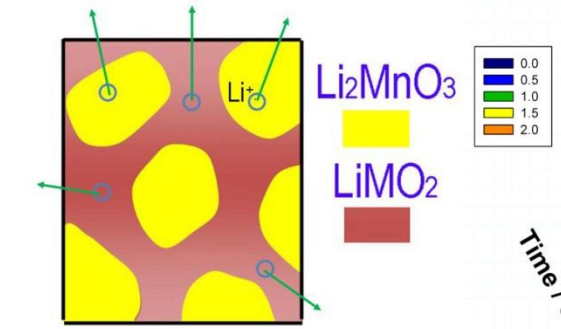
(a)Charge-Discharge curves at 1st, 2nd, 25th, 50th and 75th cycle
(b)Cyclic performance
(c)Rate capability

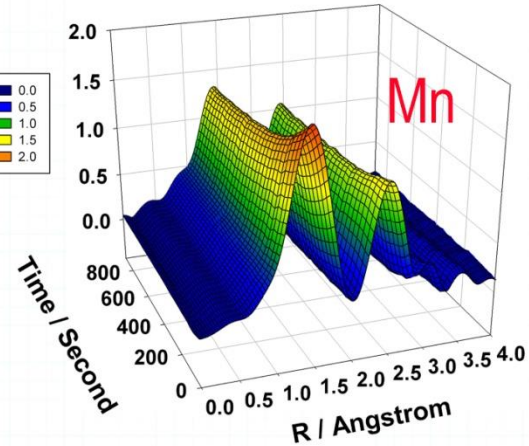
Delithiation Kinetics- Time resolved XAS

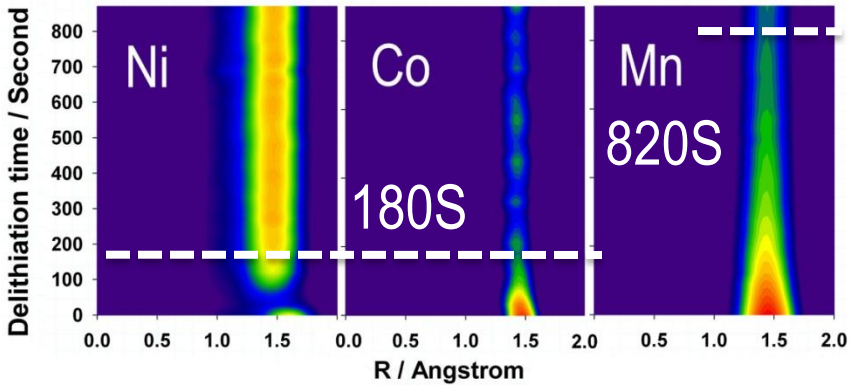
Comparing the contribution of Ni, Co, Mn to the rate capability

