Battery Industry Innovation Solutions 2020

January 2020

Shmuel De-Leon
Shmuel De-Leon Energy, Ltd.
www.sdle.co.il, shmuel@sdle.co.il

Potential Battery Technologies for Break- Through

- Lithium Ion Silicon based anode
- Li-Ion Solid Electrolyte
- Lithium Sulfur
- Lithium Metal
- High Voltage Li-Ion
- Li-Air

Amprius

Amprius Technologies High Energy Products: Span 4 Ah – 14 Ah Cells

amprius

Worlds highest energy density and specific energy Li-ion Cells

Product ID	Capacity Ah	Energy Wh	Wh/L	Wh/kg
ANW4.0-455056	4.0	14.5	1150	424
ANW8.1-4551107	8.1	29.3	1220	430
ANW14.2-8051110	14.2	51.2	1244	437

Voltage range 2.75-4.35V, measured at C/5 rate,
Operating temperature range: -20 ºC to 45 ºC

Enovix

Enovix 3D Silicon™ Lithium-ion Battery

Next-Generation Li-ion Battery: Increased energy density *and* improved safety

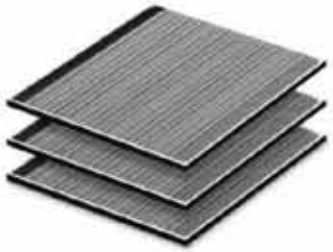
- 3D cell architecture
- High-capacity silicon anode
- Production process evolution
- Roadmap
- Improved safety characteristics
- High-speed production
- Commercialization strategy
- Intellectual property

ENOVIX

http://www.enovix.com/

Production Process Evolution

We've systematically progressed to a production process that increases energy density with cycle life and cost comparable to a conventional Li-ion battery

	GEN-1	GEN-2	GEN-3
Timeframe	2007 – 2011	2012 – 2016	2017 – 2019
Production	 3D prototype using MEMS production process	 3D silicon solar-grade wafer production (SunPower)	 3D silicon EDA™ high-speed stack production process
Energy Density	820 Wh/l	850 Wh/l	>900 Wh/l
Cycle Life	200	200	>500
Production Cost	NA	$0.30/Wh (est)	$0.10/Wh (est)

Prologium

The only SSB maker with mass production capability and commercialized experience

Current Production Capacity: 40MWh
2021 Production Capacity: 1~2GWh

Production Line

FLCB
FPC Type

- Ultra thin 0.43mm
- Flexible (R40mm, 7,000times)
- Tubular type : TLCB
- Logic circuit adoptable
- Good pressure durability: 10^{-11} ATM ~680ATM

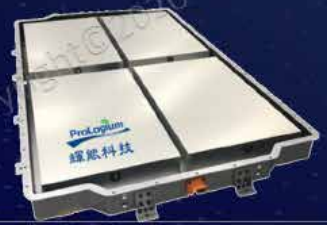
PLCB
Pouch Type

- Fast charge ability: 2018:70% in 12 mins 2019: **90%** in 12 mins
- Discharge @-40℃~115 ℃
- Storage @-65℃~115 ℃

BLCB
BiPolar⁺ Type

- BiPolar⁺ technology
- Series/ parallel inside cell
- High voltage (8.4V~49V)

