

**Shmuel De-Leon
Energy Ltd**



Li-Ion High Voltage Cells (4.4-4.45V) for Smart Phones

December 2017, Ver. 1

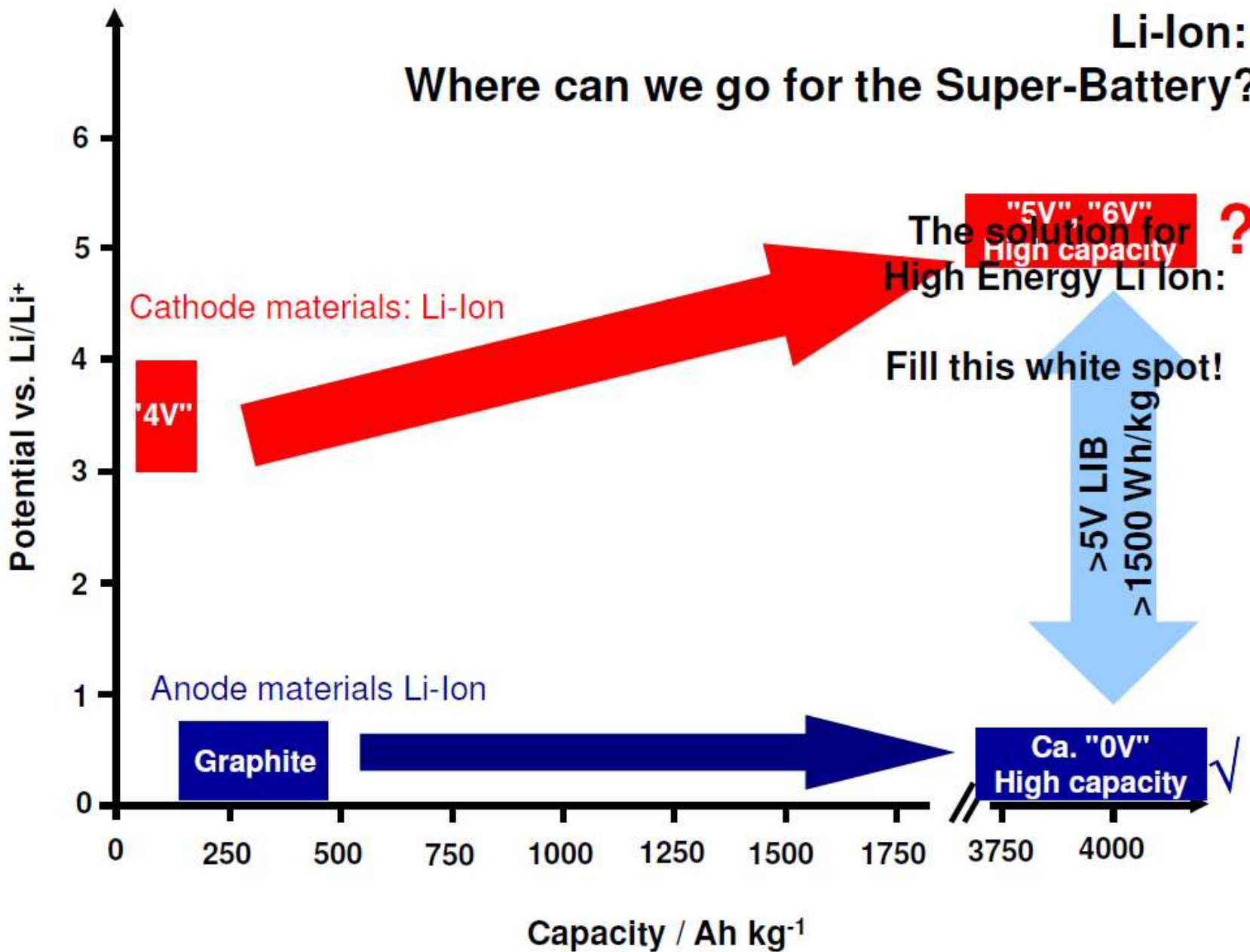
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Potential Technologies for Energy Storage Break- Through

