Status Quo and General Tendency of Vehicle Power Battery in China

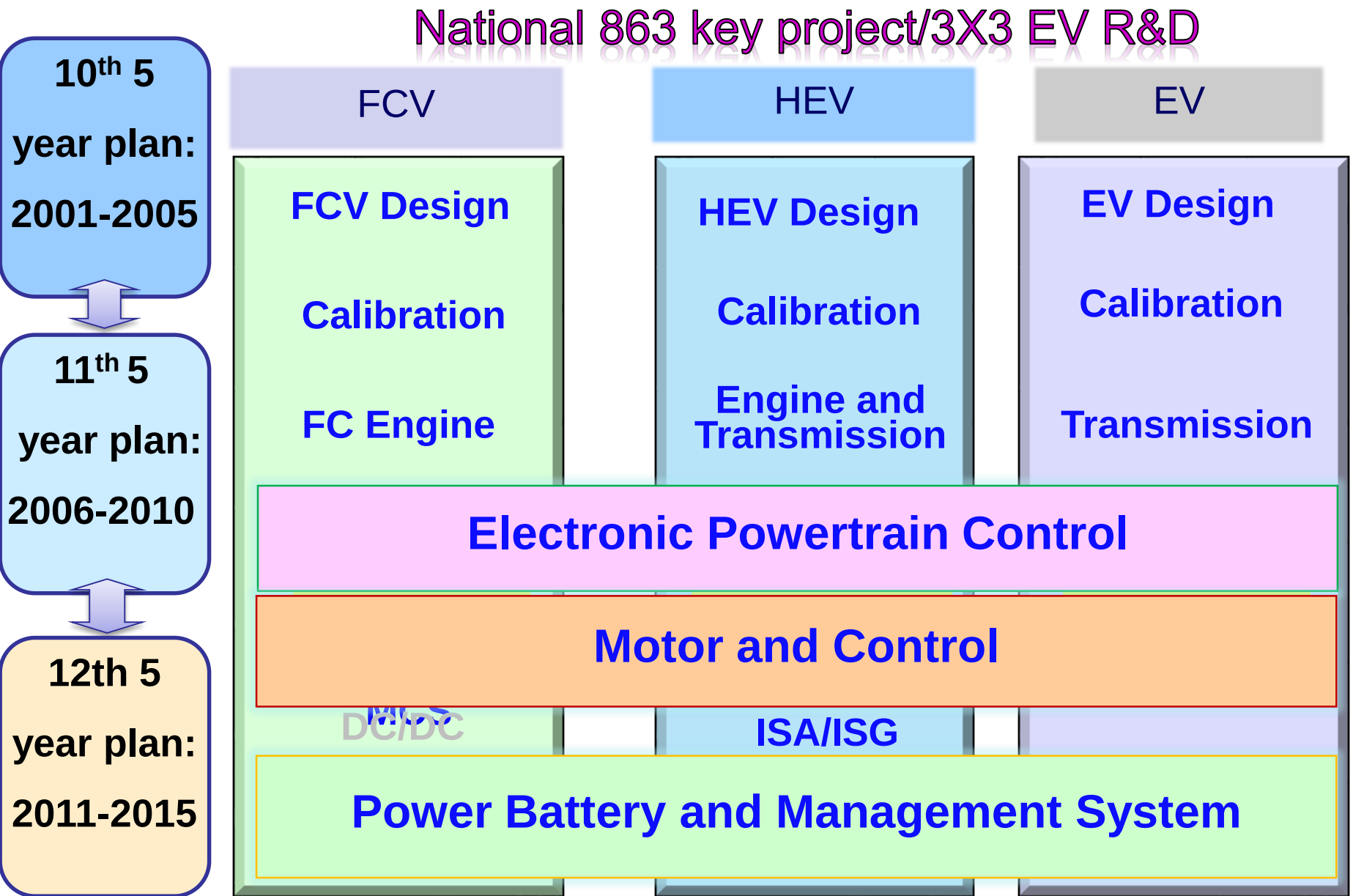
Huang Xuejie

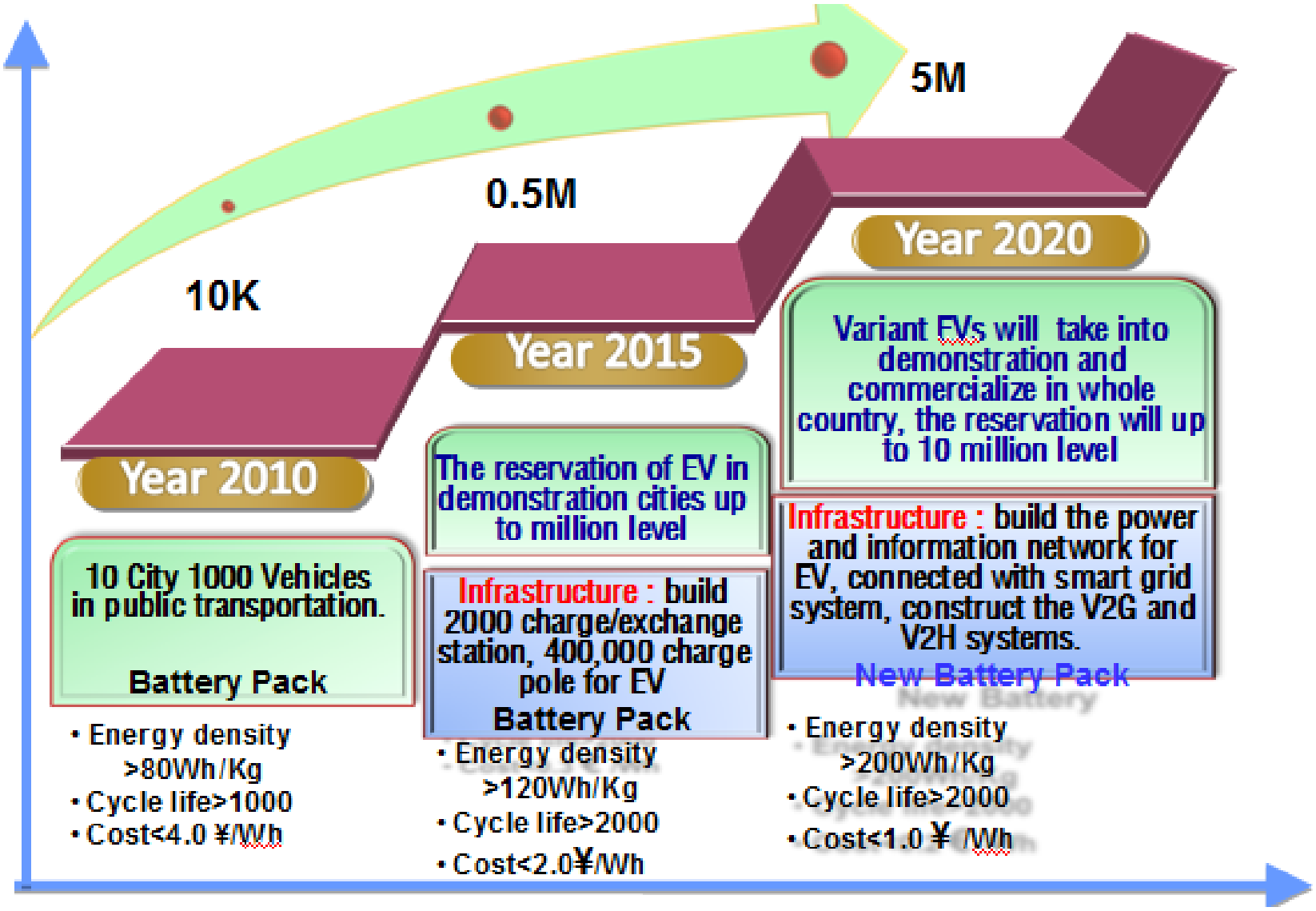
Institute of Physics Chinese Academy of Sciences

