Nanophosphate: ***Nano-LFP***

the Best Optimized Chemistry for AI server BBU

ENDRICH: ***RELIANCE*** *LithiumWerks*

TAIWAN

White Paper

Nanophosphate® Basics: An Overview of the Structure, Properties and Benefits of A123 Systems' Proprietary Lithium Ion Battery Technology

A123 Systems, Inc.

Abstract

The overall performance and reliability of an advanced battery system depends largely on the chemistry used in the cell. Lithium ion, for example, is deployed in electric vehicles, grid-scale energy storage systems and a wide variety of commercial and industrial applications.

There are a number of different lithium ion chemistries commercially available today, however, each with distinct behavioral characteristics. Understanding the differences in these chemistries can prove invaluable in determining which battery system is best suited for a given application.

This paper outlines the unique properties of Nanophosphate®, a nanoscale lithium ion technology offered exclusively by A123 Systems, and how it differs from standard lithium iron phosphate as well as other lithium ion technologies. It also describes the resulting performance advantages, including high power, excellent abuse tolerance, long life and the ability to maintain consistent power over a wide range of state-of-charge (SOC).

History of Nanophosphate

Nanophosphate is A123 Systems' patented lithium ion battery cathode active material, originally developed by professor Yet-Ming Chiang and his group at the Massachusetts Institute of Technology (M.I.T.). They reported their work in the seminal paper entitled, "Electronically conductive phosphor-olivines as lithium storage electrodes," which was published in the journal Nature Materials in the October 2002 issue (Chung, Bloking, & Chiang, 2002).

In this paper, Professor Chiang and his group discussed the development of a unique new material belonging to a class of materials called the "olivines" based on their crystal structure. This new material exhibited dramatically higher conductivity and rate capability than standard lithium iron phosphate materials, with near-theoretical energy density.

On March 4, 2008, the U.S. Patent Office granted U.S. Patent Number 7,338,734, titled "Conductive Lithium Storage Electrode" (Chiang, Chung, Bloking, & Andersson, 2002). This patent covers the Nanophosphate materials used in A123's products. The Nanophosphate material is patented worldwide and is not offered by any other battery manufacturer. Specifically, Nanophosphate should not be confused with standard lithium iron phosphate (LFP), which is has lower rate capability and power.

The Structure of Nanophosphate

Nanophosphate is an engineered nanoscale material with specific structural and chemical properties designed to maximize the performance of lithium-ion batteries. Figure 1 schematically illustrates this structure. The image on the left is a cathode electrode, with the aluminum current collector foil covered with Nanophosphate particles. The middle image is the Nanophosphate secondary particle and the image on the right illustrates the primary particles.

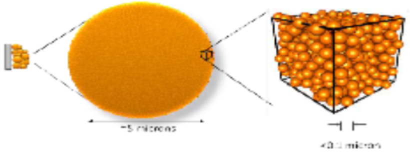

Fig. 1: Schematic illustration of the Nanophosphate structure, with secondary and primary particles

The primary Nanophosphate particles are on the order of one-tenth of a micron in diameter and are agglomerated into much larger secondary particles, which have diameters on the order of a few microns. So, although the primary particle may have a length scale on the order of several tens of nanometers, the

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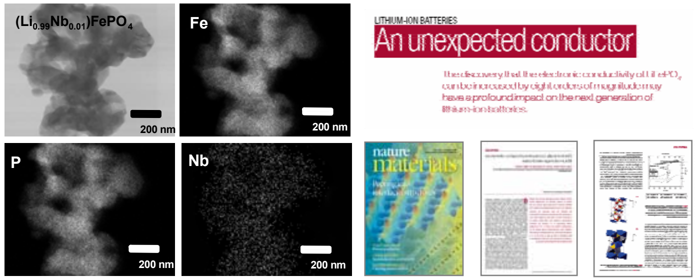
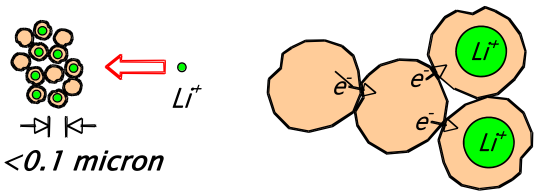
Nanophosphate Material

Nanophosphate™

Better battery enabled by new nano-materials (Nature Materials, 2002)

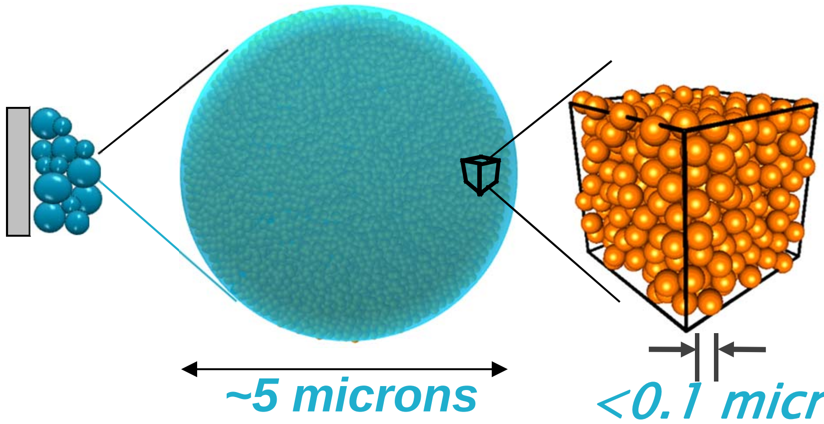


Nature Materials, 2002



Nano particle size = Extremely fast diffusion

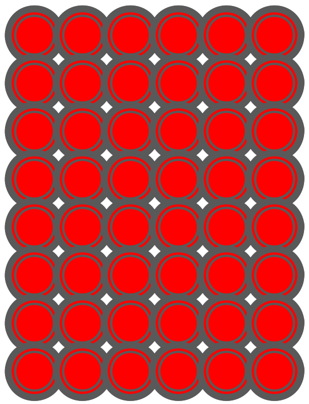
Dopant significantly increases rate capability



