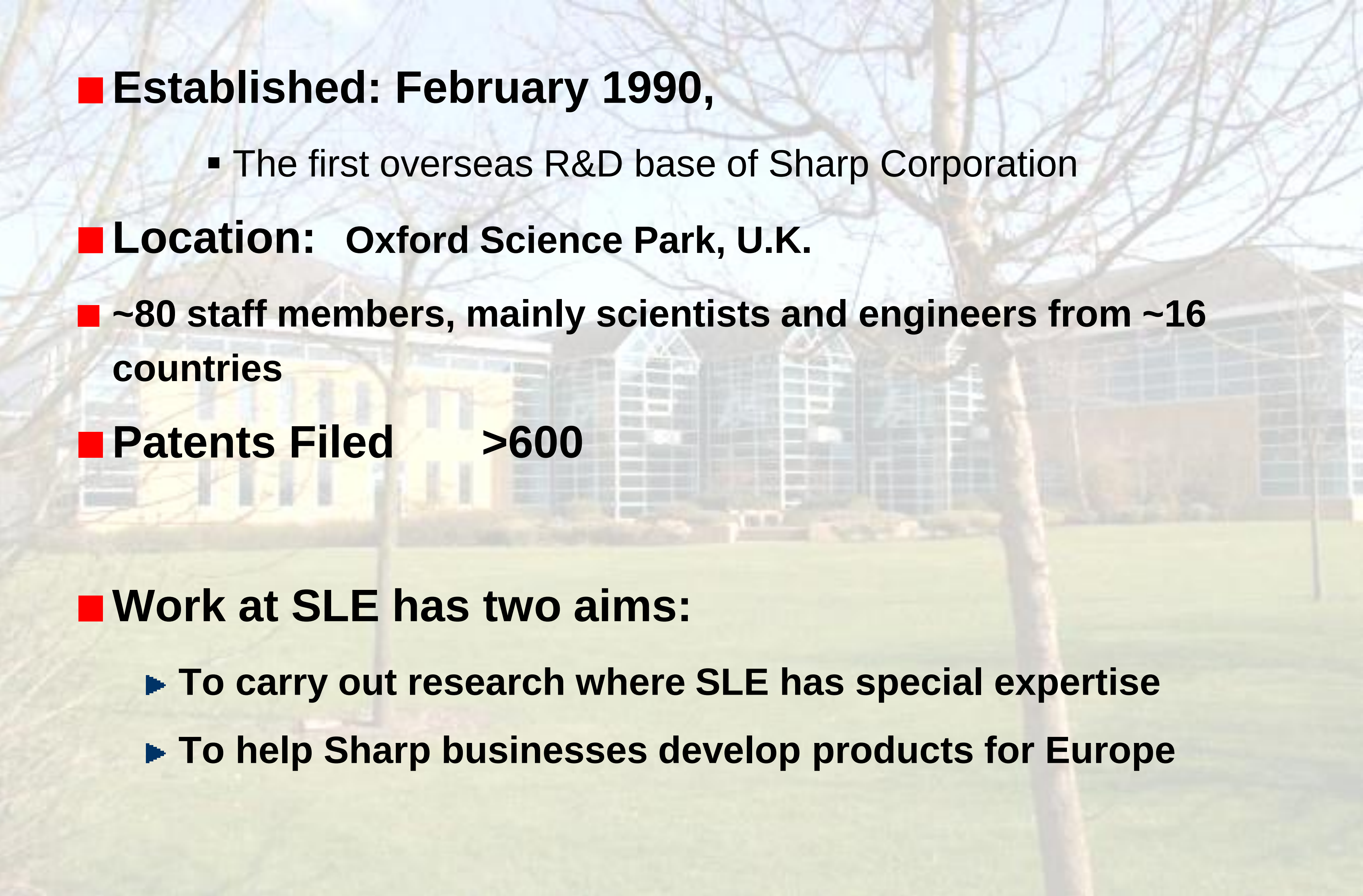
The use of carbon in next generation battery technologies

Dr. Emma Kendrick

Sharp Laboratories Europe

HVM Graphene+ 2014 Conference
Oxford, UK 15 May
www.hvm-uk.com

Sharp Laboratories of Europe

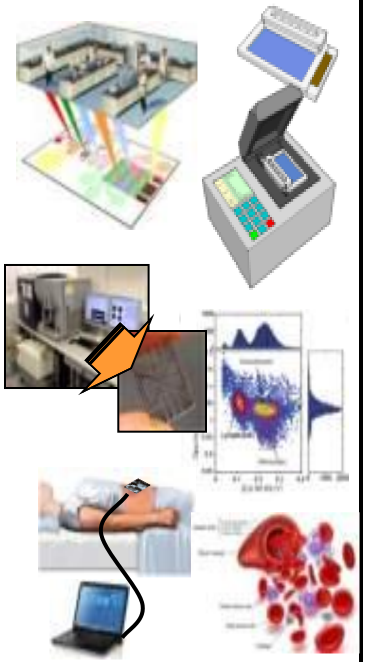


- **Established: February 1990,**
    - The first overseas R&D base of Sharp Corporation
- **Location: Oxford Science Park, U.K.**
- **~80 staff members, mainly scientists and engineers from ~16 countries**
- **Patents Filed >600**

