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PARAGONAGE

Discussion on Characteristics & Possible Applications of SIBs

21ABC Presentation at Sep.2025

2025/9/12

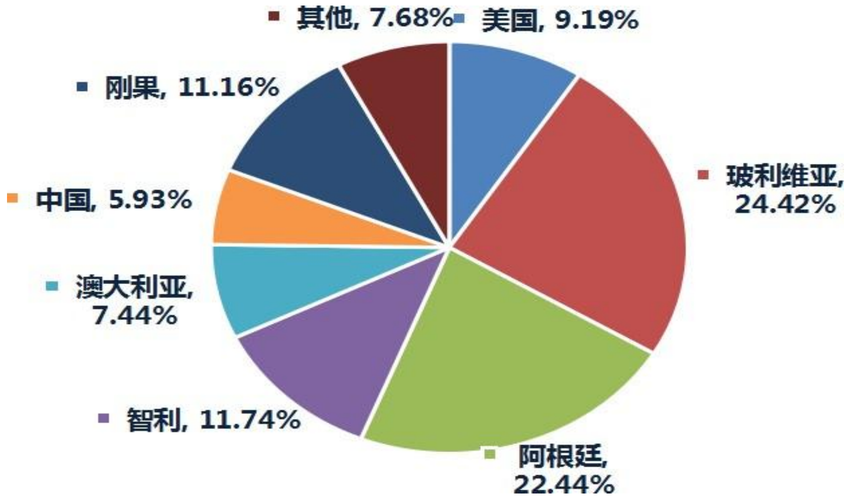
Clause Yi CTO

Why China focus on SIB (Sodium Ion Battery) ? Is SIB a choice?

- ☐ Supply of Lithium is limited;
- ☐ Some unique performance;

Why China focus on SIB (Sodium Ion Battery) ?

- Supply of Lithium is limited;
- Lithium reserve is only 5.93%, but consume 65% of Global Lithium resource



Are SIBs attractive?

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Cross comparisons of popular battery technologies

Entries	Solid-state LIB	Semi solid-state LIB	LIB-LFP	SIB NFPP	VRLA
Vn/Vw (V/cell)	3.6~5.0/2.8-5.5V	3.7/2.8-4.2	3.2/2.5-3.6V	2.9/ 2.0 -3.4V	2.0/ 1.7-2.4V
Cycle No. (80% DOD)	< 200	500	6000+	6000+	500/1200
Charging temp.	- 20 ℃	- 20 ℃	> 0 ℃	- 40 ℃	> 0 ℃
SE (Wh/kg/cell)	500-1000	300-350	180	100-120	35-50
Safety Levels	S ?	S2	S3	S5	S6
IIC Cost Multiple	6M	4M	1.5M	3M	M

Content

Safety of SIBs

There are several reasons for why SIBs is much safe than LIBs.

1, Energy density is much lower;
2, Not prone to generating dendrites which caused short-circuit;
3, Withstand over-discharge, could be discharge to zero voltage; LIB can't discharge below 2.0V/cell, otherwise copper dendrite generated;
4, The hazard caused by thermal runaway in SIBs is lighter than that in LIBs.

Safety of SIBs

The hazard caused by thermal runaway in SIBs is lighter than that in LIBs.

Comparison of 32140 SIB & LFP cell		
Item	**SIB NFPP**	**LFP**
Nominal vol.（V)	**2.9**	**3.2**
Rated capacity (Ah)	**7**	**15**
Energy (Wh)	**20.3**	**48**
IR (mΩ)	**3**	**3**
Voltage window (V)	**1.5-3.4**	**2.5-3.65**
Wt.（Kg)	**0.24**	**0.29**
Specific energy (Wh/Kg)	**85**	**165**
Energy density (Wh/L)	**180**	**426**

For the same size, the capacity of SIB is smaller, the specific energy/energy density is lower, the heat and temperature rise is less when there is a short-circuit happening.

Safety of SIBs

Safety Level Ranking

VRFB	> NaSalt/NiMH >	PEM H2 FC >	VRLA >	SIB NFPP >	LFP >	SIB O3 >	LIB NCM
S9	S7	S6	S6	S5	S3	S2	S0

- How easy prone to thermal runaway,;
- Inner cause to internal short-circuit, max temperature rise after short-circuit;
- Temperature at thermal runaway;
- what kind of gases generated during over-charge or thermal runaway; O2， H_2 or CO_2
- Hazards of thermal runaway. Fire or explosion;
- Fire could be control by physical or chemical means?

Sodium ion battery: BMS necessary?