November 21, 2014

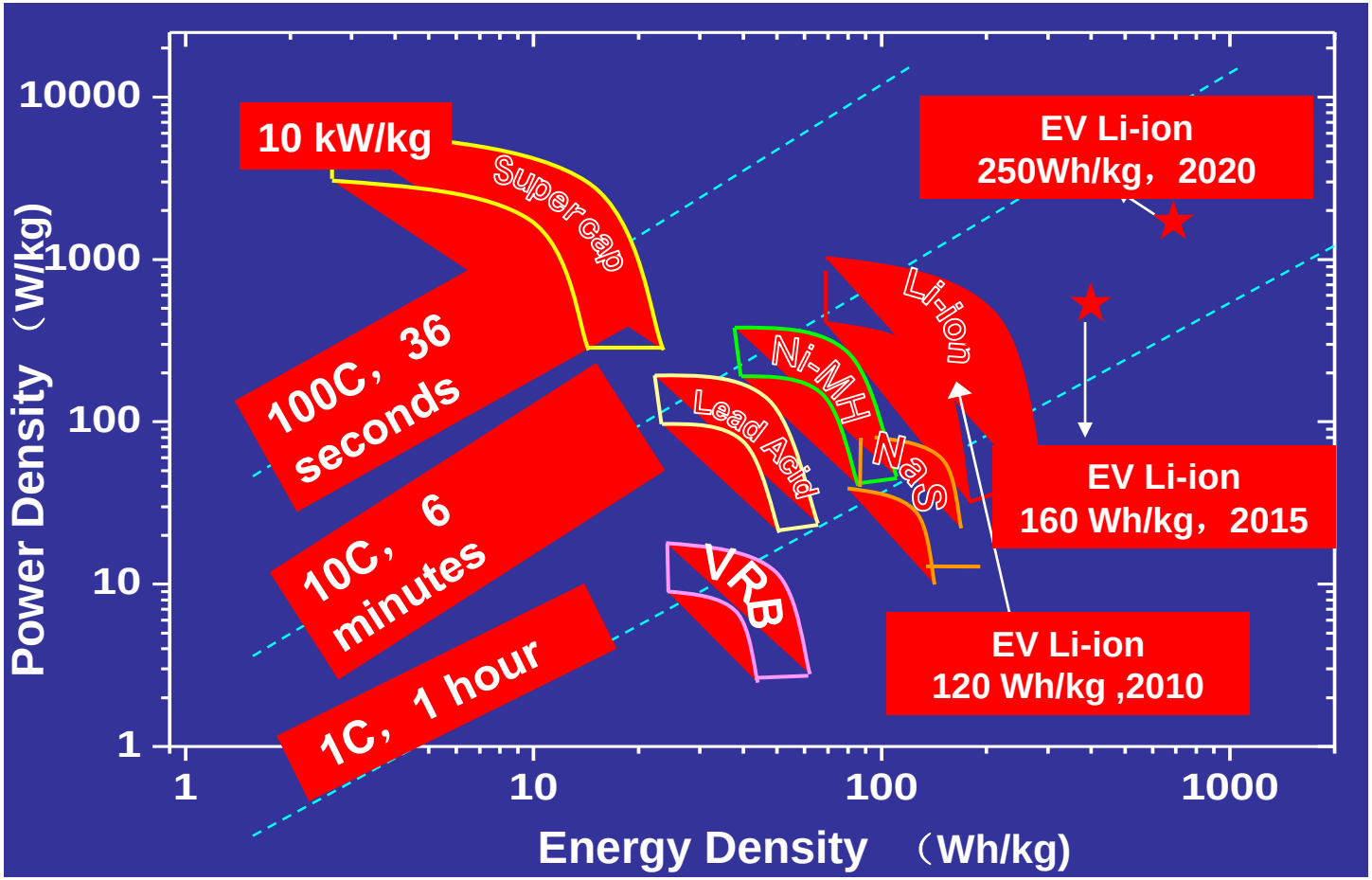
Overview of china EV

Project of EV supported by MOST

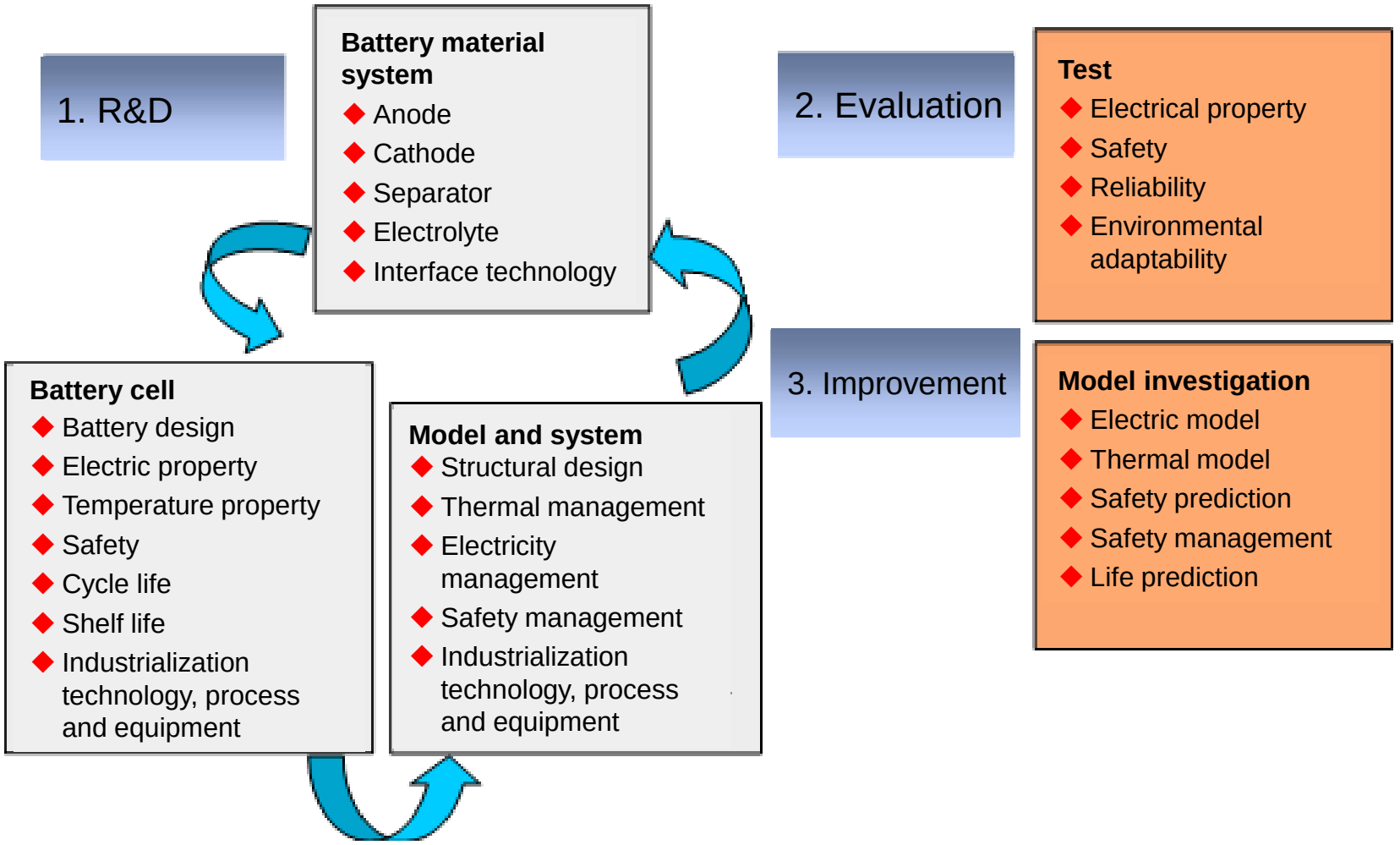



10K
0.5M
5M
Year 2010
Year 2015
Year 2020
10 City 1000 Vehicles in public transportation.
Battery Pack
• Energy density >80Wh/Kg
• Cycle life>1000
• Cost<4.0 ¥/Wh
The reservation of EV in demonstration cities up to million level
Infrastructure : build 2000 charge/exchange station, 400,000 charge pole for EV
Battery Pack
• Energy density >120Wh/Kg
• Cycle life>2000
• Cost<2.0¥/Wh
Variant EVs will take into demonstration and commercialize in whole country, the reservation will up to 10 million level
Infrastructure : build the power and information network for EV, connected with smart grid system, construct the V2G and V2H systems.
New Battery Pack
• Energy density >200Wh/Kg
• Cycle life>2000
• Cost<1.0 ¥ /Wh

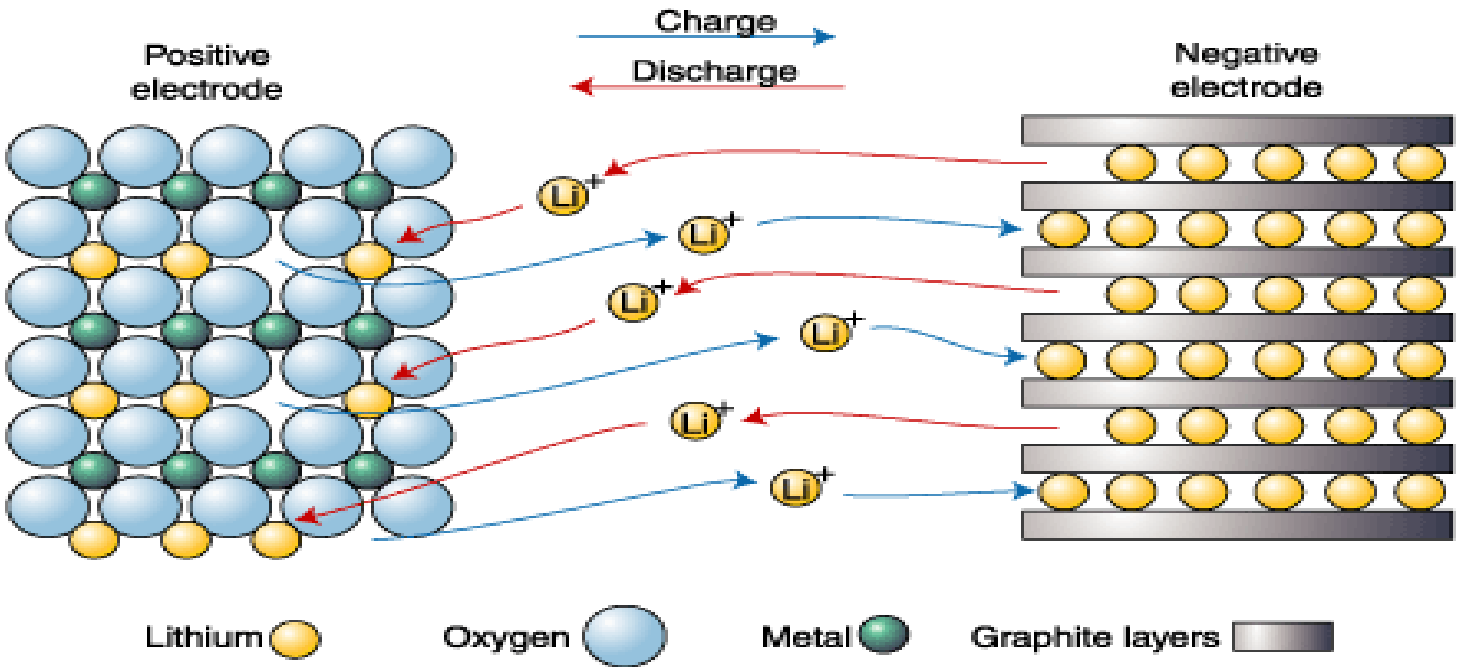
Electrochemical energy storage technologies



Power Battery Technology Chain



The development of high-performance battery depends on the technological advances of anode/cathode/separator/electrolyte and other key materials

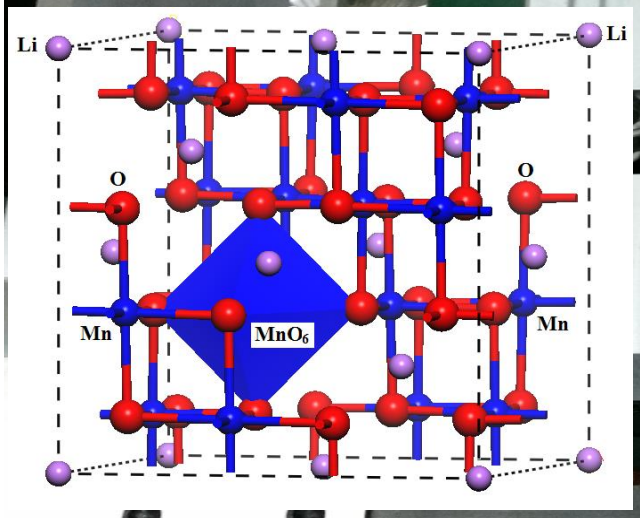


Anode Separator/Electrolyte Cathode

Cathode materials	Average voltage relative to lithium metal (V vs Li)	Specific energy available (mAh/g)	Specific energy of anode materials(Wh/kg，by the average voltage relative to lithium metal)	Expected specific energy after connecting the graphite cathode(Wh/kg)	Predication of safety, cost and service life
$LiCoO_2$	**3.9**	**140**	**546**	**200**	High battery volumetric energy density, long service life, high cost and low safety
$LiMn_2O_4$	**4.0**	**110**	**440**	**140**	High safety, low cost, but short service life
$LiFePO_4$	**3.4**	**155**	**527**	**160**	High safety, low cost and long service life
NCM	**3.8**	**160**	**646**	**220**	Poor safety, low cost and long service life
$LiNi_{0.5}Mn_{1.5}O_4$	**4.7**	**130**	**611**	**200**	High safety, low cost and technology to be broken through
Li-rich oxides	**3.6**	**270**	**972**	**280**	Poor safety, low cost and further research required

$LiMn_2O_4$(LMO) cells

- High safty
- Low cost
- 140Wh/Kg



Independent R&D of Mechanized equipment

- **Equipment feature: independent R&D suitable to flat sheet separator packaging**

The separator packaging machines have been successfully developed according to technological characteristics and have obtained patent right. Put the separator onto the surface of anode to conduct lamination works.