- **Work at SLE has two aims:**
    - **To carry out research where SLE has special expertise**
    - **To help Sharp businesses develop products for Europe**

SLE's Main R&D Themes

Health & Medical



Leveraging Sharp TFT technology for new markets:

- Point of care Lab on a chip
- Blood cell counter
- Protein chip
- Ultrasound imaging

Energy & Environment

Addressing the need for energy solutions, beyond solar panels, for both local fit & global markets:

- PV-T heating & hot water
- Low cost Energy Storage
- Materials, water Purifier

Displays & Embedded Systems

Expertise in optics and embedded systems. Continuing to support

- Mobile and large area display. Recent work in
- Robotics,
- Body scanner
- 3D printing.

System Devices & Modules

Supporting Elecom device business in

- LED
- UV technology
- GaN power device

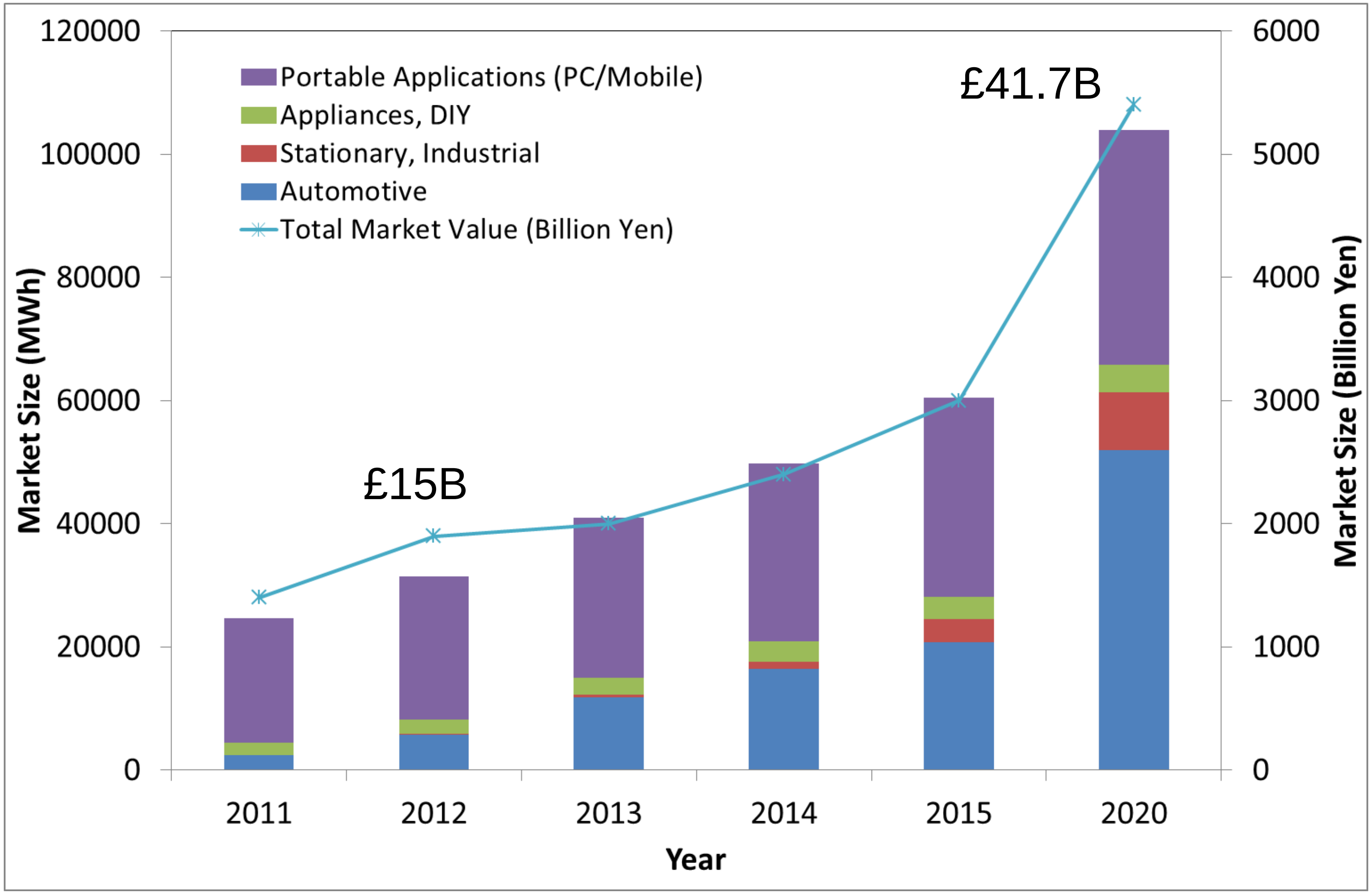
EDC

Now part of SDE Technical support for device sales in Europe.

Contents

- Energy Storage Markets
- Lithium ion battery manufacture
- Use of Carbon in Batteries
  - Conductive Additive
  - Active Materials
- SHARP Labs of Europe R&D

Global Energy Storage Market Size

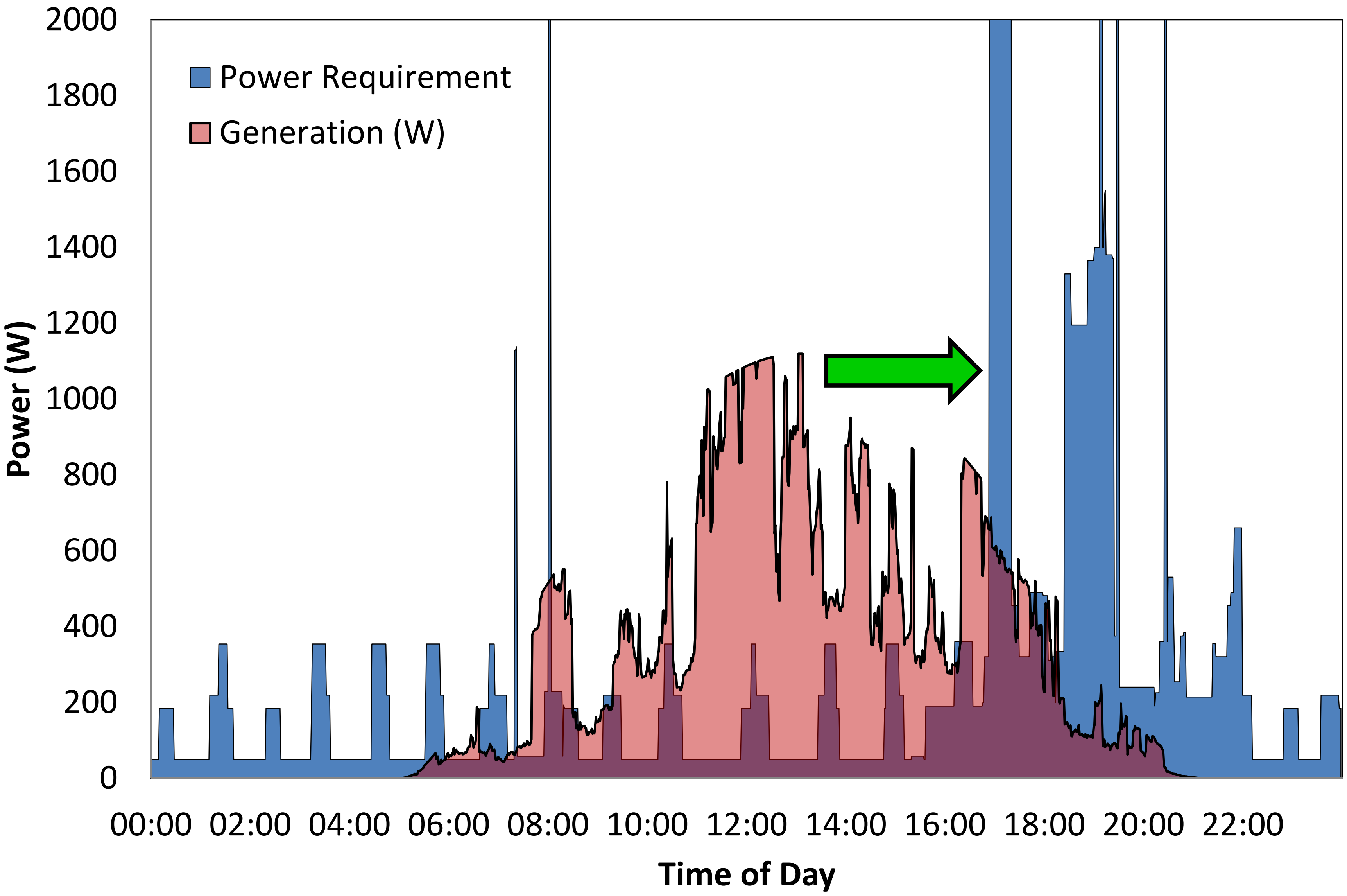


※ The figures for the scale of the automotive market were estimated in 2011 from the company production plan and from 2012 estimated by Nomura Research Institute. (March 2010)