For large and complicated systems, BMS functions are Needed to protect misuse of and for safety

BMS functions	Necessary ?	Remarks
Over-charge	YES	Max. vol. 4.5V/cell
Over-discharge	NO	Could be discharged to 0V
Over-current	YES	Short-circuit
Over-temp.	YES	Thermal runaway

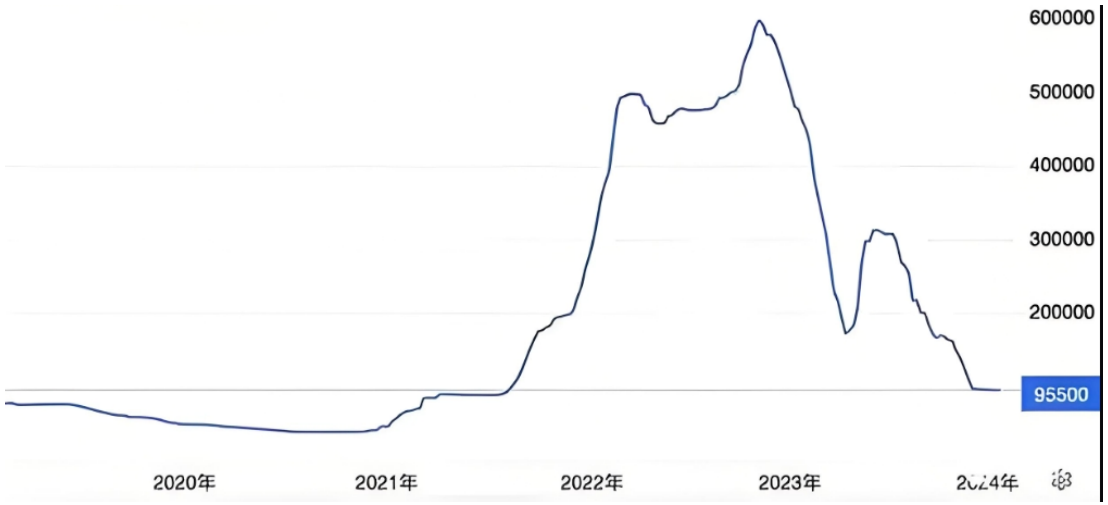
Minimum BMS Functions for simple system of SIBs, such as Starting battery

Equipped with voltage monitoring & Bluetooth communication

Cost of SIBs

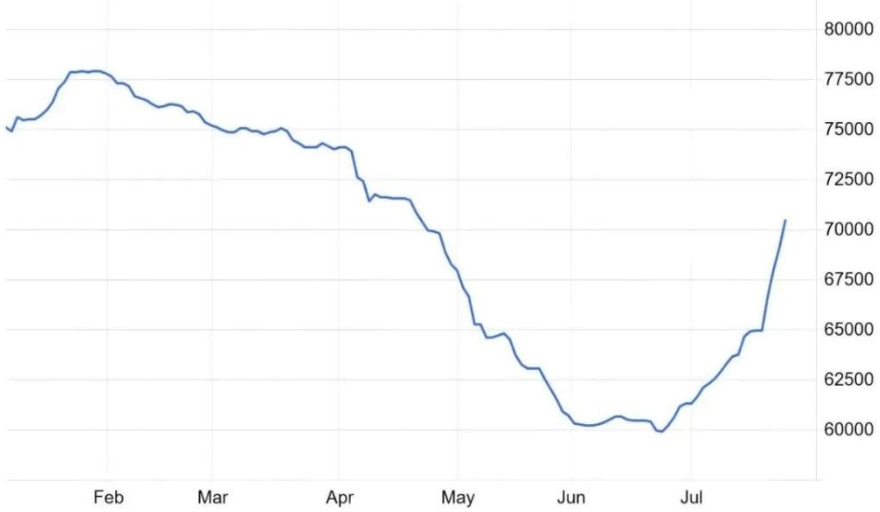
Raw material abundant and price stable/predictable, not like crazy Licarbonate

Peak Price ¥ 600 thousands/ton



Year 2020 - 2024

Peak Price ¥ 80 thousands/ton



Year 2025

Cost of SIBs

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Cost of SIB O3 /SIB NFPP Vs. LFP (same size)				
Product	**Li carbonate**	**LFP Cell**	**Layered oxide O3**	**NFPP**
Battery parameters	**N/A**	**3.2V 100Ah**	**3.0V75Ah**	**2.9V50Ah**
Year 2022	**¥ 600/kg**	**¥ 0.68/Wh**	**¥ 0.57/Wh ↓ 20%**	**¥ 0.87/Wh ↑ 28%**
Year 2025	**¥60/kg**	**¥ 0.29/Wh**	**¥ 0.45/Wh ↑ 55%**	**¥ 0.65/Wh ↑ 124%**
Future	**If ¥60/kg**	**¥ 0.29/Wh**	**¥ 0.40/Wh ↑ 40%**	**¥ 0.47/Wh ↑ 62%**
Cost Parity at	**¥120/kg**	**¥ 0.40/Wh**	**¥ 0.40/Wh ↑ 00%**	**N/A**
	¥150/kg	**¥ 0.47/Wh**	**N/A**	**¥ 0.47/Wh ↑ 00%**
SIB Cost down approach	**1, Incease energy density with high capacity material, Wh/L; 2, Cell design innovation, such as anode-free**			

