

Quality Driven
Phostech's Advanced LiFePO_4 Cathode

Thorsten Lahrs

CEO, Phostech Lithium

French Riviera
Batteries 2009
September 30TH - October 2nd

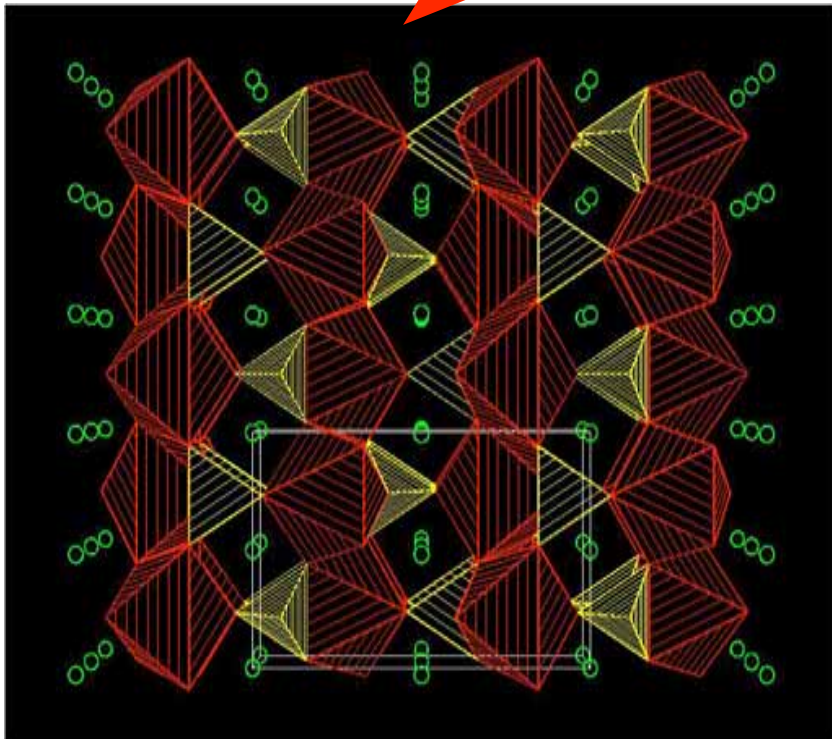
The international power supply conference and exhibition



LiFePO₄ Olivine Cathode Material

Li-extraction with preservation of structure and specific volume

⇒ High cycle stability 😊



theoretical capacity: 169 mAh/g

practical capacity: 155 mAh/g

⇒ < 10% Li-surplus in cell 😊

⇒ High tolerance versus over-charge 😊

Cell voltage:

+3,45 V vs. Li-metal

+3,20 V vs. graphite

⇒ less electrolyte aging 😊

⇒ flat-voltage discharge curve 😊

1-dim. Li⁺-conduction

1-dim. e⁻-conduction

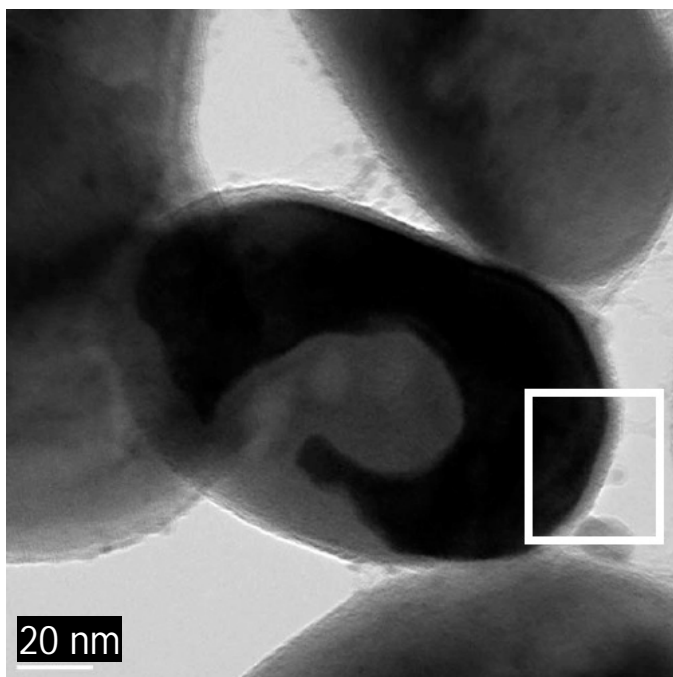
⇒ low bulk conductivity 😊

LiFePO₄ is THE cathode for large Li-Ion and HEV

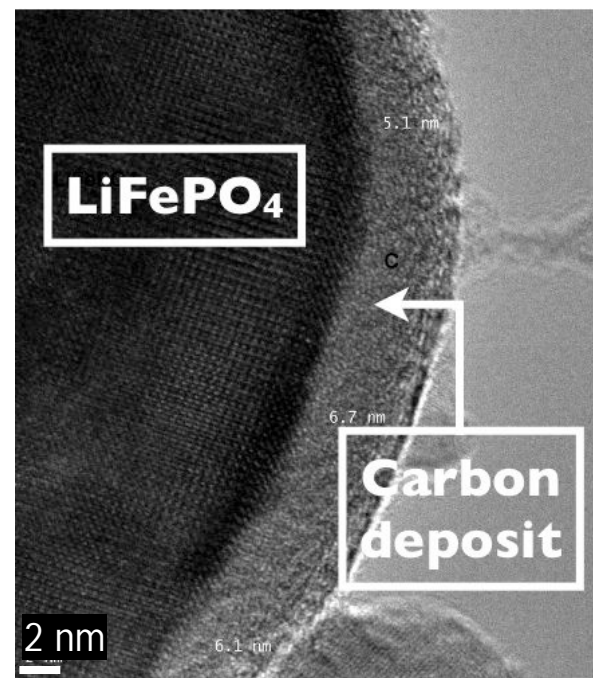
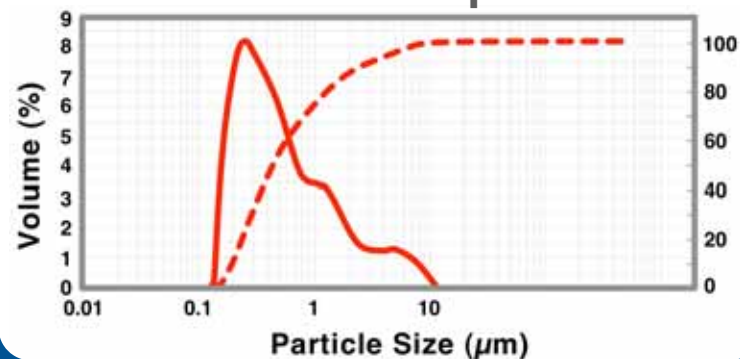
C-LiFePO₄ Technology

Pyrolytic carbon deposit !