Safety: *NO Propagation & Thermal Runaway*

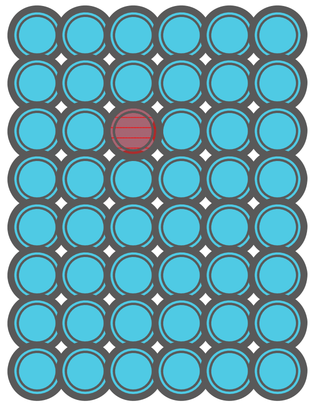
- Rapid heat generation can lead to cell-to-cell propagation

Metal oxide



Individual cell failure propagates to neighbors, consuming entire pack

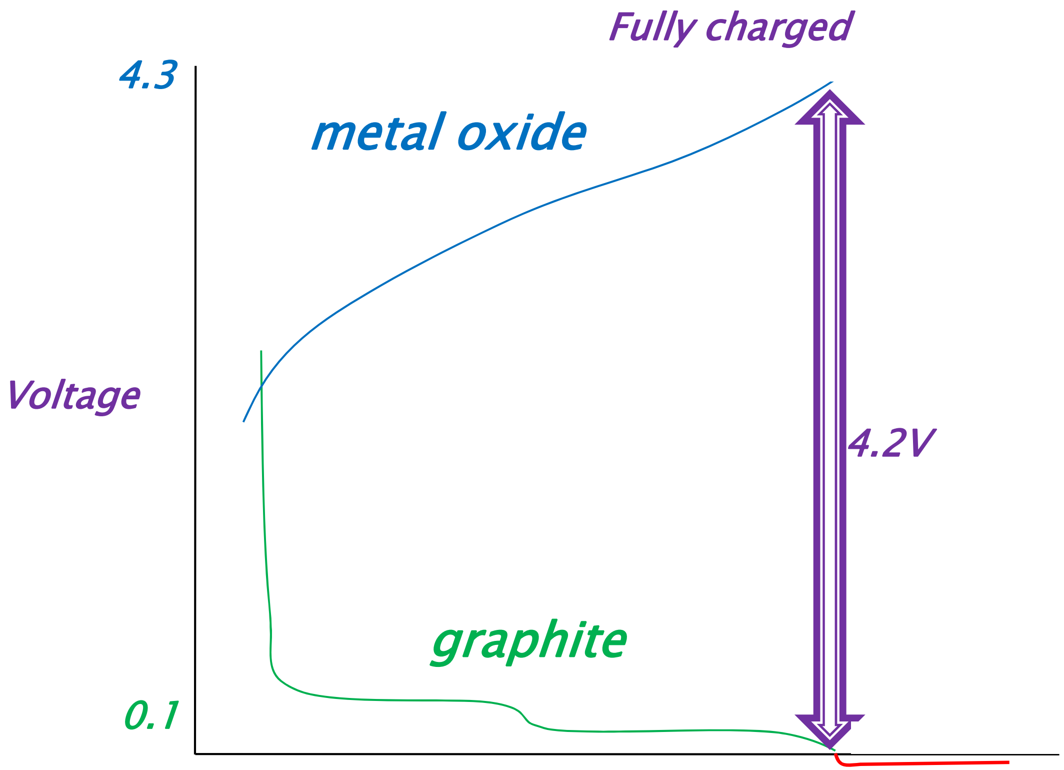
Nanophosphate

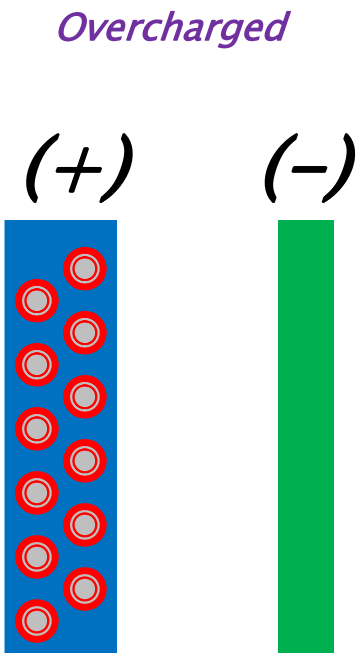


No propagation

Risk: Lithium Plating: Metal Oxide - Graphite

Typical Li-ion cell cathode (Metal Oxide) excess lithium causes anode plating when overcharging