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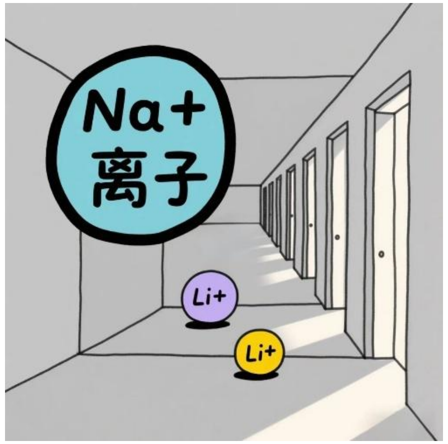
Cost of SIBs

High cost mainly because the energy density is low, the amount of materials other than cathode (Sodium-related) doubled



Type	SIB NFPP	LIB LFP
Size	50×160×112	50×160×112
Vol/Capacity	2.9V50Ah	3.2V100Ah
Wh energy/cell	145	320
Energy Density/cell	162 Wh/L	357 Wh/L
KWh per Std. C & I Cabinet	111	241

Content

SIBs-Chemistries, be careful about different chemistries

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Comparison of different SIB chemistries					
Entries	Layered oxide O3-phase	Layered oxide P2-phase	NFPP	NFS	PBA
Descriptions	**O3/HC. 3.0V/1.5-4.0V**	**P-phase/HC, 3.6V/2.5-4.2V**	NFPP/HC, 2.9V/ 2.0-3.4V	NFS/HC 3.5V/2.5-4.2V	PBA/HC, 3.12V/2.0-3.65V.
Main Features	High specific energy	High voltage, close to that of NCM	Stable material structure， high cycle number	low material cost， high voltage platform	low material cost， voltage close to that of LFP
Problem/challenge	Contain nickel; gas accumulating, uncertain long term impact; Safety issue	Contain nickel; gas accumulating, uncertain long term impact; Safety issue	Low specific energy, high Cost per Wh	Material prone to moisture	crystalline water issue

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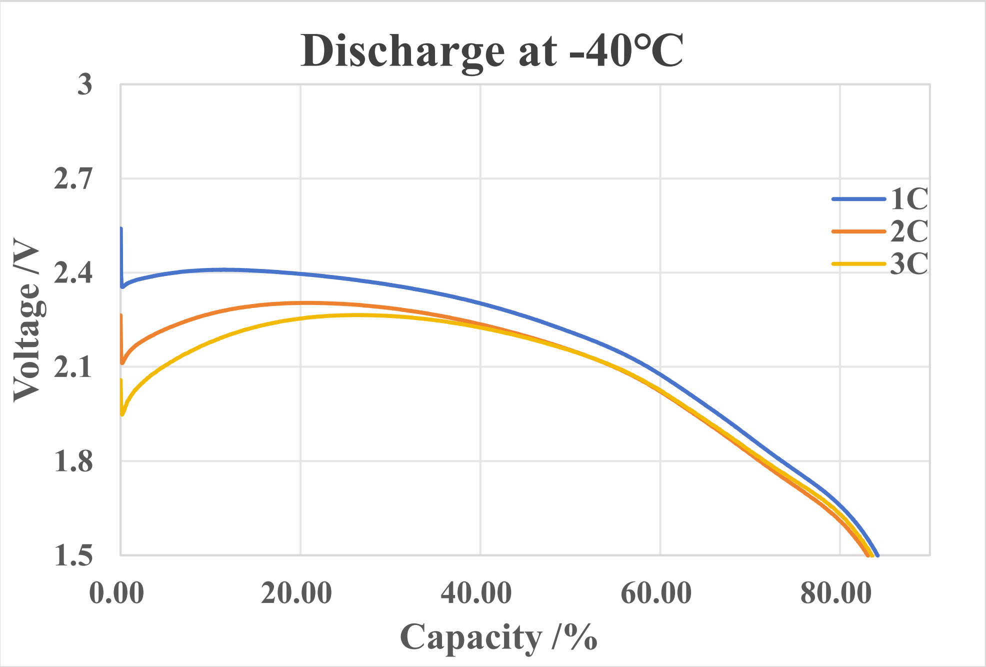
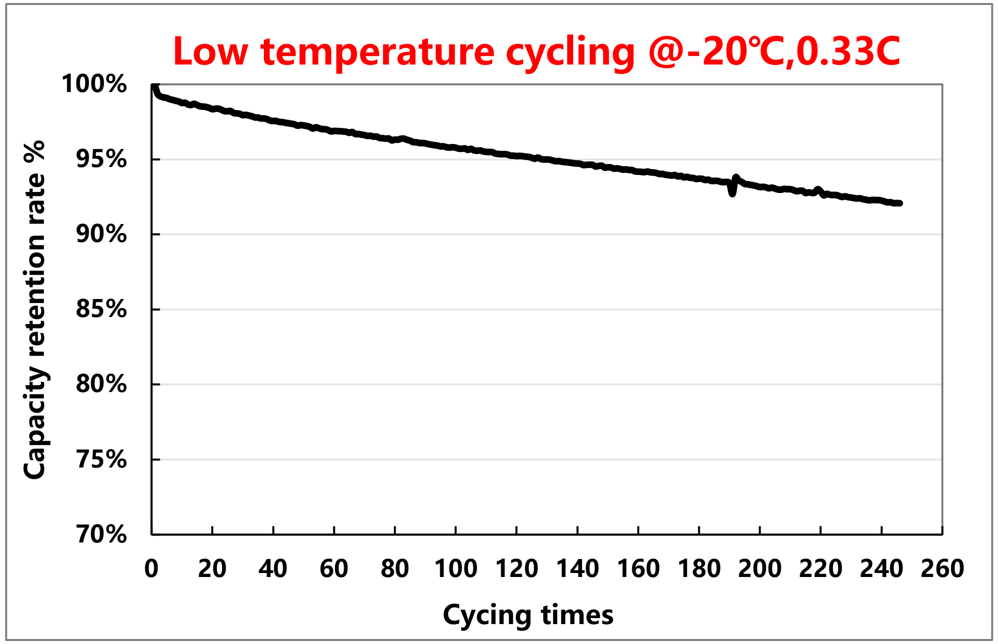
Comparison of different SIB chemistries 2/2					
Entries	Layered oxide O3-phase	Layered oxide P2-phase	NFPP	NFS	PBA
SE (Wh/kg/cell)	150+	110	100	95	120
Cycle No.	1,500+	500+	5000+	1,000+	1,000+
SL (yrs) Standby	5	5	8	5	5
Applications	Starting, outdoor portable power, light EV	Standby power	ESS, IDC, Power facility, military	light EV, replacement of VRLA	starting, light EV, power tool, ESS
Safety Levels	S2	S2	S5	S5	S4
IIC Cost Multiple	2M	2M	3M	2M	2M

