Advanced Technology
Reliable Quality
Customer Satisfaction

CALB

Development and application of CALB olivine-phosphate batteries

Agenda

- Introducing CALB
- Application and research on LFP/C batteries
- Development of high energy NCM+LMFP/C batteries
- Summary

Company profile

- Set up in 2008, CALB is a leading company in power Li-ion battery manufacturing for various applications.
- A large state-owned enterprise with headquarter in Luoyang, China, and expanding globally.
- registered capitals $130 million
- Since 2010, an investment of $600 million was made to build the new industrial park, which covers an area of 86 acres.
- As going into 2014, CALB now has more than 1,700 professional staffs worldwide.

Competitiveness

One of the largest Specialized power Lithium Battery R&D and Production Project in China

EV Models Application
Ranking **Top** in China

Energy Storage Application
Ranking **Top** in China

Power Lithium Battery Export
Ranking **Top** in China

3 Automatic Production Lines
Production Capacity: **600MWH/year**

One of the Top Large-capacity LFP Power Battery Manufacturer in China

xEV

Energy Storage

Market
Application

Mining Equipment

Telecommunication

Cell technology-material chemistry

➢ Prismatic cell

Positive active material:	LFP
Negative active material:	Graphite
Electrolyte:	LiPF6/carbonates
Separator:	PP/PE with ceramic coating
Hardware:	Aluminum or plastic case

➢ Pouch cell

Positive active material:	NCM
Negative active material:	Graphite
Electrolyte:	LiPF6/carbonates
Separator:	PP/PE with ceramic coating

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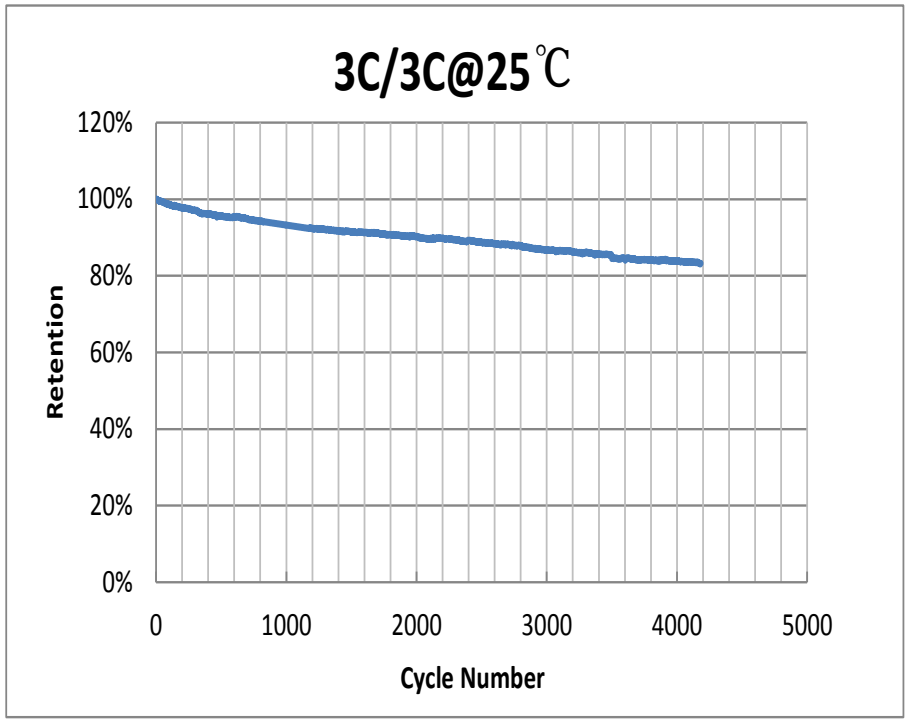
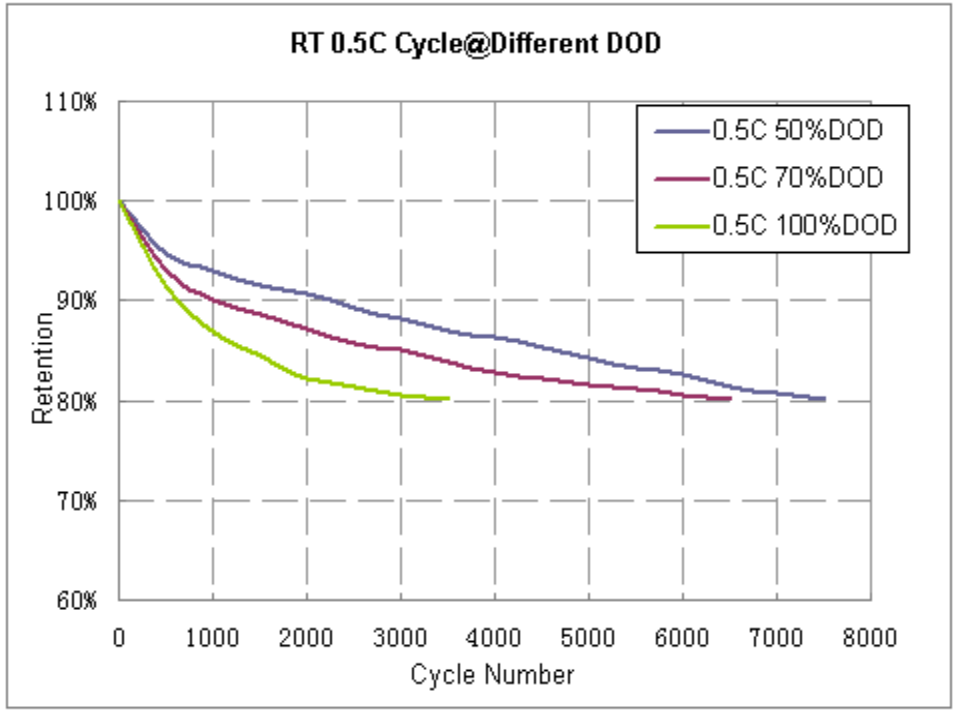
Cell performance- long cycle life

