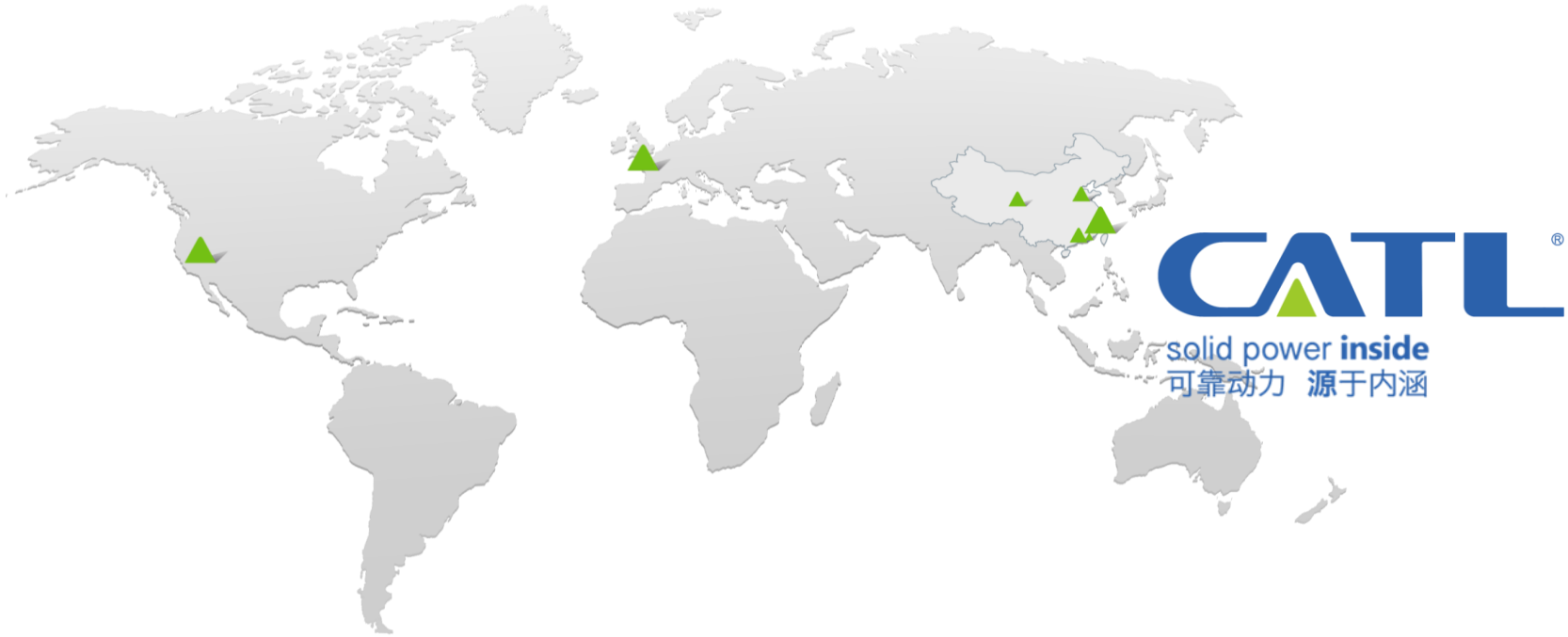


Advanced xEV Battery Development at CATL

Mainz Germany, Feb 2nd 2017

Presented by: Liang TAO

Where are we? Geographically…

Where are we? Cell Industry…

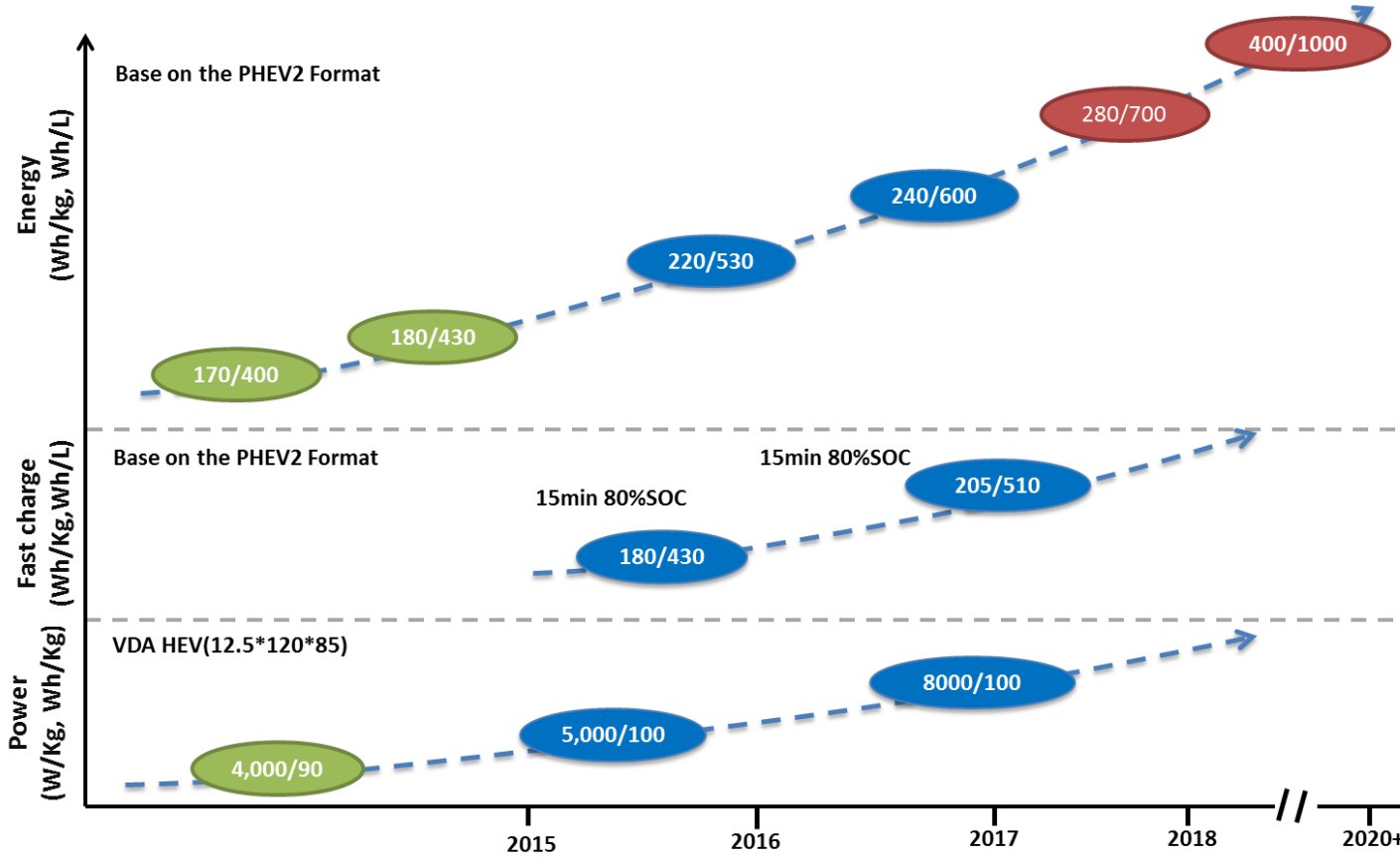
Name	2015 Shipment(MWh)
Panasonic Cylindrical	4,500
BYD	2,950
CATL	2,430
AESC	1,553
Optimumnano	1,400
LG Chemistry	1,304
Samsung SDI	1,231
Guoxuan	1,100
Panasonic Power Cell	1,075
LEJ	673
Microvast	640
SKI	623
CALB	520
Sinopoly	500
Wanxiang	460

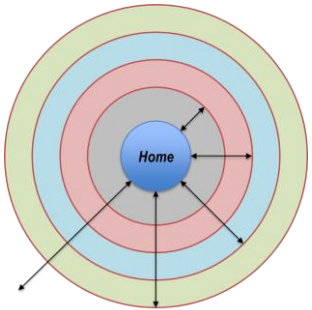
*Data based on IIT, GGII and other reports (xEV for passenger, business and special-use vehicles; including cylindrical, pouch and prismatic cells)

Some Quick Facts of CATL R&D

Founded	**2011**
Annual R&D Investment	**6%** of Revenue
R&D Employee	Over **1000** researchers Including **100+** Ph.D. (22 oversea), ~**700** MSc. holders
R&D Scopes	• **Cell Materials** (cathode, anode, electrolyte, simulation, mechanism) • **Cell Design** (energy density, **safety**, cell configuration) • **Module Design** (simulation, thermal, **safety** and mechanical management) • **Battery Pack/System Integration** (BMS soft and hardware, reliability and **safety** investigations) • **Advanced Cell** Technology (all solid state, Li metal, Si anode…)
Equipment	• **1500** pieces of equipment for cell, module and pack tests • National **CNAS** certified central lab
IP	**690** IP Patents applied, in which were **212** authorized

CATL Cell Roadmap





300Wh/kg

HOW??