First-generation separator packaging machine

Second-generation separator packaging machine

Lamination stacking machine

CADRE DE VILLE

es facteurs
e modernisent

AMÉLIORER LA DISTRIBUTION

u camion à la boîte aux lettres

the standard in safety

Underwriters Laboratories

NOTICE OF AUTHORIZATION TO APPLY THE UL MARK

2009-07-29

Phylon Battery (suzhou) Co Ltd
Mr. JAMES LEE
81 Xiangyang Rd
Snd
Suzhou Jiangsu 215011, Cn

Our Reference: File M-29933, Vol. 1 Project Number 09CA21458
Your Reference: Susie Huang, 4-7-09
Project Scope: USR - Secondary Lithium Ion cell, Model IFP32/101152HA for UL investigation.

Dear Mr. JAMES LEE:

UL's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements.

This letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark only at authorized factories under UL's Follow-Up Service Program.

To provide the manufacturer with the intended authorization to use the UL Mark, the addressee must send a copy of this notice to each manufacturing location currently authorized in File M-29933, Vol. 1.

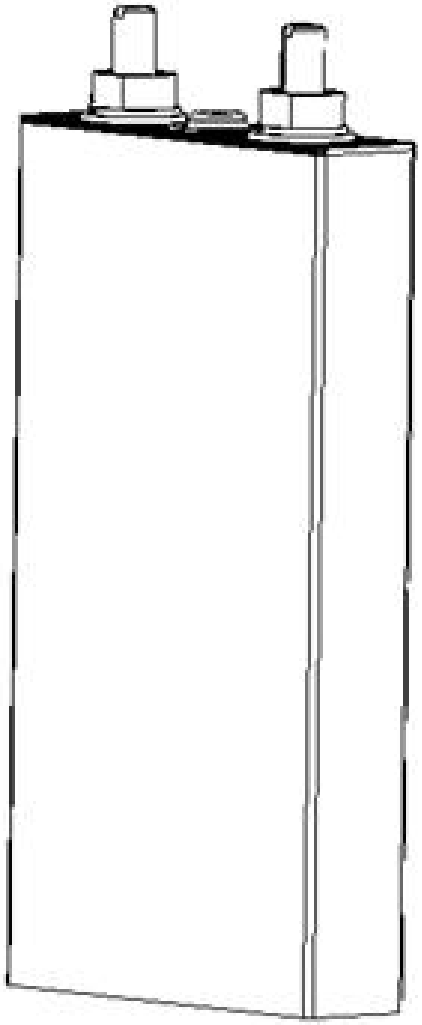
This authorization is effective from the date of this Notice and only for products at the indicated manufacturing locations. Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future.

Products that bear the UL Mark shall be identical to those that were evaluated by UL and found to comply with UL's requirements. If changes in construction are discovered, appropriate action will be taken for products not in conformance with UL's requirements and continued use of the UL Mark may be withdrawn. UL may elect to withdraw use of the UL Mark if the Applicant or Manufacturer fails to comply with UL's requirements including ongoing compliance of the product, under UL's Follow-Up Service.

This is an electronically generated letter. Signatures are not required for this document to be valid.

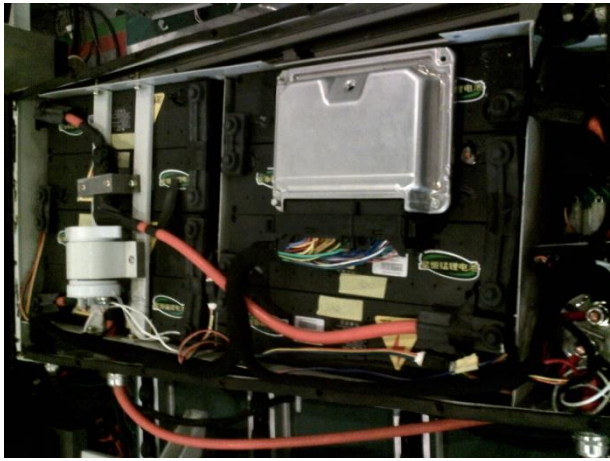
Page 1 of 2

High-power lithium-ion battery cell manufactured by Phylion Battery



1. Basic features		
Type	IMP20/66/148-08PS	
Thickness x Width x Height	20mm x 66mm x 148mm	
Nominal voltage	3.7V	
Nominal capacity	8Ah	
Internal resistance	≤6mΩ	
End-off voltage	2.7V	
Maximum charge voltage	4.2V	
Maximum charge current	8C (10s)	
Charging method	CC/CV（**Constant current and voltage**）	
Maximum discharge current	20C (20s)	
Weight	<420g	
Operating temperature	Charging	0～45℃
	Discharging	-20～45℃
Storage temperature (with 50% power and to be re-charged every three month)	-10～35℃	
2. Technical features		
Capacity at normal temperature C1	≥7.5Ah	
Rate discharge	2C	>95% C_1
	3C	>90% C_1
	5C	>85% C_1
Cycle life	1000 times (cycled to 60% at normal temperature 1C, 100% DOD）	

Lithium-ion power battery manufactured by Phylion Battery: From E-bike to EV



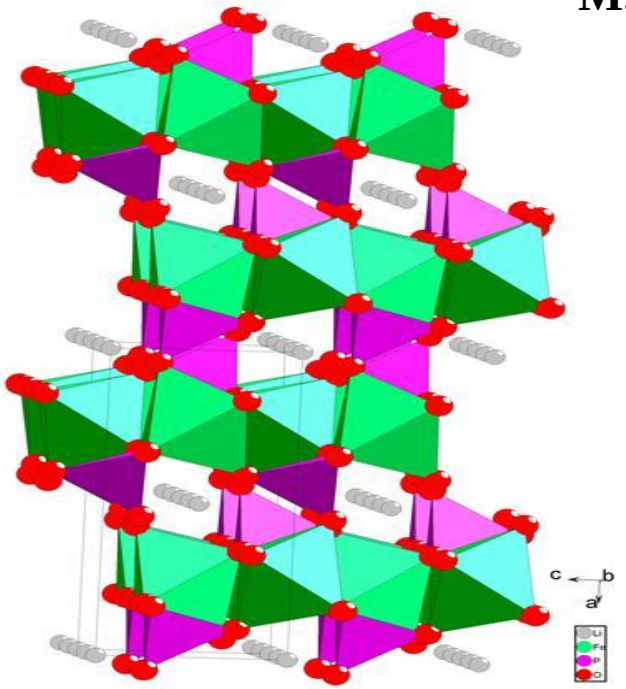
$LiFePO_4$(LFP) cells

M. Armand

$LiFePO_4$

1999

Carbon Coating



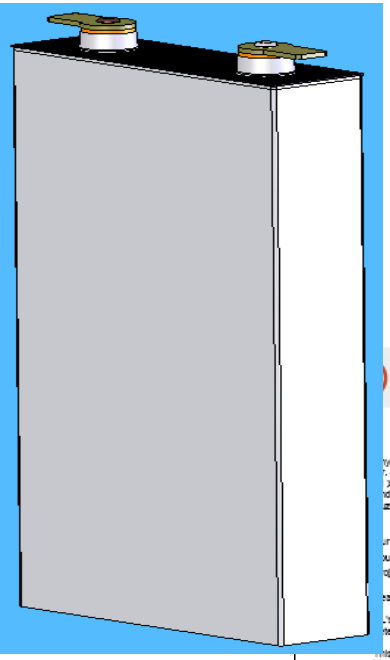
~170 mAh/g

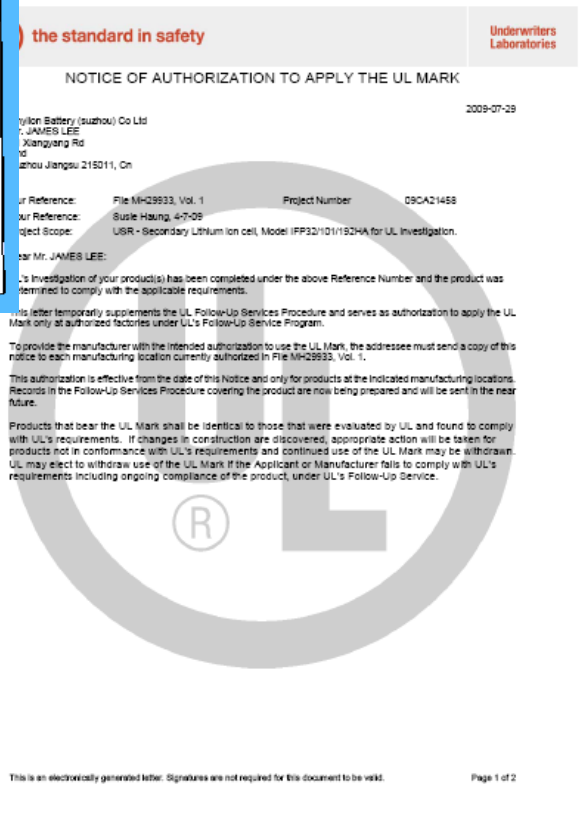
$\varphi_{Fe3+/Fe2+} = 3.4\,V$

$\varphi_{Mn3+/Mn2+} = 4.0\,V$

- High Safety
- Low cost
- Long life

40Ah LFP cells(120Wh/Kg, 1000W/Kg)





the standard in safety

Underwriters Laboratories

NOTICE OF AUTHORIZATION TO APPLY THE UL MARK

2009-07-29

...lion Battery (suzhou) Co Ltd
..., JAMES LEE
... Xiangyang Rd
...td
...uzhou Jiangsu 215011, Cn

...ur Reference: File MH29933, Vol. 1 Project Number 09CA21458
...our Reference: Susie Haung, 4-7-09
...oject Scope: USR - Secondary Lithium ion cell, Model IFP32/101/192HA for UL investigation.

...ear Mr. JAMES LEE:

...L's investigation of your product(s) has been completed under the above Reference Number and the product was determined to comply with the applicable requirements.

...his letter temporarily supplements the UL Follow-Up Services Procedure and serves as authorization to apply the UL Mark only at authorized factories under UL's Follow-Up Service Program.

To provide the manufacturer with the intended authorization to use the UL Mark, the addressee must send a copy of this notice to each manufacturing location currently authorized in File MH29933, Vol. 1.

This authorization is effective from the date of this Notice and only for products at the indicated manufacturing locations. Records in the Follow-Up Services Procedure covering the product are now being prepared and will be sent in the near future.