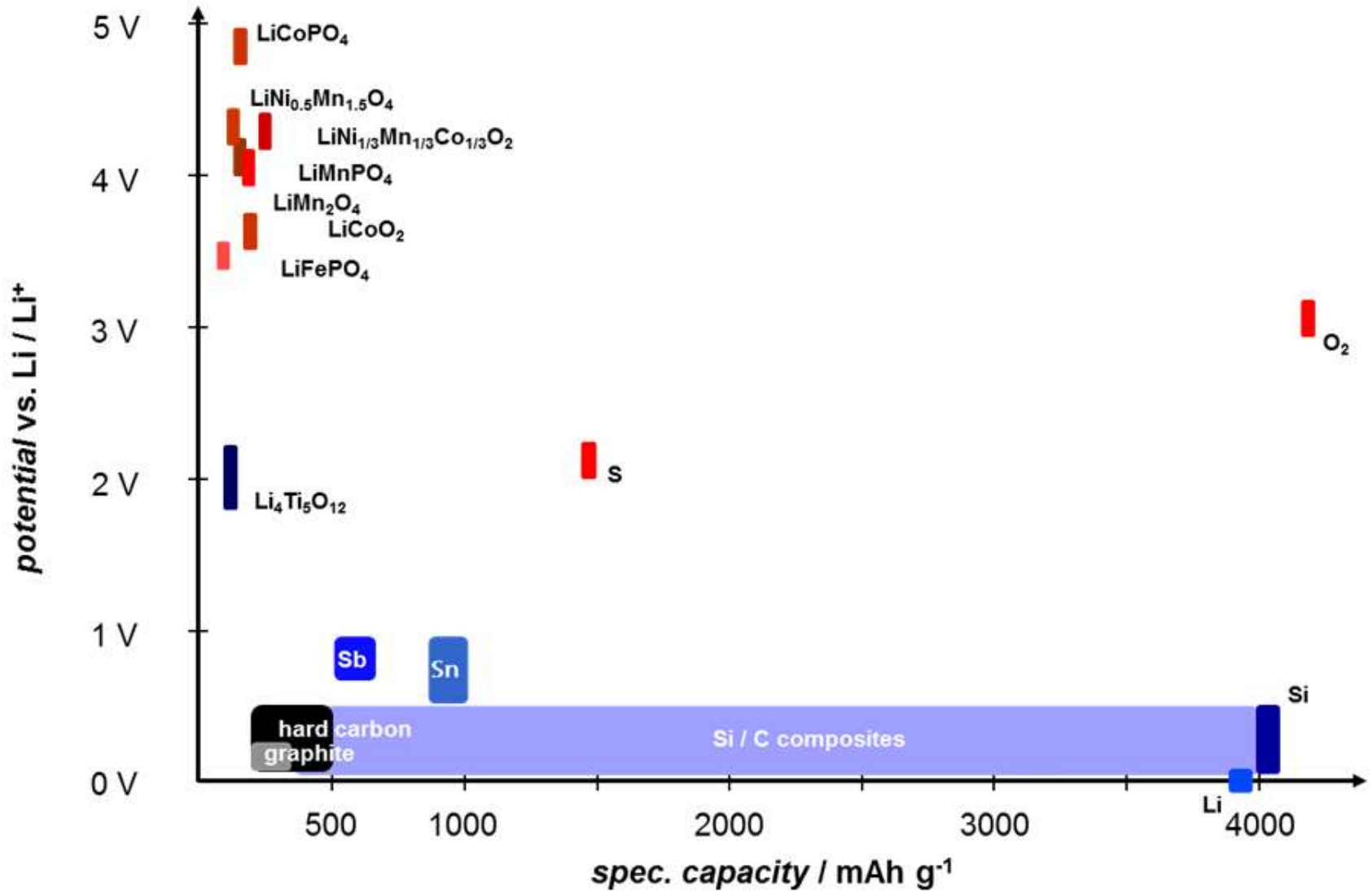
- Li-Ion Air
- Lithium Sulfur
- Lithium Metal
- Lithium Ion Silicon based anode
- High Voltage Li-Ion (>4.35V)
- Li-Ion Solid Electrolyte



Li-Ion: Where can we go for the Super-Battery?



Lithium-Ion Battery – Electrode Materials



Source: Fraunhofer

Li-Ion High Voltage Cells?