Next Generation Cell: Simple Calculation

In order to achieve 300Wh/kg…

Prismatic / Pouch

Cathode

Energy Density

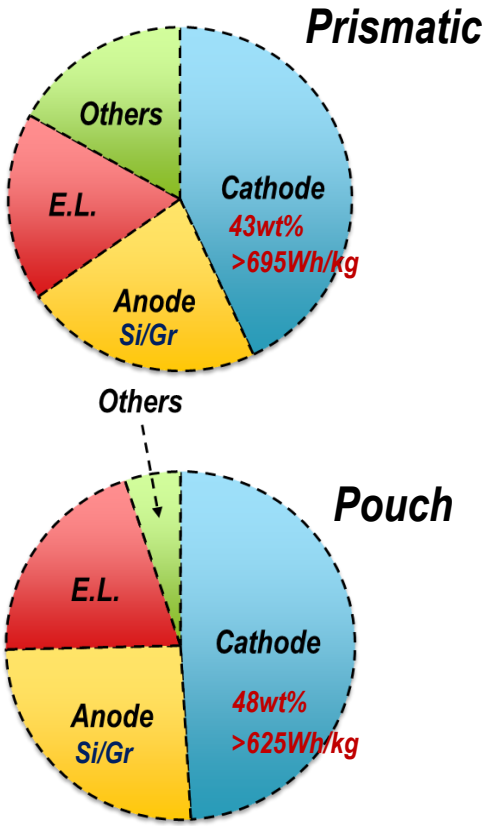
4.2V NMC811:
710Wh/kg
2555Wh/L
4.4V NMC532:
665Wh/kg
2425Wh/L
5.0V LNMO:
635Wh/kg
1905Wh/L
3.65V LFP:
570Wh/kg
1254Wh/L

Electrolyte
Separator
Binder
Carbon Black
Current Collector
Terminal
Safety Designs
Can or Package Foil
…….

Cell Balance

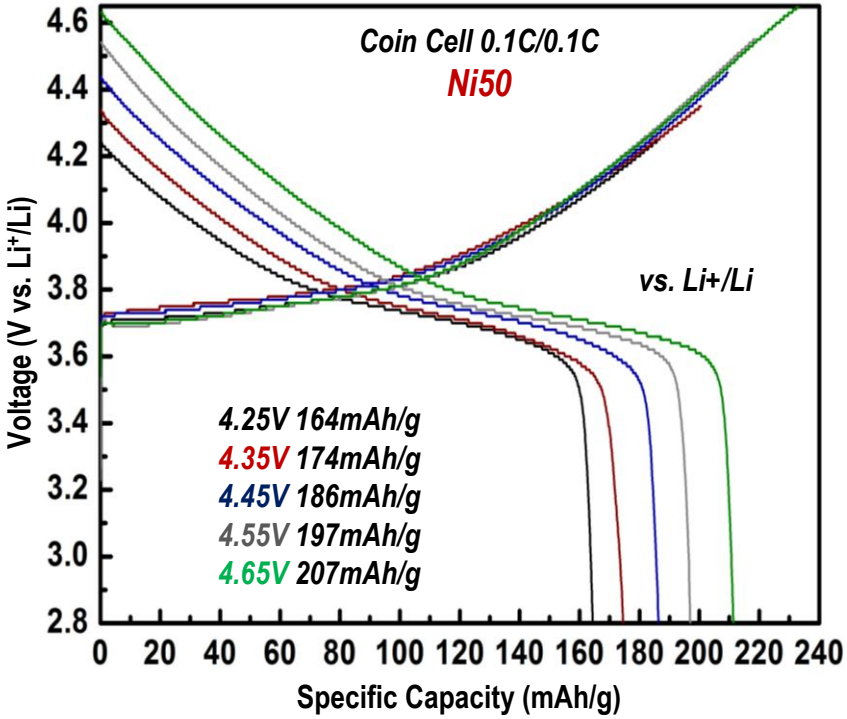
Anode

"Theoretical"
Energy Density
Gr 340:
500Ah/L
Gr 350:
515Ah/L
Gr 360:
530Ah/L
Si/Gr:
750Ah/L