Rate performance







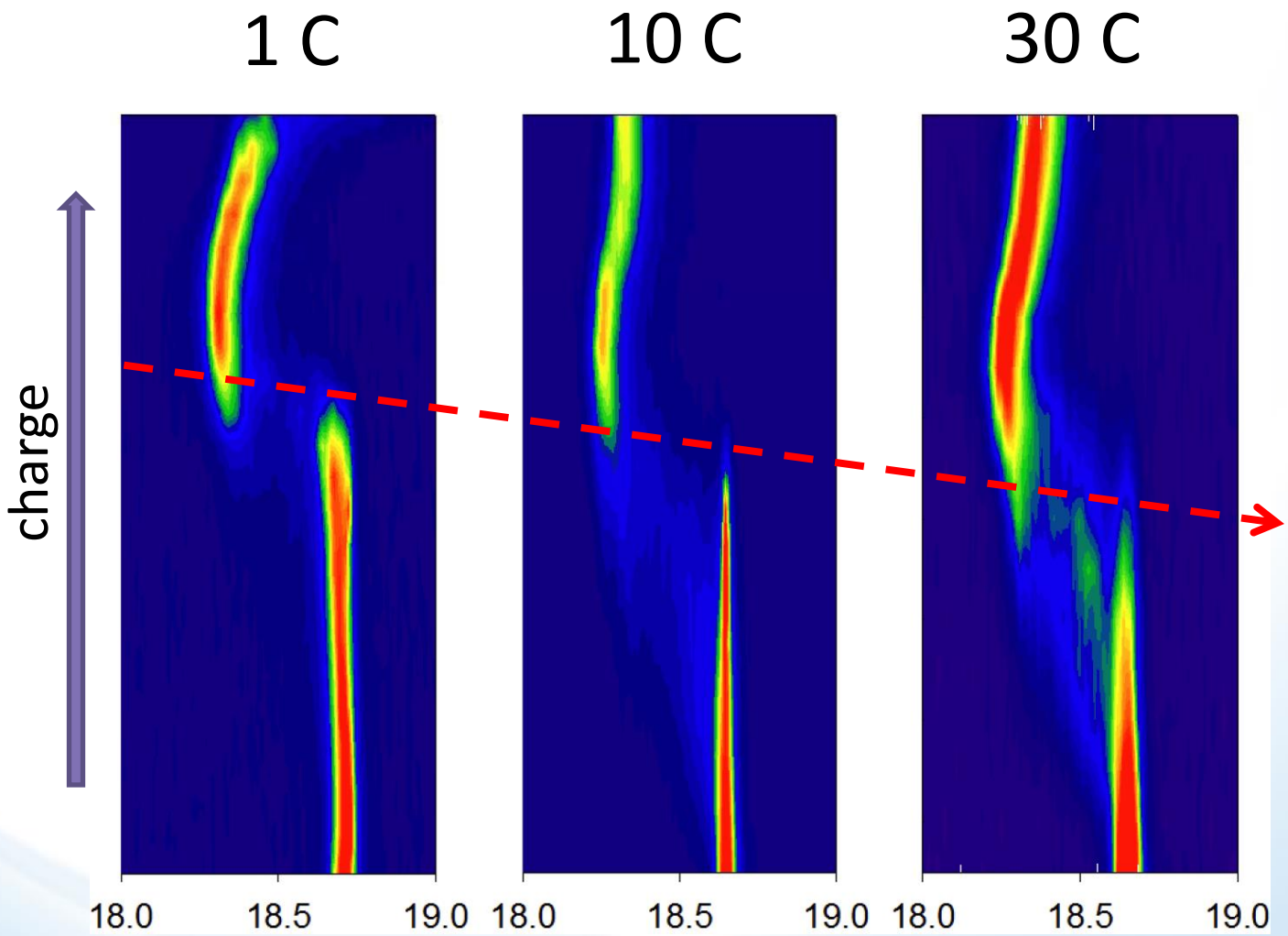


(1) $Li_{1.2}(Ni_{0.15}Co_{0.1}Mn_{0.55})O_2$ shows not too good rate performance;

(2) Sluggish delithiation kinetic of Li_2MnO_3 component.