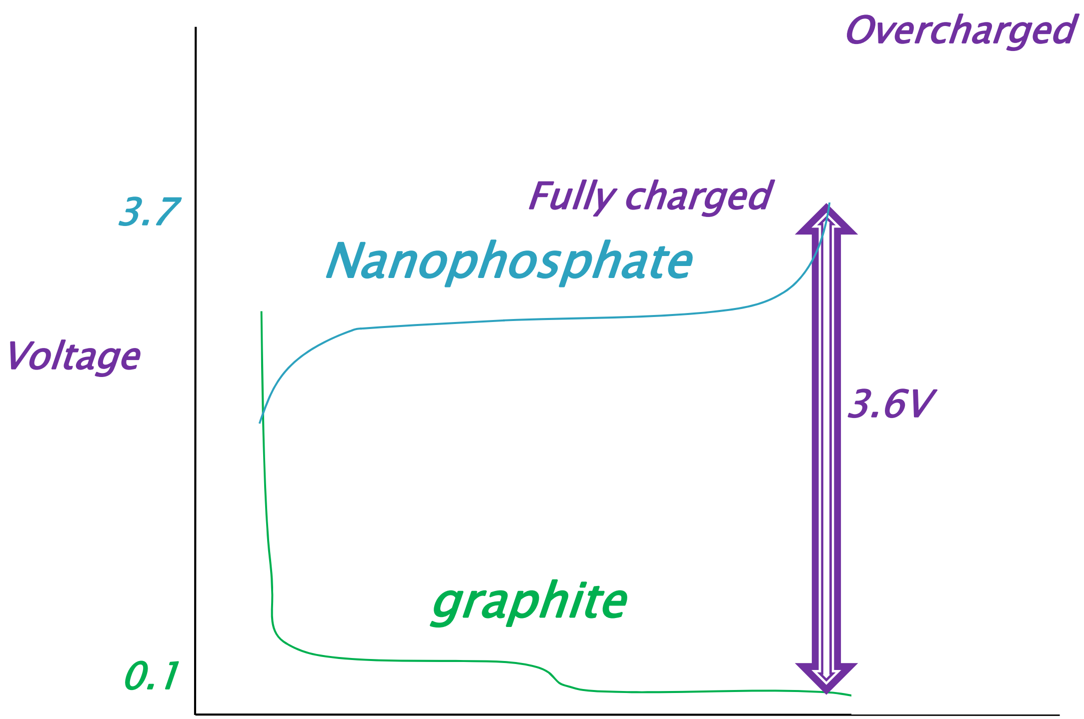


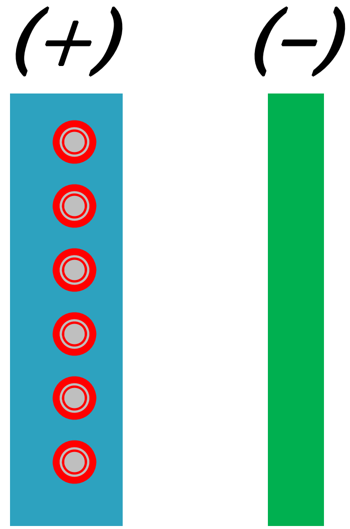


Li plating occurs during overcharge in metal oxide cells because cathode has twice as much Li as anode can accept, posing serious PERFORMANCE, RELIABILITY and SAFETY PROBLEMS.

$$LiCoO_2 \leftrightarrows Li_{1-x}CoO_2 + xLi^+ + xe^-$$

Safety: NO Lithium Plating: Nanophosphate - Graphite





No excess lithium in Nanophosphate cell

Safety: Thermal Ramp Testing from Sandia

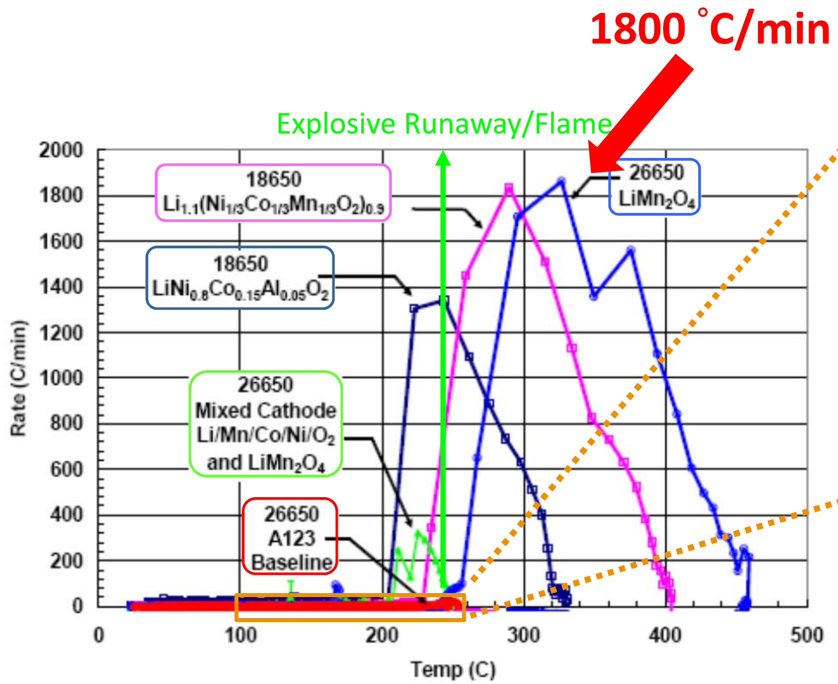


Figure : Heating rate profile comparison including additional common cathode compositions in 18650 cells.

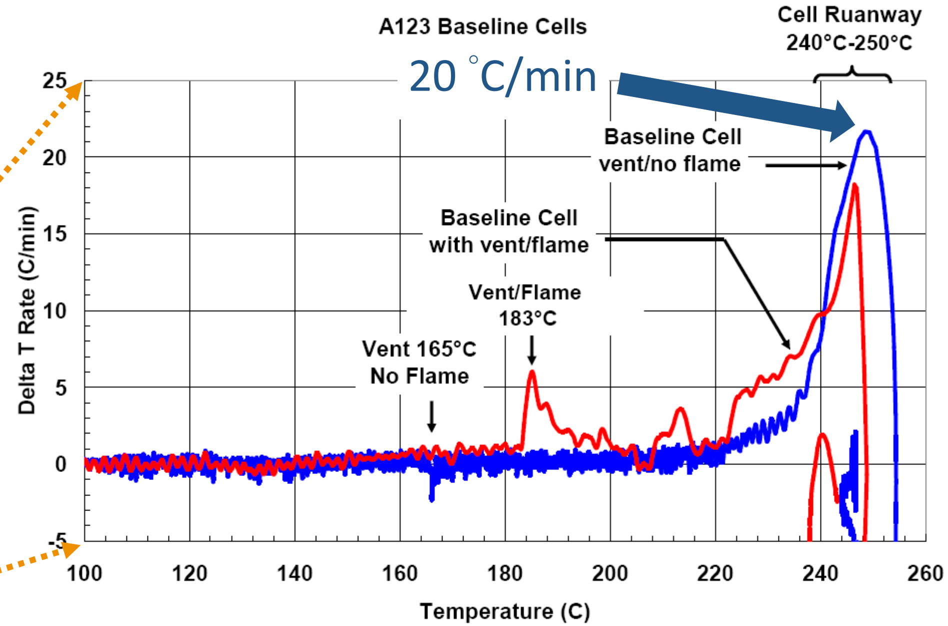


Table1 **Heating rate profiles for two A123 baseline cells, one cell with burning vent gases.**