Capacity: over 80% retention after 4000 cycles
Test: 25°C, 80%DOD



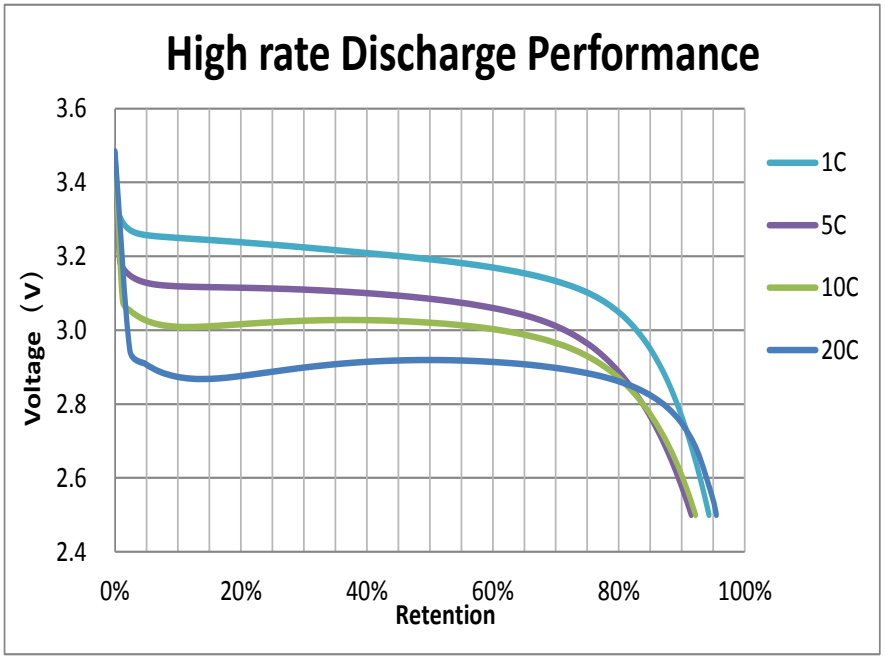
Capacity: over 80% retention after 7000 cycles
Test: 25°C, 50/70/100%DOD