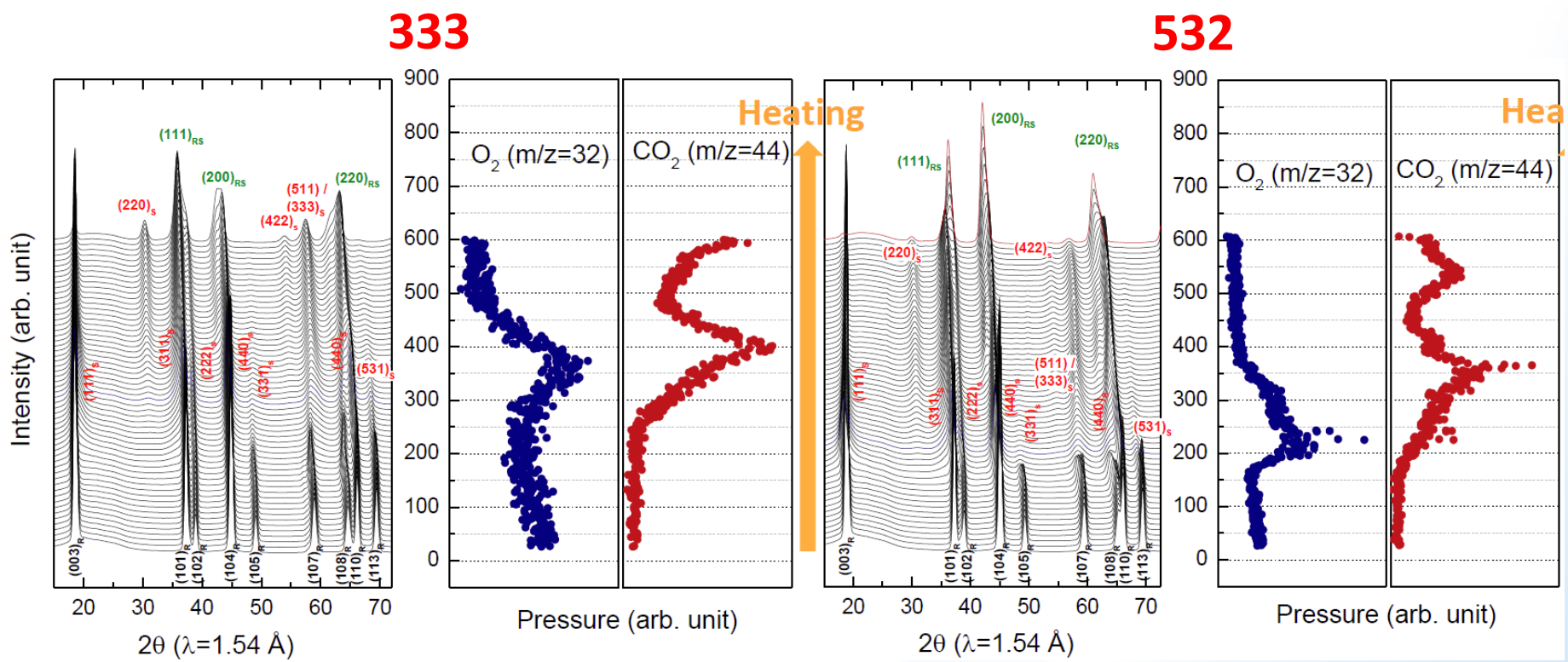
4.8V constant voltage charging, Ni, Co, Mn react simultaneously