Ravet et Al. invented in 1998 the use of a conductive pyrolytic carbon nano-deposit on LiFePO₄ (US 6,855,273, US 6,962,666 & US 7,344,659)



Submicron-sized particles !



C-LiFePO₄ build on strong innovation

Production Processes

<i>Process</i>	Solid State	Wet Process	Melt
<i>Grade</i>	Energy	Power	Alternative
<i>Status</i>	Commercial P1	Commercial P2	Pilot Scale



<= P1 in Québec

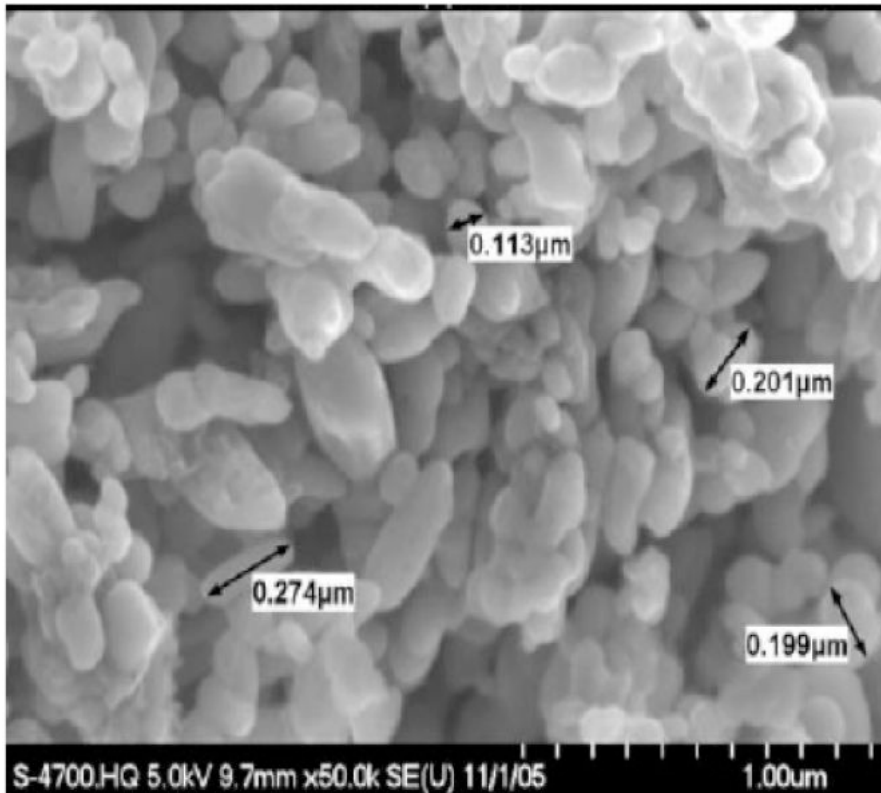
P2 in Germany =>



Phostech Lithium control several synthesis processes to fulfill needs of present & future customers and markets

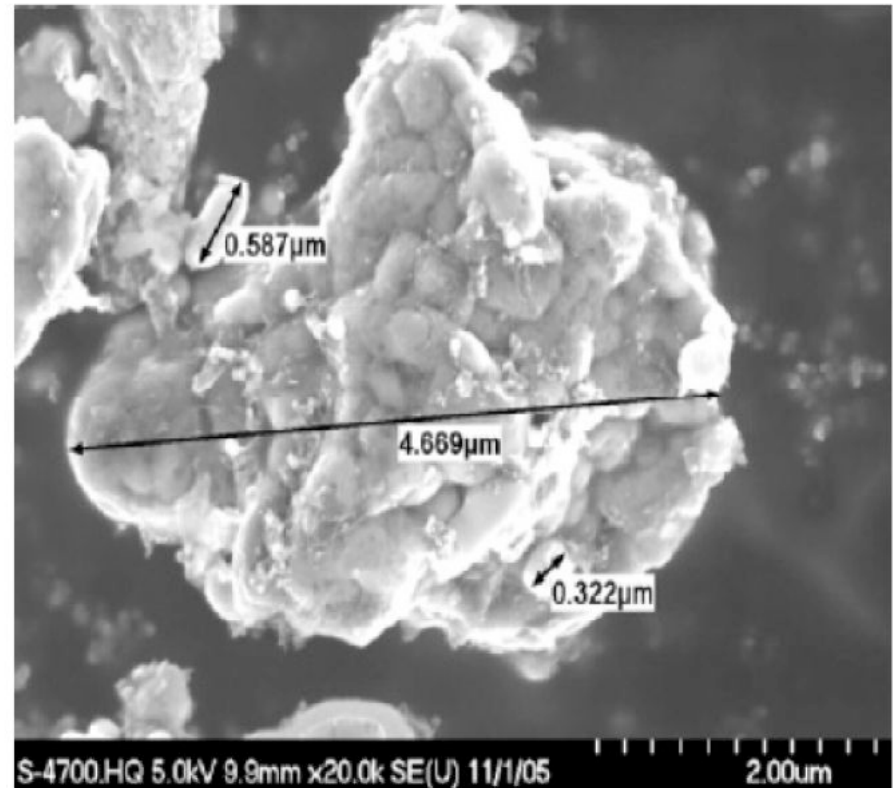
Commercial Products

P2 - Power Grade



Nanosized

P1 - Energy Grade



Micro-Aggregates

+ Under-development products to fulfill customers needs

Strong R&D investment to continuously improved products

LiFePO₄ Production Capabilities

**500 tons/year
Life Power® P1 in Québec**

**250 tons/year
Life Power® P2 in Germany**

Capacity expansion planned

LiFePO₄ Market Main Advantages

Phostech Lithium introduced LiFePO₄ on market with a specific brand name:



Life Power®

- Significantly more stable and therefore safer than conventional cathode materials
- More cost-effective as no very rare and expensive cobalt
- High-power & Fast-charge capabilities
- Wide temperature tolerance ensures performance at -40°C

LiFeP₄OWER

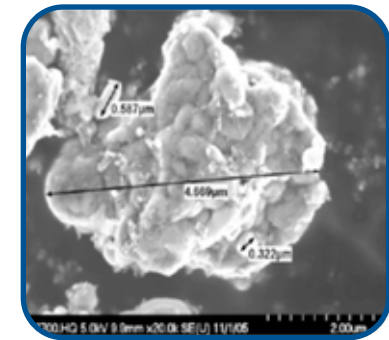
PERFORMANCE BATTERY MATERIAL

Life Power® quality recognized by battery industry

Life Power® P1 Solid State Process



- Simple: mixing + heating
- Low cost equipment (furnace)
- One-step reaction



- Depends on Fe³⁺ ion-diffusion
- Depends on solid reactants mixing quality
- Non-reversible side reaction
- Cost of precursors (FePO₄)