Content

SIBs Strong point: low temp. advantage



NFPP 2.9V20Ah Pouch cell



NFPP 2.9V20Ah pouch cell

SIBs Strong point：HRD

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Safety, HRD, and low-temp. performance are the three major advantages of SIBs - High rate discharge

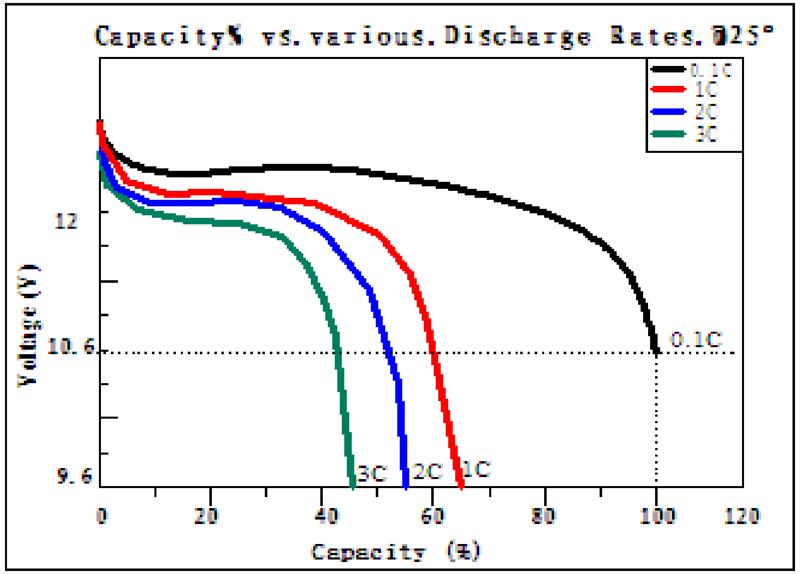

Figure 1. Rate Discharge Characteristics of VRLA battery.[2]

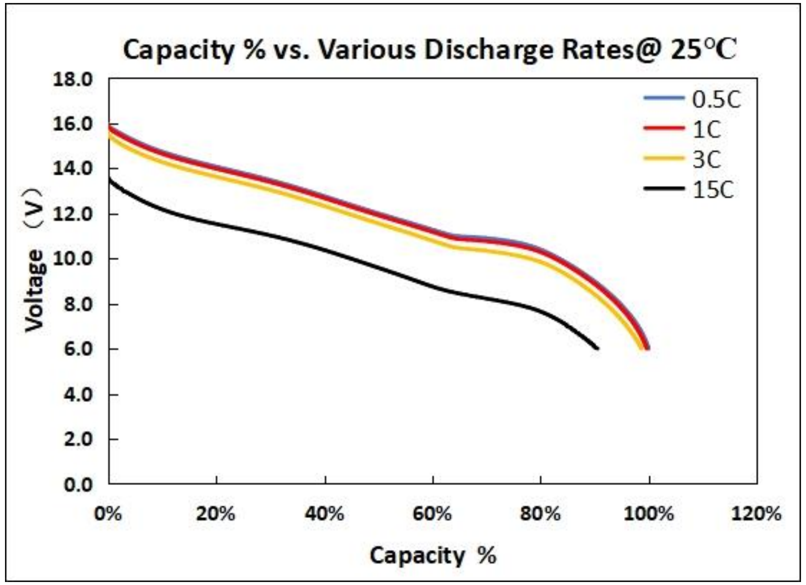

Figure 2. Rate Discharge Characteristics of SIBs .[3]