- Li-Ion rechargeable cell open circuit, Nominal and charging voltages depend on the active materials in use (Cathode and Anodes) and non-active materials (Separators and Electrolytes).
- One of the potential solutions for energy storage breakthrough are the high voltage li-ion technologies (>4.3V).
- 4.3-4.4V high charging voltages li-ion cells (with 3.75-3.8V nominal voltage) already introduced commercially in the market by most of leading players.
- >4.45V high charging voltages li-ion cells are under development (Metal, Silicon and graphite materials).



LG Chem 4.35V
charge voltage
cells



Li-Ion High Voltage Cell Advantages

- Higher energy density – more capacity
- Higher nominal voltage ($\geq 3.75\text{V}$)
- Long, stable power with a flat discharge voltage
- Perform better in room and high temperatures



LG
D1
18650

Li-ion High Voltage Cell Limitations

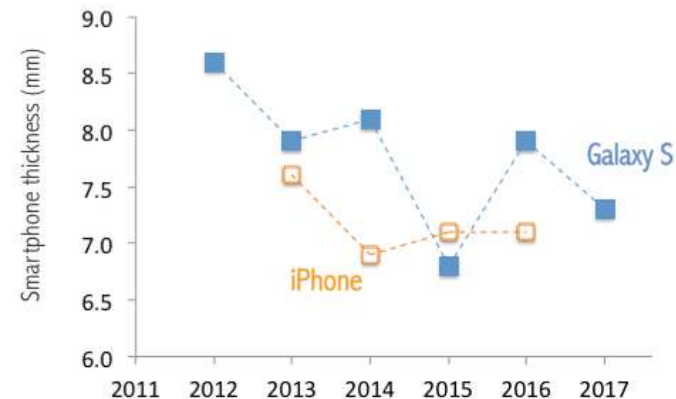
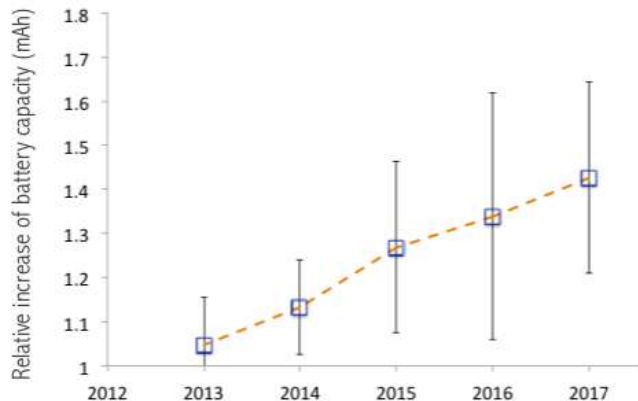
- Limited charging rate (Slower charging)
- Reduced performance bellow -10 Deg C.
- Reduced cycle life
- Higher cost



Li-ion High Voltage Cells for Smart Phones market



- Smart phones should work at least 1 full day
- Battery capacity grow to 3000-3500mAh
- Cycle Life is not important as was in the past – Customers buy a new phone every 1-2 years
- Thinner batteries less than 3 mm as the smart phones become thinner and there is less volume for the batteries