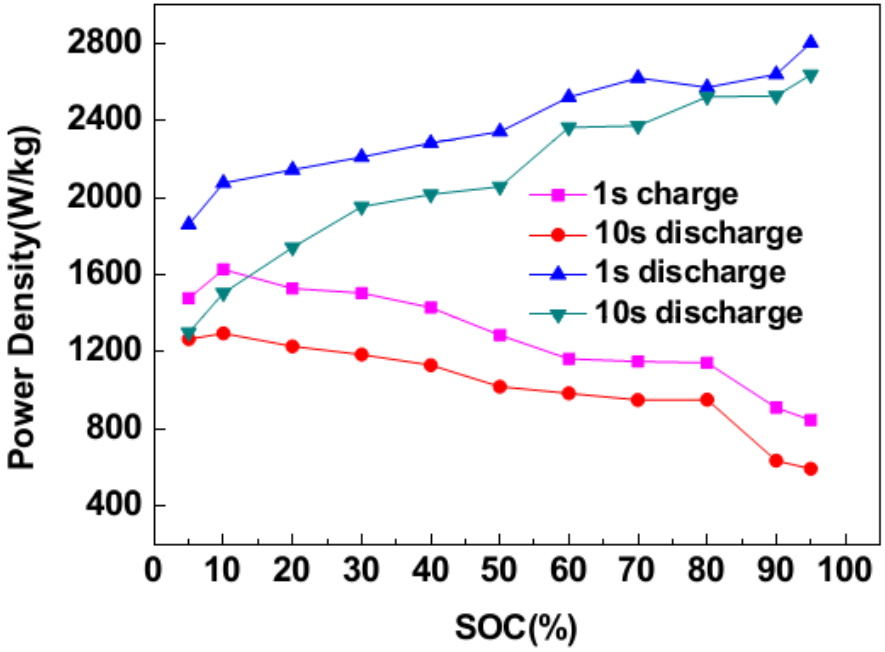


CAM battery-xEV

CA battery-ESS

Cell performance- rate and pulse power capability

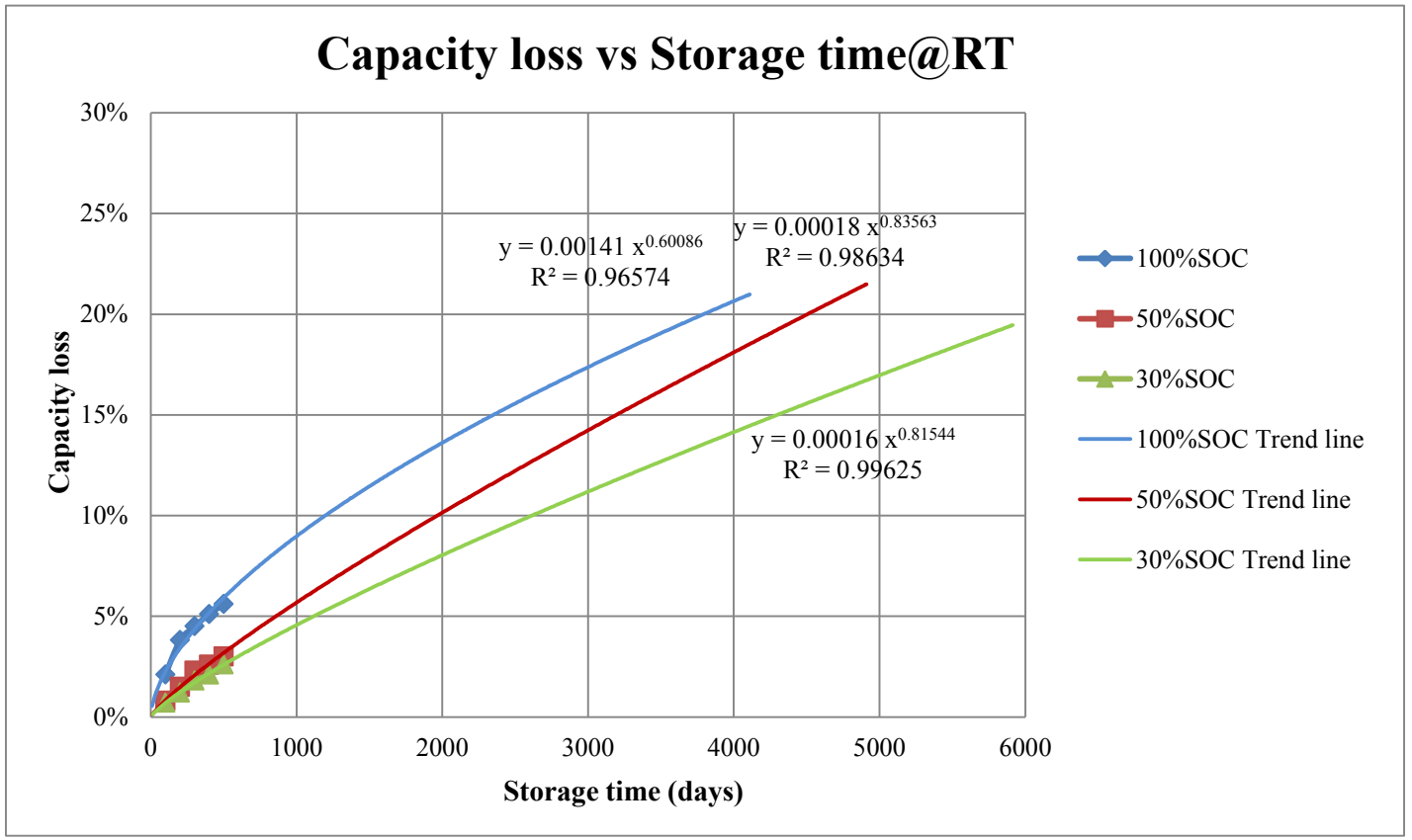




CAM battery-xEV

Cell performance- calendar life

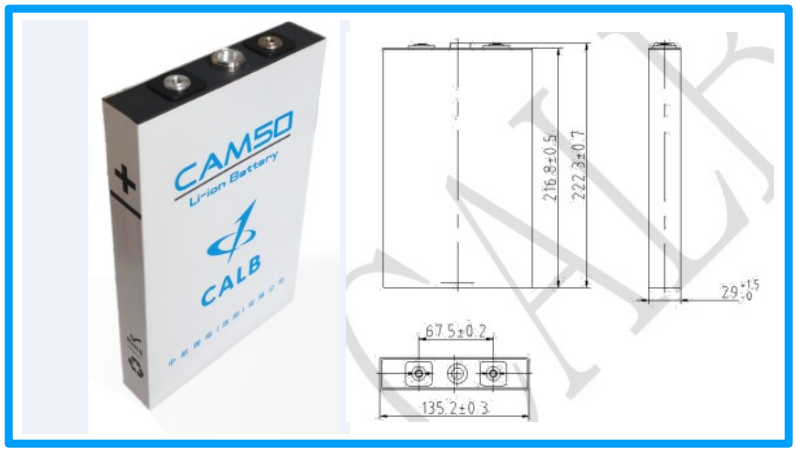
Natural degradation at rest



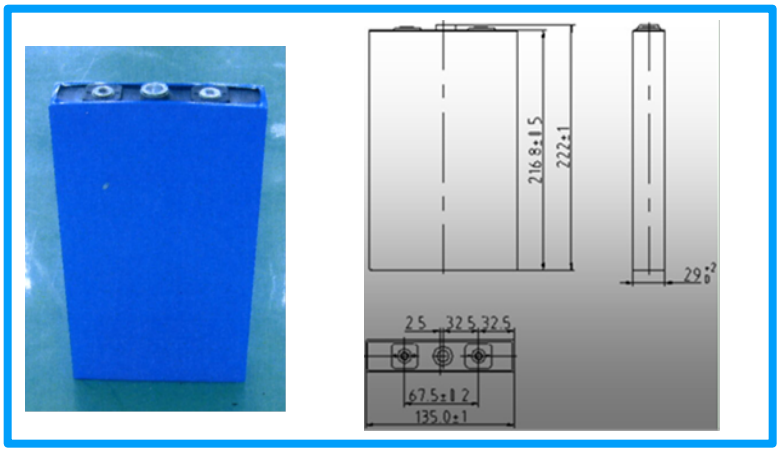
Calendar life over 10 years to match vehicle life