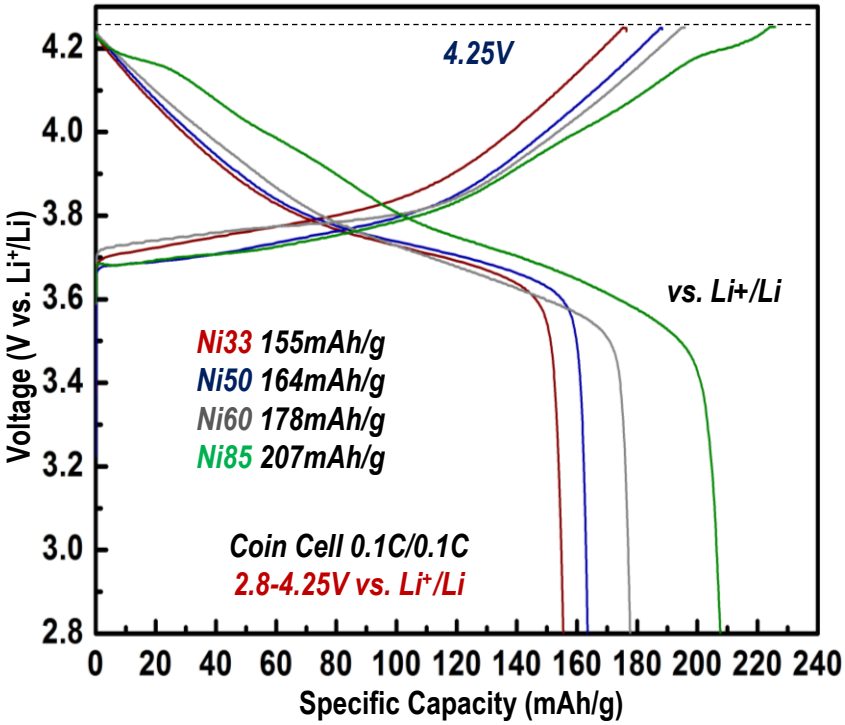


Routes to "Extract" More Energy

Elevate Cut-off Voltage

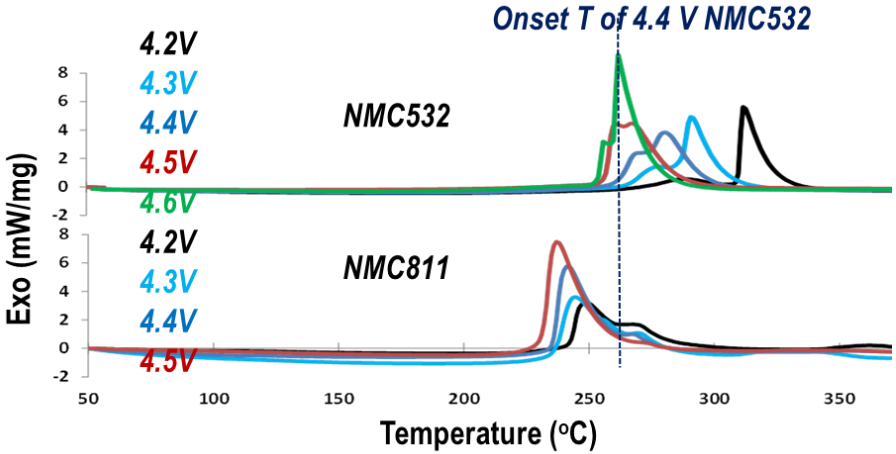


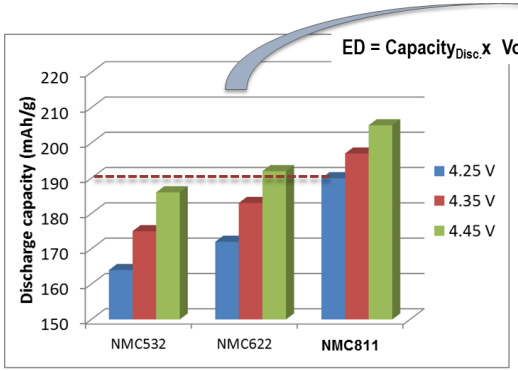
Increase Nickel Content



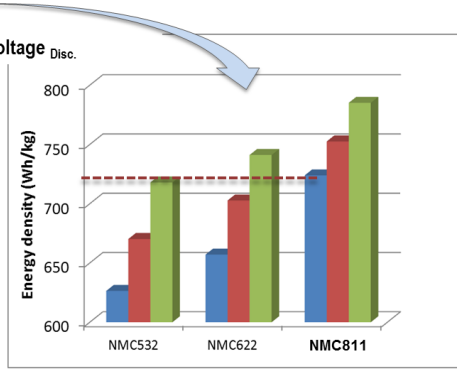
Generally speaking, there are two possible ways to gain more energy from NMC series cathodes: High Voltage or High Nickel!