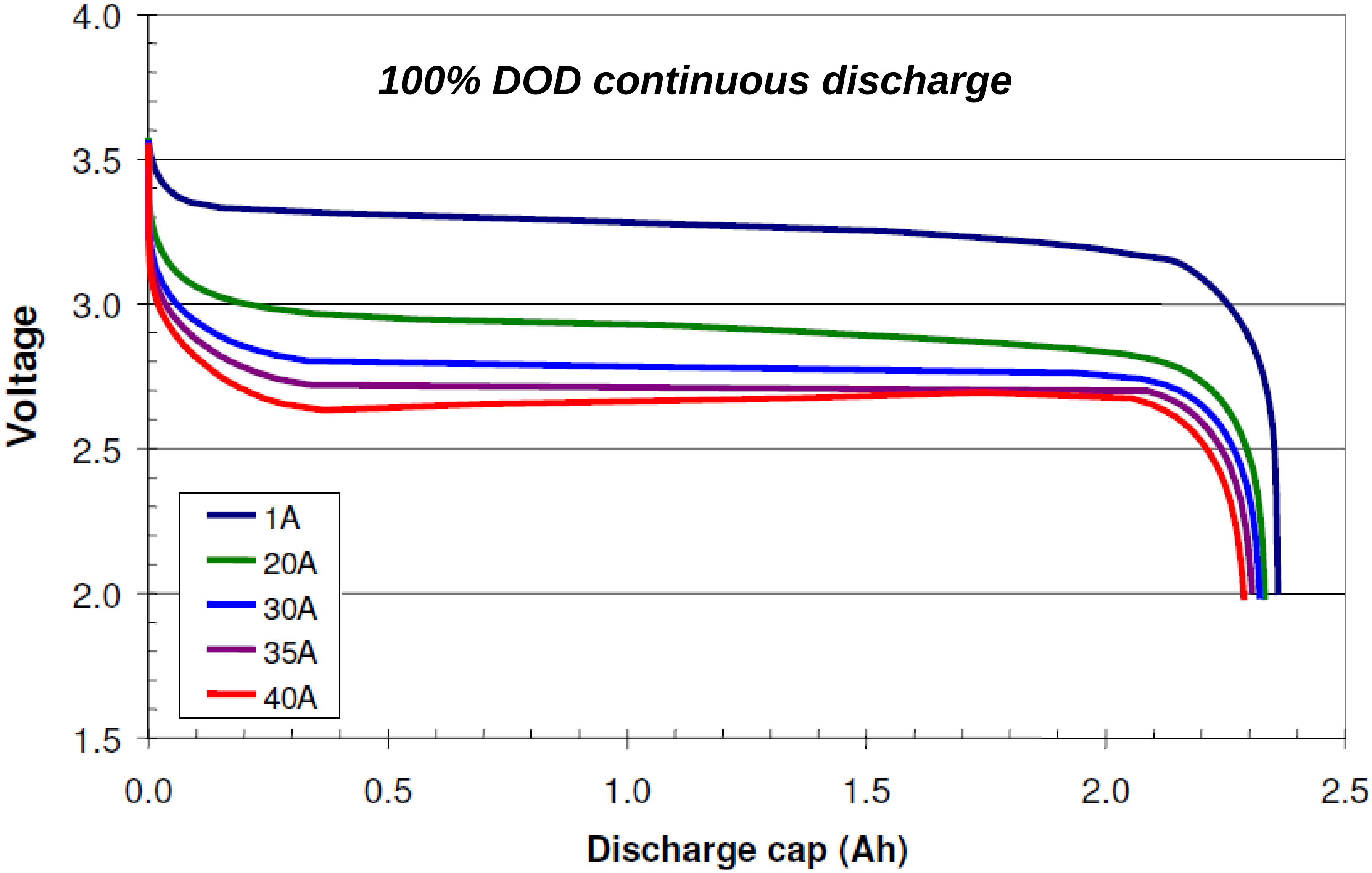
For additional comparative purposes, thermal ramp data for cells with two other common Li-ion chemistries are shown in Figure . These measurements were performed using 18650 cells with about 950 mAh capacities. The chemistries shown are for $Li_{1.1}(Ni_{1/3}Co_{1/3}Mn_{1/3}O_2)_{0.9}$ (NMC) and $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA). The NCA cells show the lowest onset temperature for runaway at 205°C while the NMC material is more stable with a runaway at 230°C. Both of these cathode chemistries showed heating rates greater than seen for the nanophosphate material although detailed quantitative comparison is not possible due to differences in cell thermal properties and capacitances. Table 1 summarizes the relative cell performances. The significant reduction in cell heating rates for the nanophosphate material is attributable to the lack of oxygen decomposition from the cathode material. However, increasing anode reaction with the electrolyte can still occur at higher temperatures leading to a low-rate thermal runaway of the cell as has been observed.

Nano-LFP cell that showed flame had a much lower self-heat rate, compared to the metal oxide cells.

