XFC – Extra Fast Charging Li-Ion Battery Market Review 2017

April 2018

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Extra Fast Charging (XFC)?

80% of full battery capacity within 5 min (more than 10C Rate)

Slow Charge	Quick Charge	Fast Charge	Extra Fast Charge
<C/3	C/3<, <2C	2C<, <10C	>10C

- **Fast charging is needed in emergency**

Fast Charging is not for daily routine use for not degrading the battery!!!

Laptop Fast Charging

- Modern laptop include 2 USB-C charging ports
- 90W “fast charge port” and a slow charge rate of 65W in the “slow charge port”
- Users instructed to use the slow charge port unless they urgently need to fully charge the battery

USB charging standards

	Voltage	Current	Max Power
USB 1.0	5V	0.5A	2.5W
USB 2.0	5V	0.5A	2.5W
USB 3.0	5V	0.5A/0.9A	4.5W
USB 3.1 (USB-C + USB-PD)	5V – 20V	0.5A/0.9A/1.5A/3A/5A	100W

Mobile Phones Fast Charging

- **New charging capabilities up to 30W**

Apple fast charging

	Voltage	Current	Max Power
USB-PD	14.5V	2A	29W

The Apple iPhone X, iPhone 8, and iPhone 8 Plus implement USB-PD, the same industry standard used by the iPad Pro, the 12-inch MacBook, Google's Chromebook Pixel, and Lenovo's X1 Carbon. Inter-compatibility is its biggest advantage — USB-PD doesn't require any special cables or wall adapters.

Qualcomm Quick Charge

Julian Chokkattu/Digital Trends

	Voltage	Current	Max Power
Quick Charge 1.0	5V	2A	10W
Quick Charge 2.0	5V/9V/12V	1.67A/2A	18W
Quick Charge 3.0	3.6V – 20V (200mV increments)	2.5A/4.6A	18W
Quick Charge 4.0	N/A	N/A	N/A
Quick Charge 4.0+	5V/9V (USB-PD), 3.6V – 20V (200mV increments)	3A (USB-PD), 2.5A/4.6A	27W (USB-PD)

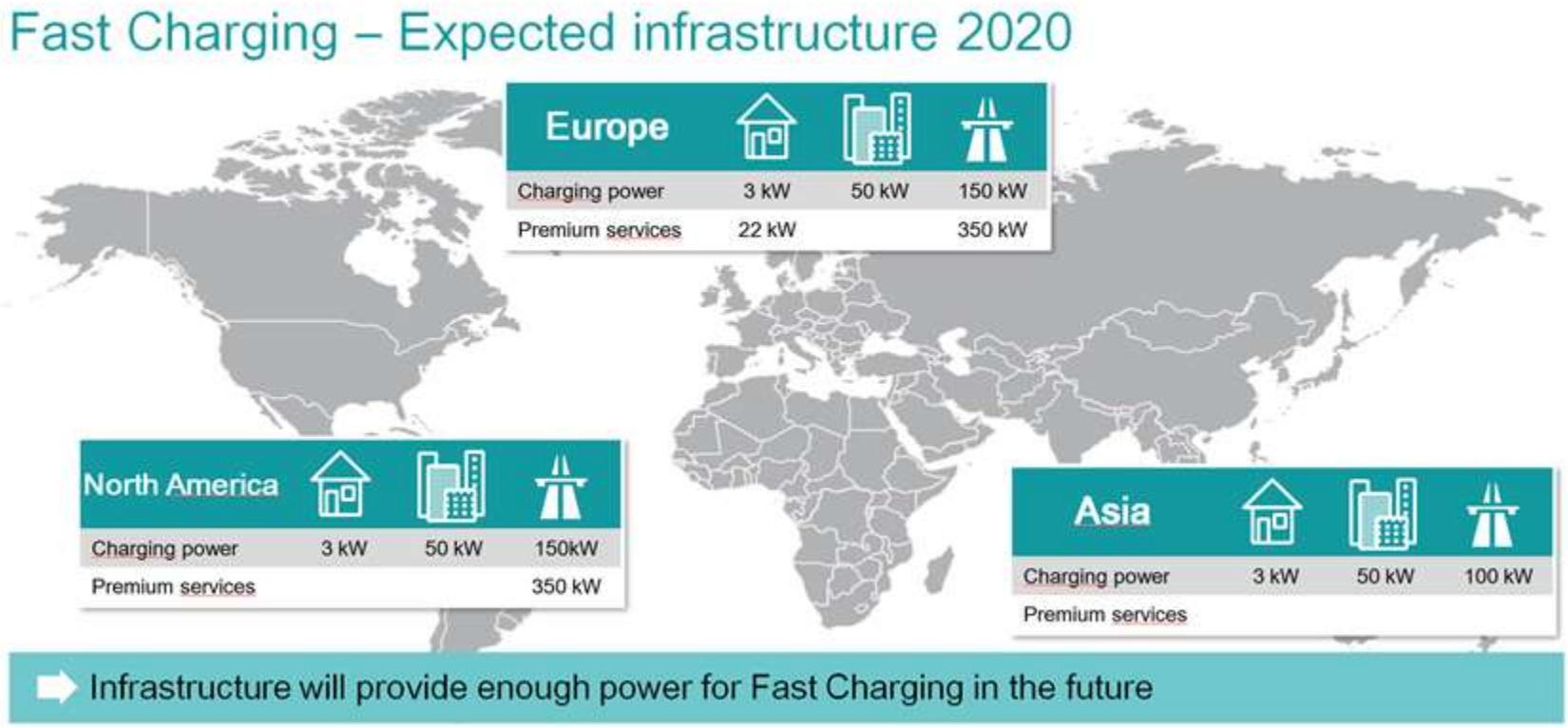
“EV for All” Demand Fast Charging Capabilities