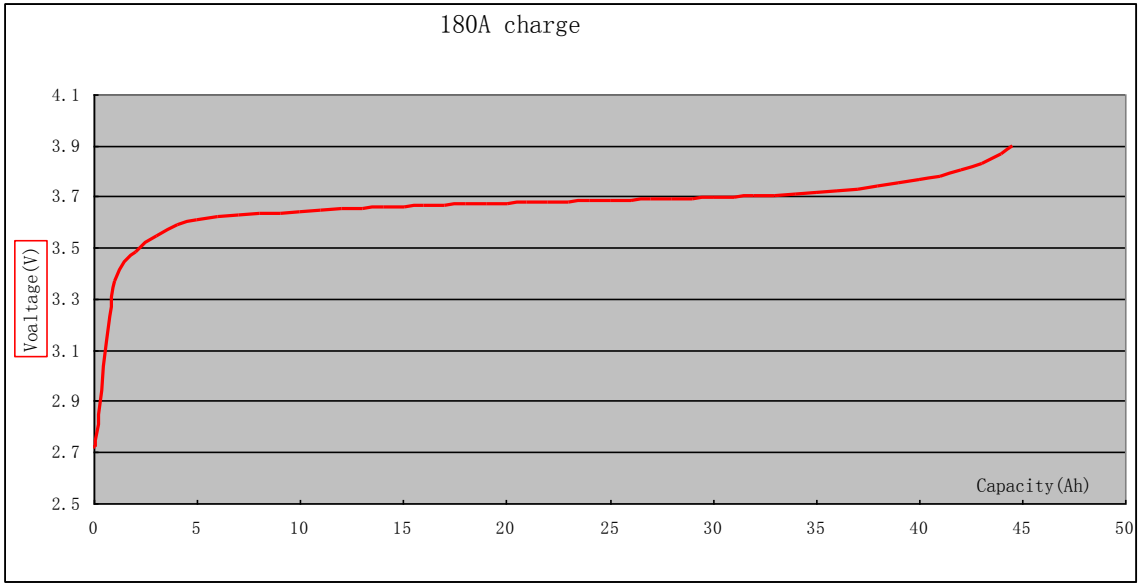
Products that bear the UL Mark shall be identical to those that were evaluated by UL and found to comply with UL's requirements. If changes in construction are discovered, appropriate action will be taken for products not in conformance with UL's requirements and continued use of the UL Mark may be withdrawn. UL may elect to withdraw use of the UL Mark if the Applicant or Manufacturer fails to comply with UL's requirements including ongoing compliance of the product, under UL's Follow-Up Service.

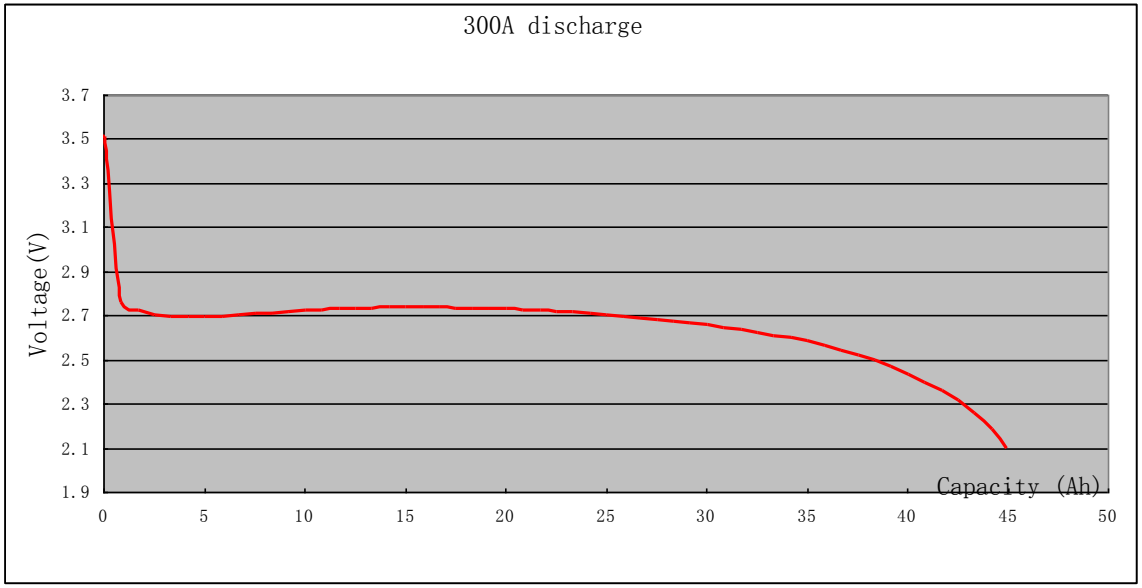
This is an electronically generated letter. Signatures are not required for this document to be valid.

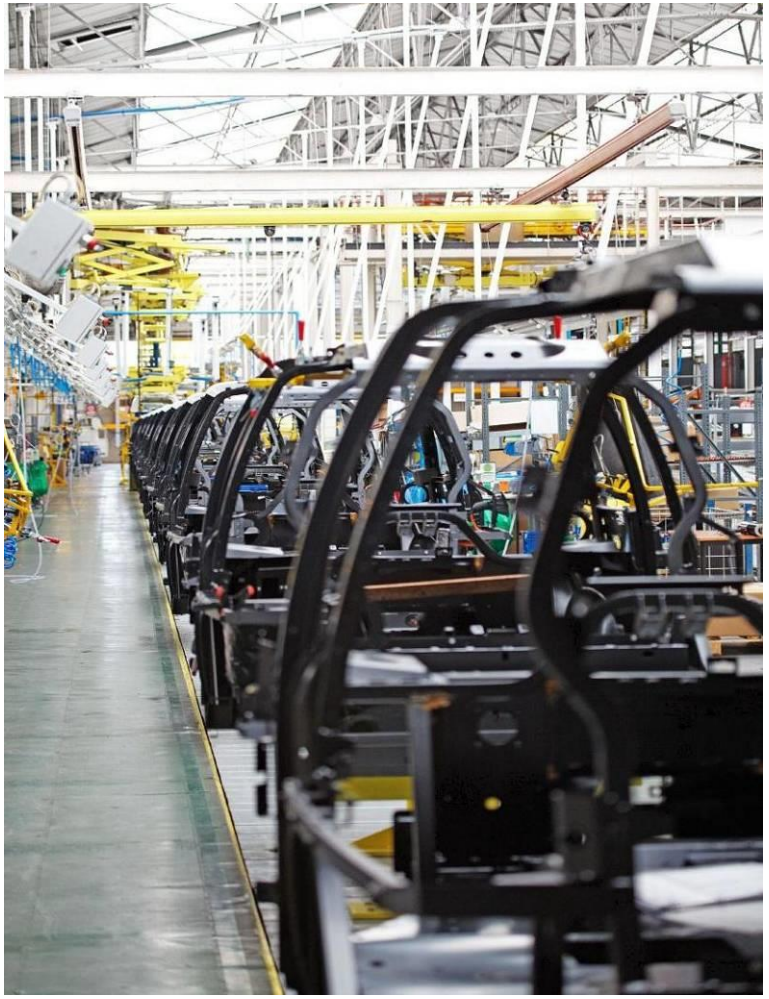
Page 1 of 2

Dimensions	32mm x 100mm x 192mm	
Nominal Voltage	3.2V	
Impedance (1KHz AC(	≤2mΩ	
Power density	1000W/Kg	
Energy density	120Wh/Kg	
Operating temperature range	Charge	0～45℃
	Discharge	-20～45℃
Storage temperature range	-10～35℃	
1C Discharge capacity	≥40Ah (C_1)	
Rate Capability	5C	>90%C_1
Cycle life	>2000（100%DOD）	

Rate performances of 40Ah LFP cell at 25°C







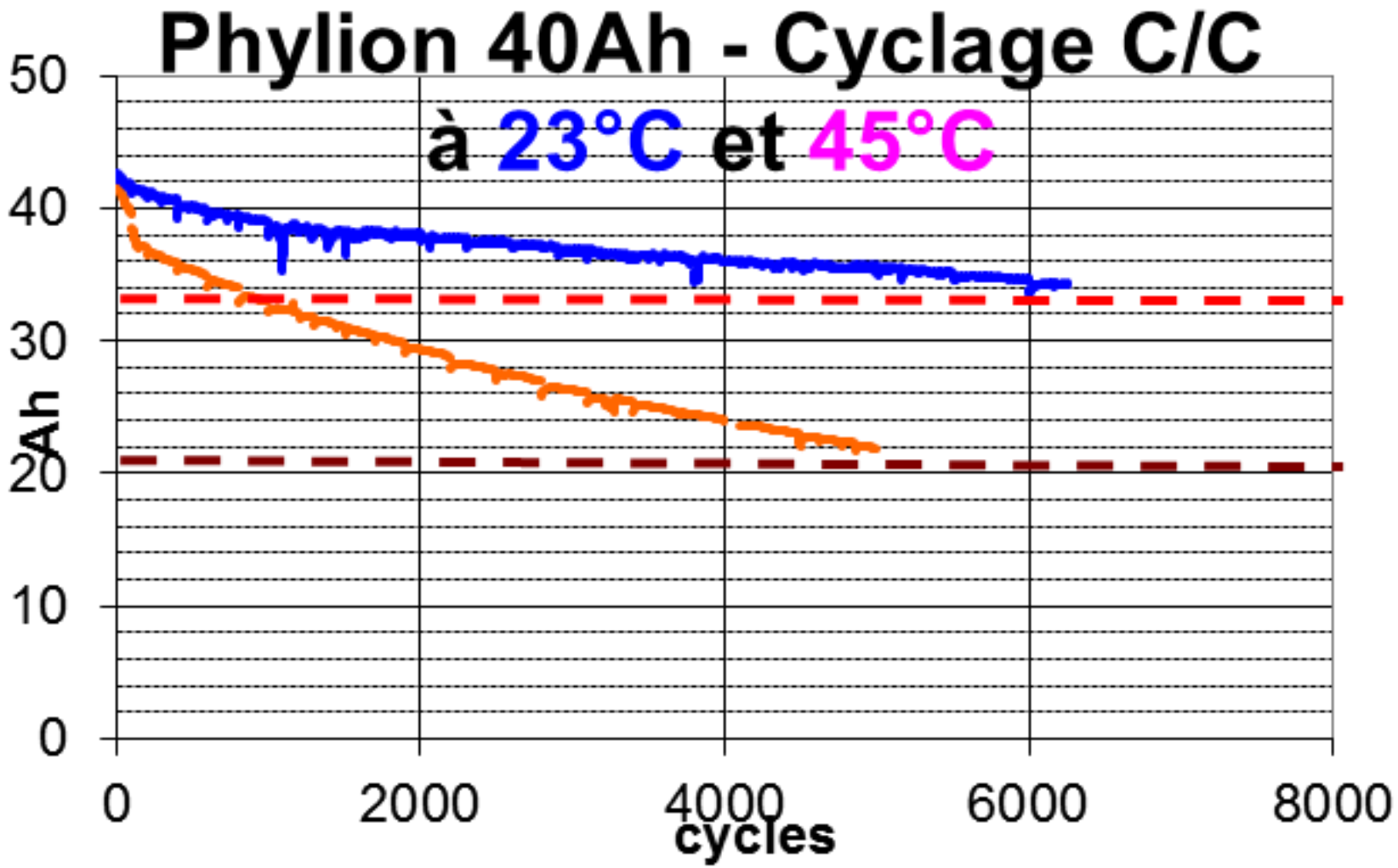
- **MIA EV in France**
- **Mileage: 128~130 kilometers***
- **Maximum speed: 110 kilometers /hour**
- **Charging time: 3 hours**
- **Market price: Euro 19500~22500**
- **Mainly used for: Urban carsharing**