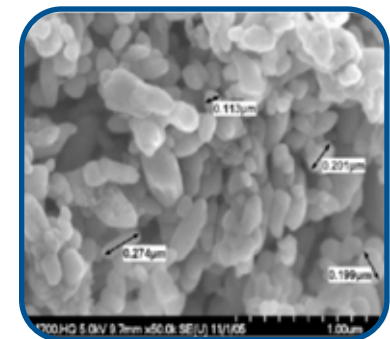
Energy grade C-LiFePO₄
=> Improved power grade in development

Life Power® P2 Wet Process

Fe source + Li source + P source \longrightarrow LiFePO₄

LiFePO₄ + C-precursor \longrightarrow C-LiFePO₄

- Low cost reactants
 - Complete reaction in liquid phase
 - + • Q/C & chemical purity control at each step
 - Particle size, morphology and purity control by precipitation
 - Consistency => low rejects and narrow cells specifications
 - Nano-sized primary particles for power applications
-
- • Capital intensive manufacturing process
 - Require large scale installations



Power grade C-LiFePO₄
=> Improved energy grade in development

Life Power® P3 Melt Process (development)

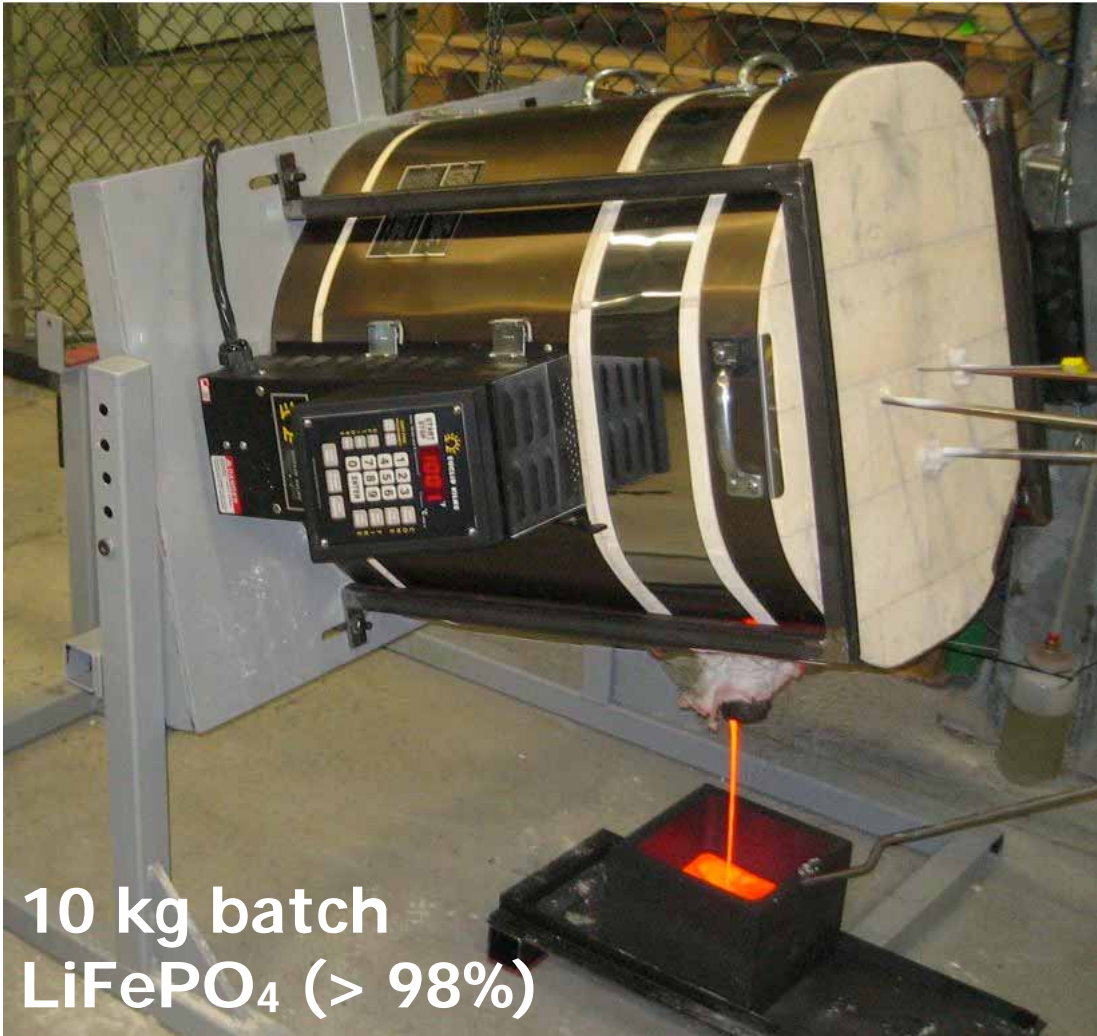


- Simple process, no waste water
 - Rapid and complete reaction at ca. 1000°C
 - Solid-liquid phase separation for purity
 - + • Many commodity reactants compatible
 - Allows substitutions/stoichiometries
 - Allows heat treatment cycles
 - Particle size up to nano conveniently obtained by grinding
-
- • Requires micron and sub-micron powderization for power grades