“Charge Point” 400kW Fast Chargers

No Parking Zoon

- **The only option for those who don’t have charging spot at home**
- **5 min charge as refueling a car**
- **Reduced demand for slow public charging infrastructure**
- **Allow to reduce EV batteries size (Cost reduction)**

2020 Plans for Fast Charging

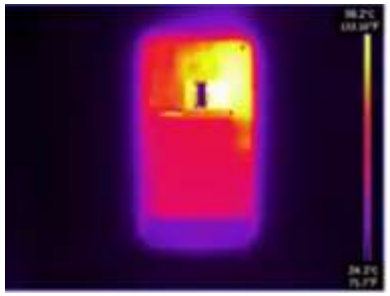


	Level 1 (110V, 1.4 kW)	Level 2 (220V, 7.2 kW)	DC Fast Charger (480V, 50 kW)	Tesla SuperCharger (480V, 140 kW)	XFC (800+V, 400 kW)
Range Per Minute of Charge (miles)	0.082	0.42	2.92	8.17	23.3
Time to Charge for 200 Miles (minutes)	2,143	417	60	21,	7.5

Fast Charging require higher voltage – 800VDC = High electronics cost

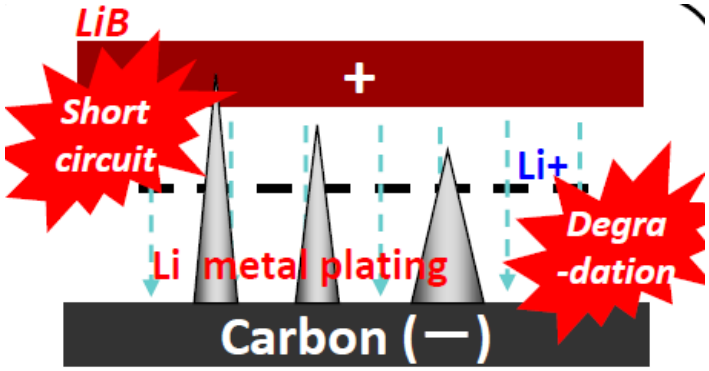
Fast Charging Challenges

- **Ability of the batteries to accept fast charging**
- **Battery safety concern**
- **Gris power delivery limitations**
- **Battery and Charger thermal management**
- **Battery and charger cost**
- **Charging efficiency rate**
- **Charger size and weight**
- **Cell cost**



Why “Standard” Batteries can`t be Charge Fast?