Cell performance- high safety

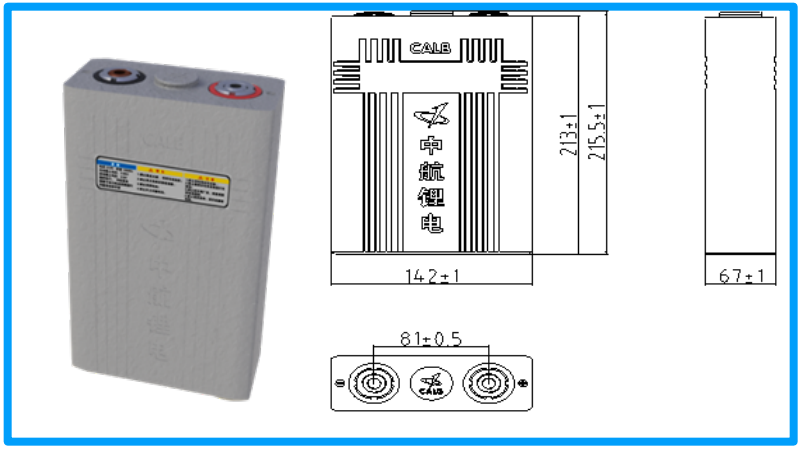
CAM50FI



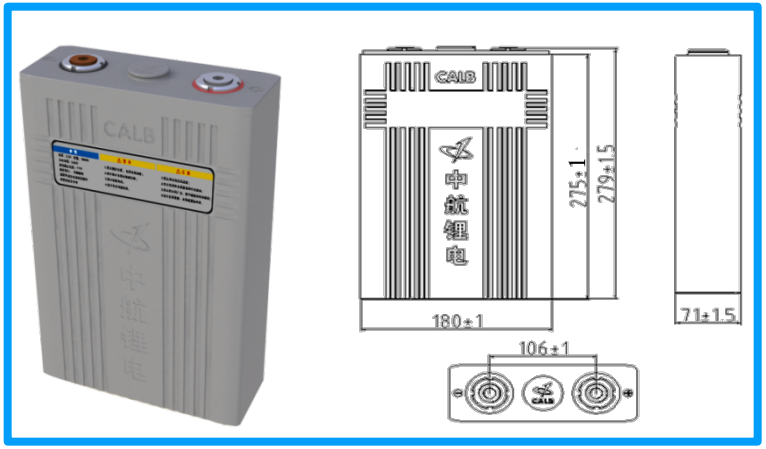
CAM72FI



CA100FI



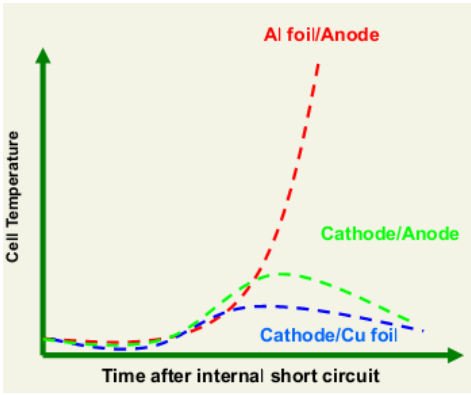
CA180FI



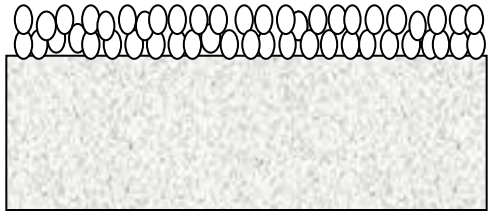
UL,
TUV,
CE,
ROHS,
MSDS,
UN38.3
certified

Safety improvement approach

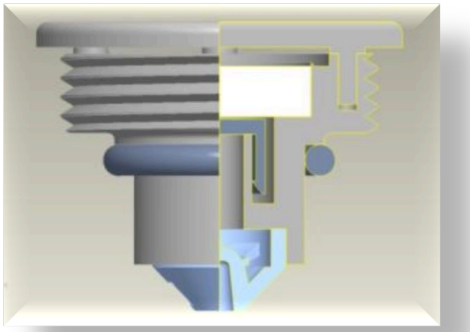
- Applying cathode electrode edge protection to prevent internal short between Al foil and anode



- Applying ceramic layer coating on separator/anode to prevent internal short and thermal runaway



- Applying safety vent with trigger pressure to prevent rapid gas buildup within the cell which might lead to explosion

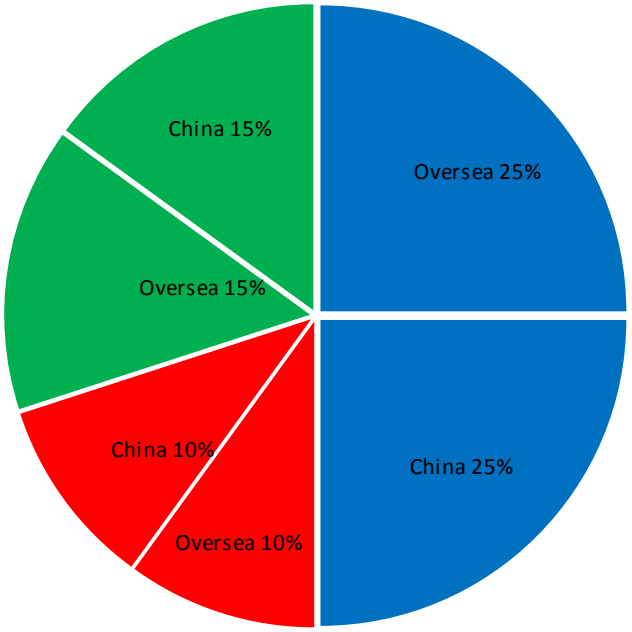


Application of LFP /C battery

EV

Energy Storage

Revenue Decomposition



- ESS 50%
- Telecom 20%
- EV 30%

Telecommunication

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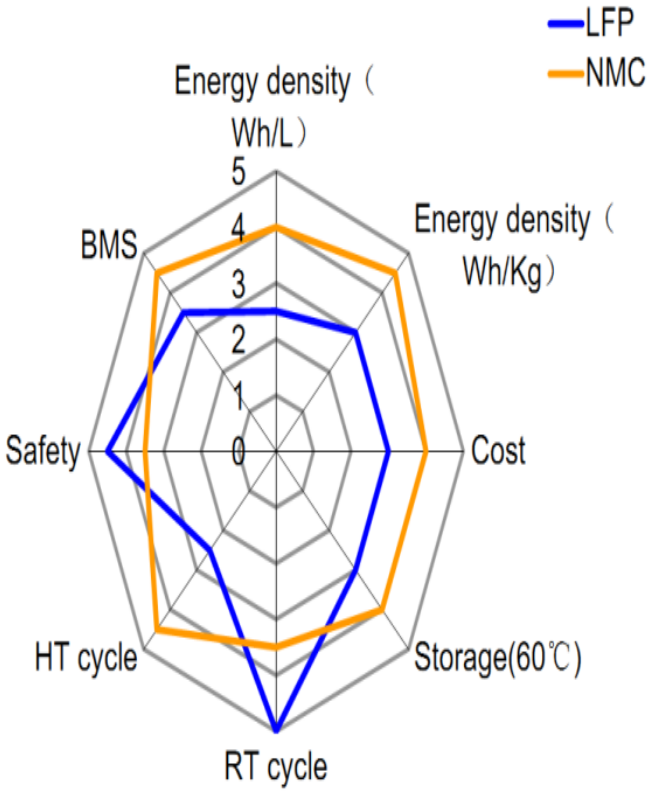
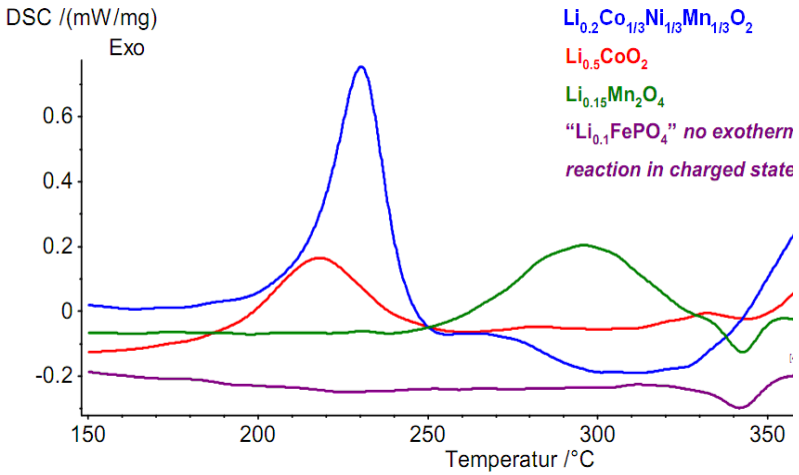