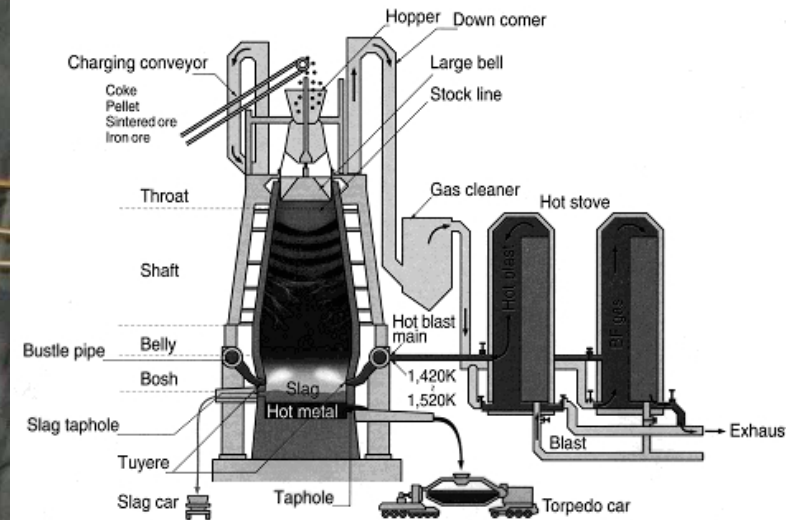


Adaptable for synthesis of energy to power grades

P3 Melt Casting



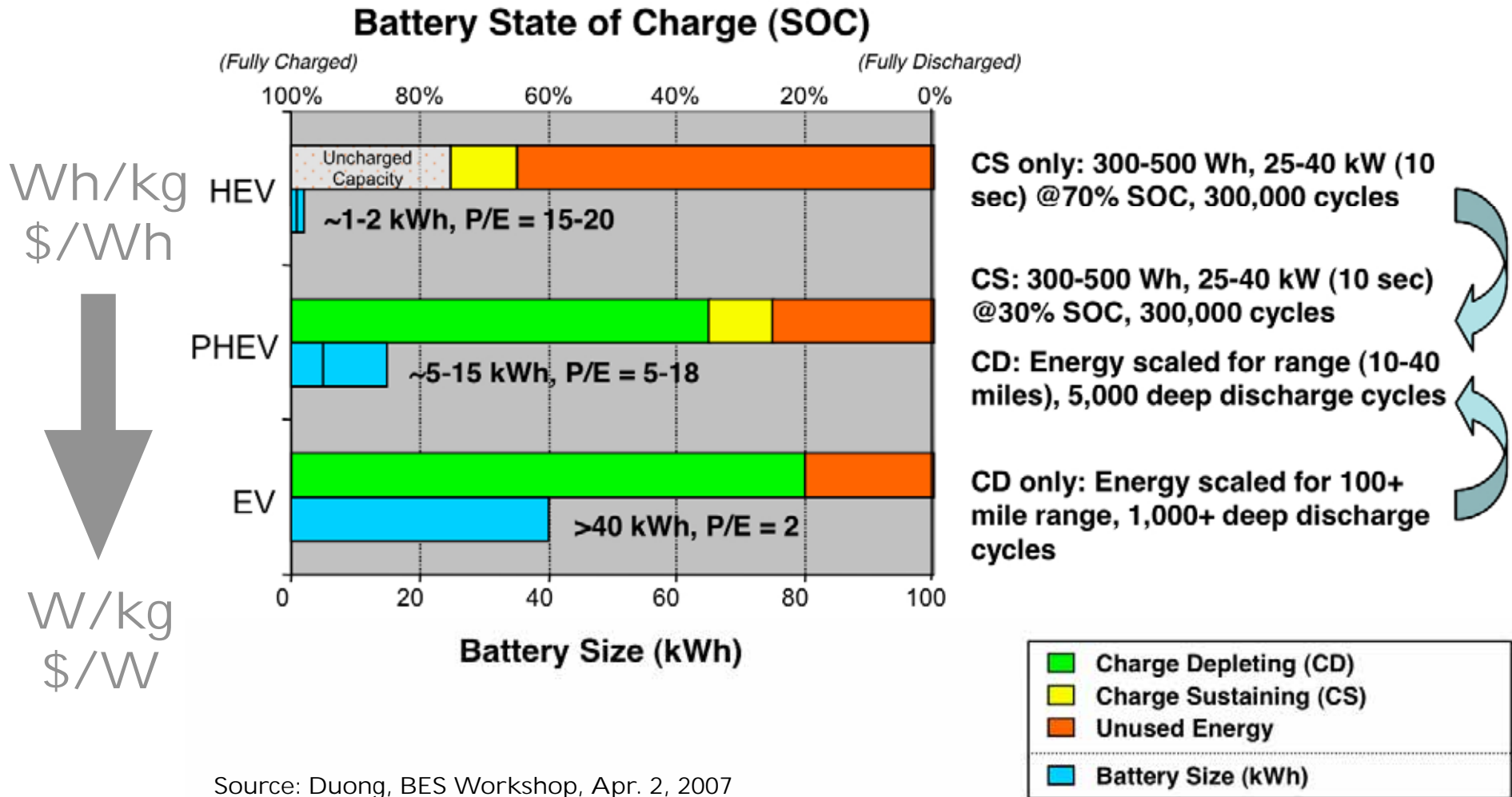
10 kg batch
 LiFePO_4 (> 98%)



Steel industry

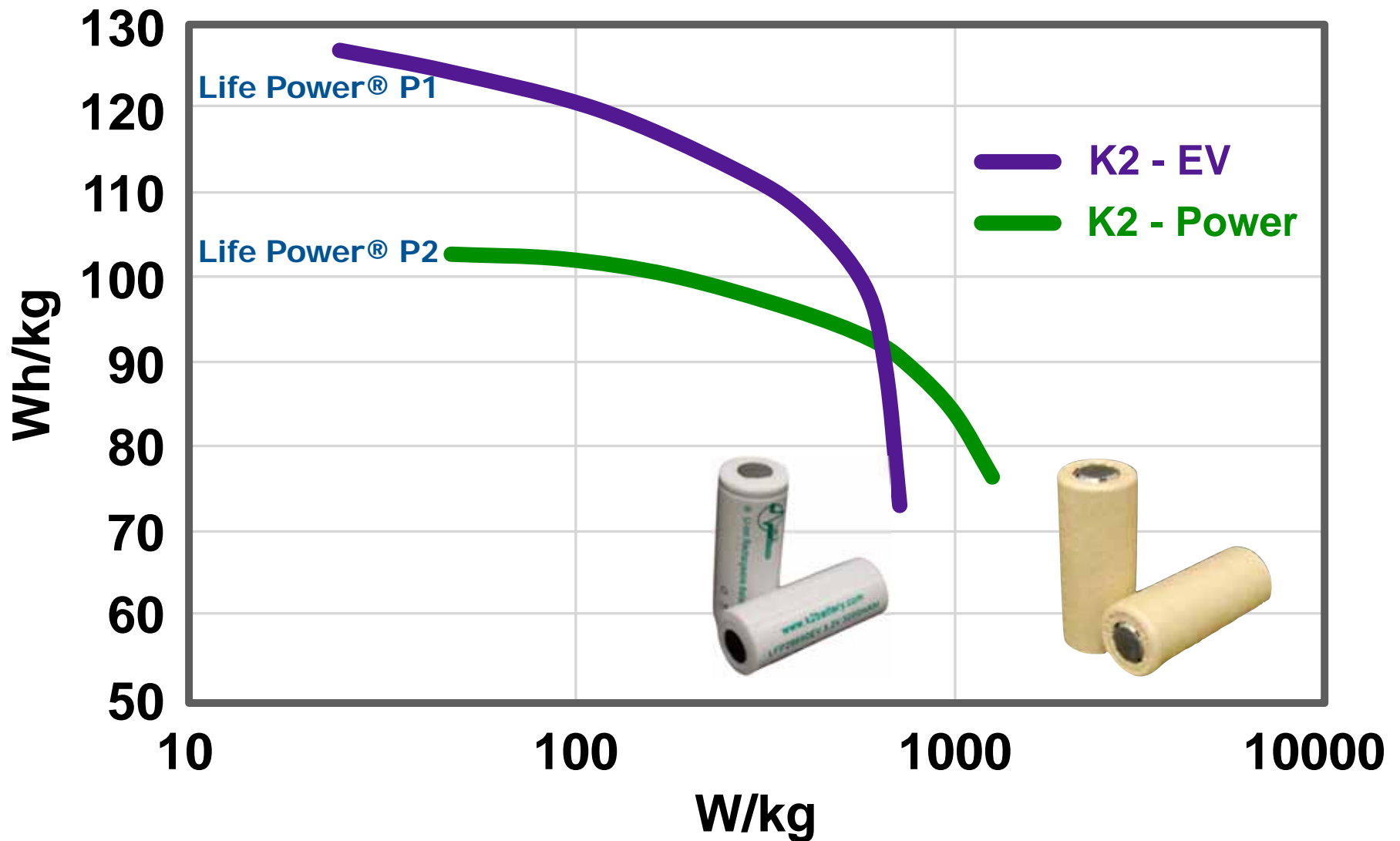
Close to well known metallurgical process

