Battery Technology & Innovation in Power Tools, Robotics, and Cordless Devices

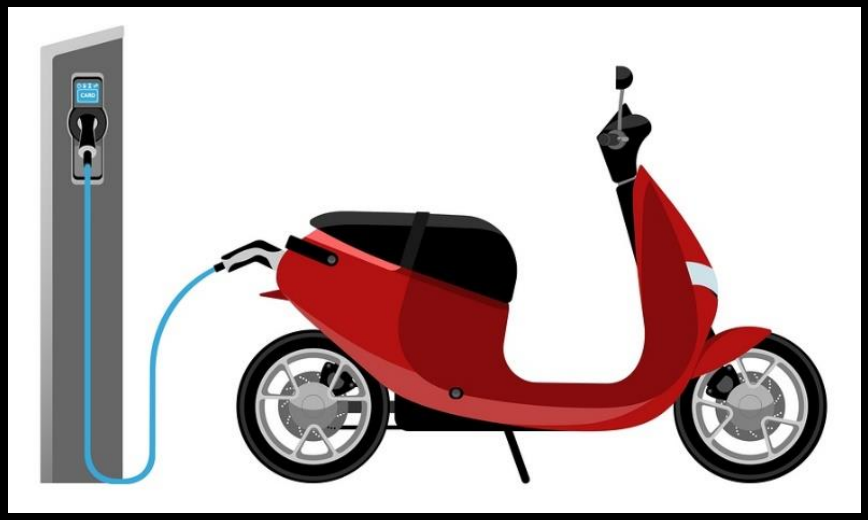
Prashanth Jampani
Matt Lai
David Grant
July, 2019

Batteries Now Power Everything

Everything Takes Too Darn Long to Charge

LONG CHARGE TIMES

3-6 hours



72 to 96 Hours at 110V
7.75 to 10 Hours at 220V
1 to 1.33 Hours at 440V

TODAY'S FAST CHARGE TECH

Brute force approach of just pushing more current into existing battery structures causes 3 problems