HE Applications: High Voltage vs. High Nickel

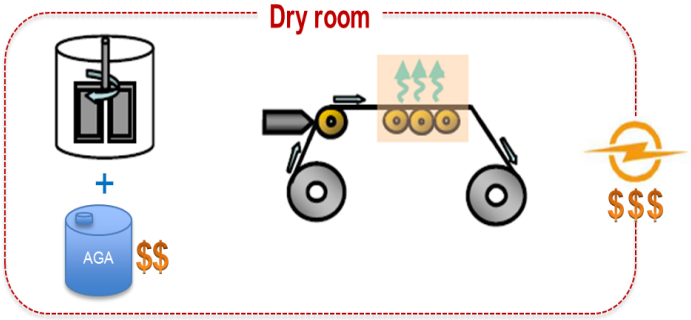




Discharge capacity vs cut-off voltage with different NMC compositions



Energy density vs cut-off voltage with different NMC compositions

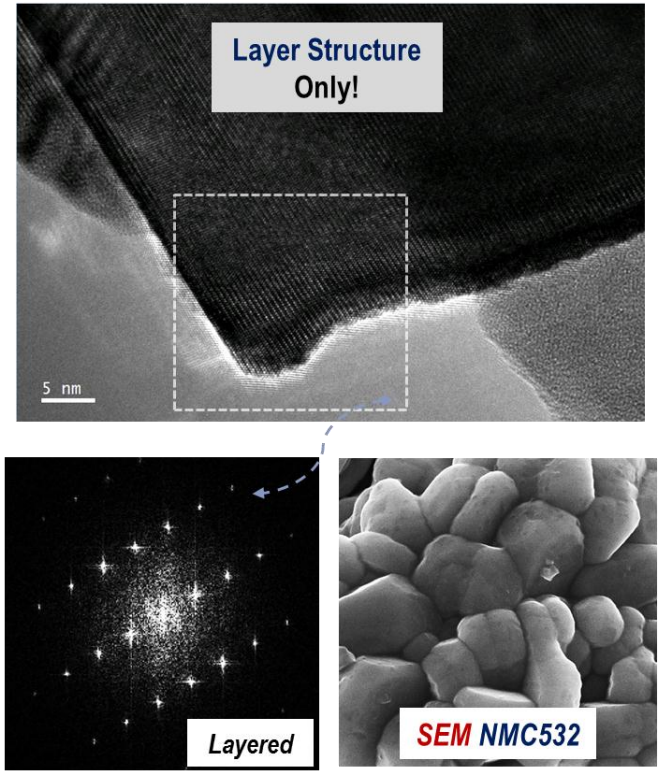


Though NMC811 is not comparable with NMC532/622 in chemistry maturity, the energy delivered by NMC 811 is higher and there are still room for improvement.

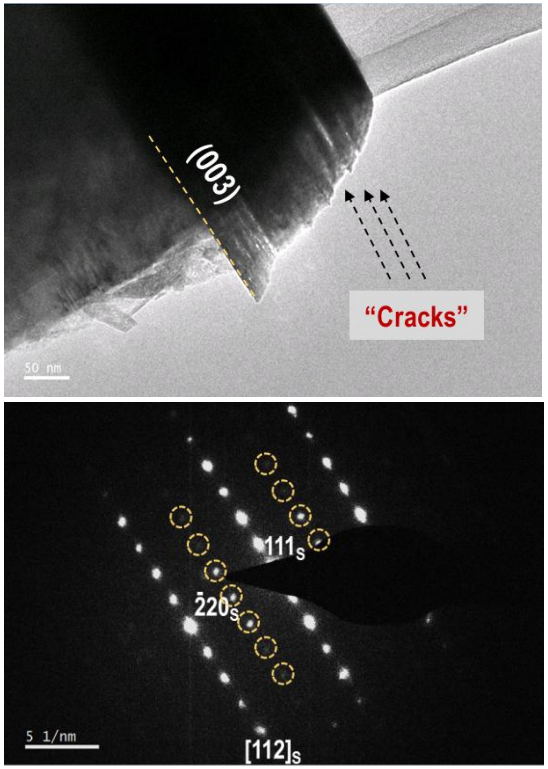
Need to consider case by case !