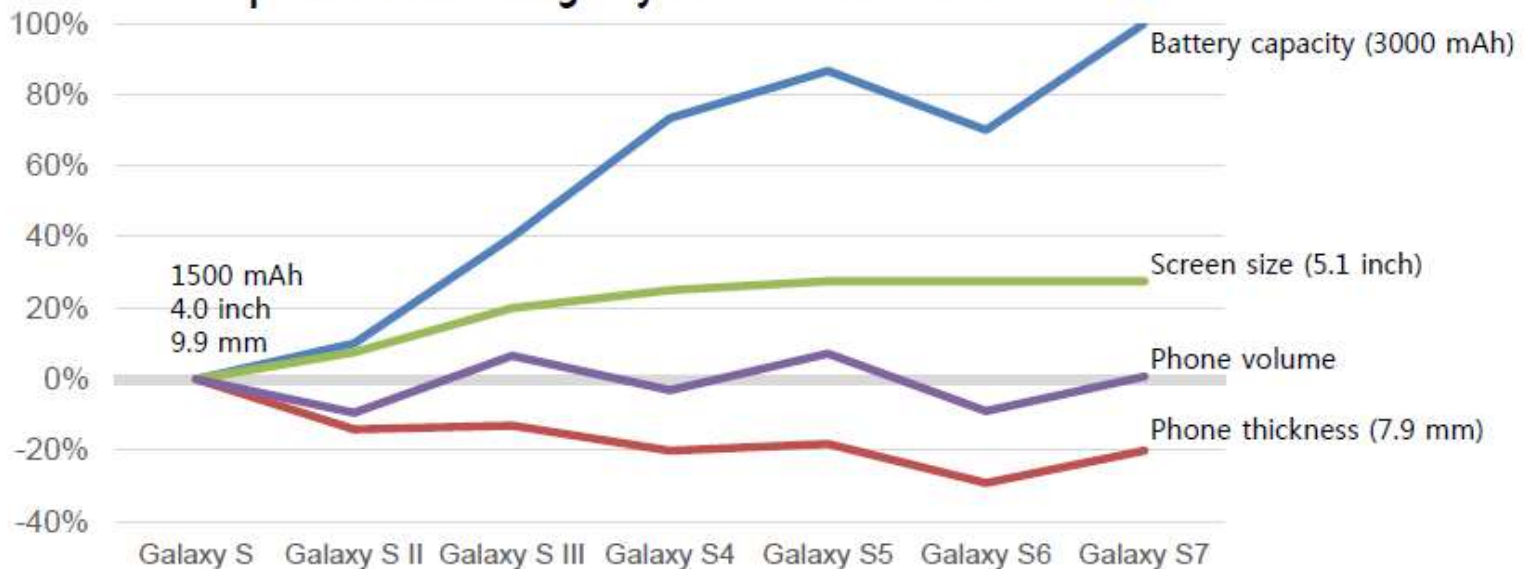


Recent Smartphone Trends

Evolution of the Galaxy S series



Specification Change by Phone Generation



**Web/Video
Battery Life**

6.2 hr

8.0 hr

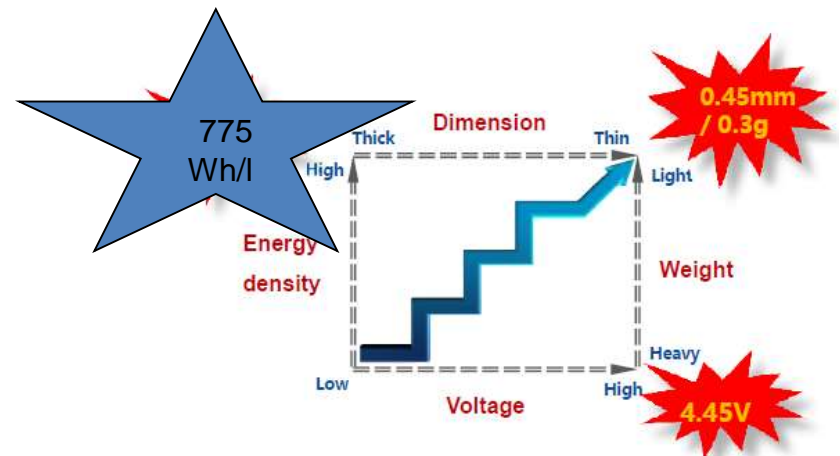
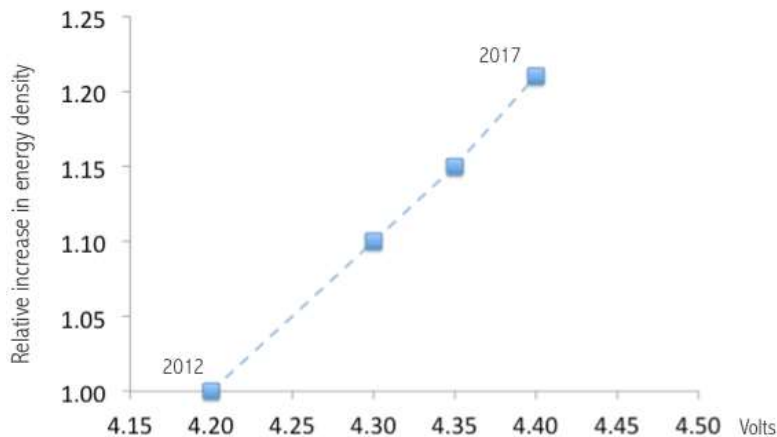
9.2 hr