Safer products

A123 Technology Nanophosphate	Oxide-based Li-ion
No thermal runaway *No oxygen evolution*	Thermal runaway above 150 °C Oxygen evolution $Li_{0.5}CoO_2 \rightarrow 0.5LiCoO_2 + ⅙Co_3O_4 + ⅙O_2$
No excess lithium in cathode *Overcharging will not plate Li* $LiFePO_4 \rightarrow FePO_4 + Li^+ + e^-$	Excess lithium can plate during Overcharge $LiCoO_2 \rightarrow Li_{(1-x)}CoO_2 + xLi^+ + e^-$
Failure mode on overcharge: venting due to gas pressure	Failure mode on overcharge: self-accelerating heat generation, Explosion
Lower voltage cathode *Less electrolyte oxidation, longer life*	Higher voltage cathode (more electrolyte oxidation)
Excellent fast-charge capability	
Good tolerance to over-discharge	

Flat discharge curves:
Lower voltage drop Higher usable energy



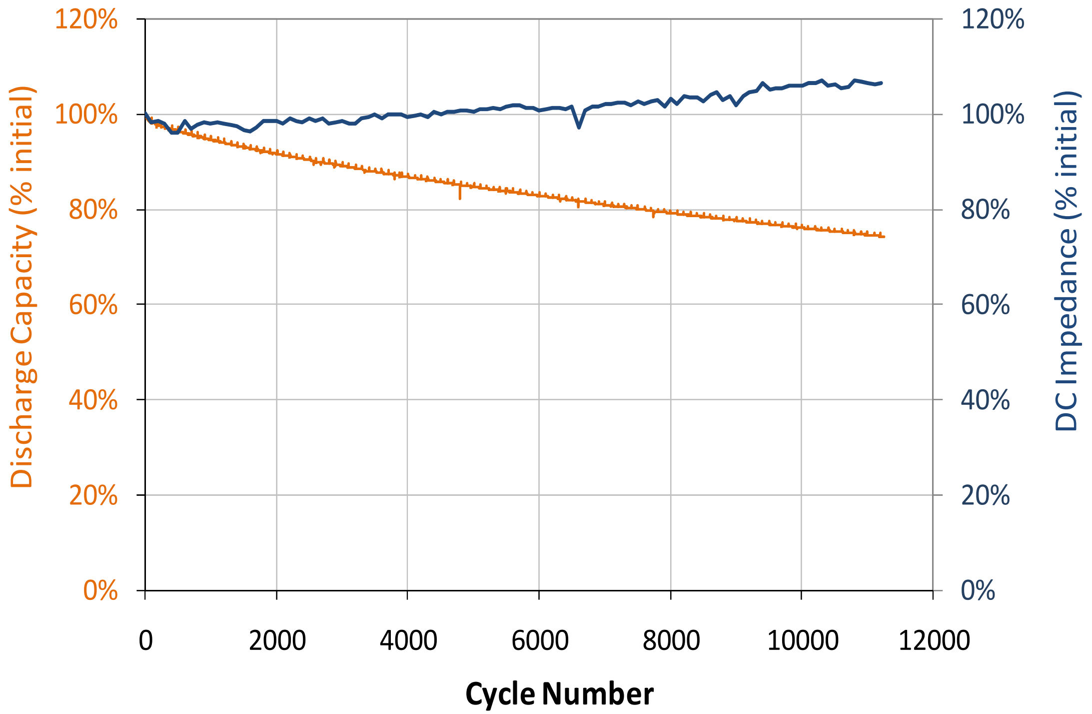
Superior Life

26650 cell