Any Problems for HE cathodes?

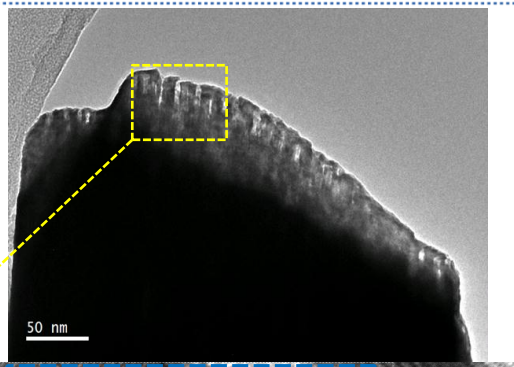
Pristine NMC 532

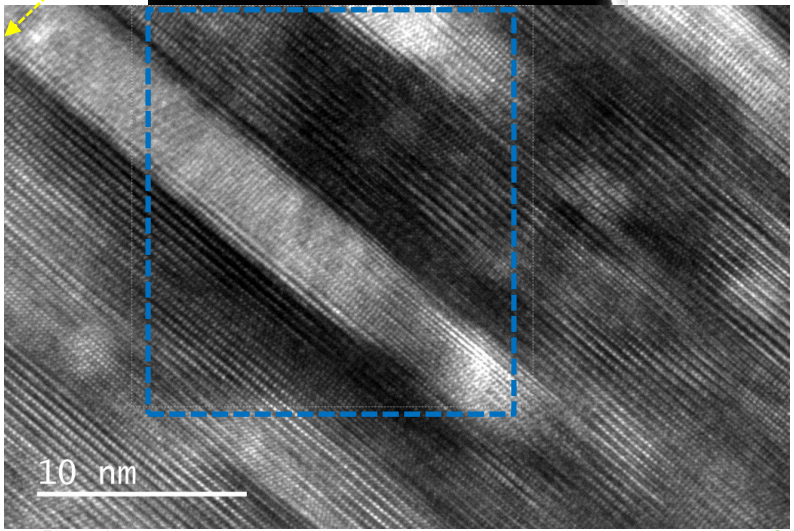


NMC 532 cycled@4.6V for 75 cycles

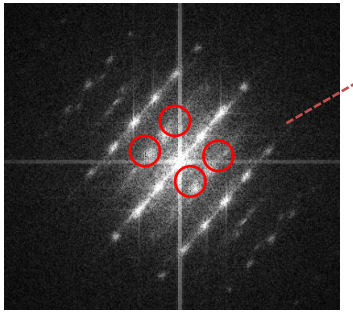


A Close Examination by TEM

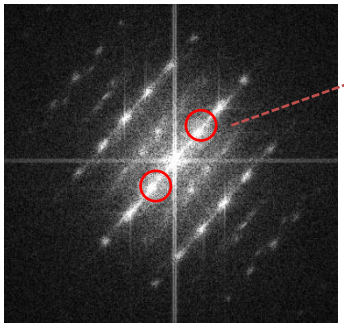




FT

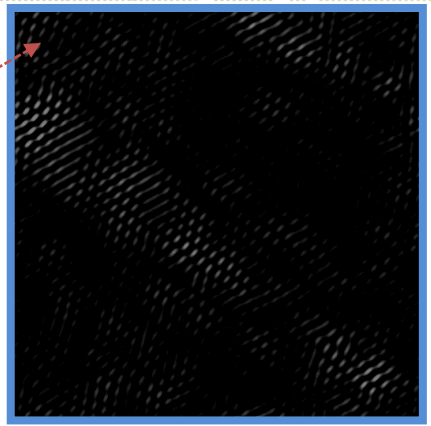


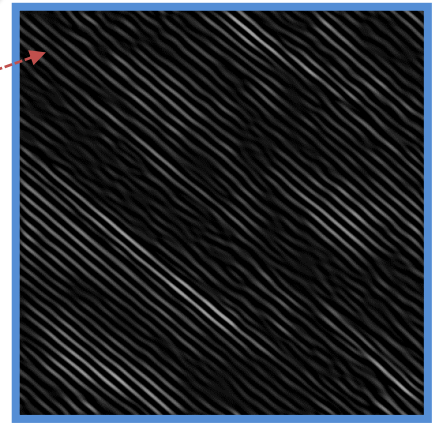