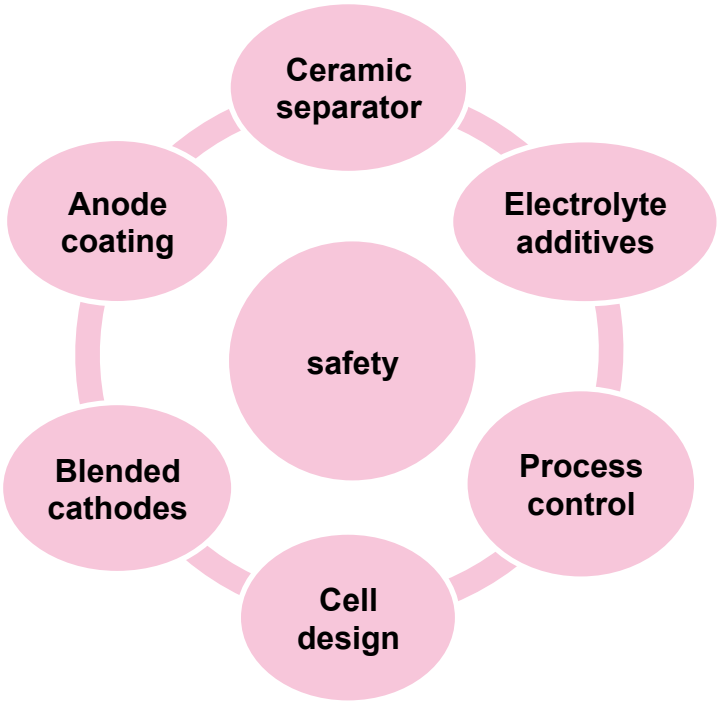
NCM based cathode dominates EV cells

Cell Maker	Chemistry	Capacity
	Anode/Cathode	Ah
AESC	G/LMO-NCA	33
LG Chem	G/NMC-LMO	36
Li-Tec	G/NMC	52
Li Energy Japan	G/LMO-NMC	50
Samsung	G/NMC-LMO	64
Lishen Tianjin	G-LFP	16
Toshiba	LTO-NMC	20
Panasonic	G/NCA	3.1

From LFP to NCM，significant energy density increase can be achieved，which is much needed in xEV application

AABC，2014





Safety improvement

through

Inspiring works

Remarkable improvement in cell safety for $Li[Ni_{0.5}Co_{0.2}Mn_{0.3}]O_2$ coated with $LiFePO_4$

W.-S. Kim [a], S.-B. Kim [a], I.C. Jang [b], H.H. Lim [b], Y.S. Lee [b,*]

$xLi_2MnO_3 \cdot (1-x)LiMO_2$ blended with $LiFePO_4$ to achieve high energy density and pulse power capability

Kevin G. Gallagher [a,*], Sun-Ho Kang [a], Sei Ung Park [b], Soo Young Han [b]

Effect of $LiFePO_4$ coating on electrochemical performance of $LiCoO_2$ at high temperature

Hong Wang [a,*], Wei-De Zhang [b,*], Lun-Yu Zhu [a], Ming-Cai Chen [a]

Dual active material composite cathode structures for Li-ion batteries☆

J.F. Whitacre [a,*], K. Zaghib [b], W.C. West [c], B.V. Ratnakumar [c]

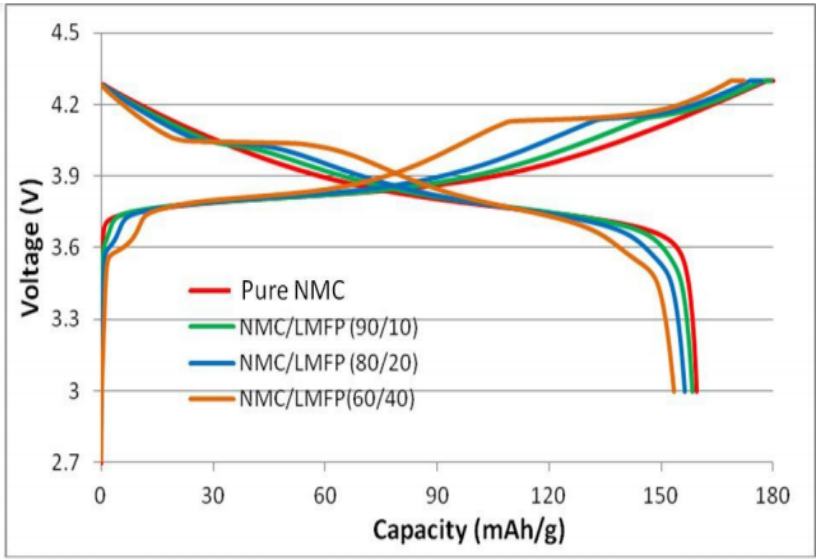
Coating or mixing with LFP can improve cell safety using layered cathode material

NCM+LMFP

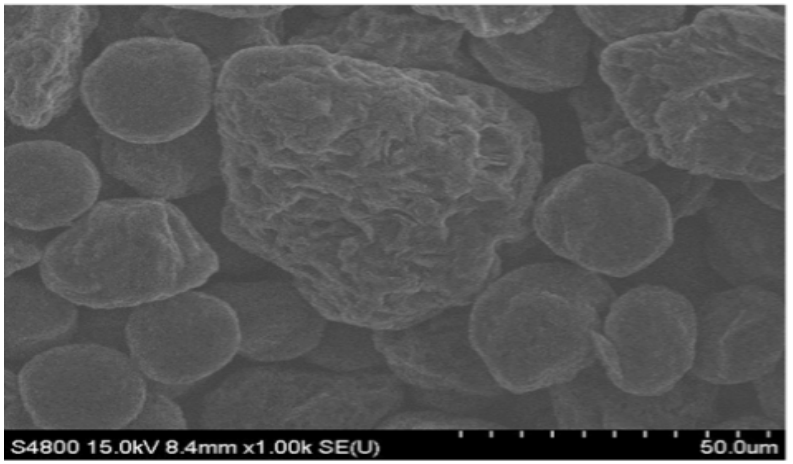
How to improve the safety of NCM cell while still achieving high energy density?