➢ **Launched in October 2010, with 73 vehicles sold in first stage;**

➢ **Carsharing services were provided in 2011 with 938 vehicles ordered;**

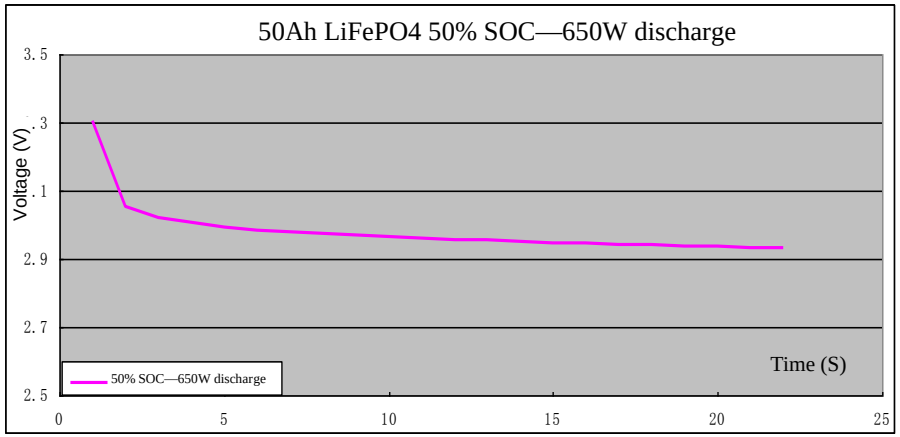
➢ **Private sales were available in 2012.**

40Ah Cell test by EDF in France (2008-2010)

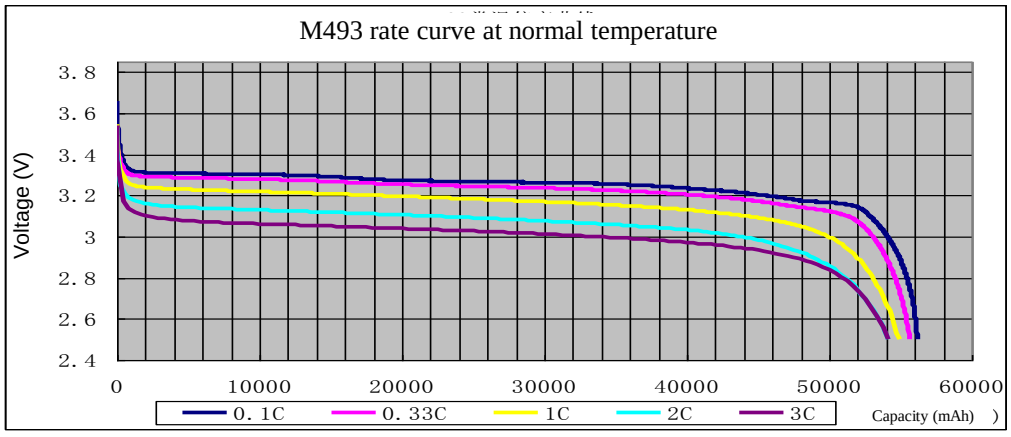


50Ah power battery with LiFePO4 shell

50Ah LiFePO4 battery	Unit	Final index	Actual measurement in 2013
Capacity	Ah	50	54.772
Power density	W/Kg	≥600	915.578
Energy density	Wh/Kg	≥140	146.982
Cycle life	%SOC	≥1600	1200次余94.1%



Power density test curve

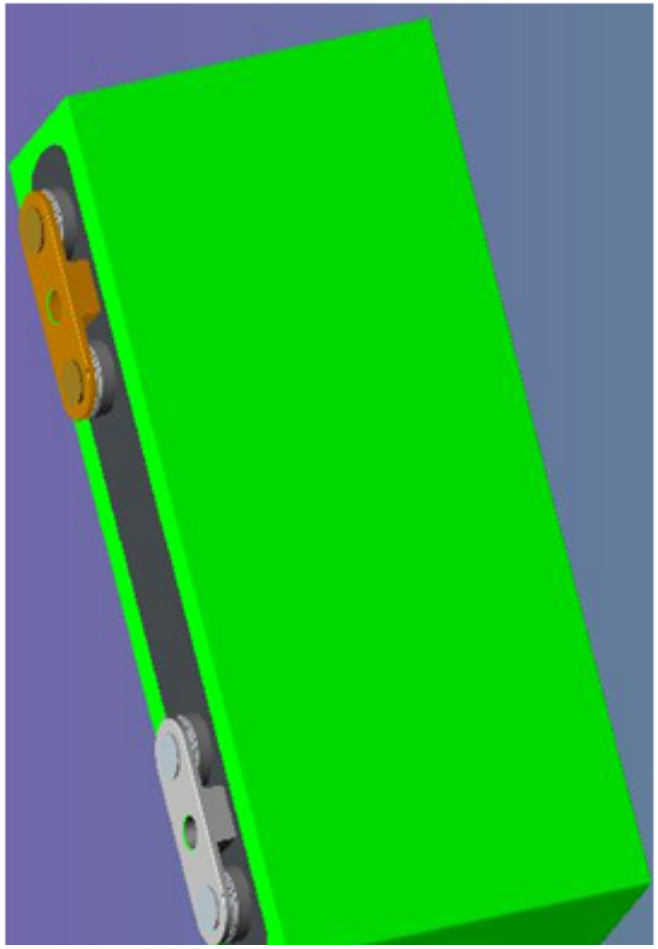


Room temperature ratio test curve

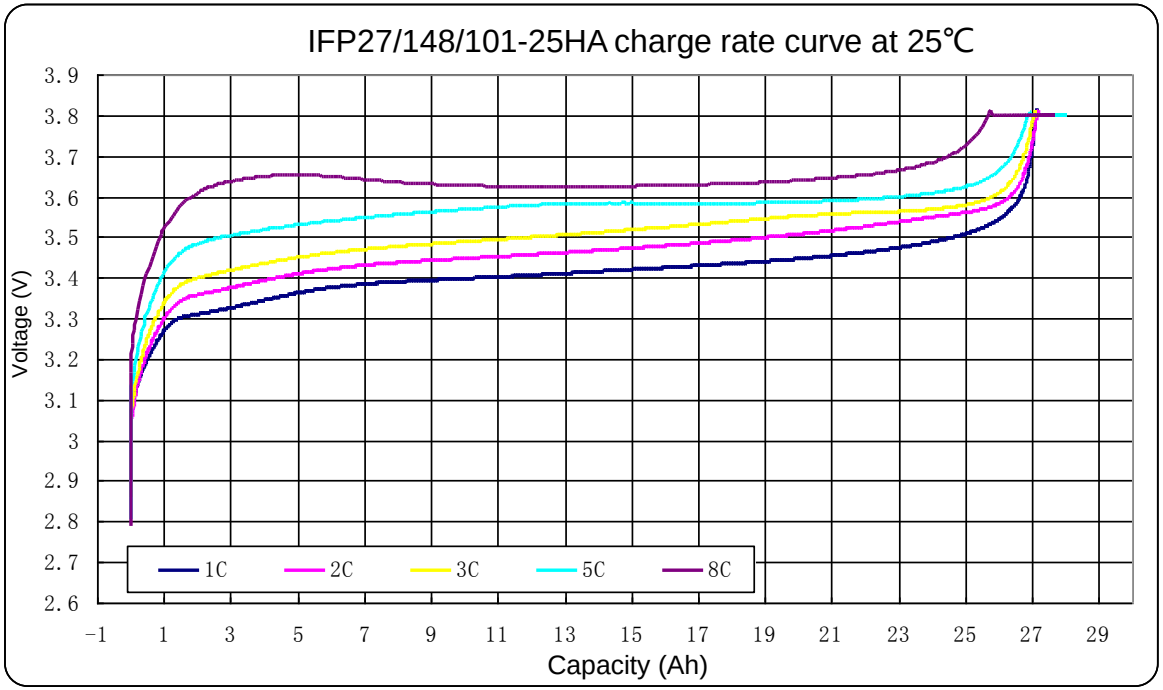
25Ah LFP Comprising Energy and Power Cell

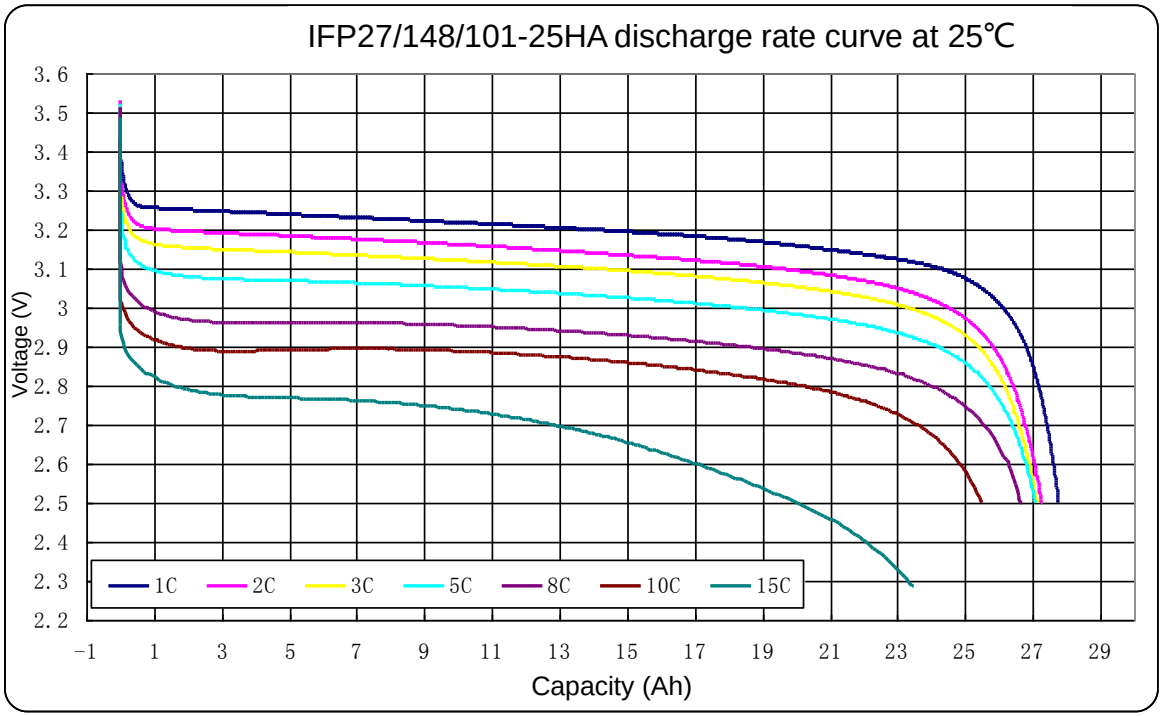
1. IFP27/148/101-25HA Prismatic Al Case Cell Specification