10.5 hr

11.5 hr

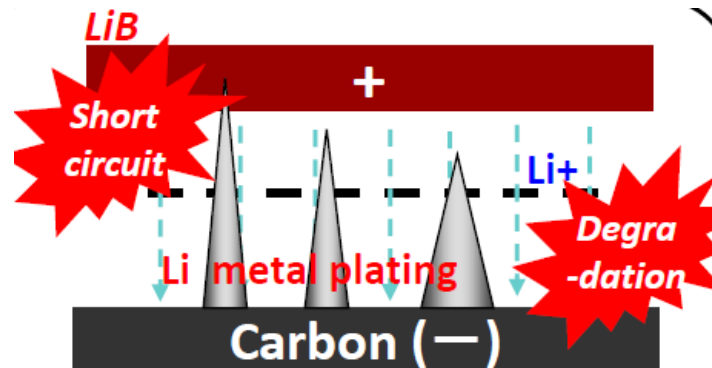
12.2 hr

- As there are a smaller volume for the battery there is a need to increase the energy density for meeting the needed run time.
 - a. Increase in electrodes energy density done by adding silicon to anodes and rich NMC for the cathodes
 - b. Increase in cell voltage
 - c. Reduce volume of cell non active materials and filling that volume with active materials
- 4.4V cells with 650-720 Wh/l are commercially available in the market for 2 years
- 4.45V cells with 720-800 Wh/l are in mass production in China from 7/2017



Li-ion High Voltage Cells Challenges

- High voltage cells face a high risk for metal lithium plating
- Manufacturing defects or design fluctuations are sufficient to cause a formation of lithium metal plating
- Smart phones manufacturers also require a fast charging (> 1C charging rate) as an integral part of the modern smart phones.
- Combination of high energy density cells + fast charging generate a high risk of safety event.
- High cell voltage + high energy density also cause an high rate of swelling.



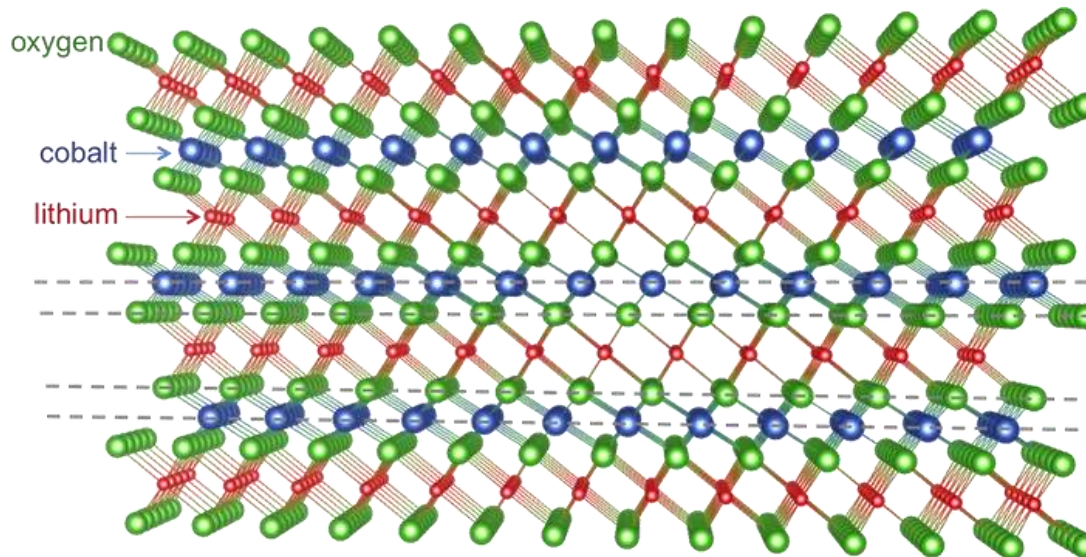
Electrolyte for High Voltage Cells

- Liquid electrolyte is the medium allow the lithium ions t move between the electrodes
- As the voltage rises , it is subject the electrolyte to increasingly higher electric fields causing its early degradation and breakdown
- We see now a new generation of electrolytes that can withstand high voltage