High energy density

Capacity of blended material of NCM and LMFP was 160mAh/g, 158 mAh/g, 156 mAh/g and 152mAh/g with the concentration ratio of LMFP being 0, 10%, 20% and 40%, respectively.



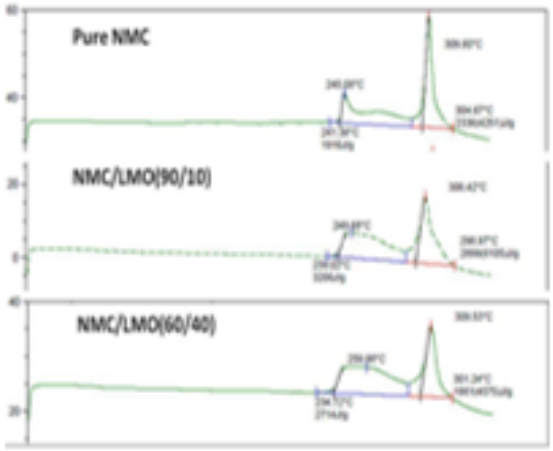
Packing density remains 3.2g/cm3 even with LMFP being 40% in the blend.

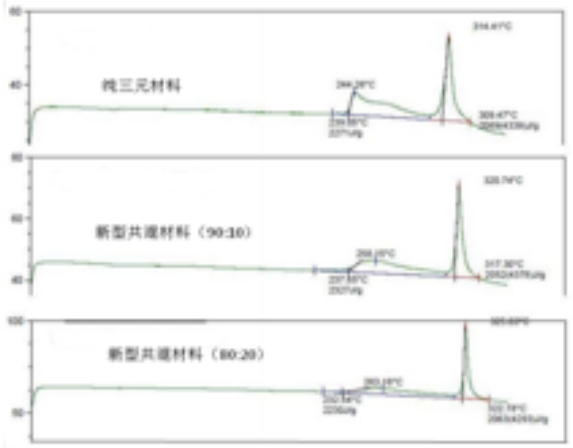


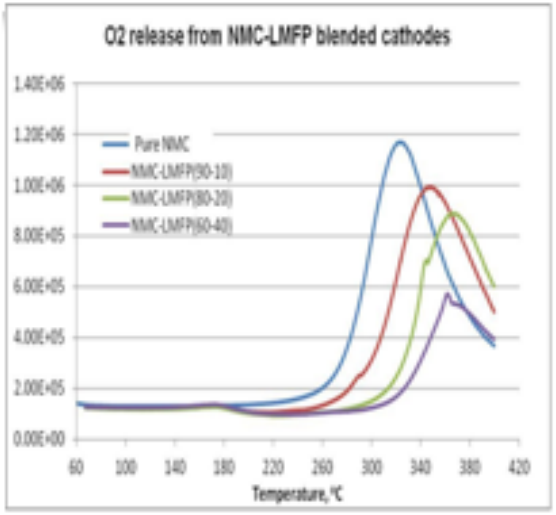
Pouch cell (20Ah) using such blend cathode and graphite anode shows high working voltage about 3.7V and energy density over 170wh/kg.

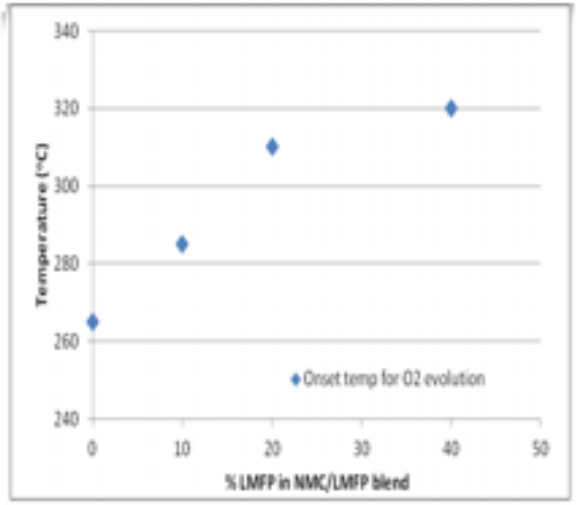
Safety improvement

DSC analysis shows O2 release decreases with the increase of LMFP concentration in the blend, indicating that intermixed NCM/LMFP shows better thermal stability over pure NCM as well as intermixed NCM/LMO.