8,000 full Depth of Discharge cycles with only 20% capacity loss

- ***Full 100% DOD***
- ***1C charge / discharge rates***

1C-1C, 100% Depth Of Discharge (DOD) Cycling 25℃

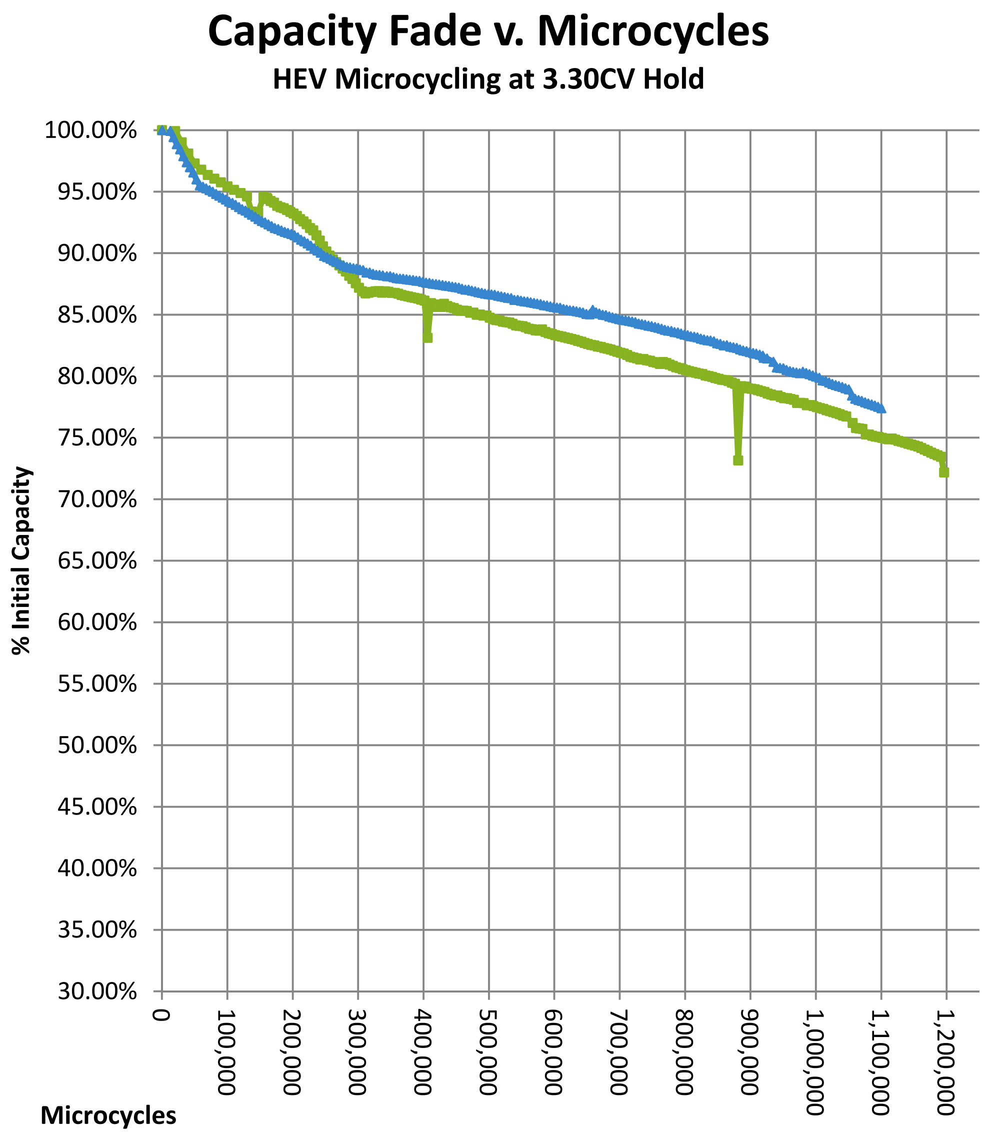


Superior Life, Micro cycles Hybrid model

More like AI server BBU working behavior

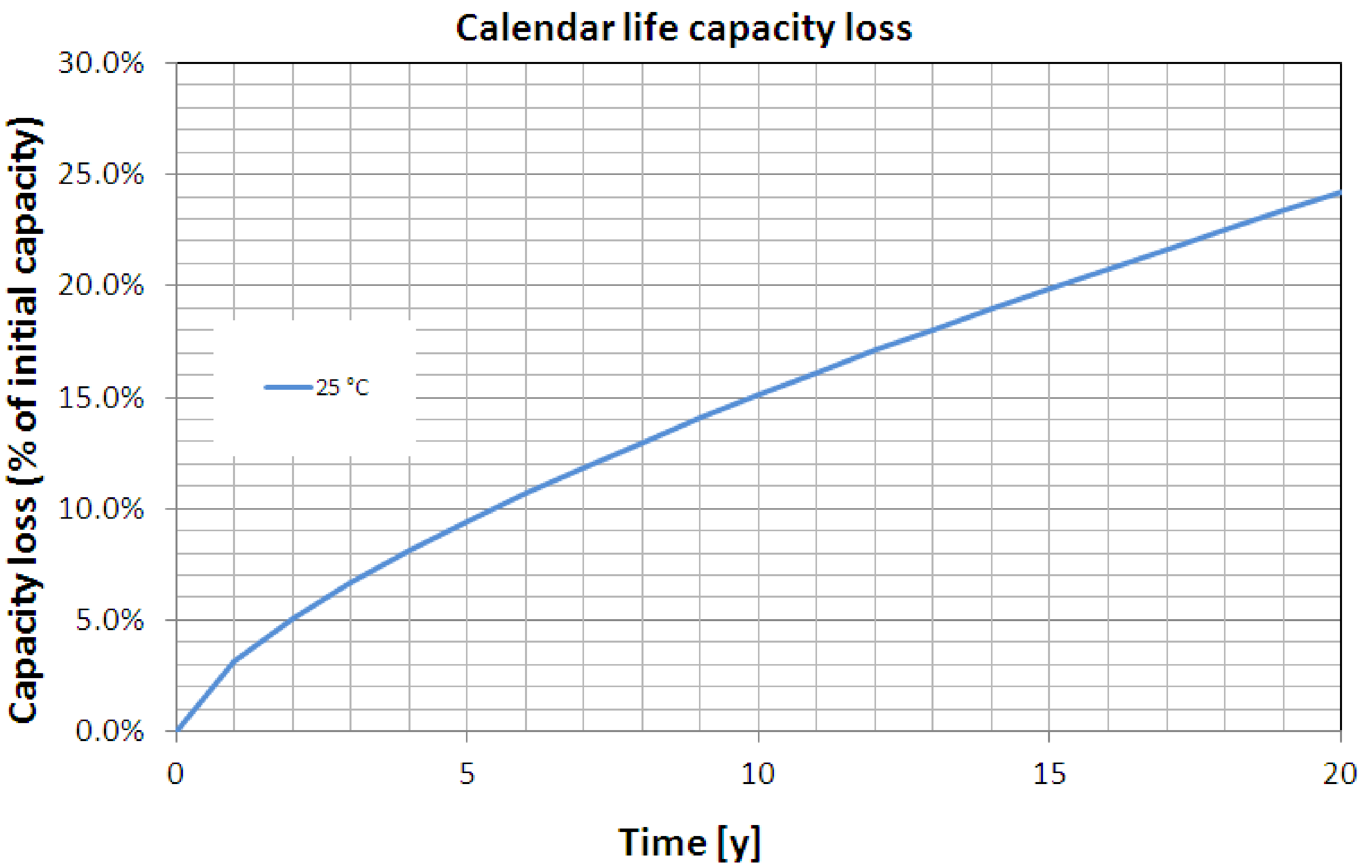
1,000,000 Microcycles with only 20% capacity loss

- 10C charge/discharge rates
- +/- 3% SOC swings
- 35% nominal state of charge



20 year float life

- Application - 20 year float life at 25 deg C
  + calendar fade prediction is 26%

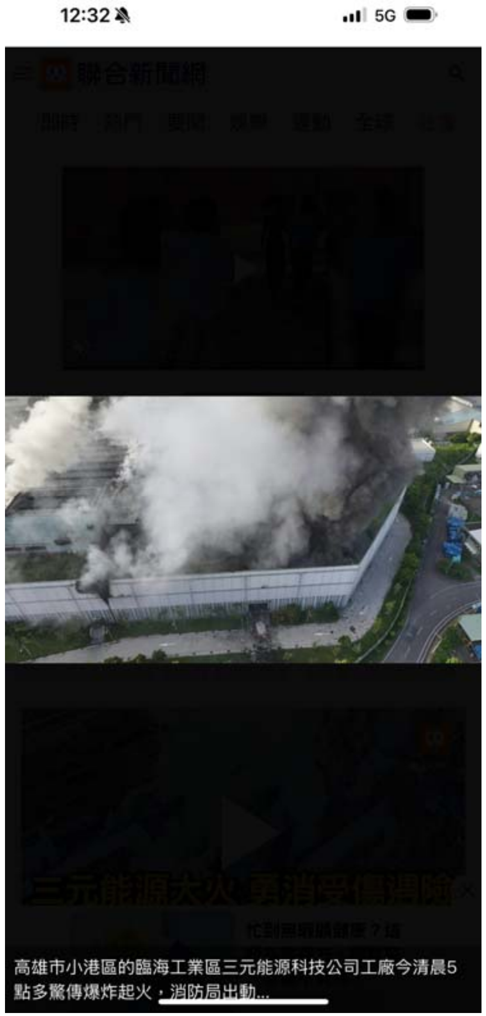


Safety and Thermal Runaway Risk

- - NMC/NCMA decomposes at ~150°C, releases oxygen, risk of fire
- - Nanophosphate stable at ~270°C, no oxygen
- - High propagation risk with NMC/NCMA, low almost no with Nanophosphate
- - Strongly recommend **CSPs** prioritize thermal safety in data centers