1. Lithium Graphite Anode accepts the lithium ions at a slow rate although the Cathode can transfer them at a faster rate.
2. During fast charging the cell faces deposition of lithium metal in the form of dendrites or as a high surface area film over the Anode.
3. That Leads to very fast capacity degradation and increase of internal impedance and also to safety problems like internal short circuit ,explosions, fires and leaks.

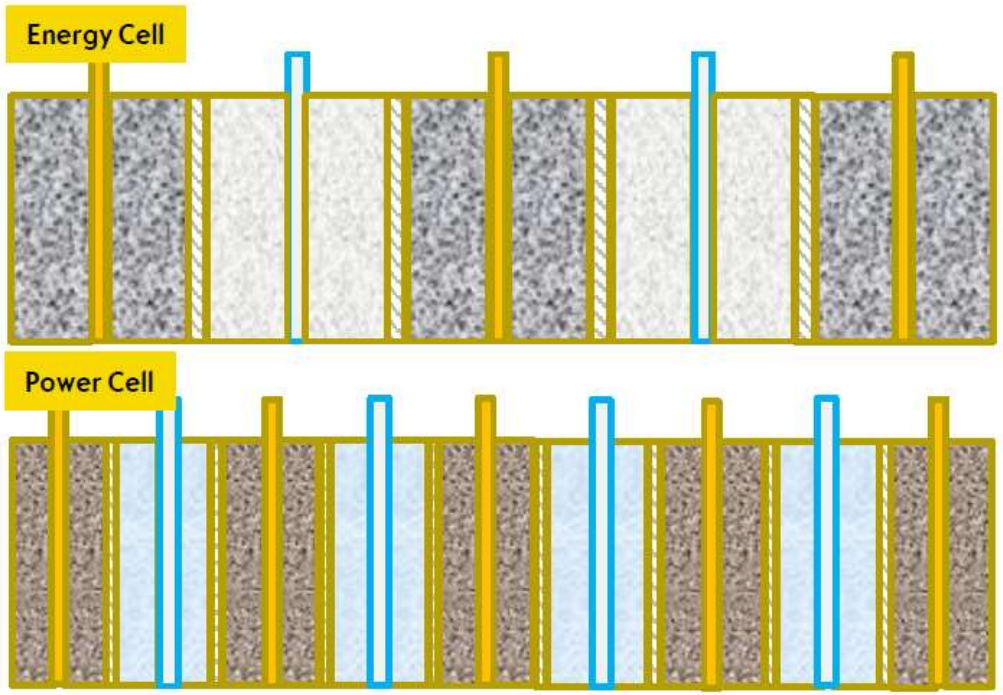


Fast discharge is easy like going down stairs.
Fast charge is difficult like climbing stairs.