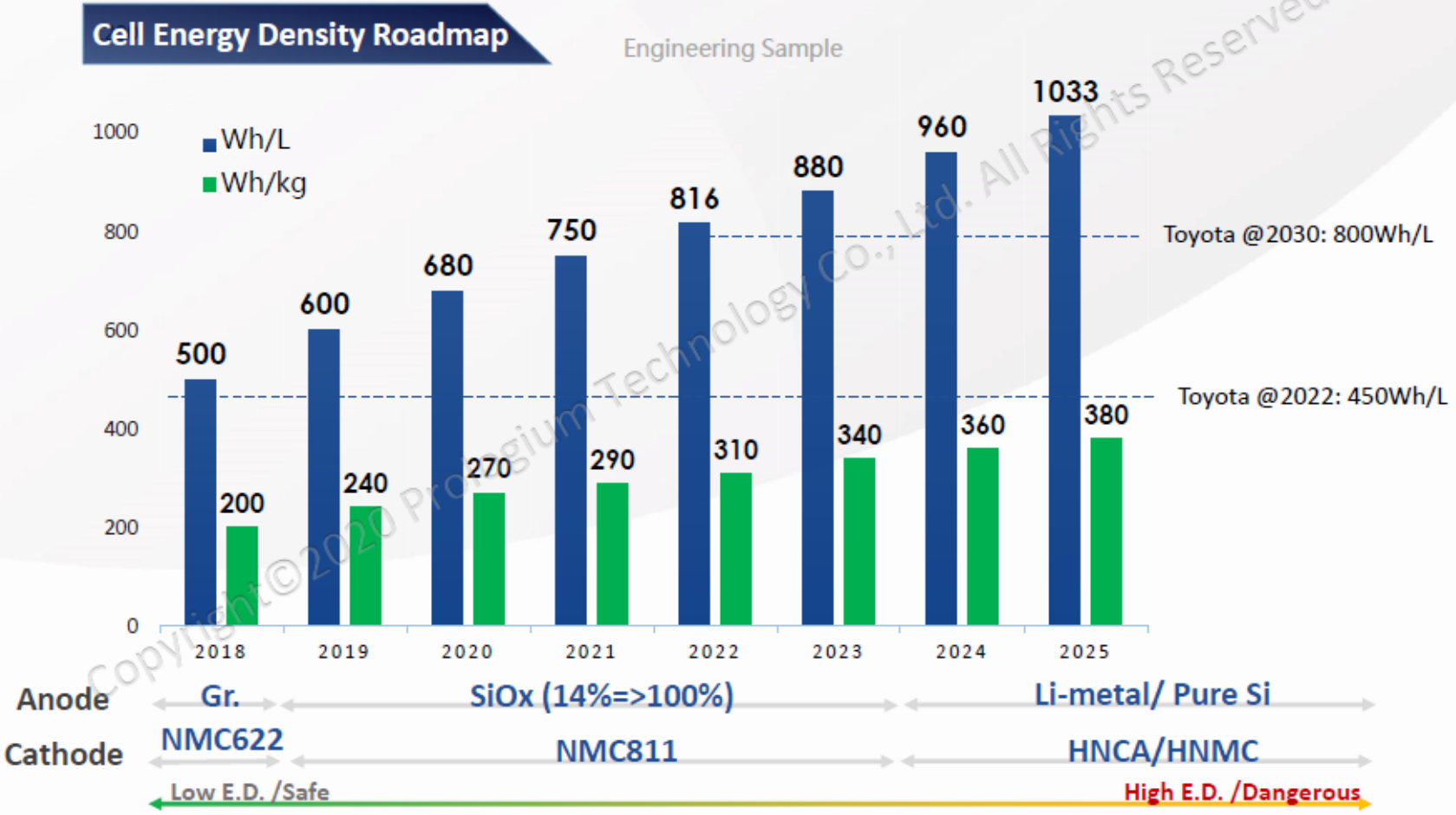
MAB
Multi-Axis BiPolar⁺ Pack



- Multi Axis BiPolar⁺ technology
- Simplify protection mechanism, cooling system and BMS to increase assembly efficiency in volume and weight
- 70% weight, 50% volume and 70% cost of traditional battery pack

ProLogium
Anything Is Possible

4. High E.D. Pack: Cell Level



Solid Power (Li Anode + Solid Electrolyte)

- Solid-state is a practical approach to improving energy density and safety in parallel
- Enabling Li metal is key to reliable long life, but cathode design is also key for maximizing performance
- Challenges remain in minimizing passive mass and volume, accommodating volume changes, and improving rate capability at low temperatures
- Opens up the design space with new materials and cell and battery concepts to ensure continued energy density gains for electric vehicle batteries

Solid Power

https://solidpowerbattery.com/

Solid Power Overview

- Leading developer of sulfide-based all solid-state batteries (ASSB):

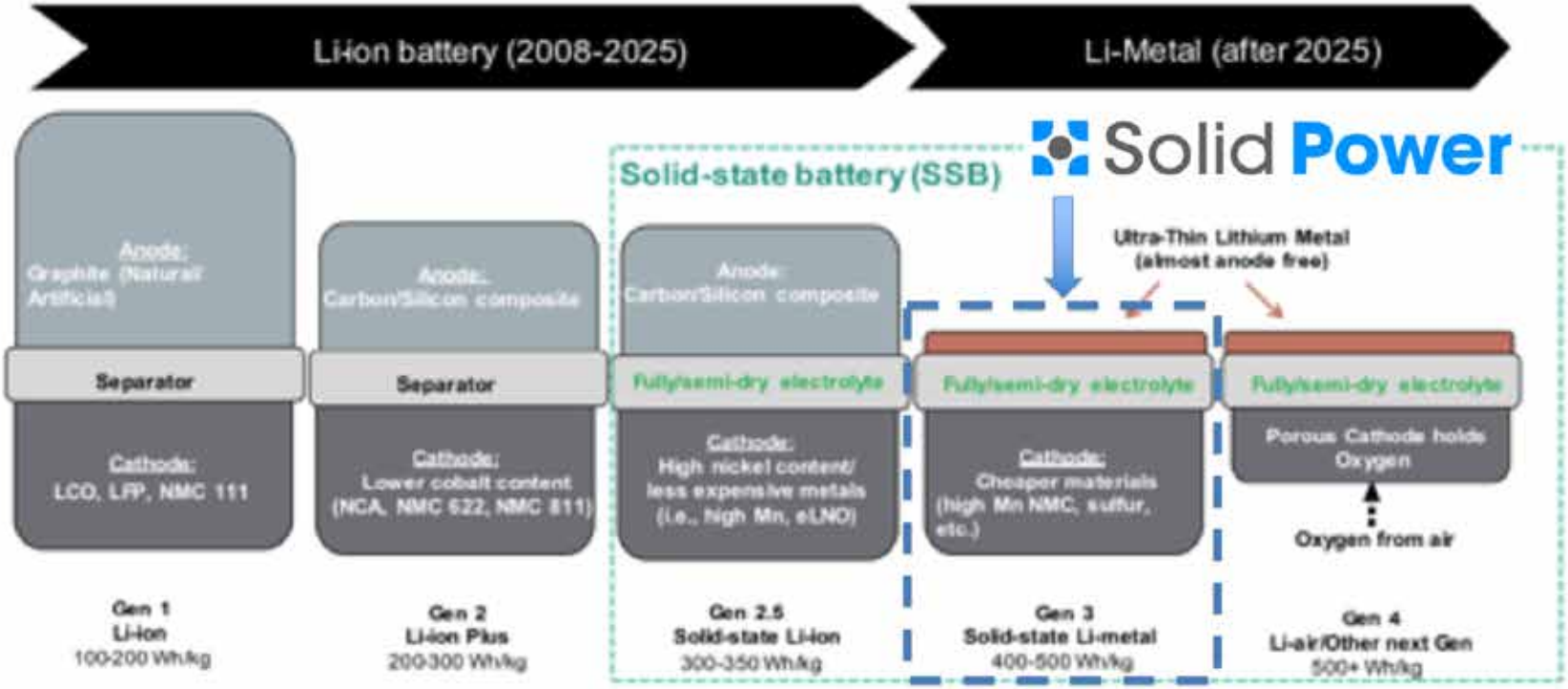
Higher energy than today's Li-ion (longer run-time per charge)