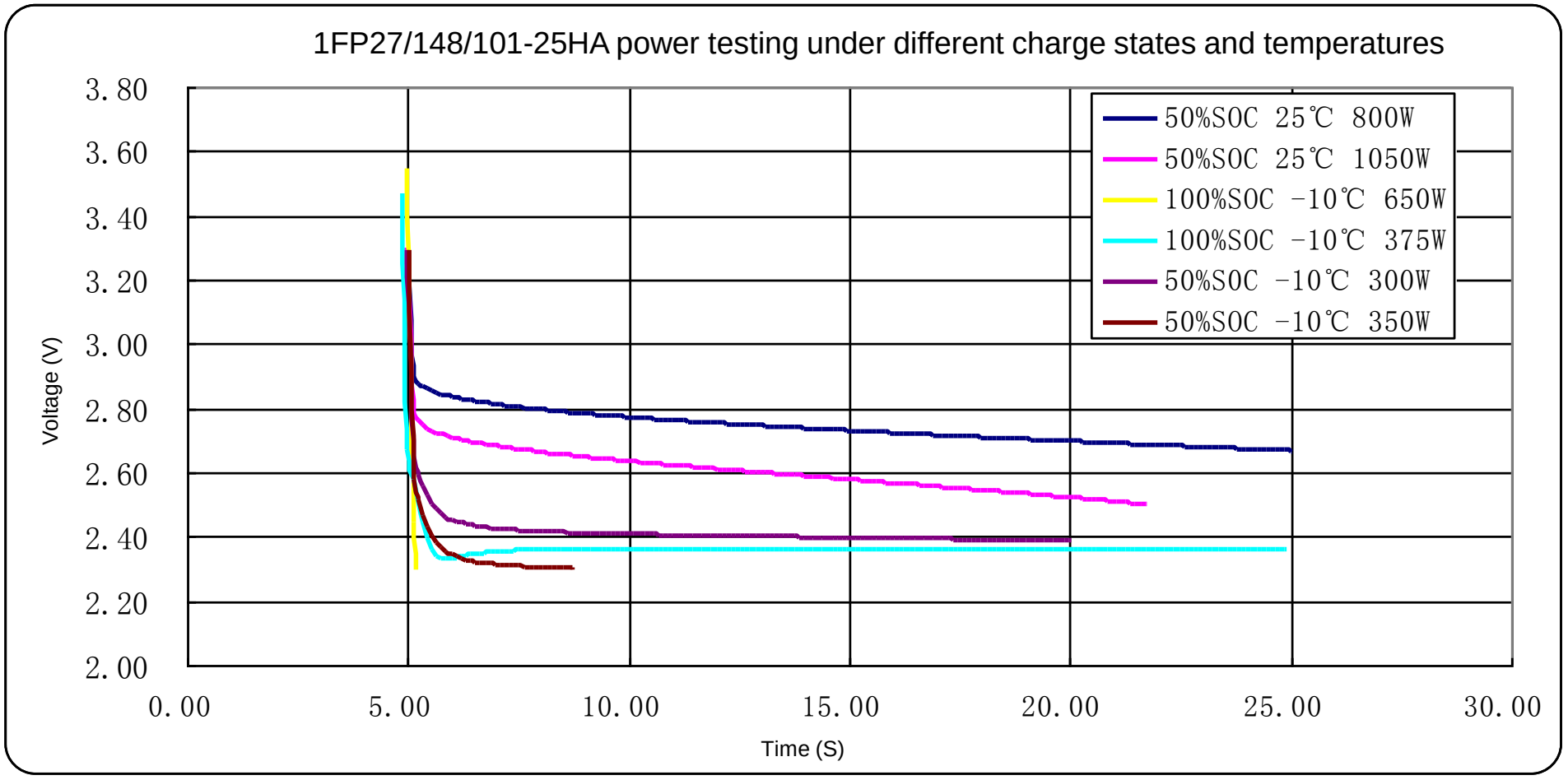
IFP27/148/101-25HA Prismatic Al Case Cell Specification			Shanghai H&D EV Battery
1 Basic parameter			
Type	IFP27/148/101-25HA		
T x W x H（max）	27mm x 148mm x 101mm		
Nominal Voltage	3.2V		
Nominal Capacity C_2	25Ah（0.5C）		
Internal Resistance	≤1.5mΩ		
Discharge Voltage Limit	2.5V		
Charge Voltage Limit	3.8V		
Max. Charge Current	5C		
Max. Discharge Current	8C		
Charge Method	CC/CV		
Weight	≤775g		
Operate Temp.	Charge	0～45℃	
	discharge	-20～50℃	
Storage Temp.（storage			