Fast Charging Cell Design

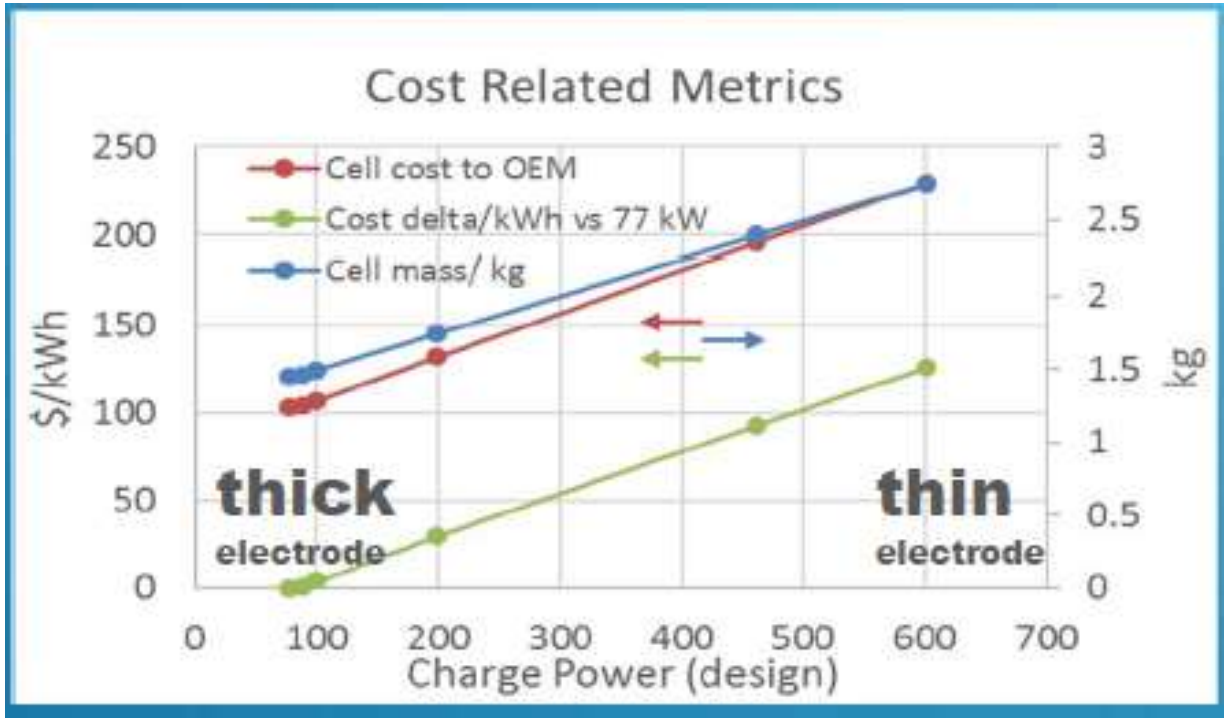
- Thick electrodes
- High ratio electrode volume to current collector volume
- High Wh/dm³ and Wh/kg
- Low W/dm³
- High Wh/€ (lower cost)

- Thin electrodes
- Relative larger surface Anode to Cathode
- Lower ratio electrode volume to current collector volume
- Low Wh/dm³ and Wh/kg
- High W/dm³
- Low Wh/€ (higher cost)



- **Fast charging require thin electrodes**
- **Thin electrode reduce energy density**
- **Thin electrodes increase the cell manufacturing cost (~50-75%)**
- **Thin electrode increase safety concern**

Fast Charging Cell Cost



BatPaC Simulation – "400kW cell" cost $196 per KWh

http://www.cse.anl.gov/batpac/

“Standard” Li-Ion Chemistries that can be Fast Charged

1. **Lithium Titanate (LTO) – Fast Anode kinetics. Anode voltage is far from the voltage needed to deposit metallic lithium, thus smaller probability for metallic lithium deposition over the anode – But low energy density.**
2. **Lithium Iron Phosphate (LPF) – Nano Materials lower voltage cells – But Low energy density and faster self discharge.**

Toshiba Lithium Titanate Rechargeable Battery - SCiB

- Recharges to 90% of full capacity in less than 5 minutes.
- Excellent safety because of high level anode stability.
- 6000 cycles of full D.O.D. to 90% of initial capacity.
- Low temperature discharge from -30C.
- Available on the Schwinn Tailwind E-Bike and EV projects with VW, Mitsubishi and Honda.

2.4Voc/ 4.2Ah	65 Wh/Kg	131 wh/l	650 W/Kg	1316 W/l

SCiB Cell

A123 Nano Phosphate Lithium Rechargeable Batteries

- Cylindrical and soft package cells
- High power density 3000 W/Kg (up to 100C)
- 15-minute charge time possible on some models (18700, 26650).
- Safer technology
- 3.3V working voltage and lower energy density
- Excellent cycle life - Thousands of cycles

A123 SYSTEMS

New Concept - Advanced Battery Raw Materials for Fast Charging Cells

Anode

- Silicon – reduce the thickness due to very high areal capacity – Could be the stronger vector for fast charging with higher energy density
- New sensitized organic materials – reported as improving the charging rates