Inherently safer than today's Li-ion (lower cost / higher reliability)

Compatible with R2R Li-ion manufacturing (minimal manufacturing risk)

- Extensive industry cooperations:
  - Auto OEMs: ASSB qual & integration
  - Tier 1 Cell Producers: ASSB processing
  - Chemical Companies: Binder, cathode active material & Li-precursor products for ASSBs

Evolution of Battery Chemistry: Solid State is the Future



Sou

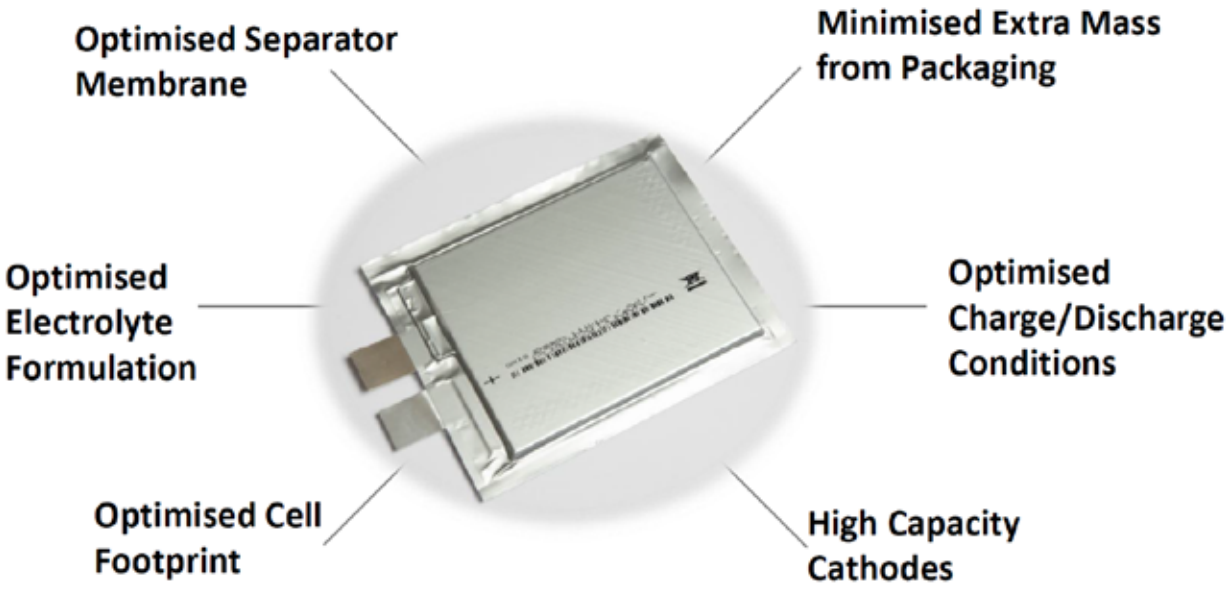
"Solid-state batteries might be the only technical solution that fulfill simultaneously energy density and safety requirements"

- BMW

Oxis Energy (Li-Sulfur)