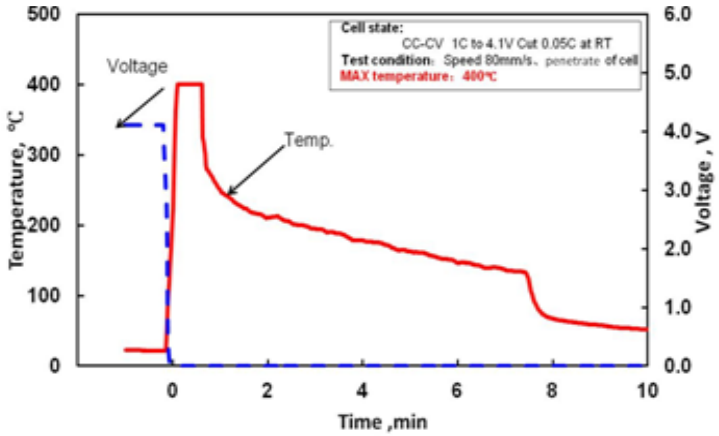




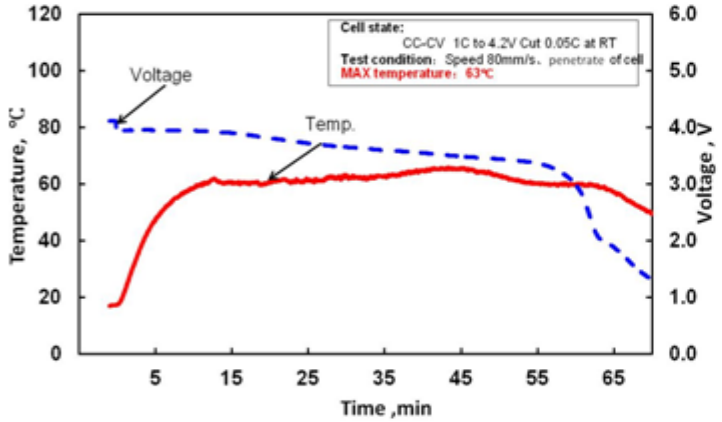




Safety improvement



Temperature and voltage change during penetration for pure NCM cell



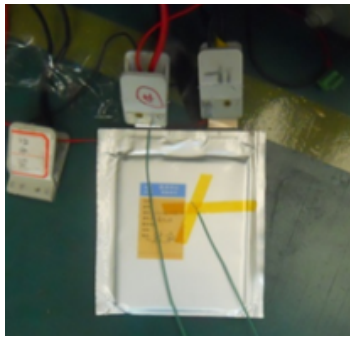
Temperature and voltage change during penetration for NCM/LFMP cell

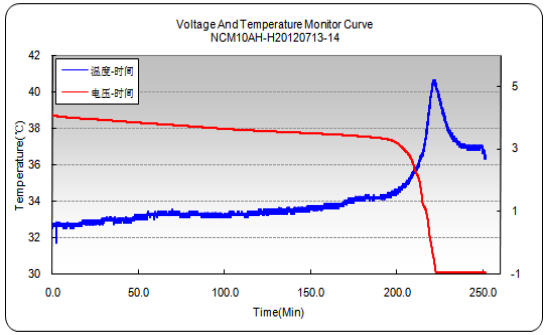
Cell safety was significantly improved after adopting blend active materials

NCM/graphite

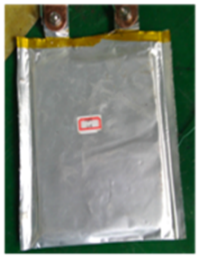
NCM/LMFP/graphite

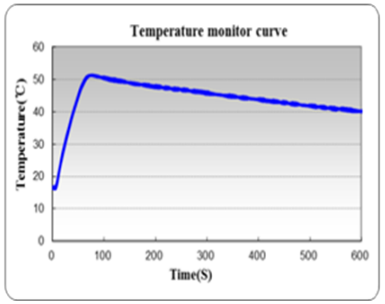
Safety improvement

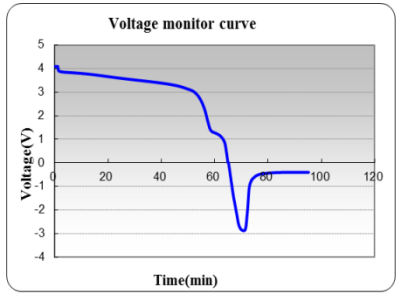


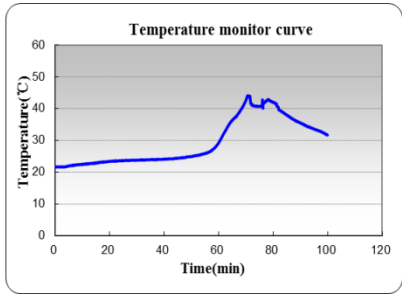


外部短路测试温度变化曲线和电池照片

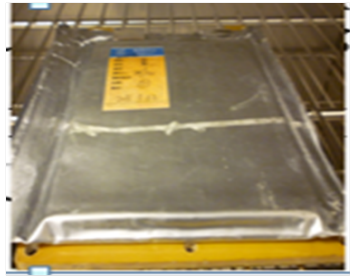


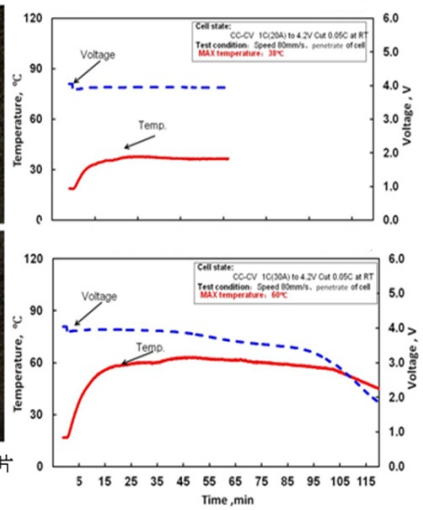






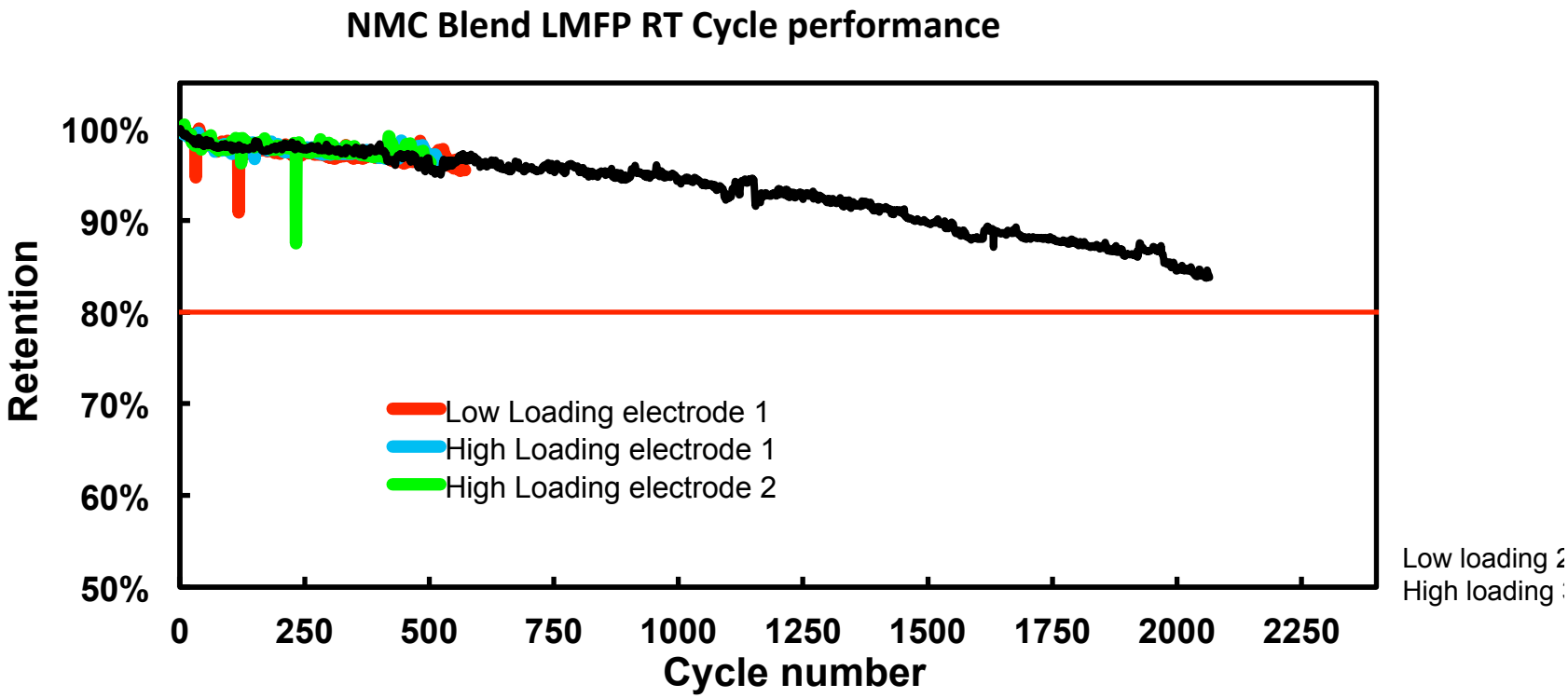
Safety test results for overcharge, overdischarge, short circuit, heating and nail penetration