Time resolved XRD of **333** at different C rate



(003) Peak evolution

Thermal stability of charged NMC during heating



Increase Ni content in NMC

- thermally unstable
- O_2 release at lower temperature

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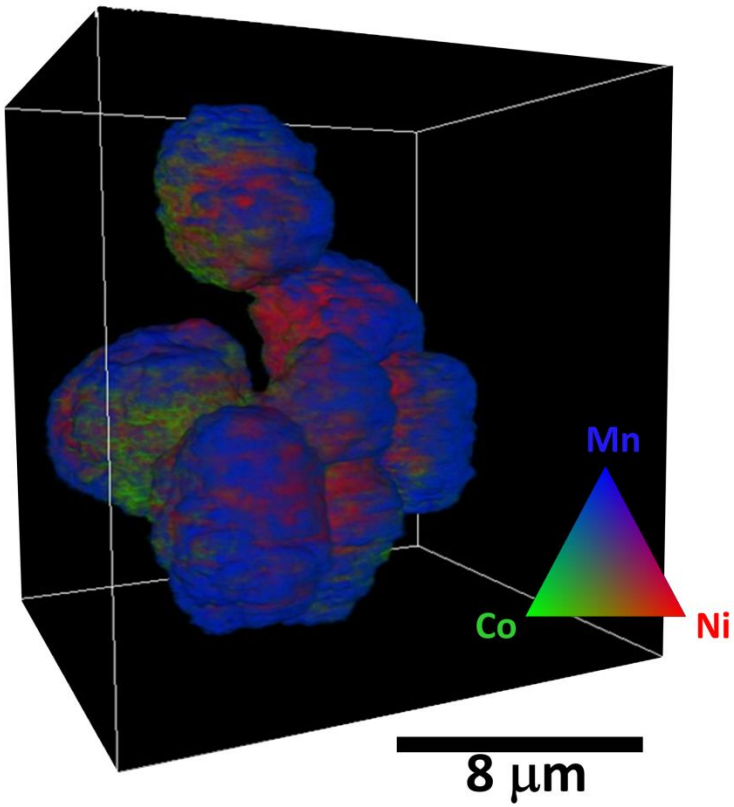
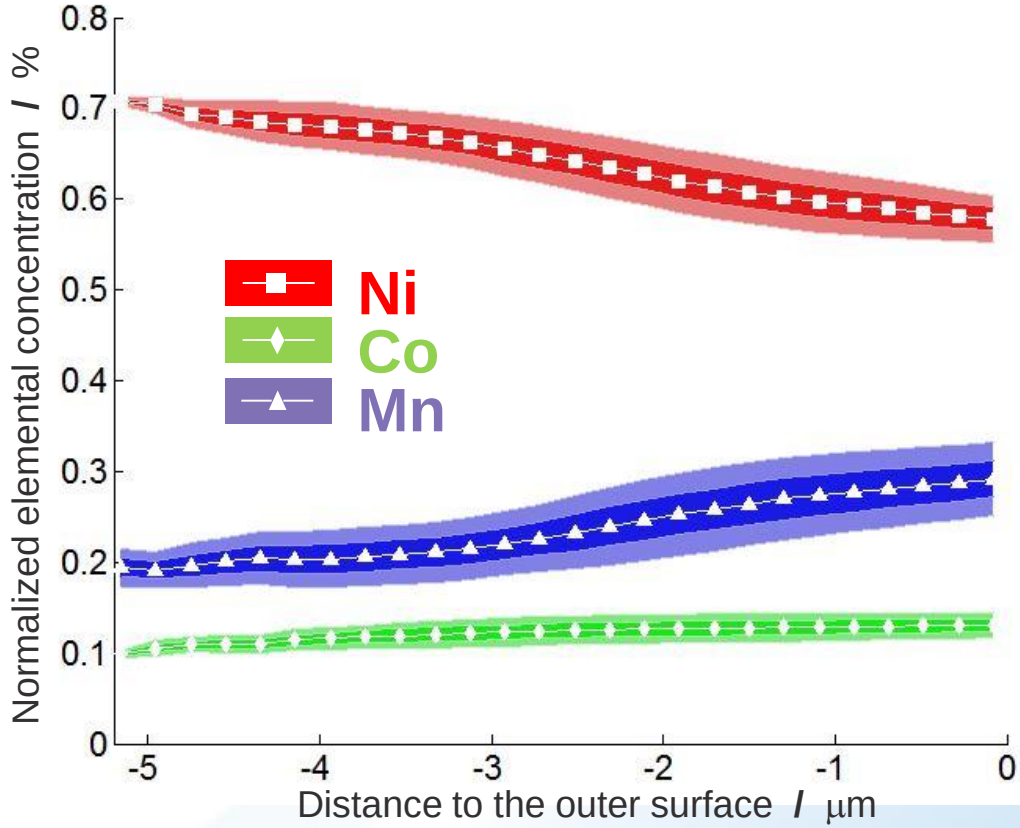
Figure 10

FCG, TXM result

(a)



(b)



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▣ Co-workers
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- X18A : Dr. S. *Ehrlich*
- X18B & X19A : Dr. *S. Khalid & N. Marinkovic*
- U7A : Dr. *C. Jaye, Z. Fu & D. Fischer*

▣ Collaborators
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New High-Energy Electrochemical Couple for Automotive Applications