Decreases Life of Battery

Chemical break downs causes batteries to have much shorter lifetimes

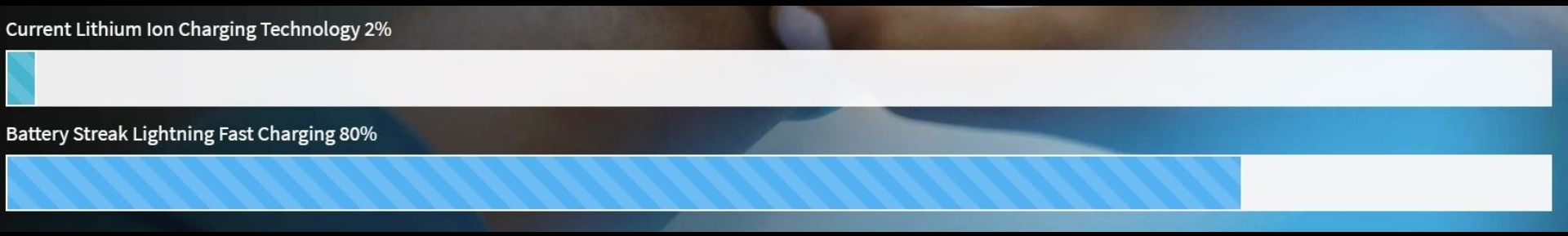
Creates Excess Heat

Wastes energy, needs to be managed, limits current & therefore speed of charge

Still Not That Fast

Chemical process is slower so basically although faster it is just not that fast

Battery Streak Batteries Charge to 80% in 10 minutes



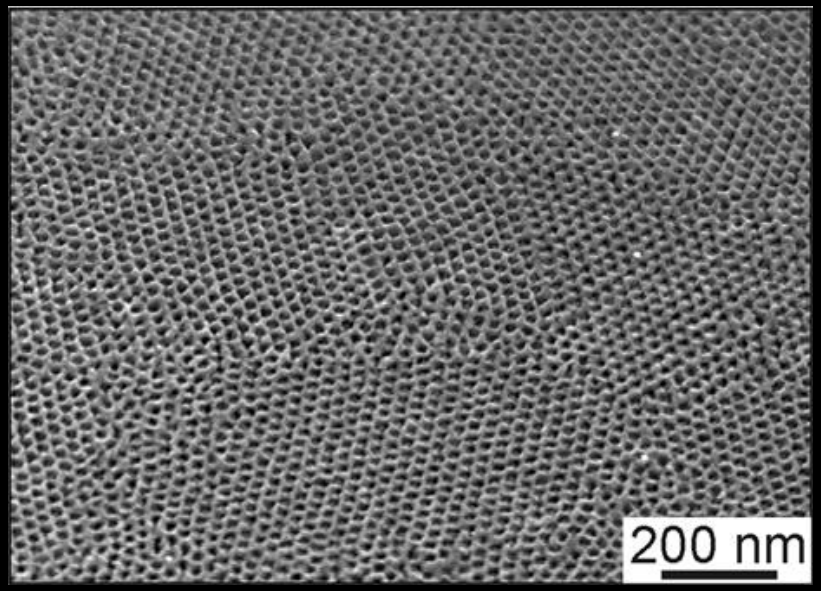
OUR BREAKTHROUGH

New nano-structured material for the electrode allows for a massively parallel charging process

- Sponge like material with pores of 20 to 50 nanometers. *(Human hair is about 200,000 nanometers)*
- Stores energy like a capacitor- electrostatic surface (Not a chemical storage) charge. Discharges like a battery
- Charges Fast …
  - Without impacting battery life
  - Without heat
  - And much, much faster

PATENTED MATERIAL - NIOBIA

Mesopourous Materials Provide Very Large Surface Area Per Unit Volume



SEM image of mesoporous TiO_2 film

- Multiple issued patents
- Material invented at UCLA, exclusively licensed and developed at Battery Streak
- Prototype batteries created with **standard lithium ion battery production process**

WHERE WE CAME FROM

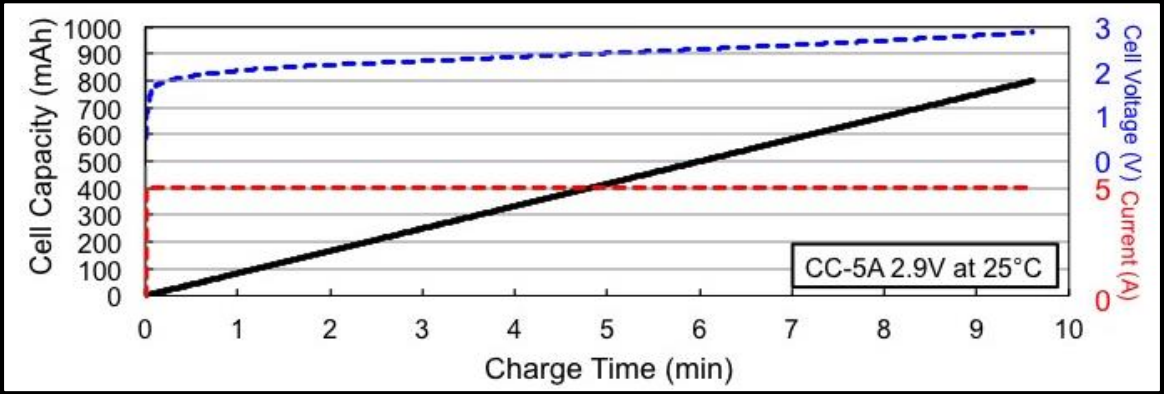
2008 - Research started at UCLA – Dr Bruce Dunn & Dr. Sarah Tolbert