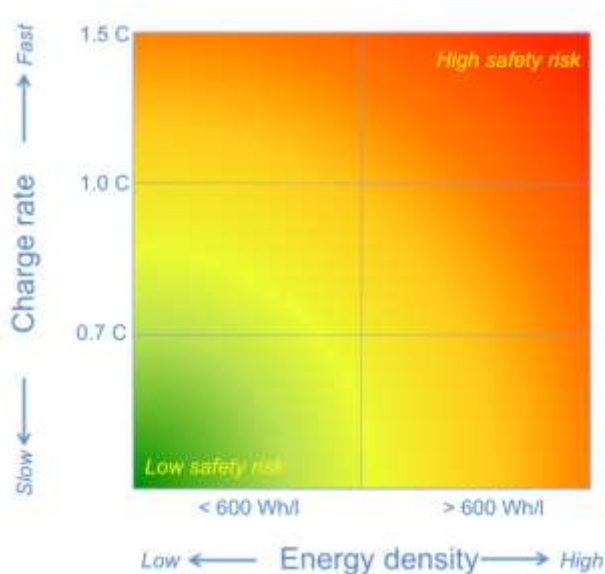
Electrodes for High Voltage Cells

- The structural integrity of the cathode is effected by the cell charging voltage
- As the cell is charged the lithium ions move from the cathode to the anode but if too many leave the cathode structure collapses and the material change its properties
- Amount of lithium ions leaving the cathode determine by the charging voltage



Safety Effects

- As cell voltage is higher the safety risk is higher as well mainly because of lithium metal plating
- Some OEMs reduce the operating voltage of the battery as it ages for example from 4.4v to 4.35v or less reducing 200-300mAh from its capacity
- Some OEMs also reduce the charging rate
- The user has a lower run time without any notice