The current collector and active material coating of sodium-ion batteries are very thin. The typical electrode thickness is 0.15mm, less than one-tenth of that of VRLA battery plates. This means that the electrochemical reaction of sodium-ion batteries can proceed at a faster rate. Moreover, the electrolyte only undertakes the role of ion conduction, does not participate in the electrode reaction, and is not involved in the diffusion effect. The polarization impedance of the electrode reaction is very small. Sodium-ion batteries can be discharged at a very high rate, and the discharged capacity is almost not lost. As shown in Figures 2, the discharge capacity at 3C is close to 100%, and the discharge capacity at 15C is above 90%. The discharge curve of sodium-ion batteries shown in Figure 2 is close to a diagonal line without a discharge platform. The ohmic voltage drop during high-rate discharge is also obvious, resulting in energy loss.

SIBs Strong point：High CCA values

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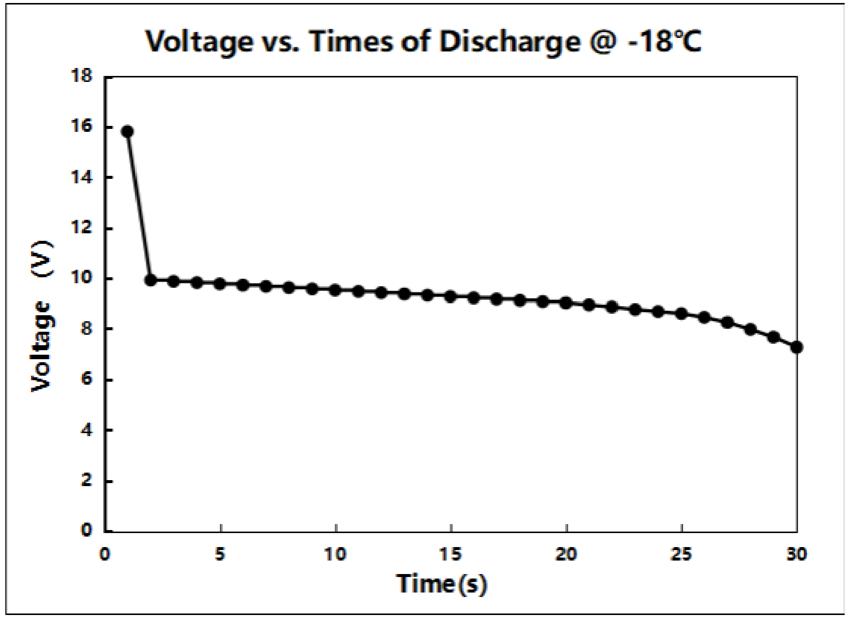
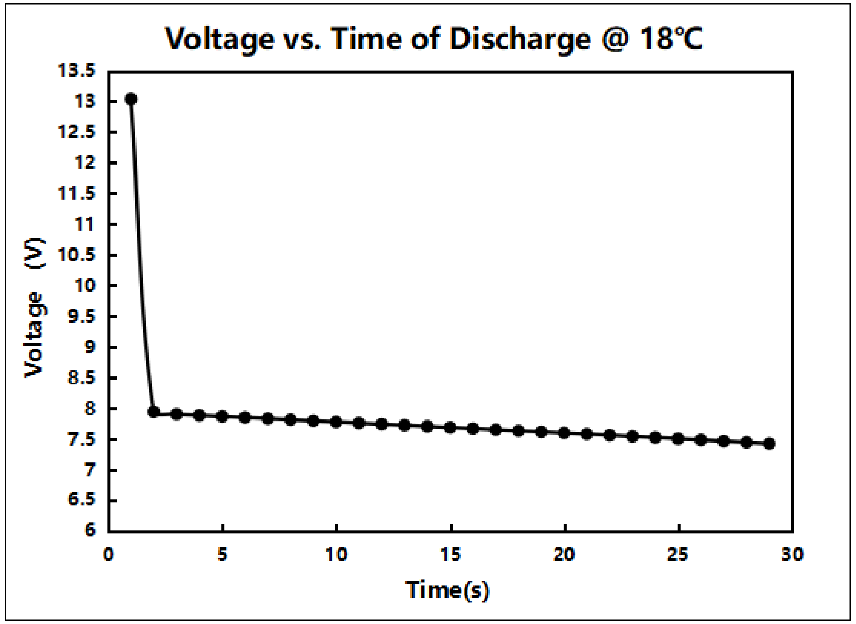
HRD + low temp. performance= Starting CCA