K. Amine (PI)

H. Wu, A. Abouimrane, Z. Chen, J. Lu, R. Xu, C.K. Lin and Y.C. Kan

Argonne National Laboratory

DOE merit review

June 15th ~20th , 2014

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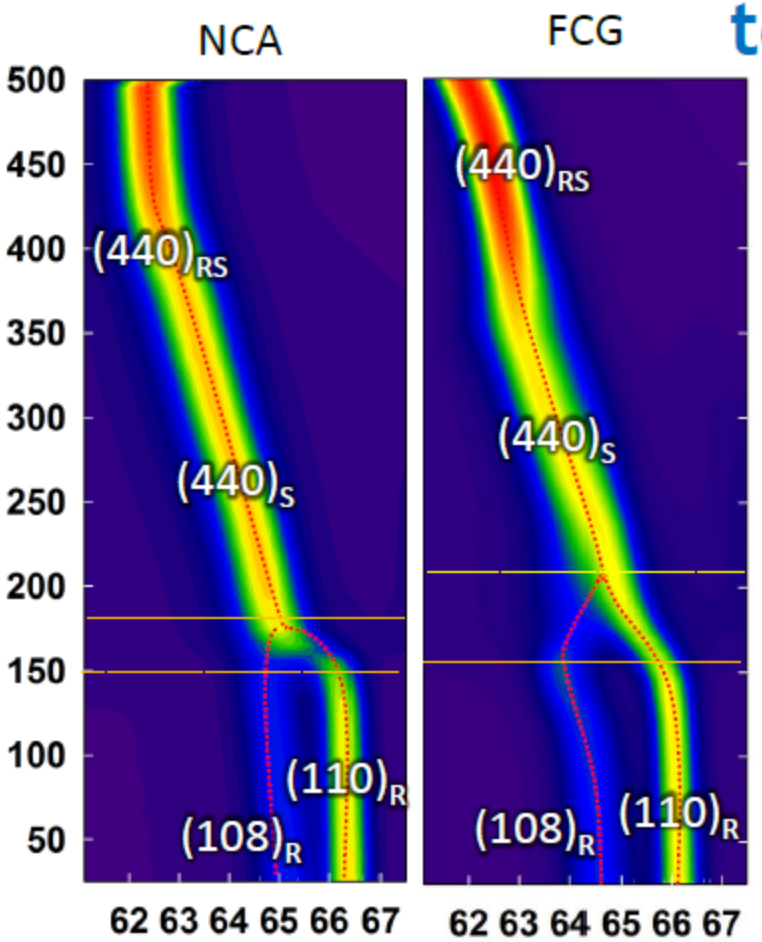
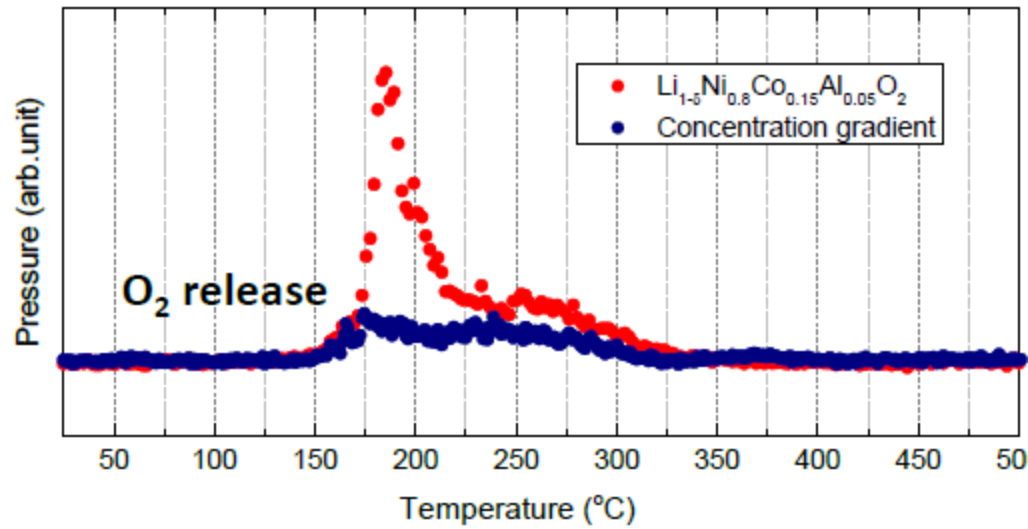
Project ID: ES208

Thermal stability of NCA and FCG charged to 4.5V using synchrotron soft X-ray at different temperatures



Synchrotron soft X-ray at different temperature.



- The FCG sample shows less oxygen release than bulk NCA samples.

The fist cycle capacity of NCA and FCG at 4.5V is around 230mAh/g. The FCG sample showed much better thermal stability

Interfacial Processes in EES Systems Advanced Diagnostics

Robert Kostecki
Lawrence Berkeley National Laboratory
Berkeley, California 94720
June 17, 2014