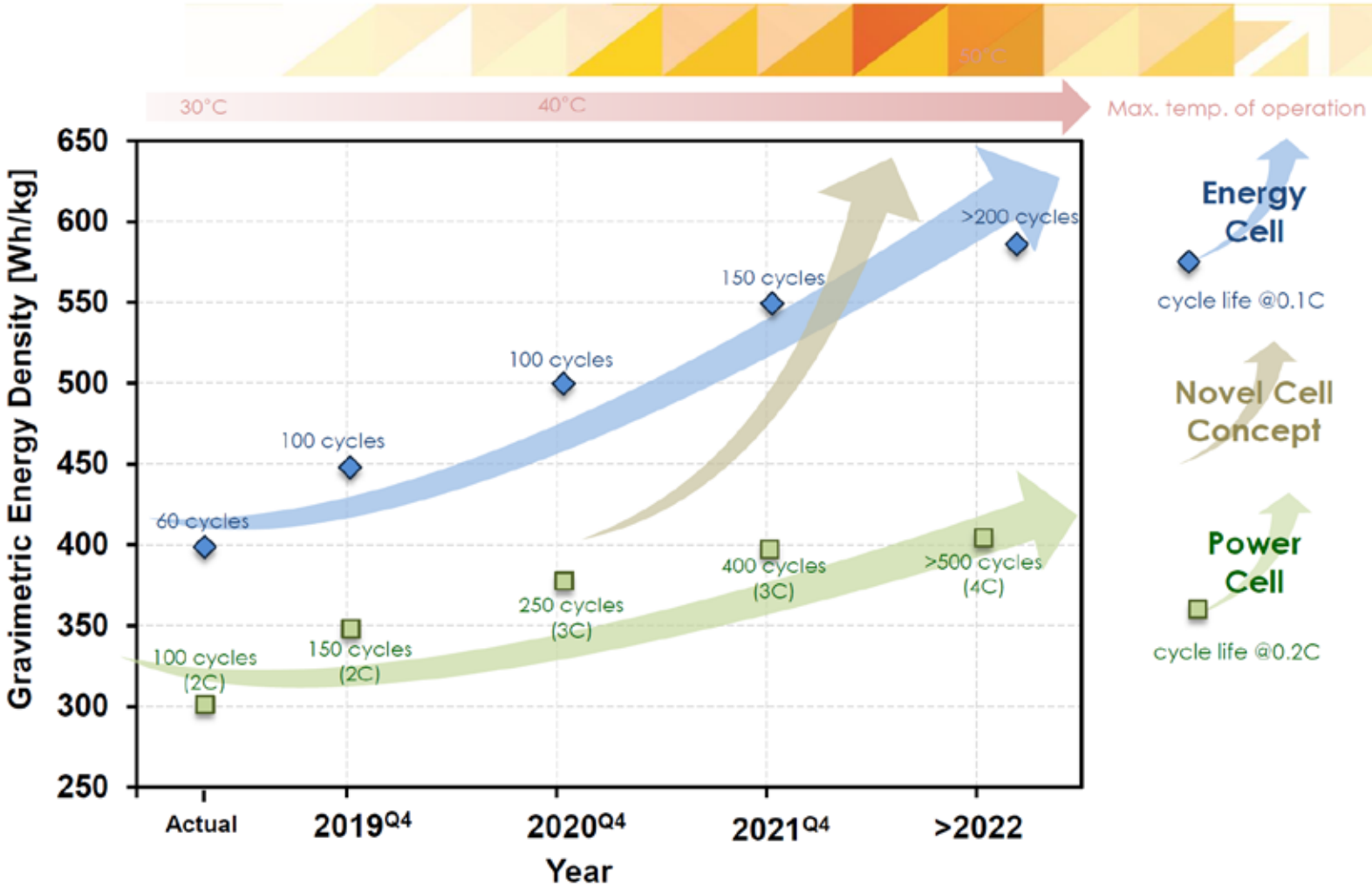
OXIS Li-S Cell Optimisation

Holistic approach:



- OXIS projects aims to integrate new materials developments into optimised High Energy/High Power Li-S cells
- Q3 2016 cell achievement: 16 Ah, 400 Wh/kg
- 2019 cell target 465 Wh/kg: Achieved
- **2020 cell target 500 Wh/kg**