Li-Ion for transportation from Wh to W



Life Power® = Power, Energy and uncompromised SAFETY

Ragone plot of Life Power® cells



K2 Energy Solution - www.k2es.com

Life Powered Electric Vehicles



Microcar



pininfarina

Bollore



Market 2010

Market 2010

Build to order

Life Power® products expands market acceptance

SAFT "Superphosphate" line of batteries

Cell	Classification	Capacity	Discharge Power (kW/kg)			Specific Energy (Wh/kg)	Maximum Discharge (continuous at 25°C)
			200 ms	2 sec	Continuous		
VL3A	Very high power	3Ah	15	9	6	57	350
VL6A	Very high power	6Ah	12	7	6	64	750
VL12V	Very high power	14Ah	12	7	6	74	1500
VL22V	Very high power	23Ah	14	9	6	84	2500
VL10VFe	Very high power (LiFePO ₄)	11Ah	7	5	4.5	57	1500
VL34P	High power	33Ah	9	7.2	1.9	120	500
VL25PFe	High power (LiFePO ₄)	26Ah	1.7	1.7	1.7	85	500
VL52E	High Energy	52Ah			0.19	185	52
VL40EFe	High Energy (LiFePO ₄)	40Ah			0.17	132	50

Source: SAFT 11th Electrochemical Power Sources R&D Symposium (July 2009)

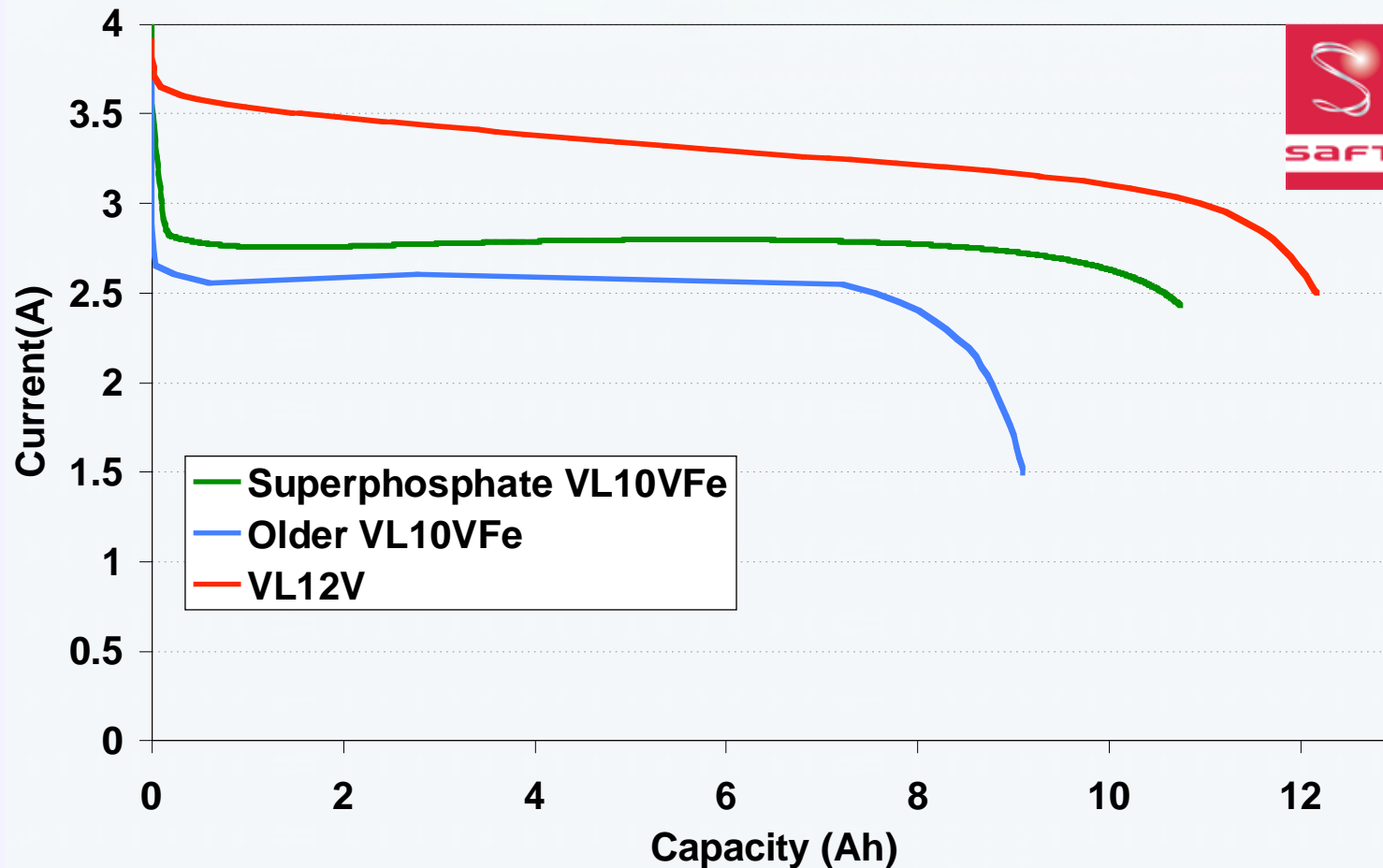
- 11 to 40 Ah cylindrical cells
- 57 to 132 Wh/kg
- 0.17 to 4.5 kW/kg (continuous)