May 2017 - Battery Streak formed to commercialize the technology

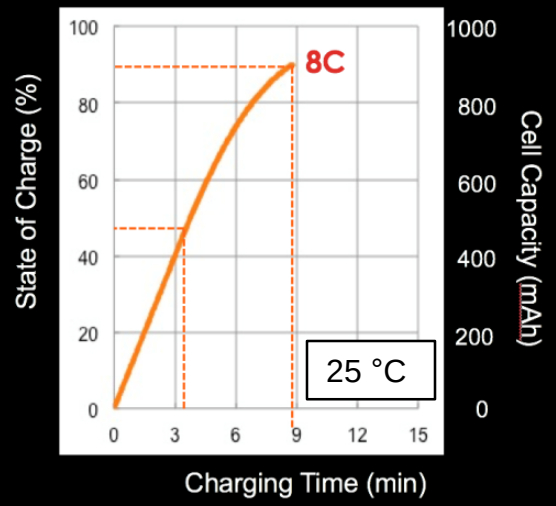
- Seed round led by Act One Ventures

PROTOTYPE BATTERIES

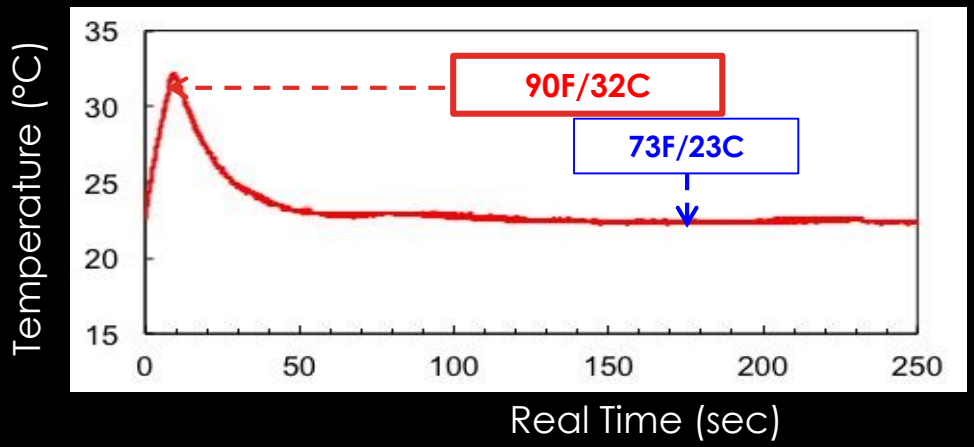
Regular Charge: >80% charged in <10 minutes