Roadmap – Energy & Power Cell



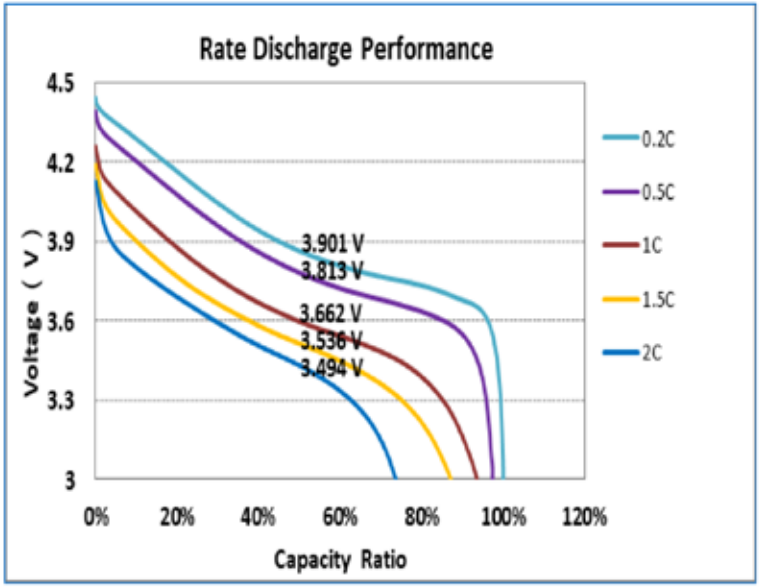
International High Power

4.48V High Energy Density Battery Technology

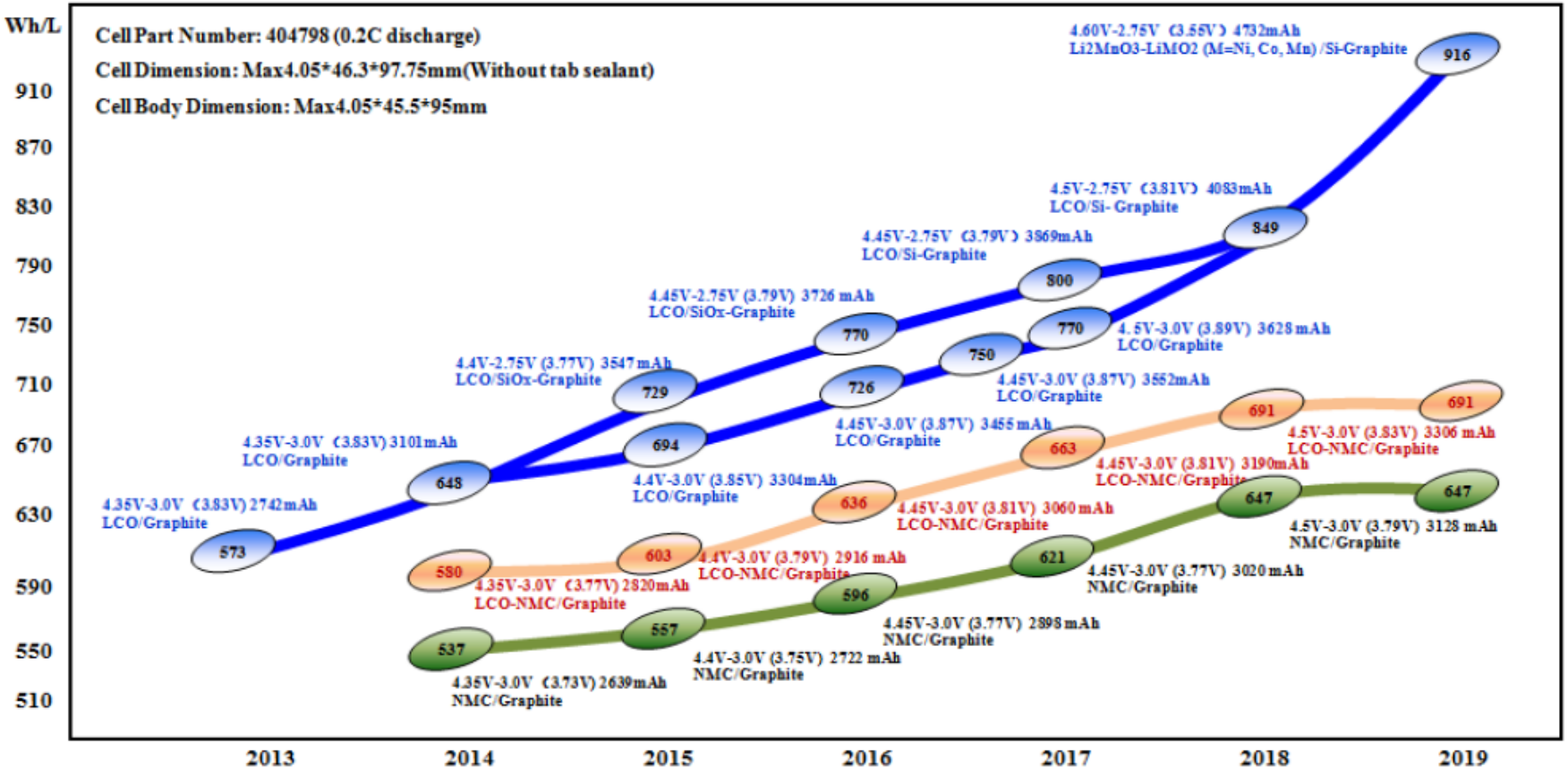
- **Research status:** Under R&D, ready for mass production in the Q4 2020;
- **Energy density:** 807Wh/L @0.2C$_{ave.}$
- **Design approach:** Doping and coating cathode, optimize the electrolyte and separator, using thinner base materials.

Cell Model:	HPP404798 (4.48V)
Capacity:	3754mAh (0.2C min.)
	3810mAh (0.2C ave.)
Nominal Voltage:	3.90V
Energy Density:	795Wh/L (0.2C min.)
	807Wh/L (0.2C ave.)

4.48V High Energy Density System Charge & Discharge Performance



High Energy Density Consumer Battery Roadmap



http://www.highpowertech.com

INTERNATIONAL HIGHPOWER 豪鹏国际

Jenax

Flexible Lithium Polymer Battery

J · FLEX

Technologies with new form factors, wearables, and future devices cannot be achieved with traditonal batteries. J.Flex, an innovative flexbile battery by Jenax, meets these challenges by freeing design limitations without sacrificing power.