Cathode

- New sensitized organic materials – reported as improving the charging rates

Separator

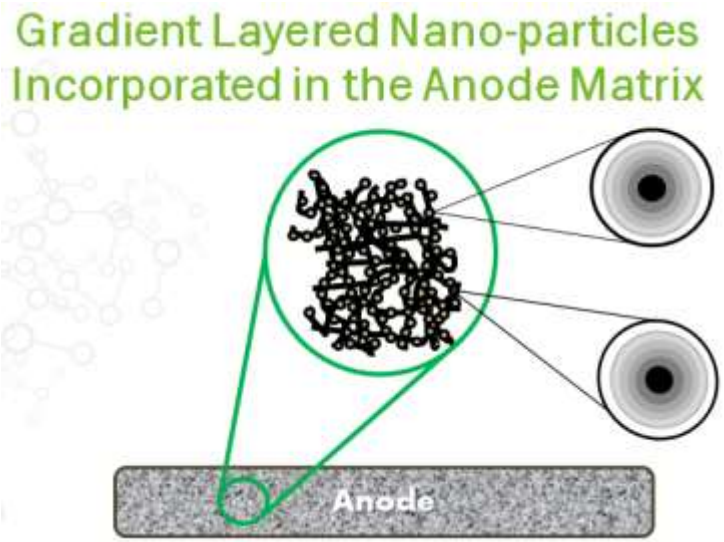
- Thinner separators with special coating to increase connectivity

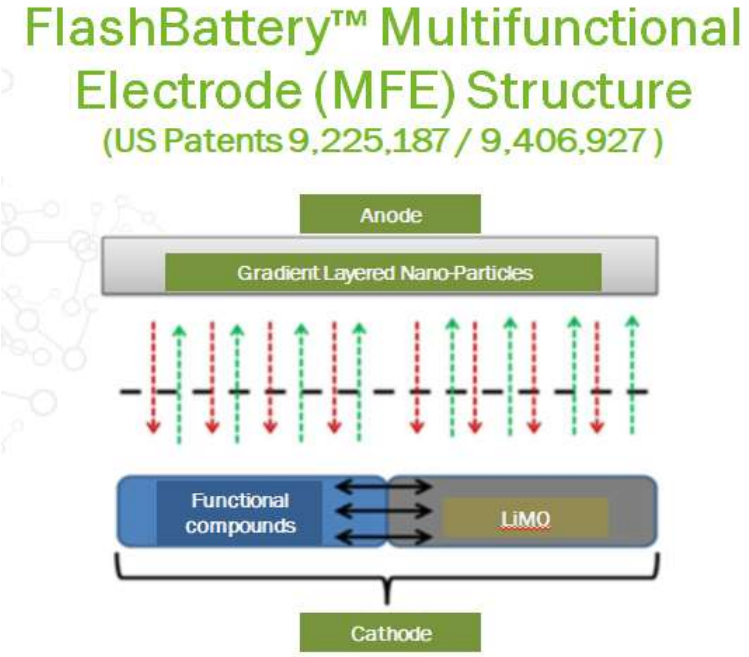
Electrolyte

- Electrolytes with new additive to increase connectivity

Storedot

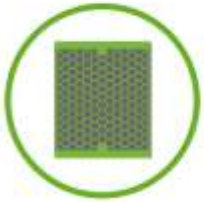
- New synthesis anode with an organic nano materials of non biological origin
- Special cathodes and electrolytes
- Separator coating
- Company completed battery generation 1 R&D and starting production





https://www.store-dot.com/

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

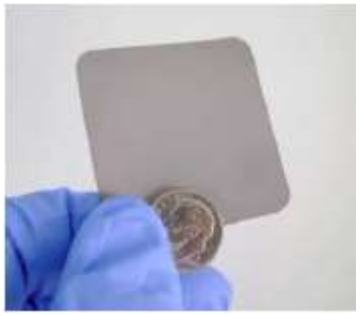
Unique charging algorithms and interface protocols