The biggest advantage of SIBs



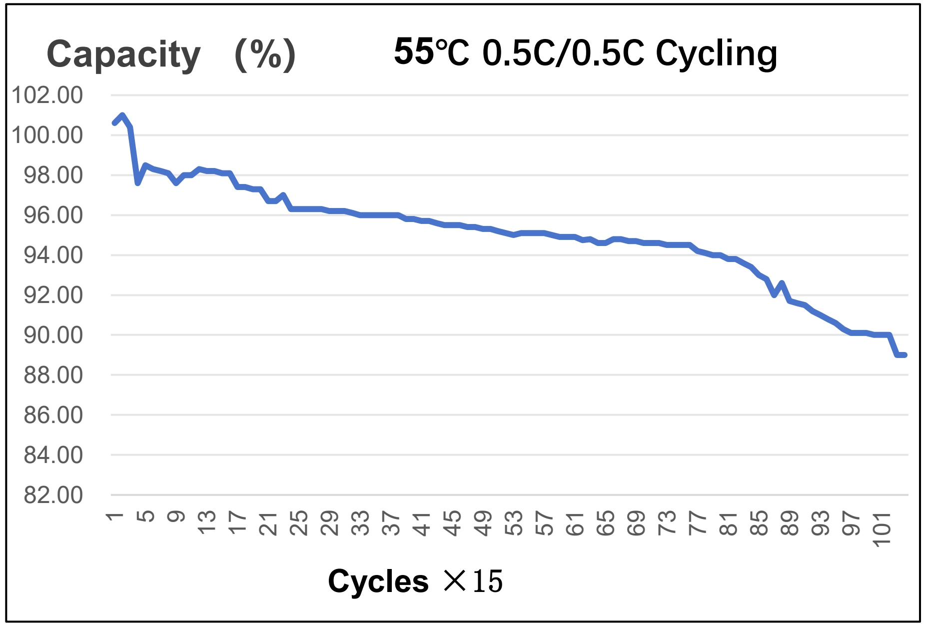
-18℃ CCA testing of 12V60Ah SIBs @ 15C



-18℃ CCA testing of 12V60Ah VRLA Battery @ 10C.

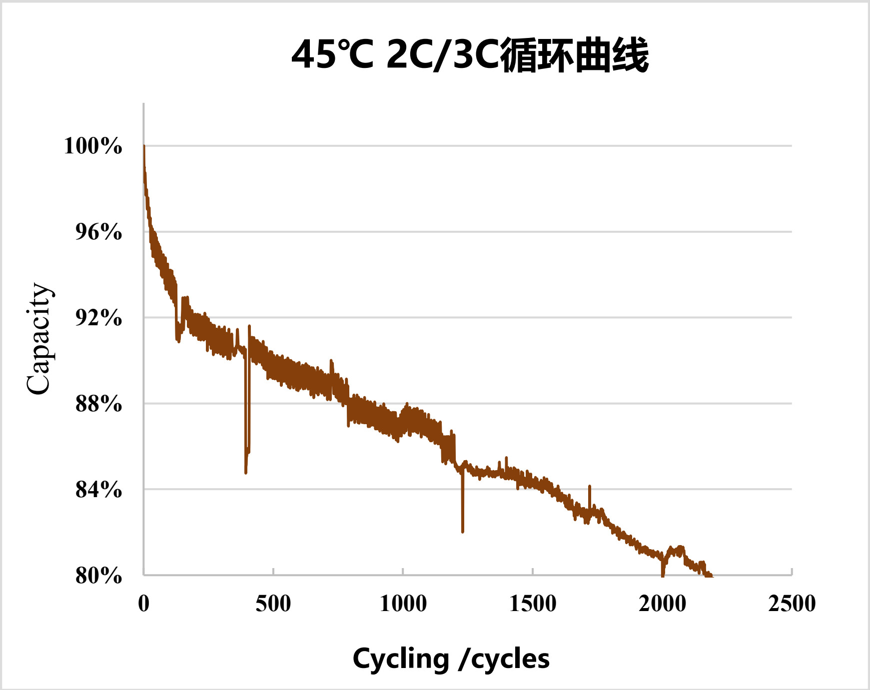
Cycling performance at Medium High Temp. Excellent

12V27Ah Starting Battery



32140 Cylindric Cell, 9Ah O3

2.9V5.5Ah Pouch cell NFPP



Size 150×140×5.5 mm

SIBs：High temp. performance

What's the upper limit of ambient temp. ? Depends on the electrolyte formula
Boiling temp. range of electrolyte 70℃-120 ℃
Electrolyte spray-out? Depends on specific chemistries, design of structure, safety valve

Chemistry	Cell shape	Test conditions	Outcome
O3	32140 Cylindric	75℃ 2 month	Raptured
NFPP	32140 Cylindric	85℃ 2 month	OK
PBA	18650 Cylindric	80℃ 2 month	OK

SIBs: Disadvantages

The biggest challenge in the application of SIBs: The difference in the working voltage window.