▶ Watch our video to learn more

https://www.youtube.com/watch?v=CzHdew6iid0

http://jenaxinc.com/product/batteries/

Storedot

Holistic Approach to Fast Charging

Cathode

Coating/encapsulation for structural stability and charge transfer

Anode

Gradient-layered nanoparticles embedded in conductive matrix, morphology design

Electrolyte

High voltage resistance, dendrite prevention

Structure

Electrode, tab, form factor: Support high power rates

Cell Manufacturing

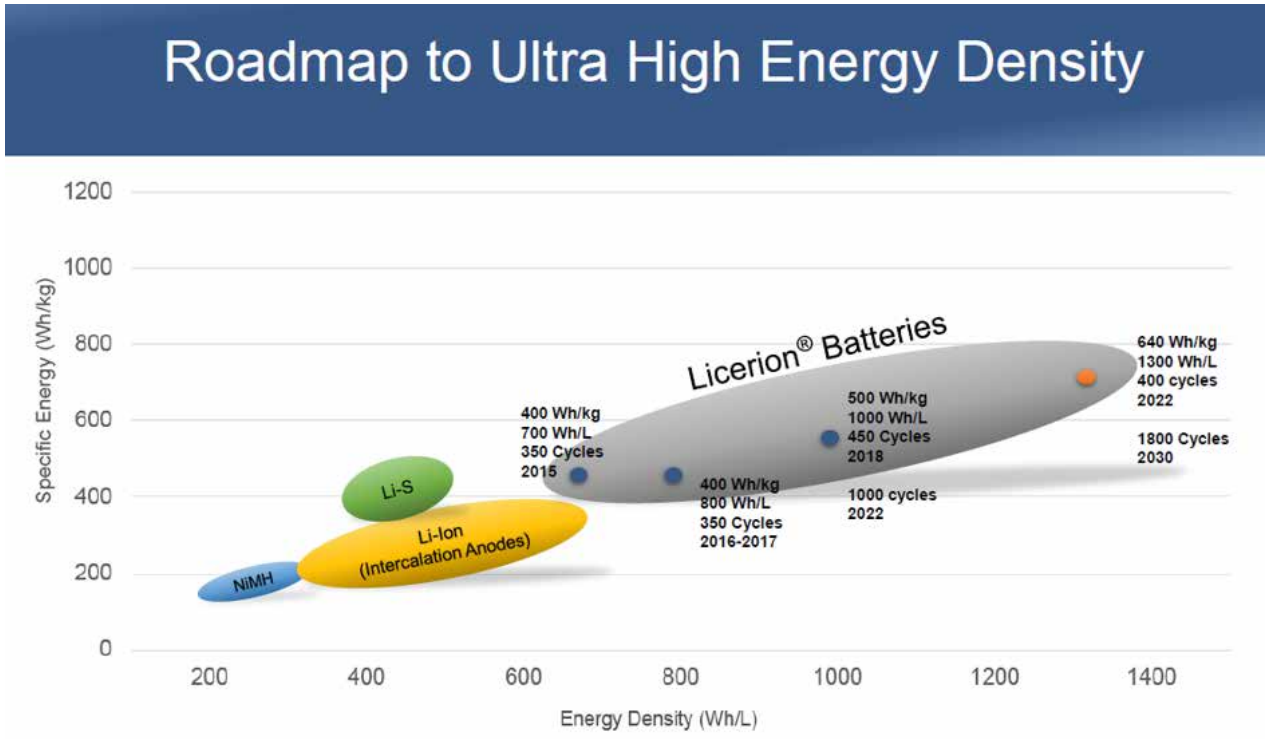
Aqueous electrode slurry, ensuring non-toxic production

Electronics

Unique charging algorithms and interface protocols

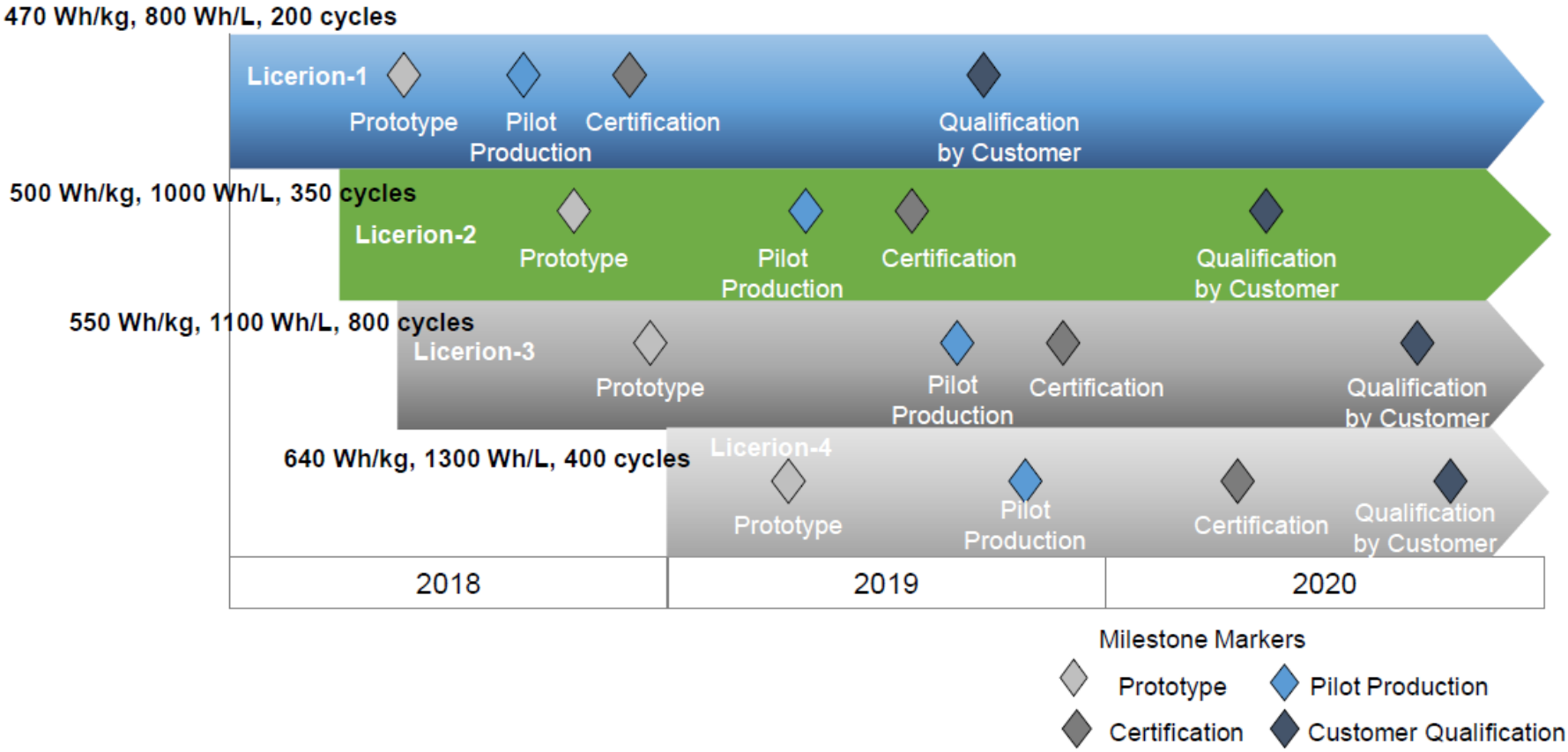
Sion Power

650 Wh/kg, 1400 Wh/L Rechargeable Batteries for New Era of Electrified Mobility



www.sionpower.com

Licerion® Cells Available at End of 2018



Tadiran Low TMV Lithium Thionyl Chloride Cells (TRR)