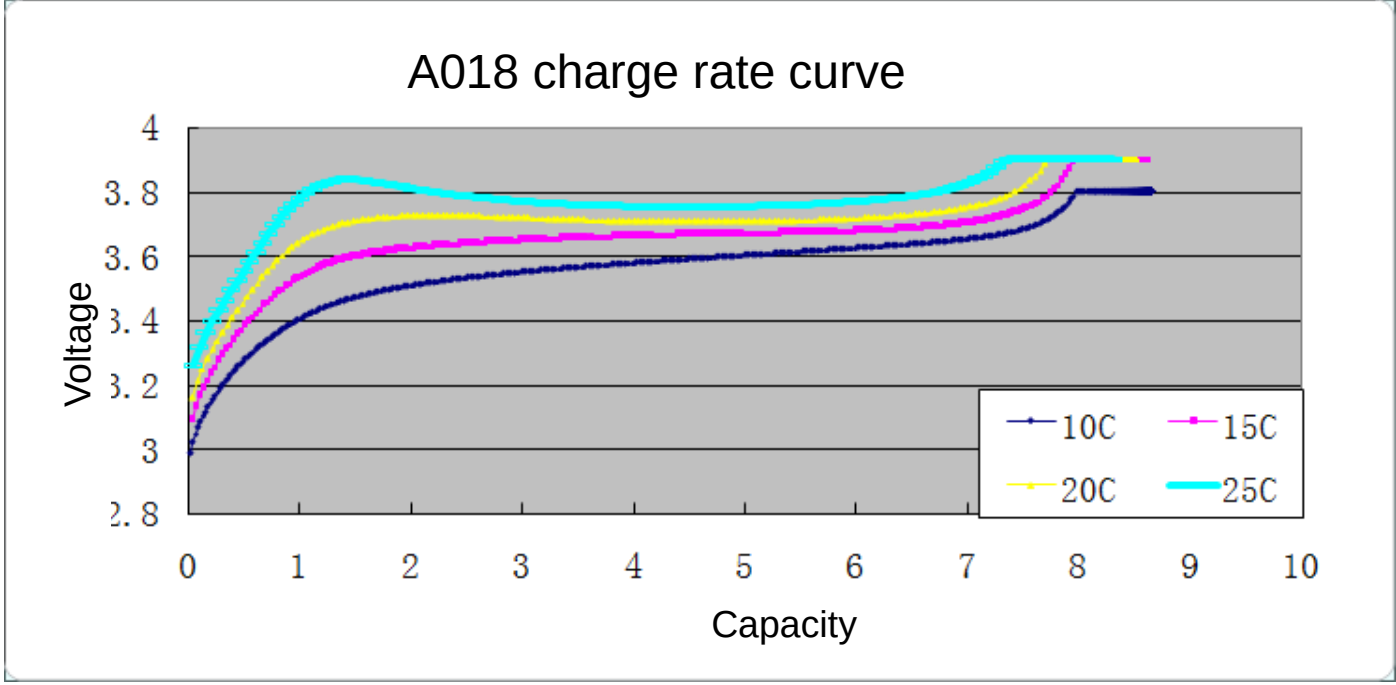
LFP/graphite cell

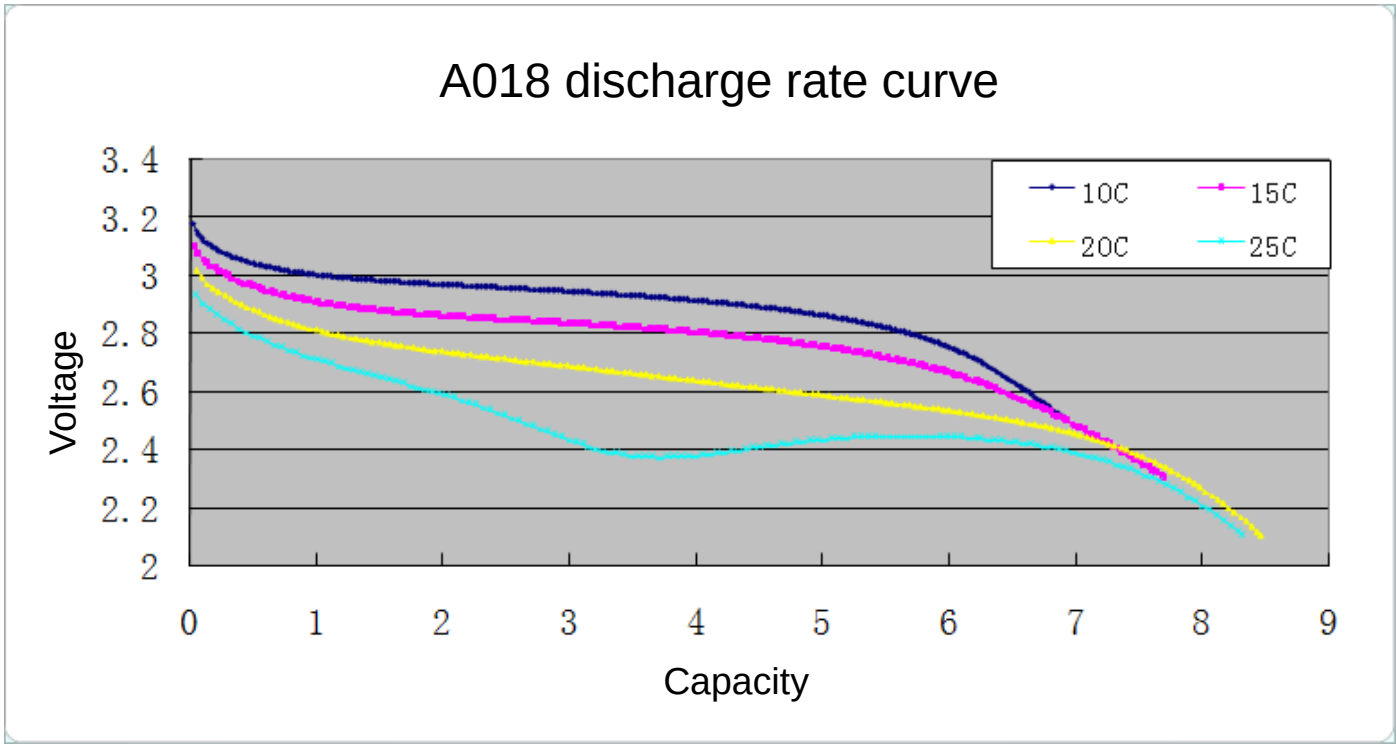




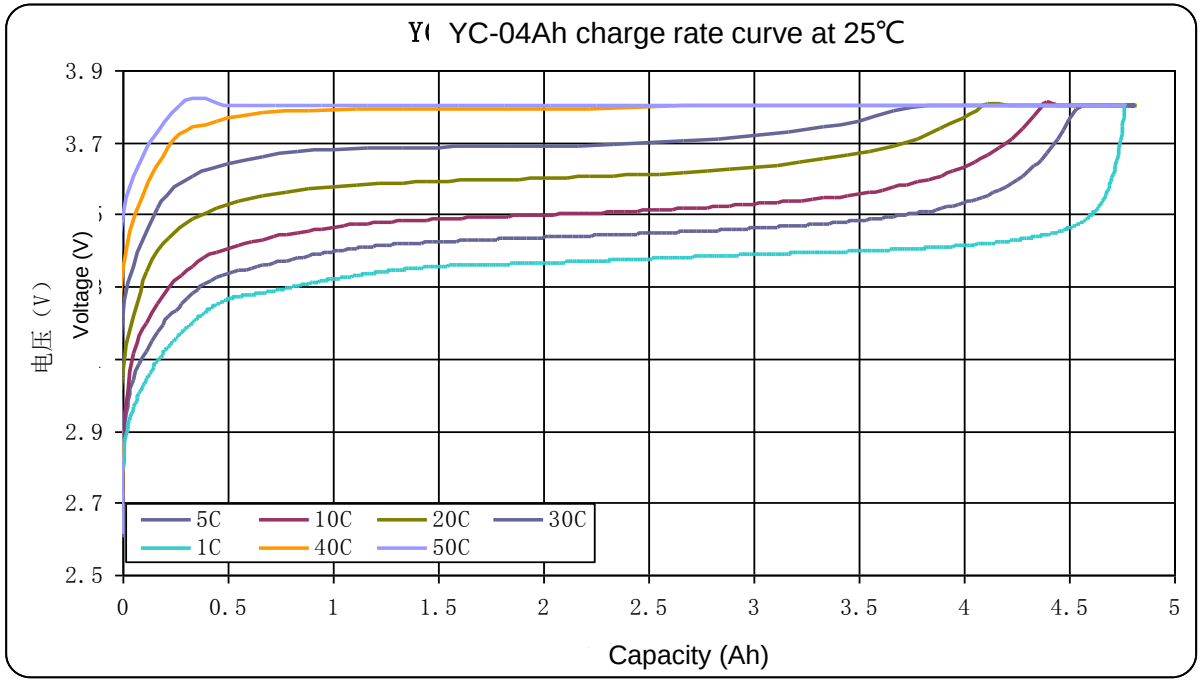

1FP27/148/101-25HA power testing under different charge states and temperatures
3.80
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
2.00
Voltage (V)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Time (S)
50%SOC 25℃ 800W
50%SOC 25℃ 1050W
100%SOC -10℃ 650W
100%SOC -10℃ 375W
50%SOC -10℃ 300W
50%SOC -10℃ 350W

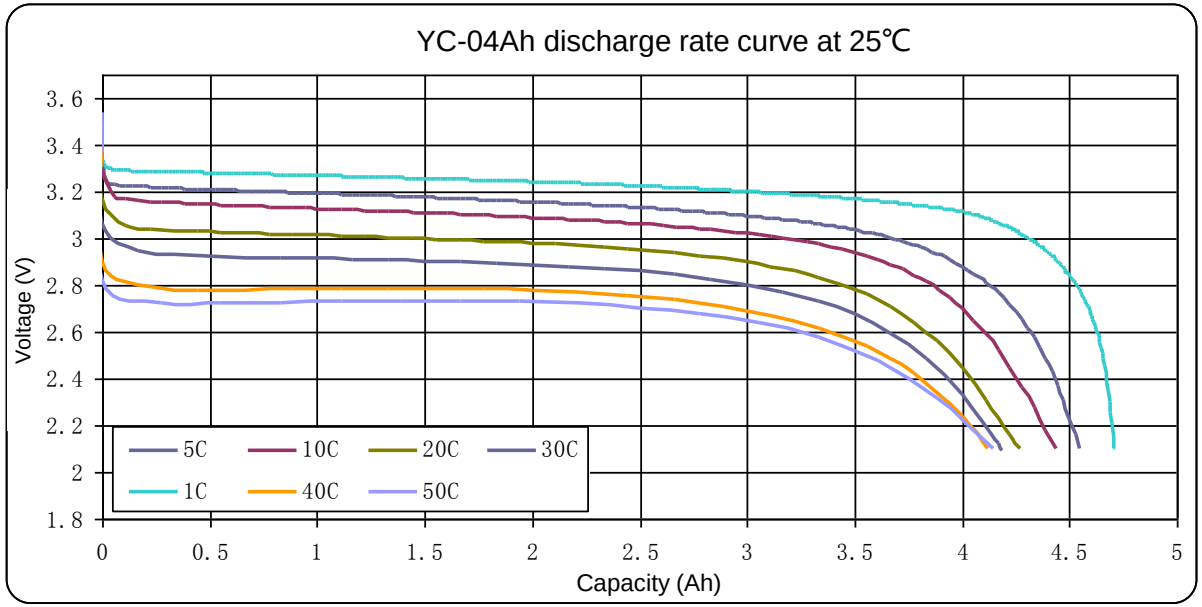
LFP/graphite cell





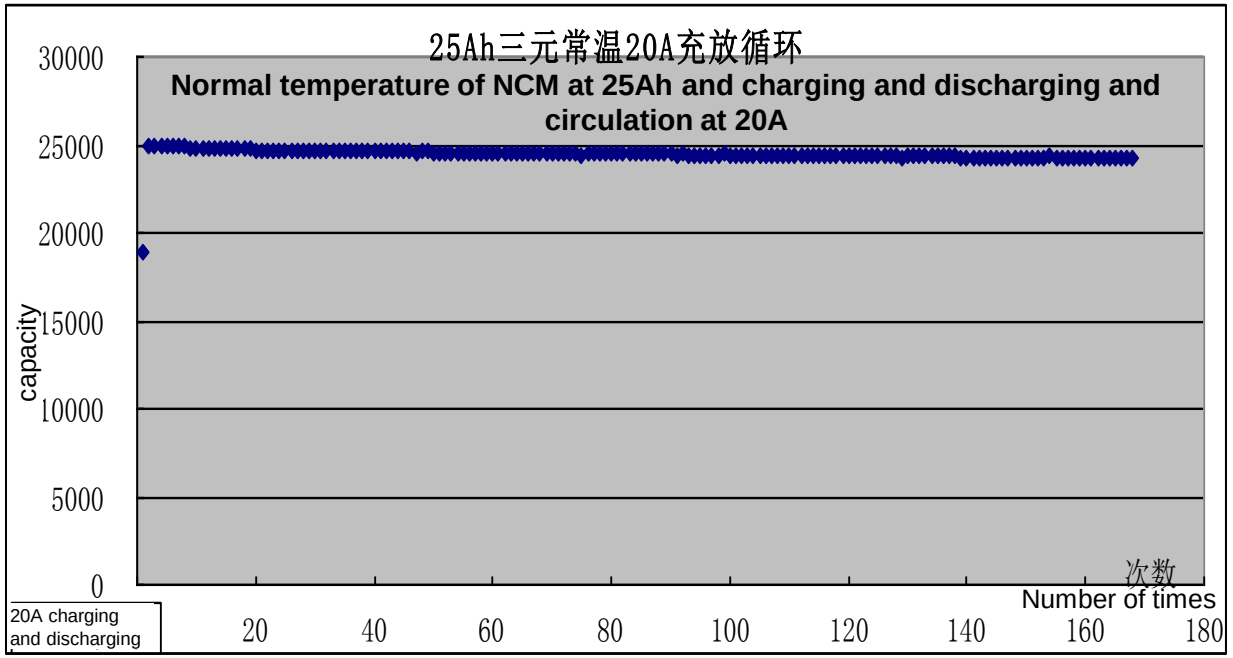
LFP/graphite+HC cell





Power battery with less energy consumption and high efficiency made of LMO and NCM

25AhLMO/NCM battery	Unit	Final index	Actual measurement
Capacity	Ah	25	28.077
Power density	W/Kg	≥600	976.465
Energy density	Wh/Kg	≥160	169.773



Results of safety test (made by the third party) on power battery with less energy consumption and higher efficiency made of LMO and NCM

Conclusion: high temperature, acupuncture, short circuit, over-charge and extrusion. Explosion and firing of battery is not detected in the test.