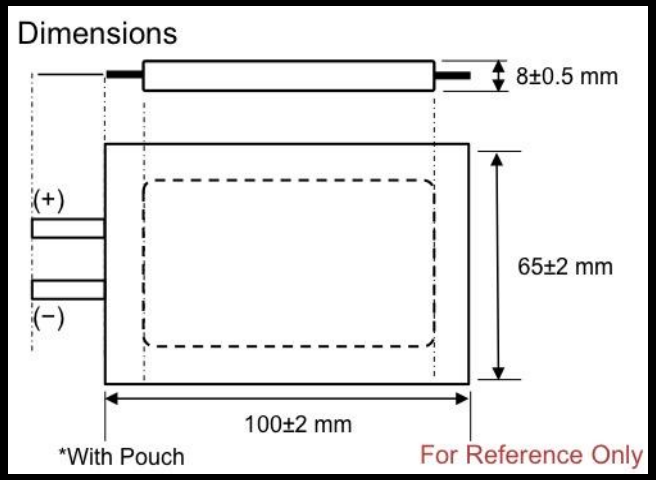
50% in 3.5 min – 90% in 9 min

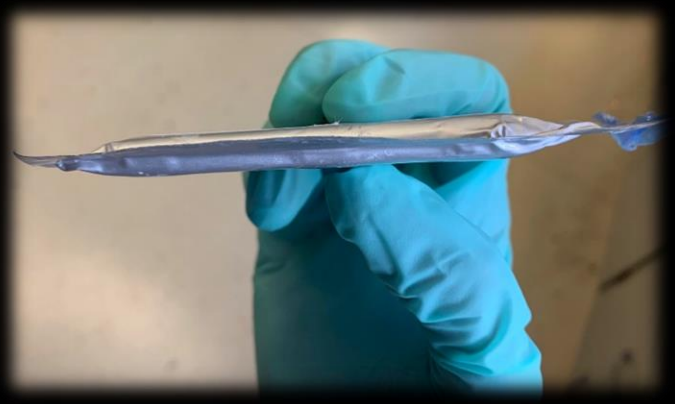


Max Temp = 90°F/ 32°C
Charging at 10C



PROTOTYPE BATTERIES



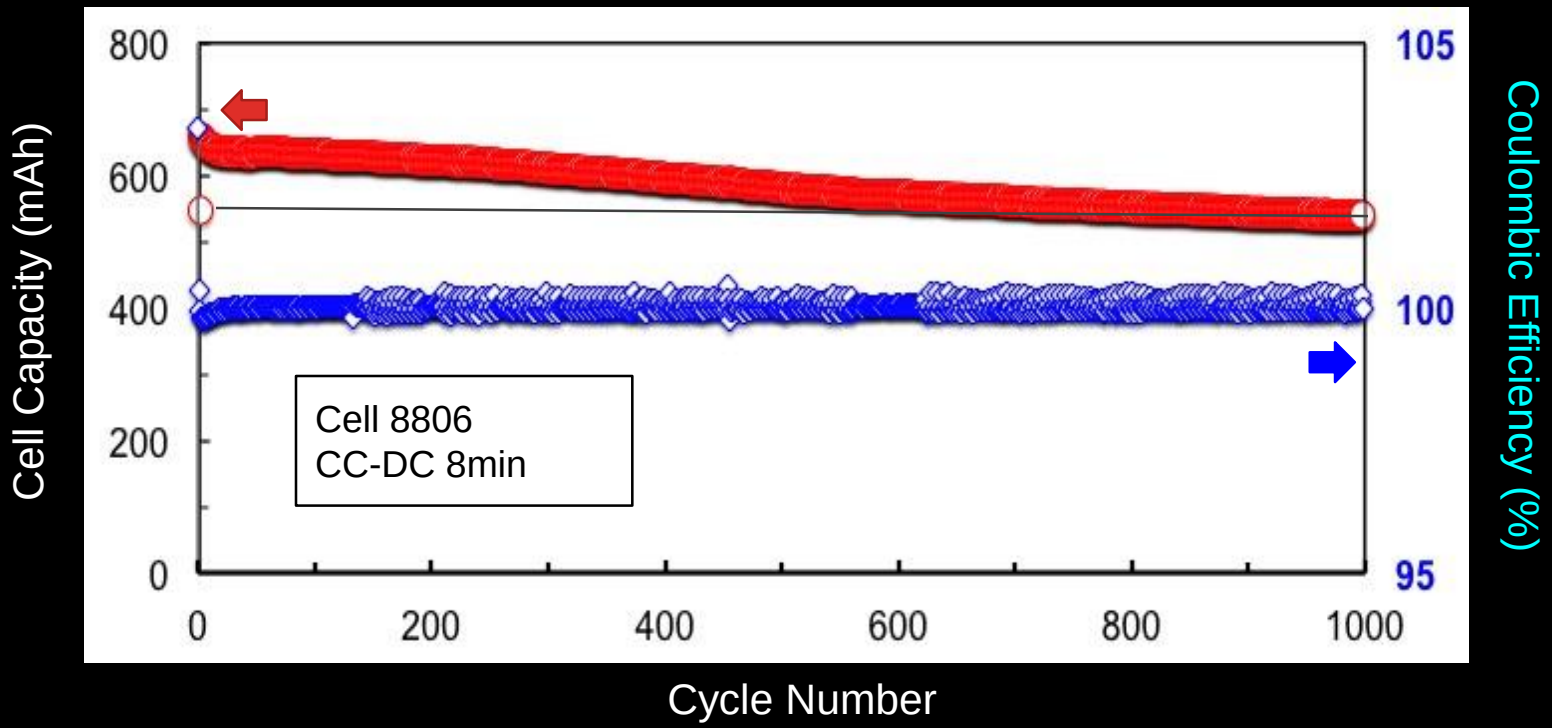


Capacity (mAh)	1000 ± 10%
Nominal Voltage (V)	2 V
Internal Resistance (mΩ)	< 30
Gravimetric Energy Density (Wh/kg)	45 ± 5%
Volumetric Energy Density (Wh/L)	86 ± 5%
Charge Time to 50% SOC (min)	6
Charge Time to 80% SOC (min)	< 10
Discharge Cut-Off Voltage	0.5 V
Max Charge Voltage	2.9 V
Standard Charge Current	5 A
Maximum Charge Current	6 A
Standard Discharge Current	0.2 A
Maximum Discharge Current	2 A
Weight W package, pouch	55 g
Dimensions - W/O package (mm)	W45 X L80 X H7.6
Dimensions – W package, pouch (mm)	W65 X L100 X H8
Operating Temperature	25 °C
Self-Discharge (mV per 100 hours)	< 25

LONG BATTERY LIFE

Long Lasting

85% Capacity Maintained For 1000 cycles



FUNDAMENTAL NEW TECHNOLOGY

People wanted bigger TVs

Tube TV

Bigger screen required exponentially more depth and weight

Largest commercial TV was 40" and 750 pounds

Flat Panel

Fundamental new tech comes along without those limitations

Large screens possible without huge depth or weight

New markets created to put screens in cars, phones, etc.