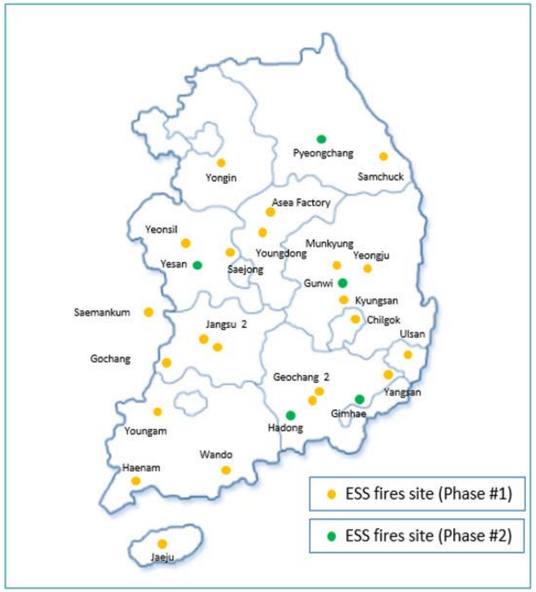
Serious Accidents

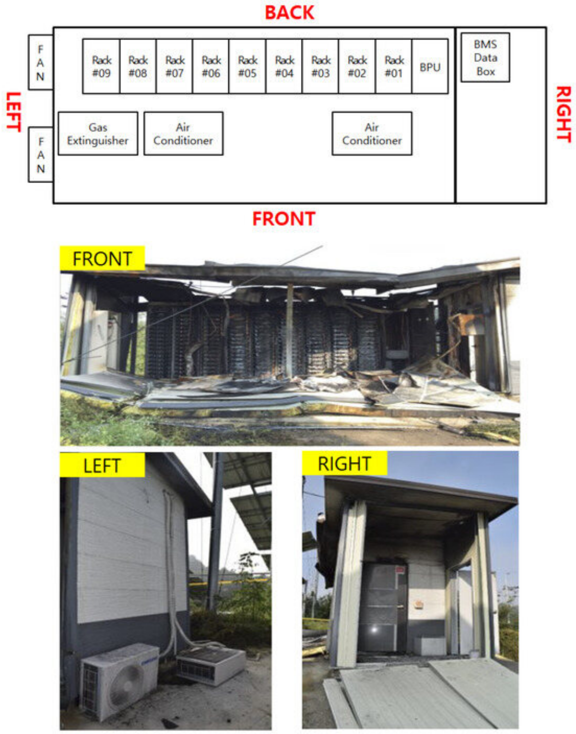
- 2025 July in south Taiwan NMC / NCA cell factory fire



Serious Accidents

- 2017~2020 around 30 ESS fires in Korea





A result of experiments under salt water condition

Serious Accidents in US

Summary of Energy Storage System (ESS) Fires in the United States

More than 20 utility-scale and commercial-scale ESS fire incidents have occurred in the U.S. over the past decade.

[Sources: firesafetysearch.com, sevoifp.com, MDPI, UL Solutions, energystorage.org, storagewiki.epri.com]

In April 2019, a major explosion occurred in Surprise, Arizona. A 2.16 MWh ESS experienced thermal runaway and deflagration, resulting in severe injuries to four firefighters.

[Source: fsri.org – official incident investigation report]

Serious Accidents in US

In May 2024, a fire broke out at the Gateway Energy Storage facility (Otay Mesa, San Diego County). The 250 MW / 250 MWh system burned for five days, leading to community evacuations and air quality concerns.
[Sources: AP News, Wikipedia, Politico]
In September 2022, a Tesla Megapack at the Elkhorn battery facility (operated by PG&E in California) caught fire. The incident triggered an emergency shutdown, but no injuries were reported.
[Source: Wikipedia]
In January 2025, a massive fire erupted at Moss Landing – the world's largest battery energy storage facility, with a capacity of approximately 750 MW. The fire prompted the evacuation of 1,200 to 1,500 residents and triggered lawsuits and regulatory reviews.

Cycle Life and Maintenance Cost

- - NMC/NCMA: *500–1,500 cycles*, fast degradation under load
- - Nanophosphate: ***2,000–8,000 cycles***, stable under high-rate use
- - Nanophosphate: Lower replacement frequency reduces TCO and management burden