Fast Charging Market Roadmap

2019	2020	2022
		
Power-banks & Smartphone **Premium Cost / Low Volume**	Smartphone & EV **Attractive Cost / Medium Volume**	Electric Vehicle **Li-ion standard Cost / High Volume**
Target Markets		
Power Bank Market Penetration Technology leadership for fast charging got early adaptors	Smartphone Market Share Fast charging as a standard for consumer electronics	EV Market Penetration Establish market leadership in EV charging market

Enevate

- **New silicon-dominant li-ion thin anode (>70%) , special separator, material coating**
- **300Wh/kg reached**
- **Safe technology – No lithium metal plating**
- **Work up to -40 Deg C**
- **The company license the technology but also have a pilot production line and can deliver cells**



http://www.enevate.com/

GS Yuasa

Table 1 Specifications of LIM25H and LIM30H Li-ion cell.

Model	LIM25H	LIM30H
Nominal capacity / Ah	25	30
Nominal voltage / V	3.6	3.6
Dimension (W×L×H) / mm	44×171×111	47×170×136
Mass / kg	1.5	2.1
Specific energy / Wh kg^{-1}	60	51
Energy density / Wh L^{-1}	108	99

Fig. 1 Appearance of LIM25H Li-ion cell.

The LIM25H electrochemical system consists of a spinel-type lithium manganese oxide cathode with non-graphitic carbon anode. The electrolyte solution composition has been optimized and improved relative to the one for existing LIM30H. The improvements in the cell chemistry have reduced the internal resistance of the cell.

The LIM25H Lithium-ion cell is designed for applications requiring very high charge and discharge currents. This 25Ah battery can handle currents of up to 600A (24C) and is capable of more than 10,000 cycles at 100% depth of discharge.

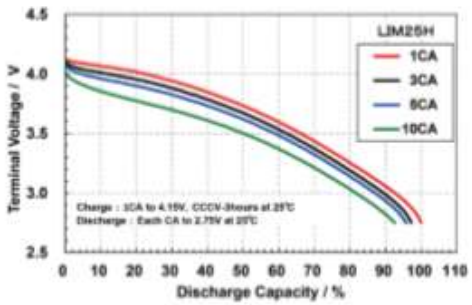
Applications:

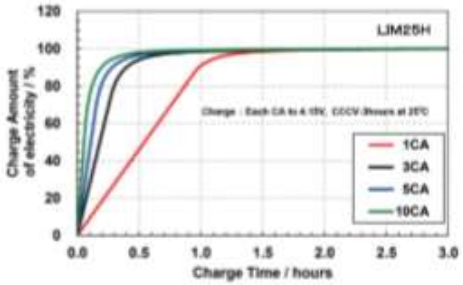
- Military electric and hybrid electric systems
- Hybrid cranes and mining equipment
- Hybrid trains
- Railway systems
- Automated Guide Vehicles (AGV)
- Load leveling systems
- EV charging stations
- Other high power systems

Features:

- Excellent power handling
- Superior cycle life
- Low self-discharge
- High reliability
- Sealed structure

Charge / Discharge characteristics (example)





Huawei


HUAWEI
5 Minutes Quick Charging Demo
Quick Battery Capacity:3000 mAh
The battery is charging for 5 minutes.
Watt Lab
HUAWEI

Samsung SDI

Samsung SDI Presents an Innovative Next Generation Battery with Fast Charging Capability and High Energy Density that enables Electric Vehicles (EV) to Drive 600km

Post. 2017.01.09

◇ With an aim to contribute to the widespread EV adoption, Samsung SDI introduces the cutting-edge battery cell technology with the fast charging capability and high-energy density for a driving range of up to 600km