EVE Energy

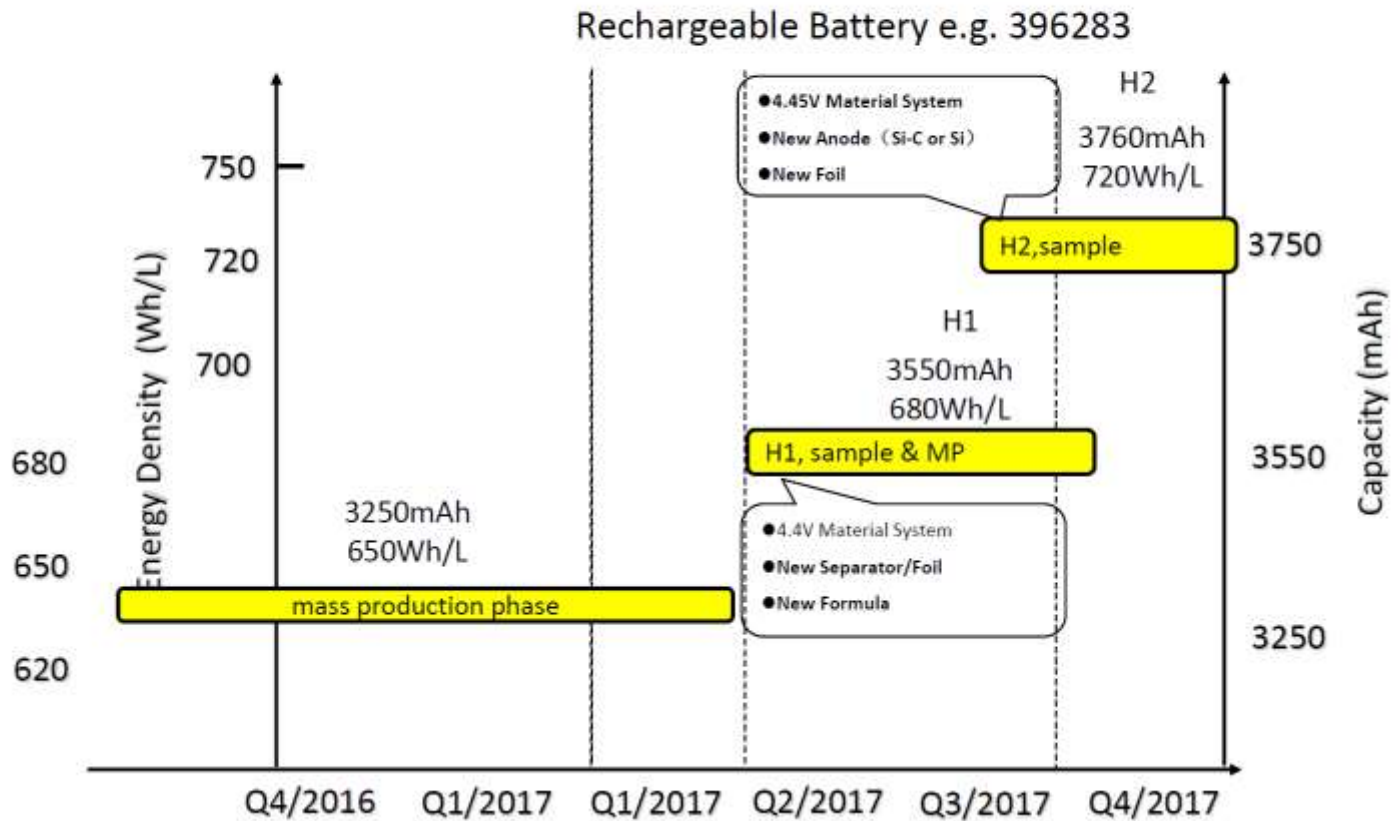


Lithium-ion Prismatic Battery

Key Feature :

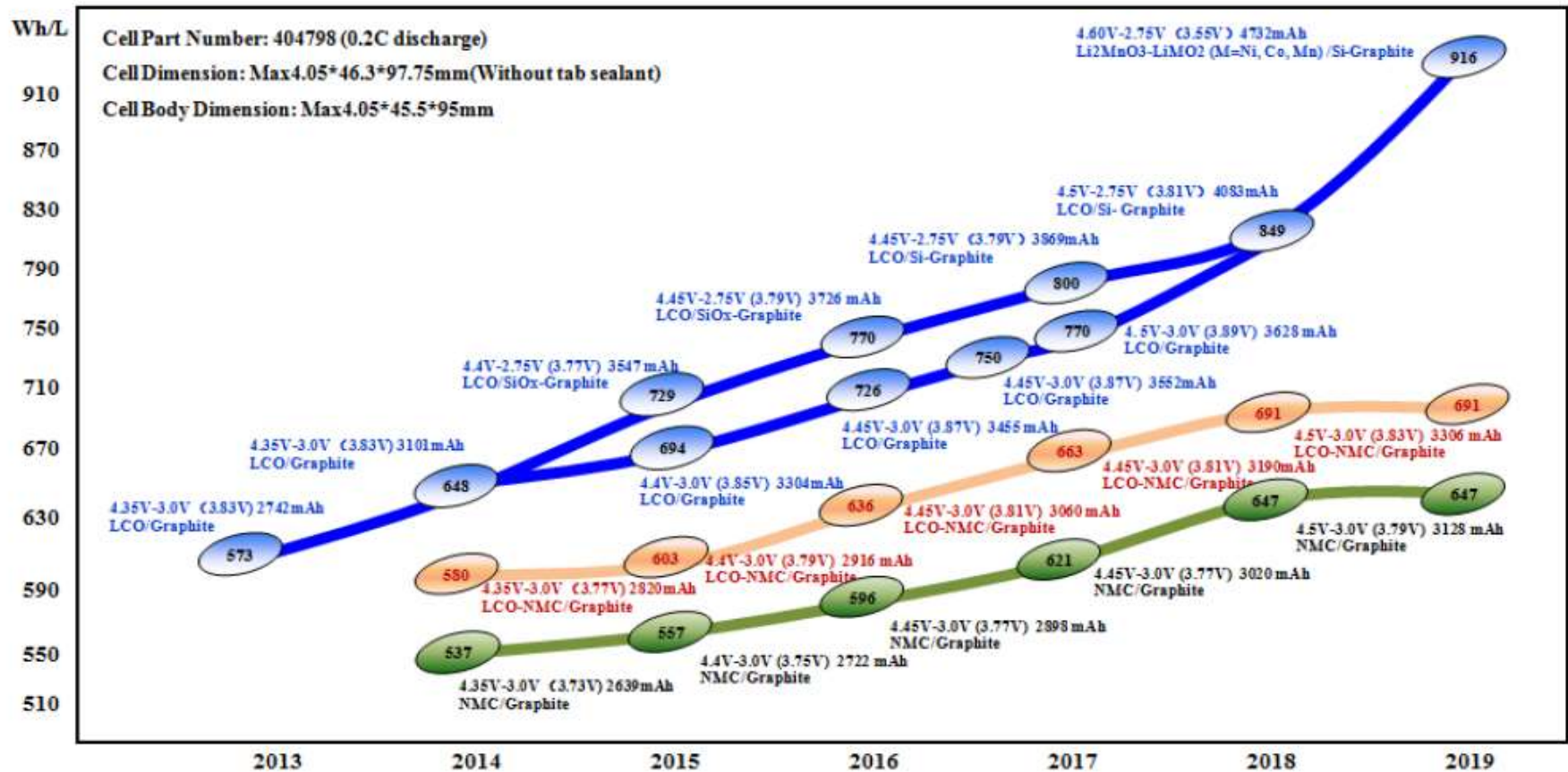
- High Voltage, 4.2V, 4.35V and 4.4V, high energy density(680Wh/L);
- Ultra thin(0.45mm), bending type;
- High specific capacity, low self-discharge rate;
- Wide working temperature range (-30°C—60°C);
- Can be designed and customized;
- Green, environmental, passed ISO14000, UL1642, UN, ROHS.