Cell over-discharging

Cell over-charging

Cell short circuit

Cell dropping

High cell temperature

Cell extrusion

Cell acupuncture

Module over-discharging

High module temperature

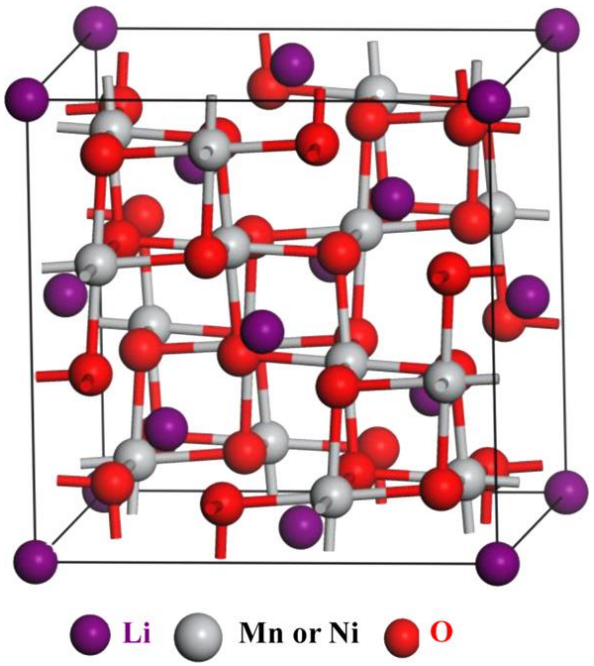
Module short circuit

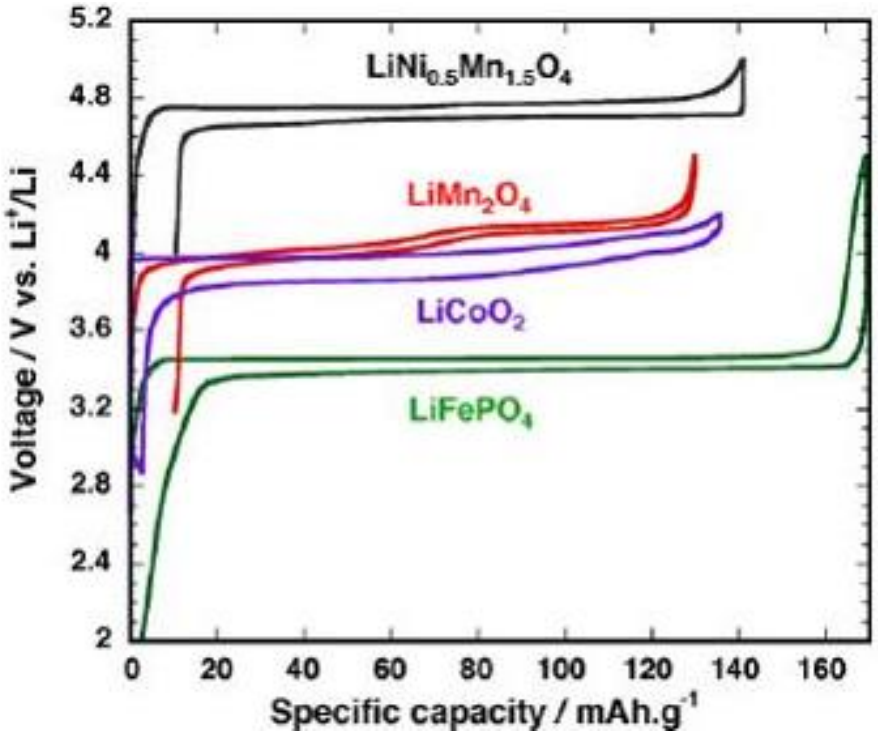
Module extrusion

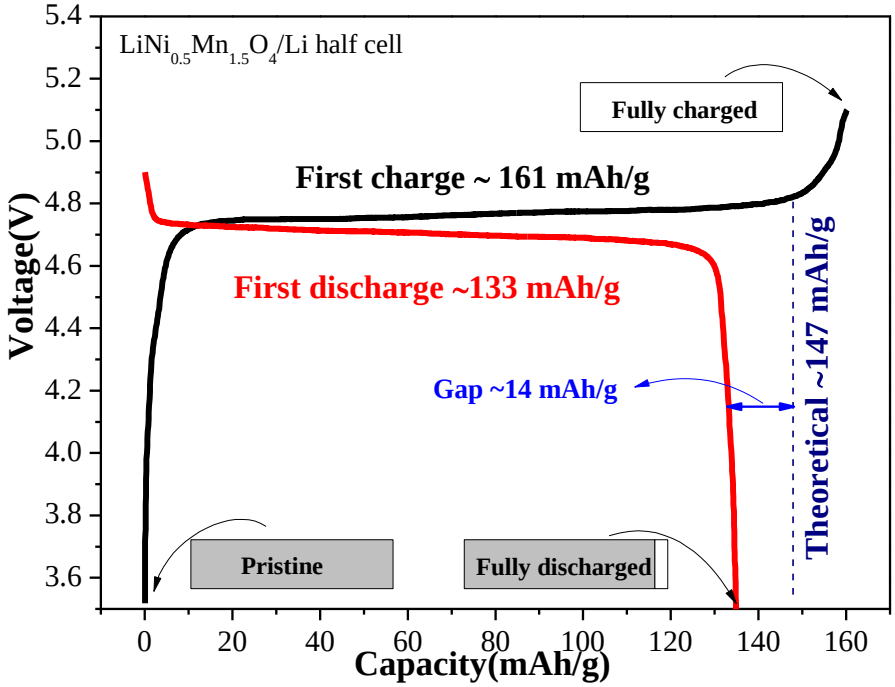
Module acupuncture

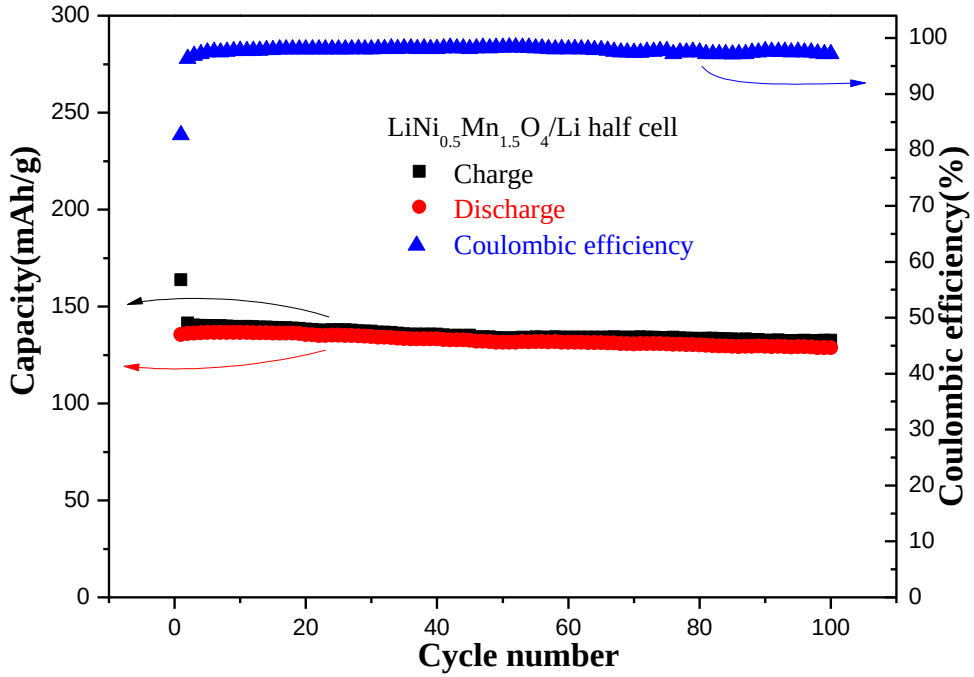
$LiNi_{0.5}Mn_{1.5}O_4$(LNM)

- High Voltage
- Low cost
- High safety









250Wh/Kg in 2020

Utilization ratio of lithium in typical lithium-ion cathode materials

- Available capacity of cathode materials of $LiNi_{0.5}Mn_{1.5}O_4$ is approximately 135mAh/g，with the utilization rate of lithium up to 100%. Equipped with a 4.7 V voltage platform (relative to lithium metal), the utilization rate of lithium can be maximized to 1 Kg Li ~ 16 KWh
- $LiCoO_2$ ~ 7 KWh,
- $LiMn_2O_4$ ~ 11 KWh,
- $LiFePO_4$ ~ 12 KWh.

Power battery and its management

To improve the industrial chain of power battery, the focus should be put on strengthening the capacities in design, manufacturing and system integration

Battery cell

Battery system

	Material	Individual design	Battery production	Group technology	Automobile-based
R&D	Development of new materials Characterization of material properties Material production technology	Fine vehicle requirements Parts selection Design criteria Property measurement	Pilot test technology Process design Quality control Equipment development Rapid detection sorting	Mechanical connection Electrical safety Heat flux design Reliability management BMS	BMS/charging/communication Automobile operation condition User characteristics Stagger utilization
Core technology	Material Nanometer	Transmission of material/electro-chemicals Current coupling design for heat engine	Detection Production facility automation Quality control	Mechanical electrical flow control	State predication Vehicle communication Model development Operating condition analysis
Development time	10 years	Several years	Several years	Several years	Several years

广州中国科学院工业技术研究院
地址：广州市南沙区海滨路1121号
邮编：511458
电话：020-22912515
网址：http://www.gziit.com/

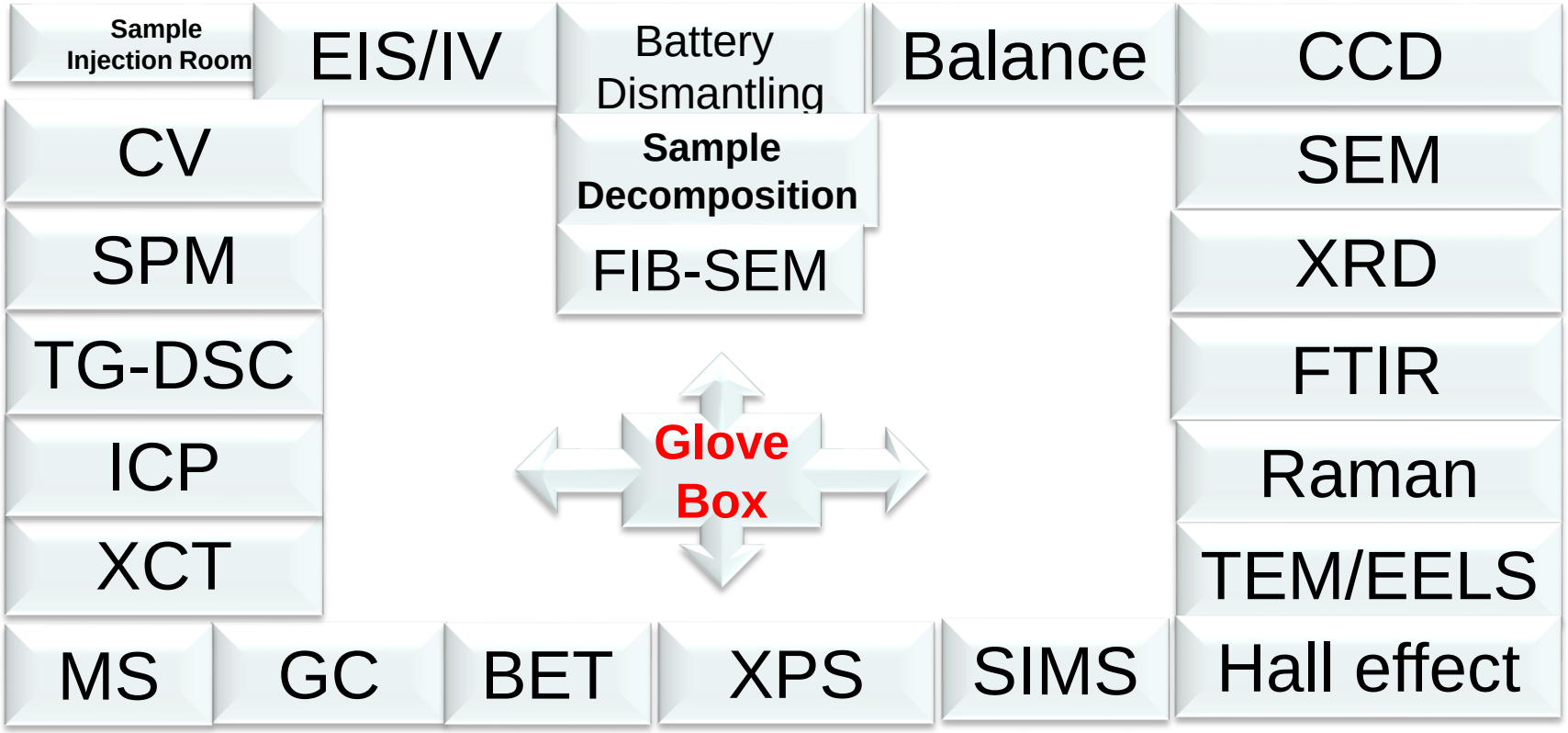
广州中国科学院工业技术研究院
Institute of Industry Technology, Guangzhou & Chinese Academy of Sciences

锂离子动力电池工艺装备技术基础服务平台

主持单位：广州中国科学院工业技术研究院
合作单位：中国科学院物理研究所
广州中国科学院沈阳自动化研究所分所
深圳市吉阳自动化科技有限公司
深圳市赛普自动化设备有限公司

Platform for Comprehensive Analysis and Test on Battery

IOP/CAS



1. It connects various testing equipment through glove box and sample transfer system;
2. It provides one-stop overall analysis on battery materials and components;
3. It provides in-situ and ex-situ measurements;
4. A platform for high-level R&D, testing, diagnosis and failure analysis;
5. It is used in research institutions and enterprises, etc. and open to the whole world.

Thanks!