ESG and Carbon Footprint Concerns

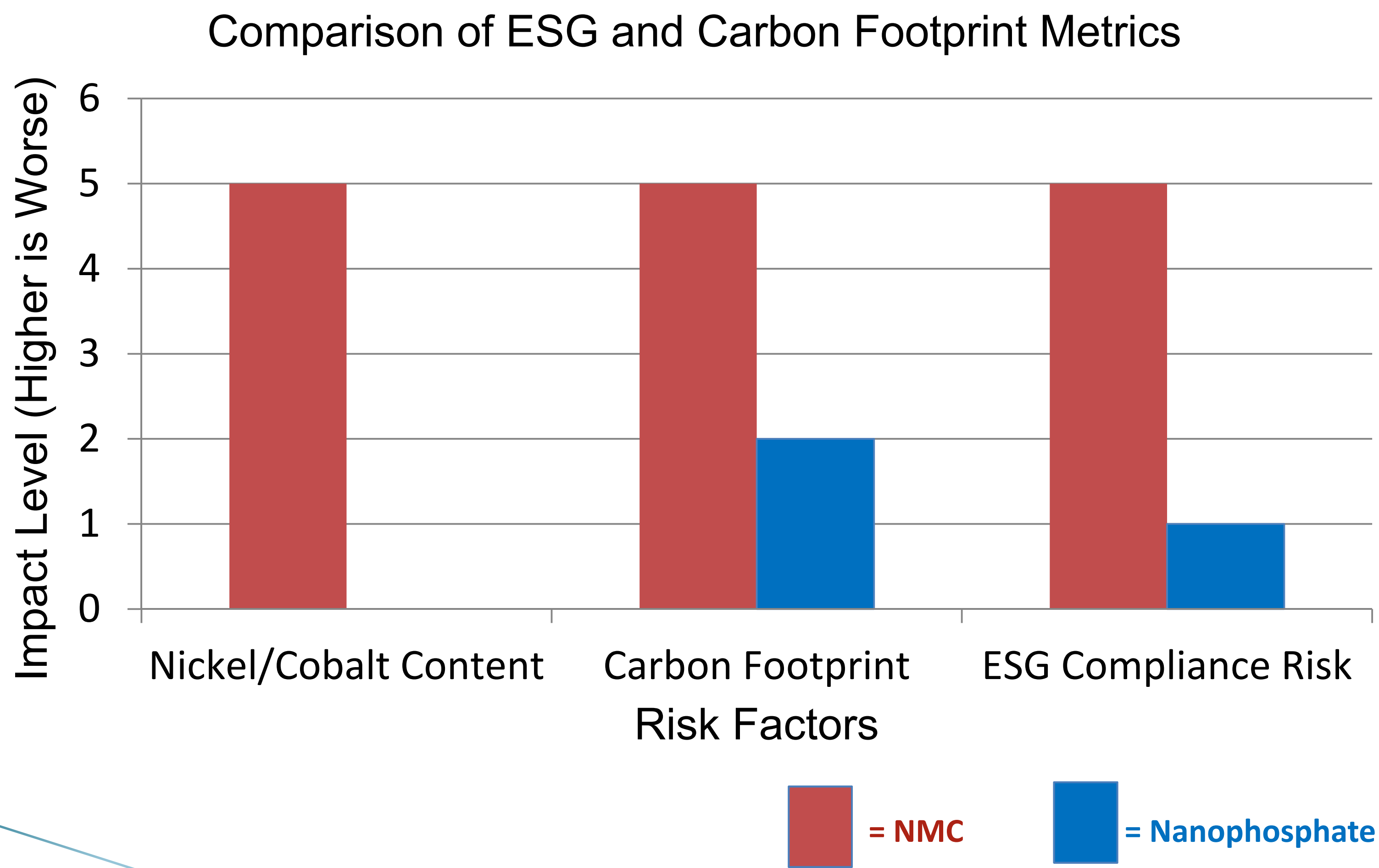
- - NMC/NCMA: High ESG risk due to Nickel/Cobalt sourcing and emissions

Nickel/Cobalt sources	A significant portion of these raw materials is sourced from regions with ongoing human rights concerns, such as the Democratic Republic of the Congo.	
Carbob Footprint	Refining is energy-intensive, and smelting causes significant pollution.	
ESG Compliance Level	Subject to intense scrutiny due to ESG-related pressures from NGOs and shareholders.	

Leading tech firms like AWS, Google, Meta, and Microsoft have pledged Scope 3 carbon neutrality and supply chain transparency in alignment with human rights standards. Continued using on NMC/NCMA batteries could weaken ESG performance and expose companies to significant reputational and compliance risks.

- - Nanophosphate: Cobalt- and nickel-free, low carbon manufacturing
- - Aligns **CSPs ESG** procurement criteria

ESG and Carbon Footprint Comparison Chart



Procurement Trends

- - Remove high-carbon batteries by 2030
- - Enforce 24/7 carbon-free operation
- - Require long-life, low-risk BBU in data centers
- - Transition to UL1973, low-carbon batteries by 2025

Zero accident Nanophosphate

ANR26650M1B

APR18650M1B

Excellent safe, stable and mature Nanophosphate
since A123Systems to RELIANCE *LithiumWerks*

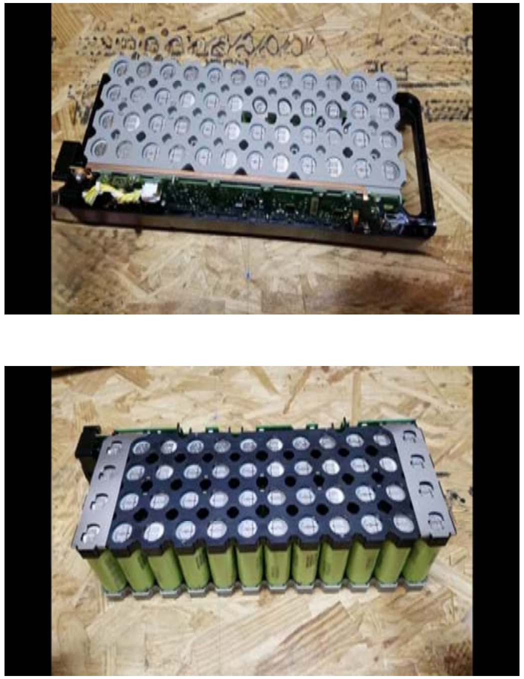
On DELL, NEC, YAMAHA, FERNO, F1, Ferrari, McLaren, Porsche, BMW, Mercedes-AMG, Pagani…

乾坤富實業有限公司
ENDRICH Co.,Ltd.

Real Result

BBU in Power Rack (side car)

Cell



Cell in BBU

BBU in Power rack (side car)