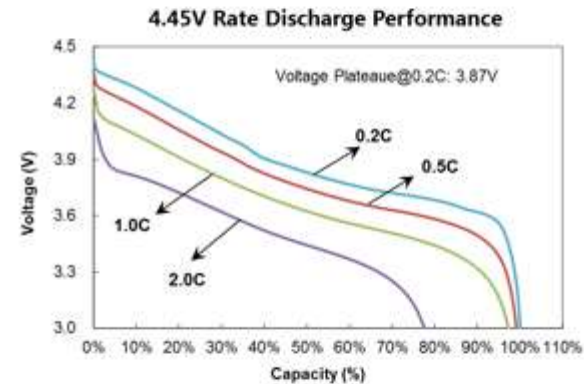
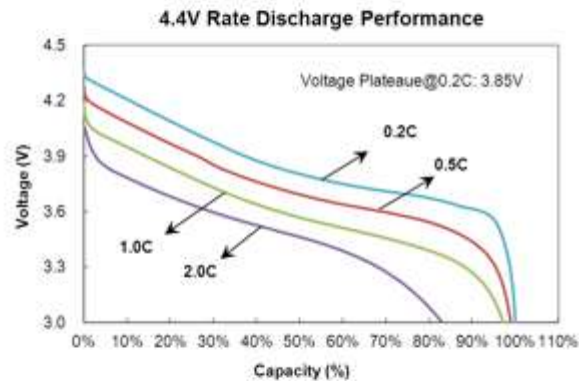
High Power

High Energy Density Consumer Battery Roadmap



Product Description

1. The maximum charging voltage is 4.35V, 4.40V & 4.45V;
2. High energy density:
4.35V system: 630Wh/L-680Wh/L
4.40V system: 650Wh/L-720Wh/L
4.45V system: 700Wh/L-750Wh/L
3. Higher battery capacity for longer working time in terminal applications;
4. The capacity retention of 4.35V & 4.4V system remains more than 80% after 1000 cycles;
5. The capacity retention of 4.45V system remains more than 80% after 500 cycles;
6. Expanded application of high-power electric equipment.



Product Specification

High Voltage Batteries							
Model(e.g.)	Voltage (V)	Minimum Capacity (mAh)	Dimension (mm)			Internal Resistance (mΩ)	Approximate weight (g)
			T	W	H		
2961112-3030	3.8	3030	3.0	60.9	111.5	45	40.0
385583-3040	3.85	3040	3.8	55.0	83.0	60	49.0
435192-3040	3.8	3040	4.4	51.1	91.8	50	49.0
404798-3250	3.85	3250	4.0	47.0	98.0	60	52.0
404798-3620	3.87	3620	4.1	47.0	98.0	60	52.0
446878-4000	3.85	4000	4.4	68.6	76.2	60	63.0
486082-4000	3.85	4000	4.8	59.9	82.4	60	63.0

Market Forecast & Trends

- **High voltage Li-Ion cells may provide the break through we are waiting for – farther development needed.**
- **Technology Status – 4.3-4.45v high charging cells available commercially - >4.45v cells Still under development – few companies to reach prototype manufacturing level.**
- **Power capacities and low temperature better performance are essential for that technology success**



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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>