MARKETS

- Warehouse Robots 40,000
- Power Tools (WW/YR) 15,000,000
- Industrial Tablets (WW/YR) 159,000,000
- Cell Phones (WW/YR) 160,000,000
- Video Cameras (WW/YR) 8,000,000
- Electric Vehicles (US/YR) 1,000,000
  - Battery Packs
  - Regenerative braking

GAS VS ELECTRIC CAR

- Gasoline car range 300 miles
- Electric car range 300 miles

- Gasoline fill time 3 to 5 minutes
- Electric car fill time 1.5 hours minimum

- **78% of trips < 10 miles**

Source: Rob Van Haaren, World Electric Vehicle Journal 2019

CHARGE TIME CALCULATION

60 KWh battery pack provides about 200 miles

60 KWh Battery pack X 60min / h = 3,600 KWmin

To charge in 10 minutes = 3,600 KWmin / 10 min = 360 KW

ChargePoint Express Plus Charger = 500 KW

THE NEW EV MODEL

COULD make cars with a smaller range

- 100 to 200 miles
- Smaller battery packs
- Regenerative braking

Battery chargers at every gas station

- Cup of coffee or Check your email

Increase the TAM for EV and chargers by many 0000s.

Need to move from a
MAX MILES per charge mindset
To
MINUTES TO CHARGE mindset

WAREHOUSE ROBOTS (AGV)

- The global warehouse robot market
  - US$2.2B in 2016
  - expected to grow at a CAGR of 45.2% 2016-2021
    - Projected US$6.7B

Source: BIS Research (2018)

- Robots as a Service (RaaS)
  - Market estimated to be $5B by 2023

- > 50 companies involved in this space
  - 6 Rivers Robots
  - Boston Dynamics
  - Fetch Robotics
  - Amazon
  - FedEx
  - Vecna
  - inVia Robotics (RaaS)
  - Vex robotics
  - GE
  - UPS

- 620,000 Battery units annually @ $480 each = net spend of $300 Million

BATTERY OPTIONS

- Two methods for recharging a warehouse robot
  - Charging station
    - Multiple hours
    - Robot down time
  - Swap batteries — "Biggest Pain Point"
    - 4 minutes
    - Up to 6 per robot - Annually — (6 X $80/battery = $480)
    - Human swaps the batteries — ($$ / hour)
    - Substantial space — ($$ per ft^2)
- "What good is a robot worker if it doesn't ensure superior efficiencies?" – www.azom.com article 1531

CHARGE TIME VS SWAPPING

ARTICLE IN PRESS

JID: EOR [m5G;January 6, 2018;0:35]

European Journal of Operational Research 000 (2018) 1–21

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Evaluating battery charging and swapping strategies in a robotic mobile fulfillment system

Bipan Zou[a], Xianhao Xu[b], Yeming (Yale) Gong[c,*], René De Koster[d]

[a] School of Business Administration, Zhongnan University of Economics and Law, 182 Nanhu avenue, Wuhan 430073, China
[b] School of Management, Huazhong University of Science and Technology, Wuhan 430074, China
[c] EMLYON Business School, 23 avenue Guy de Collongue, Ecully Cedex 69134, France
[d] Rotterdam School of Management, Erasmus University, P.O. Box 1738, DR Rotterdam 3000, The Netherlands

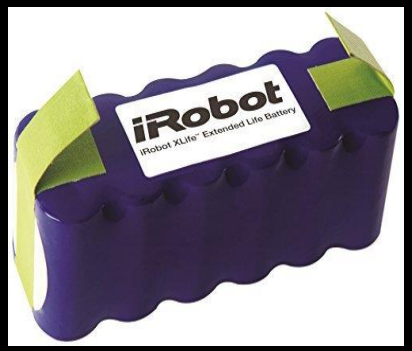
1 hour charge time **VS** 4 minute swap time

SWAPPING BATTERIES WINS!

BATTERIES USED FOR ROBOTS

Two types of batteries most commonly used:

- Lead acid batteries
- Nickel-metal hydride



Specifications		
	In-market batteries	**Battery Streak**
Nominal Voltage (V)	7 – 12	12
Energy (Wh)	12.8 - 32	36
Cycle Life (full cycles)	500 – 2,000	3,000
Specific Energy (Wh/kg)	30 – 40	45
Energy density (Wh/L)	50 - 70	85
Charge time	2-8 hrs	<10 minutes

BATTERY SOLUTION

Best methods for recharging a warehouse robot

- Charging station
  - Less than 10 minutes
  - 2 batteries per robot
  - No human employee
  - Much less space
  - Fully automated operation

BATTERY STREAK
CHARGE LIGHTNING FAST

Thank you For Your Time

Battery Streak, Inc
1270 Calle El Cameron
Thousand Oaks, CA 91360
www.batterystreak.com