1. **Coating of the lithium anode by a novel lithium ion conducting solid electrolyte interphase film markedly improves the voltage delay behavior of the Li/SOCl2 cell.**
2. **TRR cells available on all sizes.**

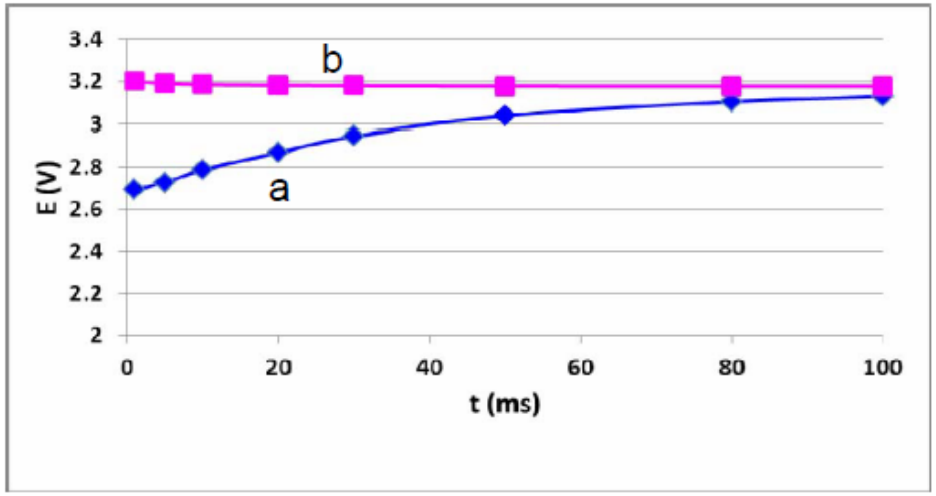
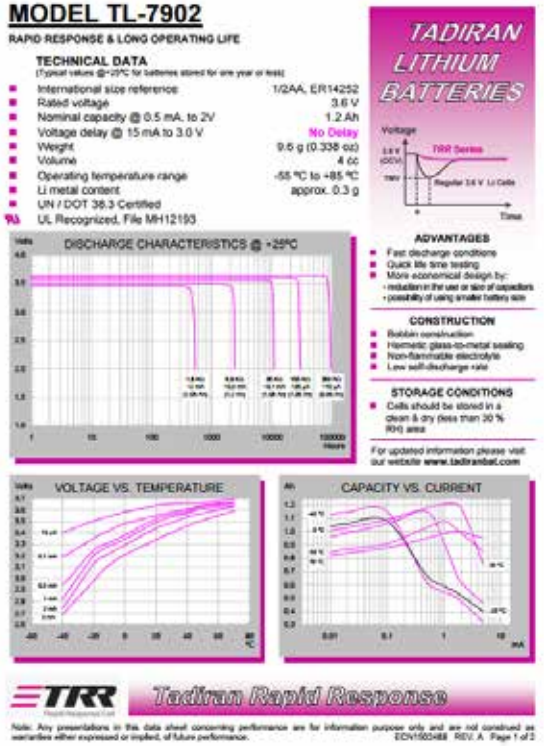
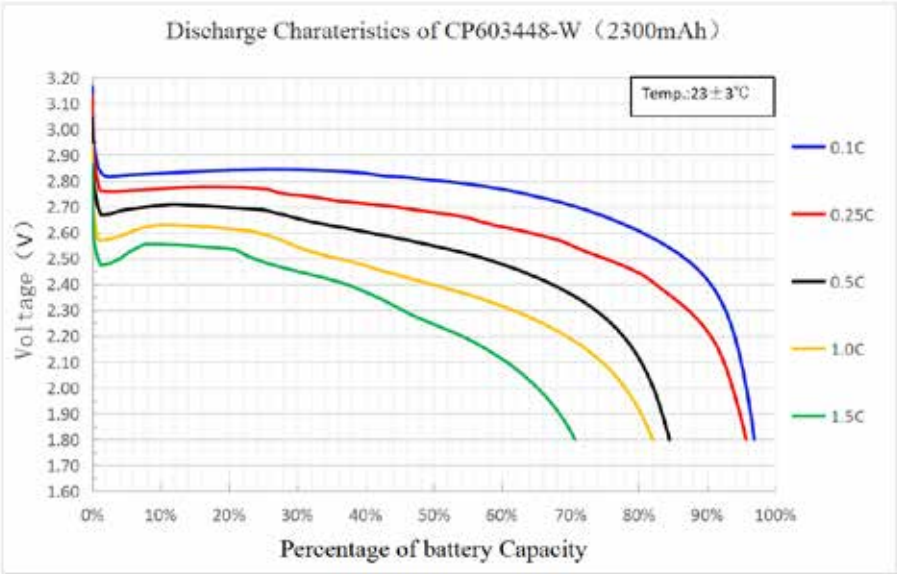


Figure 1: 100mA/100mSec Pulse of 427 day-old a: D size reference cell; b: D size test cell