Spinel Fd-3m



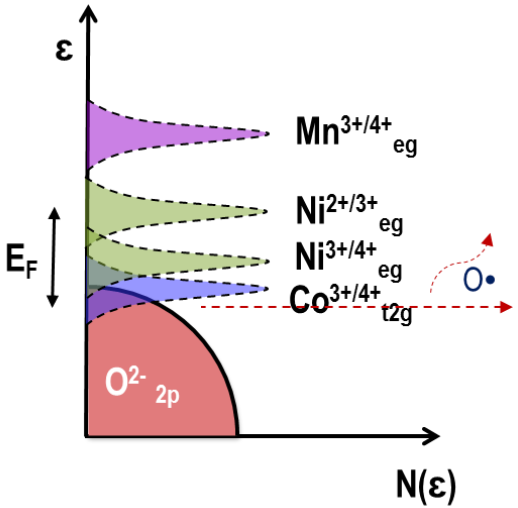
Layer R-3m

R-FT





Fast Decay Cause and Solution



Simultaneous Oxygen Release from Structure
--- Promote Phase Transition and Degradation of E.L.

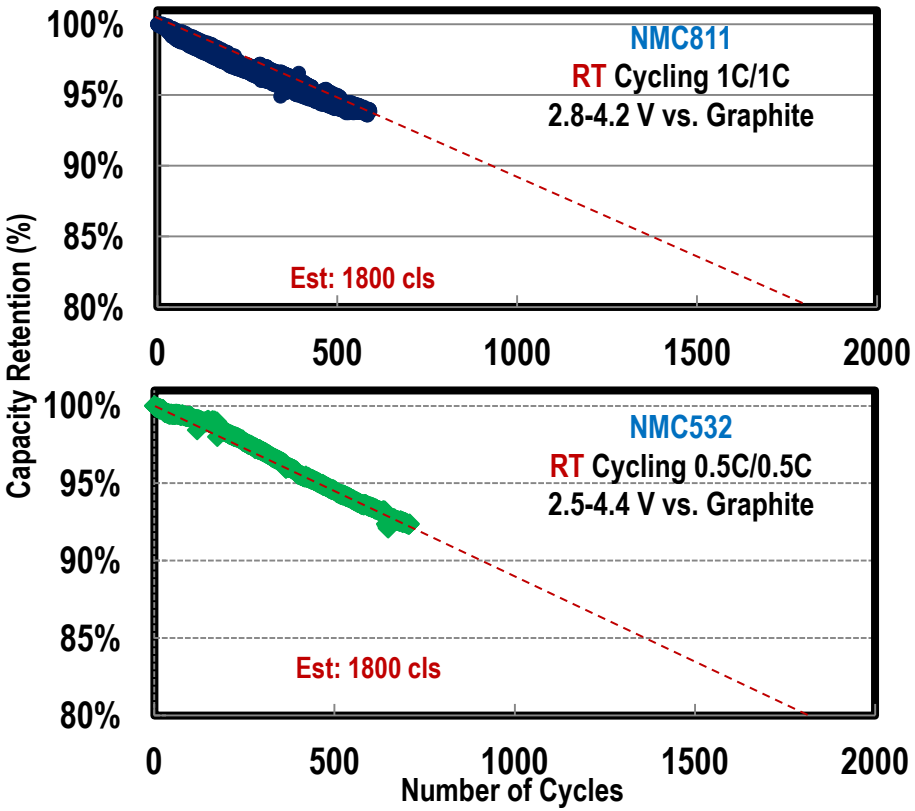
Find the Li^+ Removal Limit for Each NMC Composition
--- Keep a Distance from the Limit