Project ID# ES085

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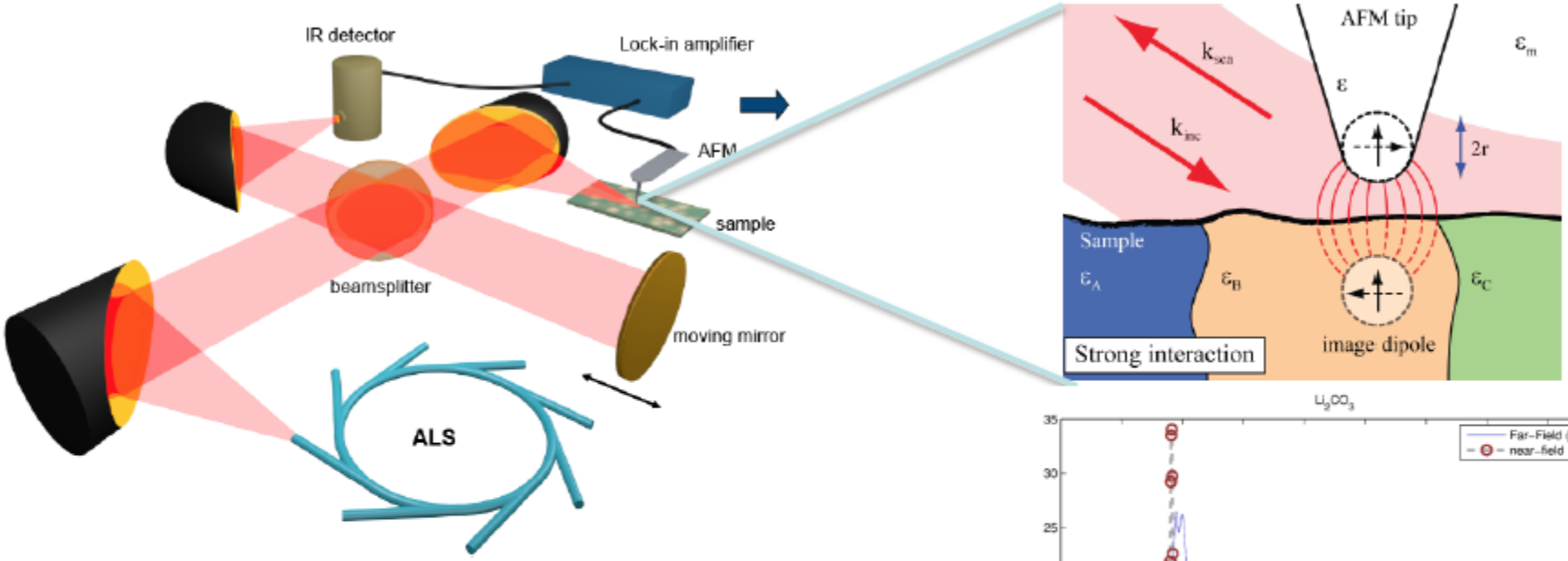
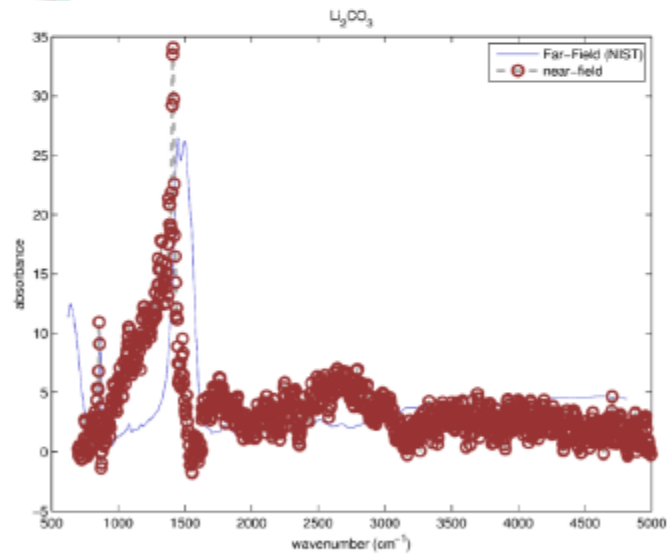
Nano-spectroscopic Characterization of Battery Materials with Synchrotron Infrared Radiation





- Nanometer spatial resolution
- Wavelength independent
- Soft and hard matter
- Amplitude and phase of optical field

IR nano-spectroscopy allows identification of very similar phases with unprecedented 3D sensitivity in gentle beam conditions at <20 nm resolution