High-quality LiFePO₄ + SAFT engineering = Superphosphate brand

Uncompromised quality key to success

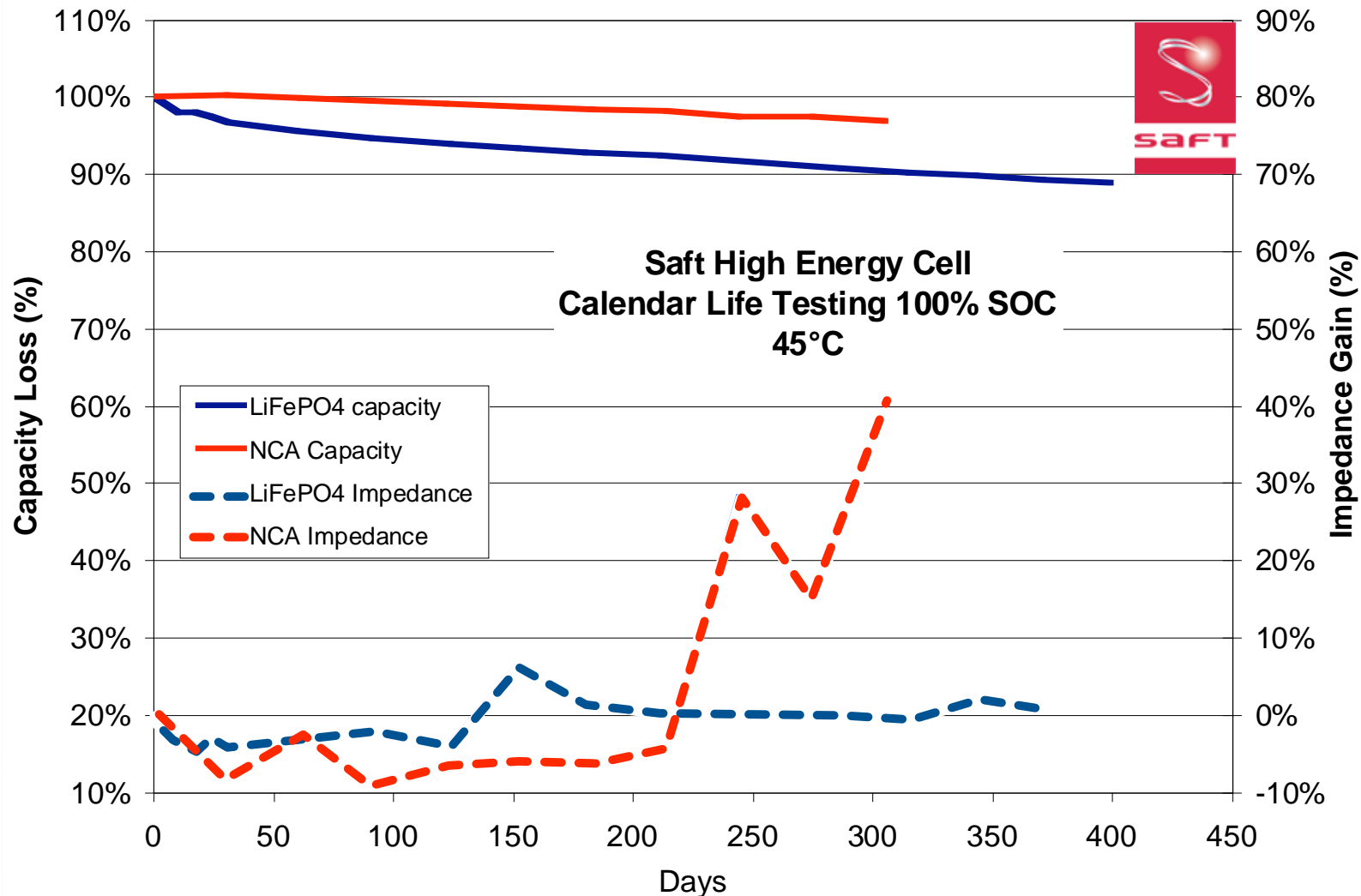
Continuous Discharge of VL10VFe and VL12VFe Cells at 25°C
750A



Source: SAFT 11th Electrochemical Power Sources R&D Symposium (July 2009)

Close collaboration with customers help improve performance

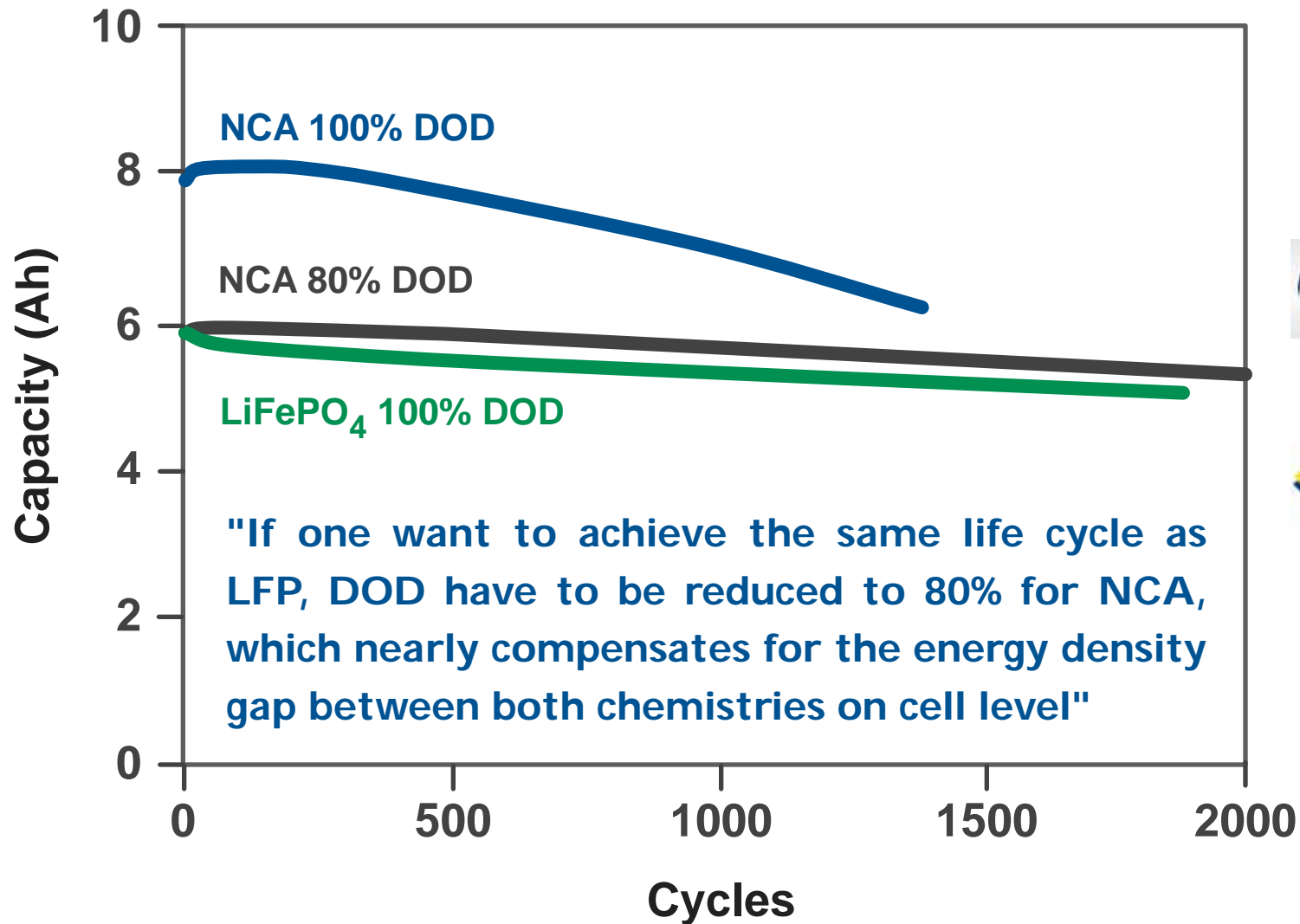
Uncompromised quality key to success



Source: SAFT 11th Electrochemical Power Sources R&D Symposium (July 2009)