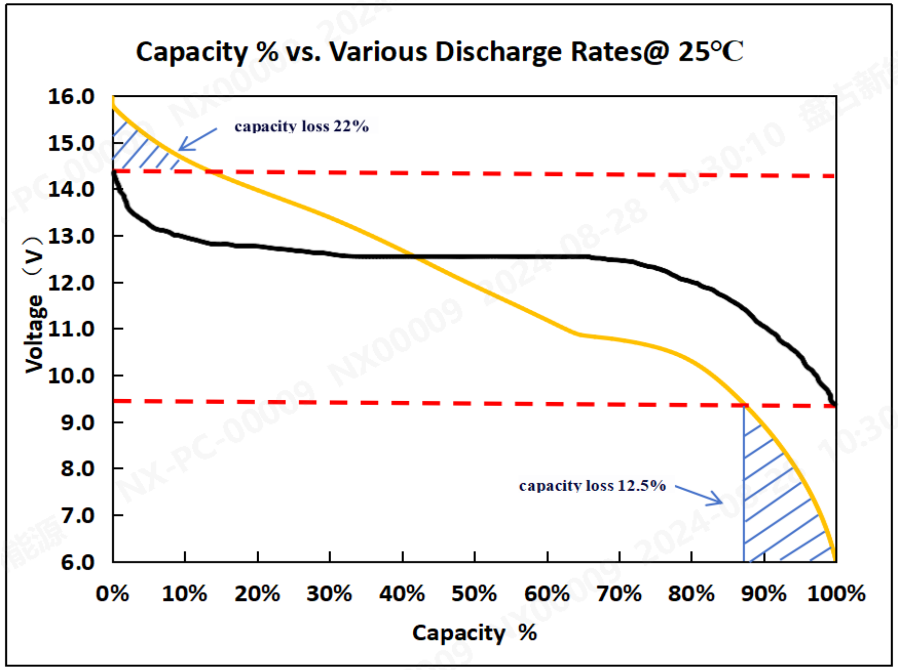
Comparison of working voltage range of sodium-ion batteries with VRLA batteries.

Voltage window for different technologies					
	Voltage window	Nominal Voltage	12V	24V	48V
Layered oxide O-phase	2.0 V-3.9V	3.0V	8.0V-15.6V	16.0V-31.2V	32.0V-62.4V
Polyanion (NFPP)	2.0 V-3.4V	2.9V	8.0V-13.6V	16.0V-27.2V	32.0V-54.4V
PBA	2.5V-3.65V	3.12V	10.0V-14.6V	20.0V-29.2V	40.0V-58.4V
LFP	2.5V-3.6V	3.2V	10.0V-14.4V	20.0V-28.8V	40.0V-57.6V
VRLA(12V)	1.75V-2.4V	2.0V	10.5V-14.4V		
VRLA(24V)	1.75V-2.4V	2.0V		21.0-28.8V	
VRLA(48V)	1.75V-2.4V	2.0V			42.0-57.6V

Currently, the working voltage range of most electrical equipment is set based on the charging and discharging voltages of lead-acid batteries. The charging and discharging voltage range of sodium-ion batteries is significantly different from that of lead-acid batteries, resulting in a mismatch between the battery working voltage window and the electrical equipment. See Table 2.

Disadvantages of SIBs

The biggest challenge in the application of SIB: The difference in the working voltage window.



The working voltage range of sodium-ion batteries is 15.6V - 6.0V, while that of VRLA batteries is 14.4V － 9.6V. If the working voltage range of VRLA is followed, the discharge capacity of sodium-ion batteries is only about 65%, and up to 35% of the effective capacity cannot be utilized. This requires users to make changes and adjustments to the electrical equipment to adapt to the working voltage of sodium-ion batteries.

Voltage compatible of SIBs for starting batteries

	O3	NFPP	PBA
12V Cars 7.2V-14.4V	4S 6V - 15.6V Undercharge	4S 6V - 13.6V Over-charge	7.2V-14.4V/8V-14.6V
12V Motorcycles 7.2V-14.4V	4S 6V - 15.6V Undercharge	4S 6V-13.6V Over-charge	14.4V-14.4V/6V-14.6V
24V Trucks 19.2V-30V		9S 18V-30.6V	7.2V-14.4V/8V-29.2V

For O3, it's possible to adopt no BMS solution, but Bluetooth is recommended.

Content

Feasible Applications of SIBs

The application principle of SIBs: Leverage strengths, address weaknesses, and compete for cost-effectiveness.

The first market: E-bikes

The first large-scale application of SIBs for batteries. Based on the safety and low-temp. discharge performance of SIBs, mainstream electric vehicle brands have all participated in the process. Moreover, the mainframe manufacturers have cooperated with the upstream and downstream of the supply chain to adjust the working voltage setting range of the "three-electric" system (motor, electronic control, and charger) to adapt to the charging and discharging voltage of SIBs. Many cities are promoting the battery exchange mode of sodium-ion two-wheeler batteries. The price is also a favorable factor, with a stable decline and good predictability.