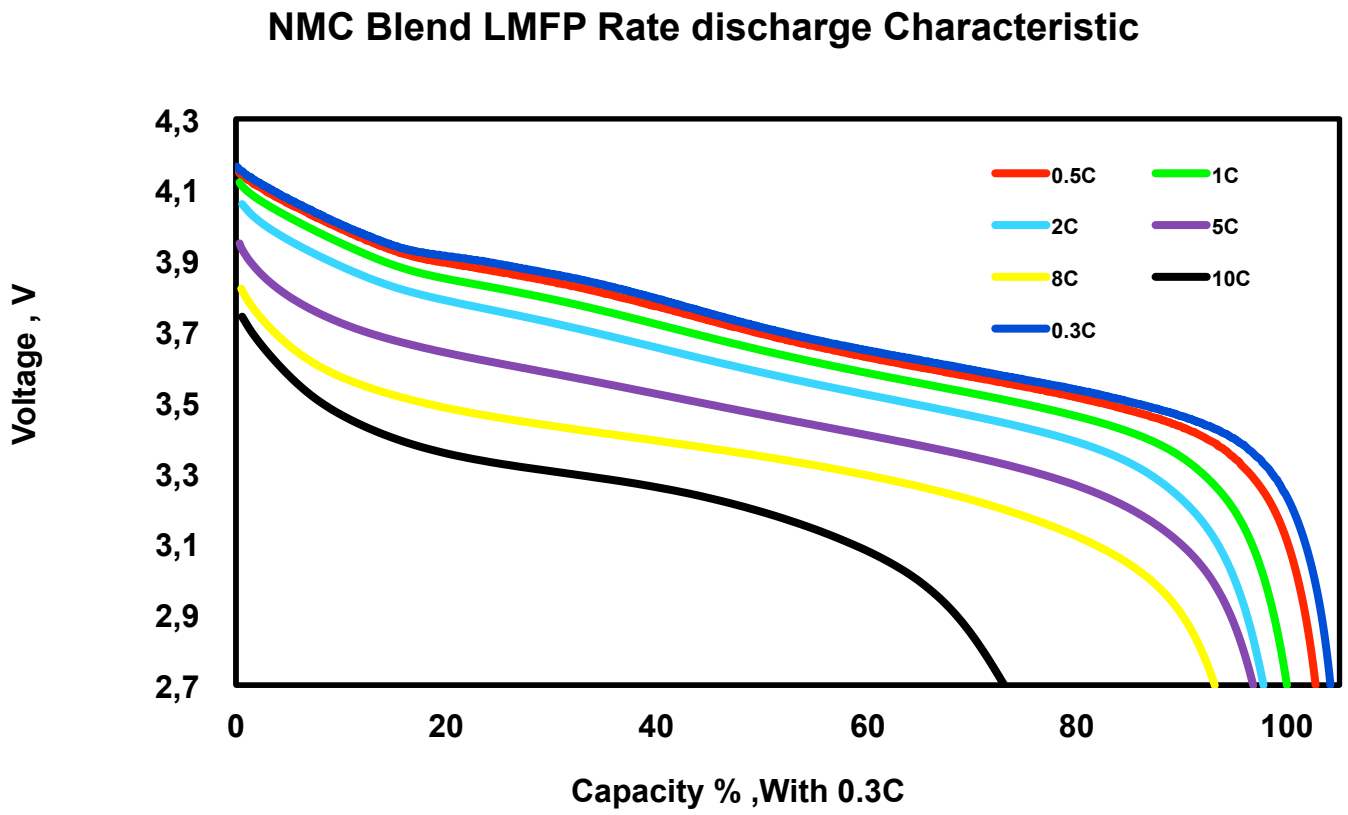
针刺过程温度和电压变化曲线和电池照片

Cycle life



Battery with blend cathode undergoes 2000 cycles at room temperature with capacity retention over 85%, which is comparable to LFP battery

Rate performance



Battery with blend cathode shows good rate capability even discharged up to 10C

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Summary

- Long-term cycling、good rate capability and high thermal stability has made Olivine-structured LFP an ideal positive material for EV and ESS battery.
- Promoted by Chinese battery manufacturers, LFP batteries have been widely adopted in EV、ESS、telecom and many other applications
- NCM+LMFP blend shows high energy density、long cycle life、good thermal stability and enhanced safety improvement compared to pure NCM or NCM+LMO blend, making it a promising cathode candidate for xEV battery
- CALB is committed to continuous research and improvement of Olivine-phosphate batteries，and will keep expanding its application in a lot of areas.

Thanks !

CALB

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