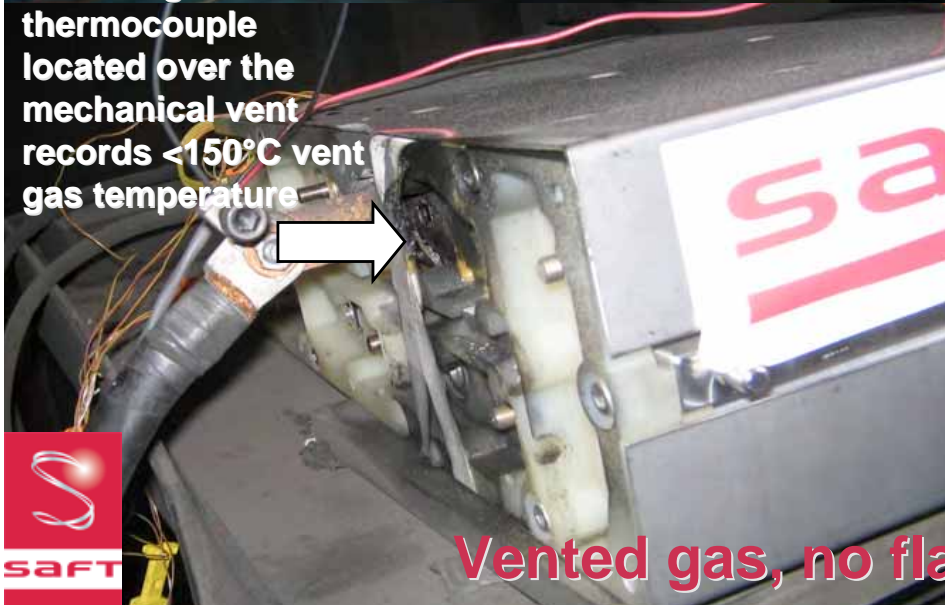
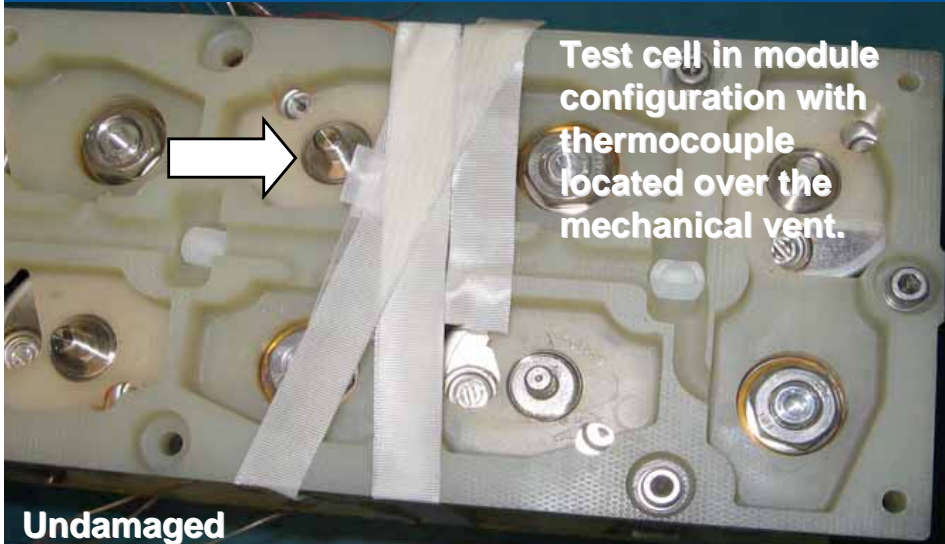
Minimal impedance growth !

How does LiFe Power® LFP compare to NCA ?



Any hesitation for your HEV batteries ?

High rate overcharge of one VL10VFe cell



Vented gas, no flame, NO PROPAGATION !

High rate overcharge is possibly the most abusive test for Li-ion !

The challenge of future EV market

- High battery cost amortize during whole life of EV's
- Favorable TCO of EV's



- TCO reasoning difficult to sold to consumer
- Solution: leasing of EV and/or battery pack
second life of battery (storage)

Profitability of battery pack leasing business implied long-life batteries = high quality LiFePO_4