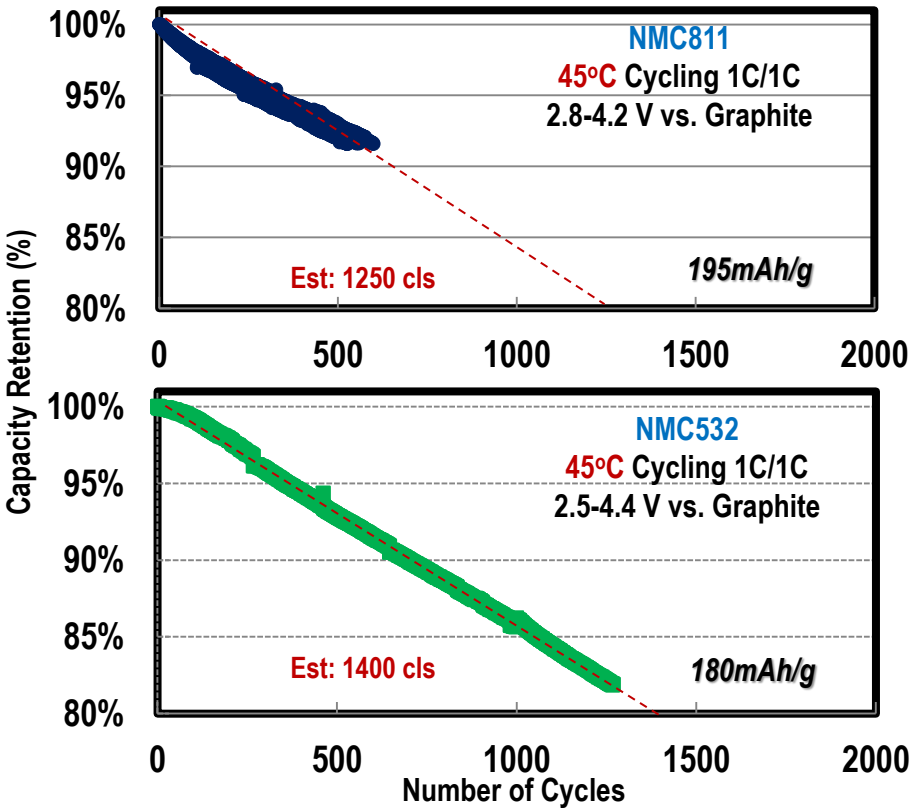
Make Sure All Cathodes Homogeneously Delithilated
--- Avoid Local Phase Transformation within Limitation

Homogenize Current Prevent Direct Contact: ***Coating*** ***New Electrolyte*** ***New Additive***

Better Tolerance of Structural Variation: ***Doping*** **Modify the Electronic Structure: Elevate M_{trans} 3d orbital**

State of Art: 811 vs. 532 2Ah Pouch





What about 500Wh/kg or even Higher?

Gravimetric Energy Density Target

500Wh/kg

~ 67%

300Wh/kg

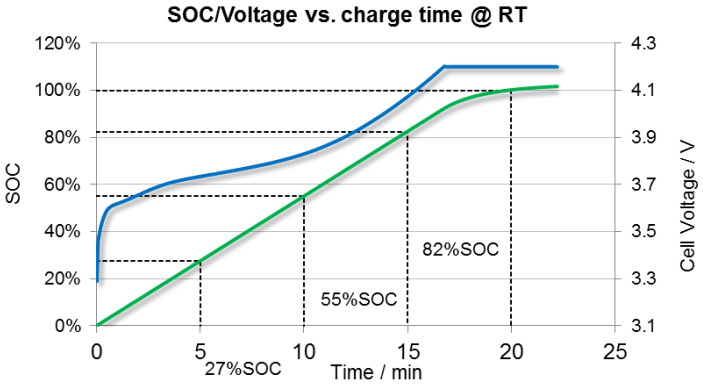
Not Enough Potential

NMC Cathode

Si/Gr Anode

But do we really need a car that covers more than 500km driving range?

What if we can do relatively fast charge?



Summary

- ***CATL is technology driven company***
  No. 3 of battery shipment in Wh worldwide in 2015 & 2016
- ***There are not much choices for HE cells (300Wh/kg)***
  --based on Si/Gr, either HV NMC or HN NMC needed to be used
- ***There are still a lot of technical issues of HE cathode***
  --formation of rock salt/spinel structure on the surface hinders Li^+ transportation
  --interface needs to be taken into consideration (cathode surface & CEI)
- ***CATL demonstrates that both HV & HN cathodes are ready for the next generation cells in chemistry aspect. Recommended to use case by case!***
- ***Fast charge might be an alternative choice other than squeezing the last drop of juice from organic solvent based Li-ion batteries.***

solid power inside™
可靠动力 源于内涵

advanced automotive battery conference europe

Thanks for Your Attention!

Liang Tao

Mainz, Feb. 2nd 2017