Feasible Application Fields of SIBs

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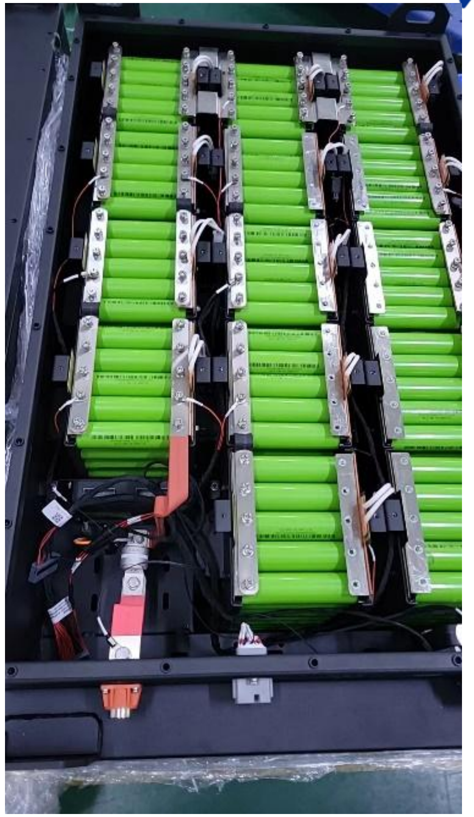
The application principle of SIBs: Leverage strengths, address weaknesses, and compete on cost-effectiveness.

The most potential market: Truck and motorcycle starting, parking air conditioning

Starting and parking air conditioning. This is a potential application field for sodium-ion batteries. The lower limit of the discharge voltage of sodium-ion batteries is no longer a limiting factor. The starting battery is miniaturized. See the test results in Figures 9 and 10.

Feasible Application Fields of SIBs

The application principle of SIBs: Leverage strengths, address weaknesses, and compete for cost-effectiveness.



Essential market: Outdoor engineering machine in cold regions

Utilizing the low-temperature characteristics of SIBs, outdoor power supplies and outdoor engineering machine can operate all day long without worry of low-temperature and low-capacity issues.

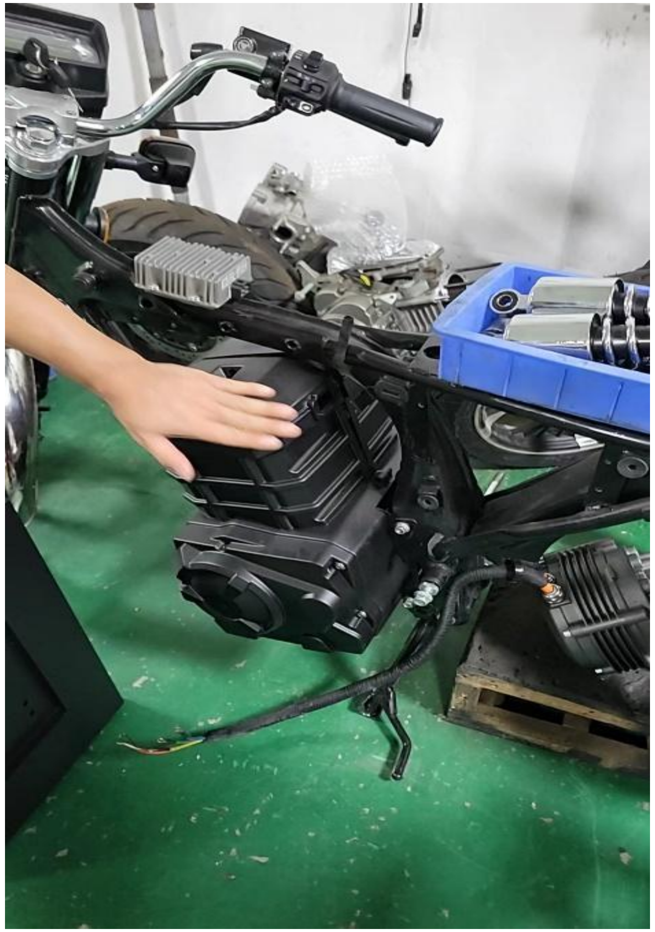
Feasible Application Fields of SIBs

The application principle of SIBs: Leverage strengths, address weaknesses, and compete for cost-effectiveness.

Scenarios with high safety requirements

Home ESS, IDC, Power facilities, mine, subway, military, portable power, etc

Opportunities and challenges co-exist.



Conclusion:

As a new technology, sodium-ion batteries have unique advantages but also disadvantages. Its safety, low-temperature, and high-rate discharge performance can play a significant role in certain application fields. In order to use sodium-ion batteries on a large scale in more application fields, users need to make some improvements and adjustments.

Content

SIB research began in 2015 and mass production in June 2024.

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2015	2021Q3	2022H1	2022H2	2023
Began basic theoretical research on SIBs	Relied on VISION Group for technology incubation	The first-generation smart battery cell samples were verified	Formed an entrepreneurial team and determined the technical route	Improved the organizational structure and management system, put the pilot production line into operation, and initiated the construction of the first-phase mass production line

Vision

SIBs make the world green.

Mission

Use technological innovation to fulfill people's vision for the future of energy.

Core Values

Be strict with oneself, dare to innovate.
Be cautious in details, be brave to take the lead.

Three bases to serve customers

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Thanks For Your Attention

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