Business economic strongly link to quality

Phostech investment in quality



St-Bruno dry room dedicated to QC

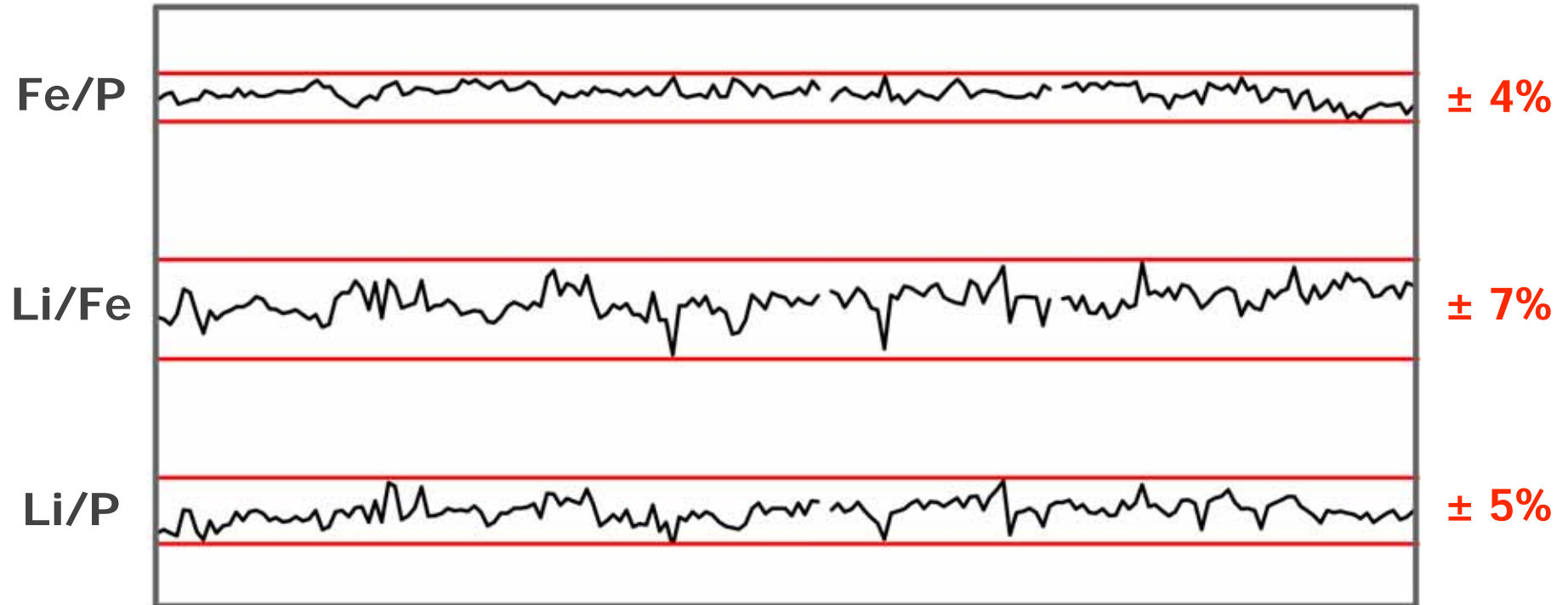
Phostech investment in quality



St-Bruno cycling facility for Life Power® QC

Automotive QC requirements

Exemple: LiFe Power™ Stoichiometry (at.%) QC



190 consecutive lots including off-spec

Automotive requirements with > 25 parameters to control !!!

Huge QC investments to enter automotive market

Phostech C-LiFePO₄ is used and evaluated by numerous companies (PT, HEV, PHEV, EV, UPS...)



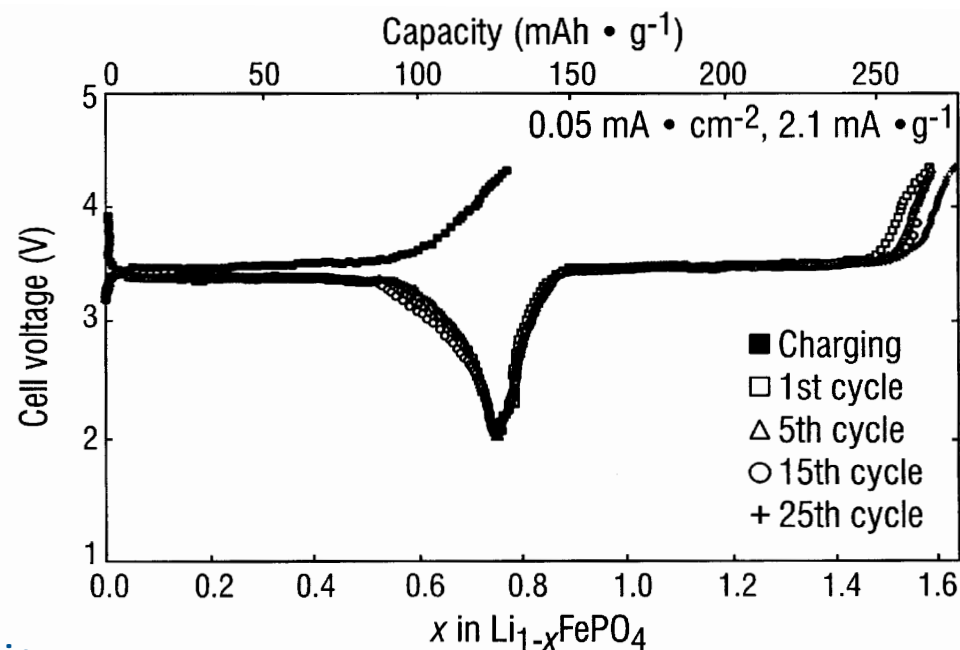
Others customers ★★★★★

Intellectual Property Important Milestone

- Successful reexamination of US 5,910,382 !!!
LiFePO₄ application as cathode materials
- Successful reexamination of US 6,514,640 !!!
Optionally doped (Mg, Nb,...)

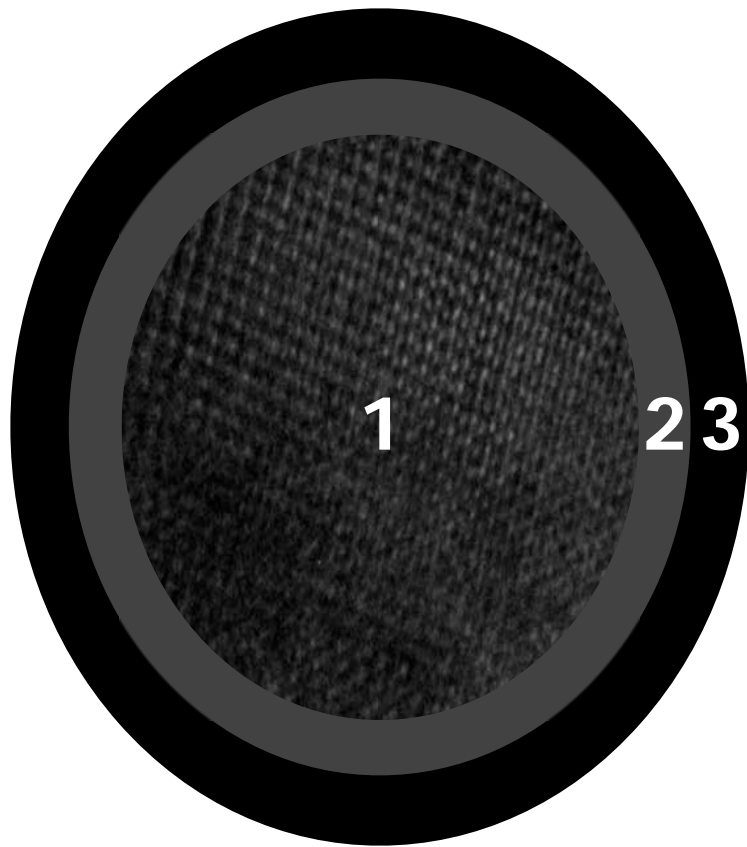


Dr. John Bannister Goodenough
Lithium Metal Phosphate cathode inventor
Japan Prize 2001 for his works on batteries
U.S. Presidential Enrico Fermi award (2009)
Professor at the University of Texas at Austin



IP position reinforced after positive reexamination !

Multicore "Material" Intellectual Property



Core 1: LiFePO₄ (HQ/UT)

US 5,910,382 C1 US 6,514,640 C1

CA 2,251,709 EP 0904607

**Core 2: Carbon deposit 1
(ACEP, UdM, CNRS co-ownership)**

US 6,962,666 US 7,344,659

EP 1049182 EP 1796189

CA 2,307,119

+ JP examination

**Core 3: Carbon deposit 2
(HQ, UdM, CNRS co-ownership)**

US 7,457,018

KR 100879839

CN 100421289

+ JP, EP and CA examination

Necessary "free to operate" LiFePO₄ material IP

Thanks for your attention !

LiFePO₄W₄WER
PERFORMANCE BATTERY MATERIAL



**For more
information:**

info@phostechlithium.com

www.phostechlithium.com