Wuhan Fanso



Electrical characteristics

Typical values relative to cells stored for one year

Nominal capacity	2300mAh
Discharged capacity at 2mA,+25℃, 1.8V cut off.	
Nominal voltage	3. 0V
Max. recommended continuous current	1200mA
Discharged to 1.8V at 25℃ permitting 50% of the Nominal capacity to be achieved	
Max. Pulse current	2500mA
15 seconds at 25℃ drained with 50% of the nominal capacity, yield voltage reading above 1.8V. The value may vary with the pulse characteristics, the temperature and the cell's previous history	
Storage	Max 30℃
Operating temperature range	-40~+60℃
Weight	≈18g

Epsilor

6T NATO Battery

NATO Standard 6T Rechargeable Lithium Batteries

Epsilor's product line of lithium rechargeable 6T batteries offers an advanced alternative to traditional lead-acid NATO batteries, while revolutionizing armored vehicle capabilities and logistics.

These "drop-in" replacement batteries triple the "silent watch" capabilities of newly designed as well as existing armored vehicles, while expanding the battery life cycle from hundreds of charging cycles to thousands of cycles.

This development dramatically changes the operational capabilities of armored vehicles and the way in which military organizations manage the inventories of their vehicle batteries.

Using Epsilor's batteries eliminates the expensive and sensitive need to deploy battery inventories for armored vehicles as the new batteries are installed in the vehicle when manufactured and need to be replaced only at the vehicle's mid-life upgrade.

Main Features

Epsilor's 6T batteries have the following features:

- Best-in-class energy density in the Li-Ion configuration for extremely long silent watch
- More than 3,000 charging cycles and up to a 10-year operational life in the LiFePO4 configuration
- Drop-in replacement for lead-acid batteries
- Self-balancing, self-charging and charge current management capability that support smooth operation of new vehicles as well as older generation vehicles
- Serial and parallel connectivity with additional batteries supporting group operation

Xalt Energy (LTO, NMC)

https://www.xaltenergy.com/

XALT Energy

Obrist Powertrain

New Li-Ion Extra High Energy Density Battery
with Revolutionary Vacuum Fixation Technology

PROTECTED TECHNOLOGY

Design Features

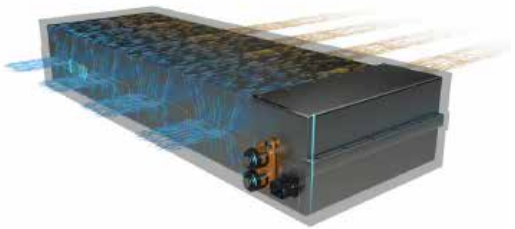
- Revolutionary Vacuum Fixation Technology that leads to:
  - low weight with extreme specific energy density values
  - low cost and flexible battery pack design (cylindrical or pouch cells)
  - efficient air cooling system
  - fewer battery pack parts for improved cost and reliability
  - improved battery pack safety due to rigid construction
  - rugged design for challenging environments (IP69k certification)
- Thermal insulation for independence from ambient conditions (extends service life)
- Battery Management System with wireless voltage sensing (improved reliability)
- Can be designed from low (48VDC) to high voltage (1200VDC)
- Universal battery that can be customized per customer demand (modular design)
- Module aluminum housing works as a temperature heat sink, eliminating internal heat exchangers

Potential Applications

- Automotive, truck, bus, heavy-duty transportation, electric aviation, marine
- PHEV, HEV, BEV

Vacuum Fixation Technology

Air Cooling System



Technical Details PHEV (cylindrical)

- Samsung INR18650-30Q (3000mAh)
- Energy: 17.3kWh (100s16p)
- Nominal voltage: 360VDC (420V-240V)
- Continuous charge power: 26kW
- Continuous discharge power: 110kW (200kW pulse)
- Battery Dimensions: 1017 x 359 x 166mm
- Battery Weight: 98kg
- **Module energy densities: 203Wh/kg, 446Wh/l**

Technical Details BEV (cylindrical)

- LG INR18650-MJ1 (3500mAh)
- Energy: 20.2kWh (100s16p)
- Nominal voltage: 360VDC (420V-240V)
- Continuous charge power: 10.1kW
- Continuous discharge power: 60kW
- Battery Dimensions: 1017 x 359 x 166mm
- Battery Weight: 103kg
- **Module energy densities: 224Wh/kg, 520Wh/l**

Technical Details BEV (pouch)

- Customized (140mAh)
- Module Energy: 7.05kWh (14s1p)
- Module Nominal voltage: 50VDC (59V-34V)
- Continuous charge power: 3.5kW
- Continuous discharge power: 21kW
- Battery Dimensions: 559 x 2234 x 103mm
- Battery Weight: 30.5kg
- **Module energy densities: 231Wh/kg, 527Wh/l**

Shmuel De-Leon
Shmuel De-Leon Energy Ltd
www.sdle.co.il
shmuel@sdle.co.il

Information for presentation obtained by:

1. **Public web sources.**
2. **Shmuel De-Leon Battery/Energy Sources DataBase ® (Includes 29000 cell PDF data sheets) http://www.sdle.co.il/Default.asp?sType=0&PageId=45580**

This presentation has been compiled for the exclusive, internal use by our client. Within the framework of the engagement, Shmuel De-Leon Consultants will act solely in the interest of the client. Property rights in favor of third parties will not be constituted and no protective effect shall arise for the benefit of third parties.

The presentation shall be treated as confidential and may not be passed on and/or may not be made available to third parties without prior written consent from Shmuel De-Leon Energy.