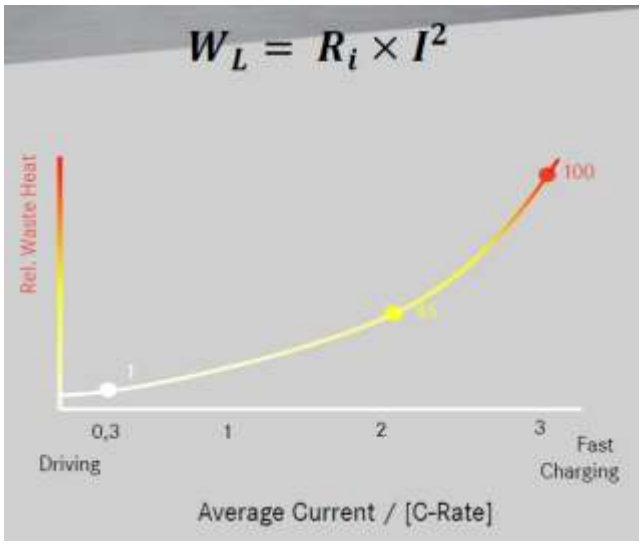
◇ Advanced "integrated battery module" is the latest concept that the company is working on, to maximize the safety and energy efficiency

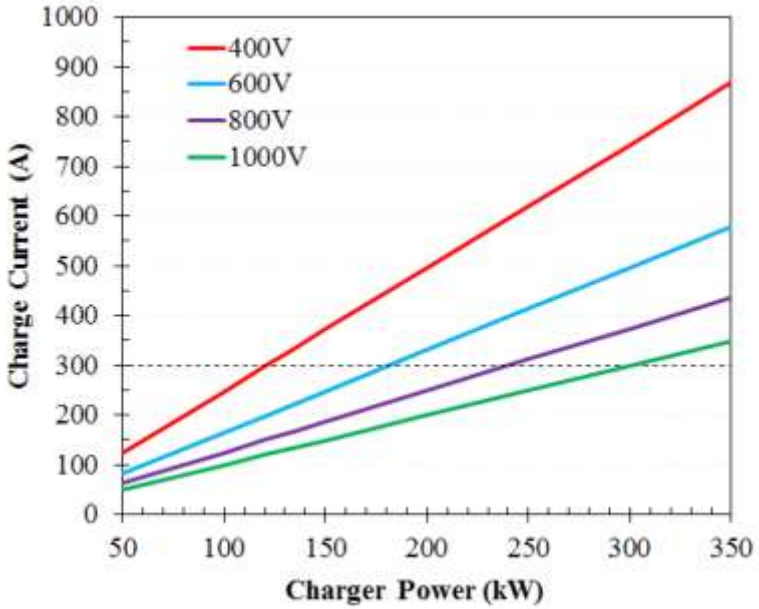
SEOUL, South Korea-- Marking its 4th consecutive year, Samsung SDI (President and CEO: Namseong Cho) (KRX:006400) participated at the North American International Auto Show (NAIAS) 2017 held on the 9th of January, 2017 in COBO Center, Detroit, MI.

http://www.samsungsdi.com/sdi-news/1502.html

Fast Charging Effects on EV Battery Design

- 800-1000V battery instead of 400V Battery (Less current, heat and energy loss)
- Smaller cells capacity 10-20Ah instead of 20-40Ah
- Smaller batteries – 40kWh instead of 50kWh for a sedan Vehicle (Range anxiety declines)
- Less weight in overall because of less wiring weightless package, HV Cells





Summary

- **EV for all mean fast charging is must**
- **There is an high demand for battery Energy and Power density break through**
- **As the progress is slow – Fast Charging will fill the gap**
- **Current batteries are not sufficient for fast charging**
- **New technologies are under R&D – We found 12 companies to develop NMC Fast charging technology (Described in our market report)**
- **We expect a new battery technologies to support fast charging in mass production within the next 5 years**

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Information for presentation obtained by:

1. **Public web sources.**
2. **Shmuel De-Leon Battery/Energy Sources DataBase ® (Includes 30000 cell PDF data sheets) http://www.sdle.co.il/Default.asp?sType=0&PageId=45580**
3. **Shmuel De-Leon Energy Fast Charging Li-Ion battery Market Reports**