※ PC, mobile market scale figures estimated from Nomura report (Dec. 2010)

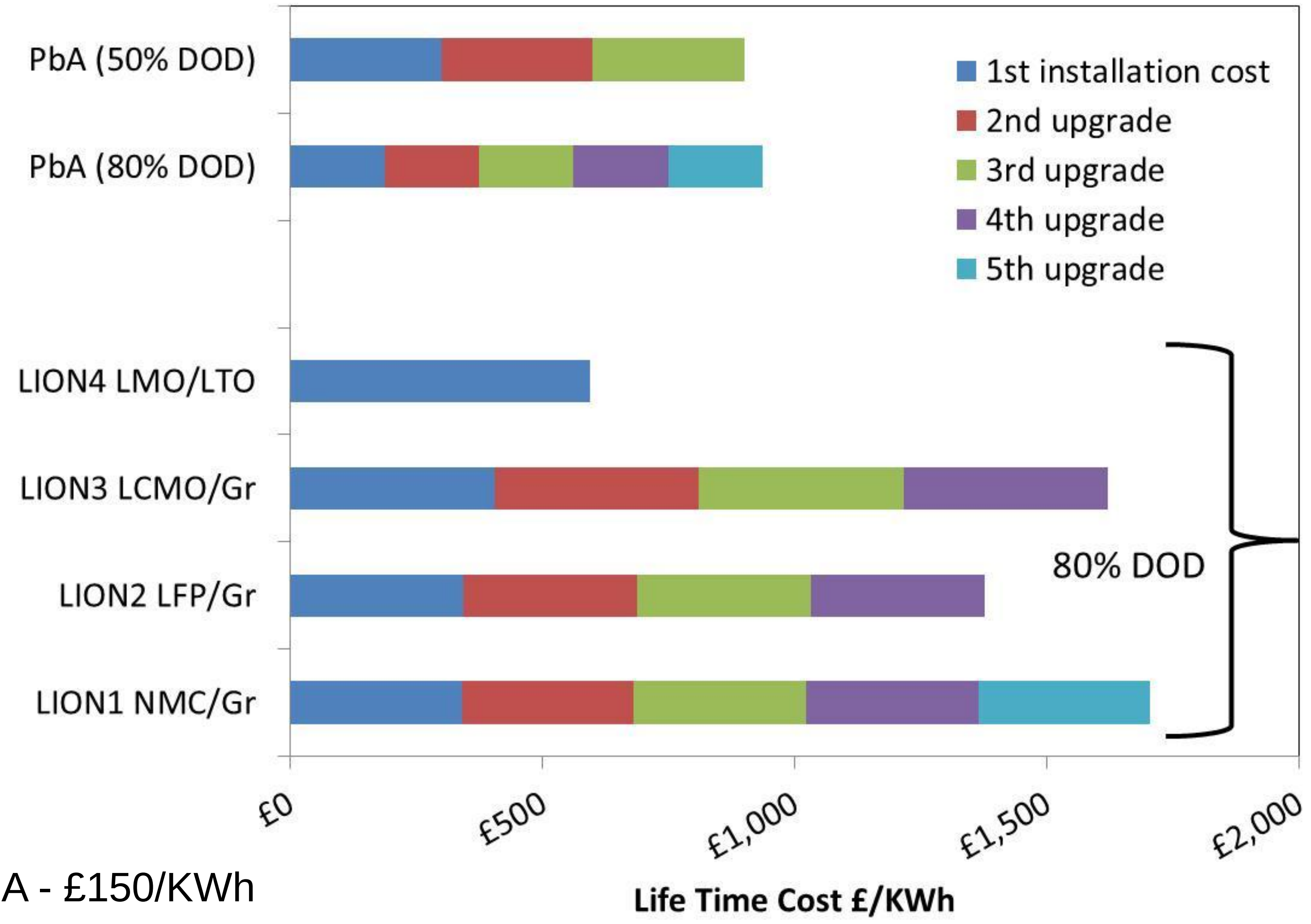
※ Provisional calculation of storage cell requirements for PV installations as storage cells: 3kWh to PV 1kW.

Solar Domestic Electricity Generation



Lifetime cost analysis

SHARP

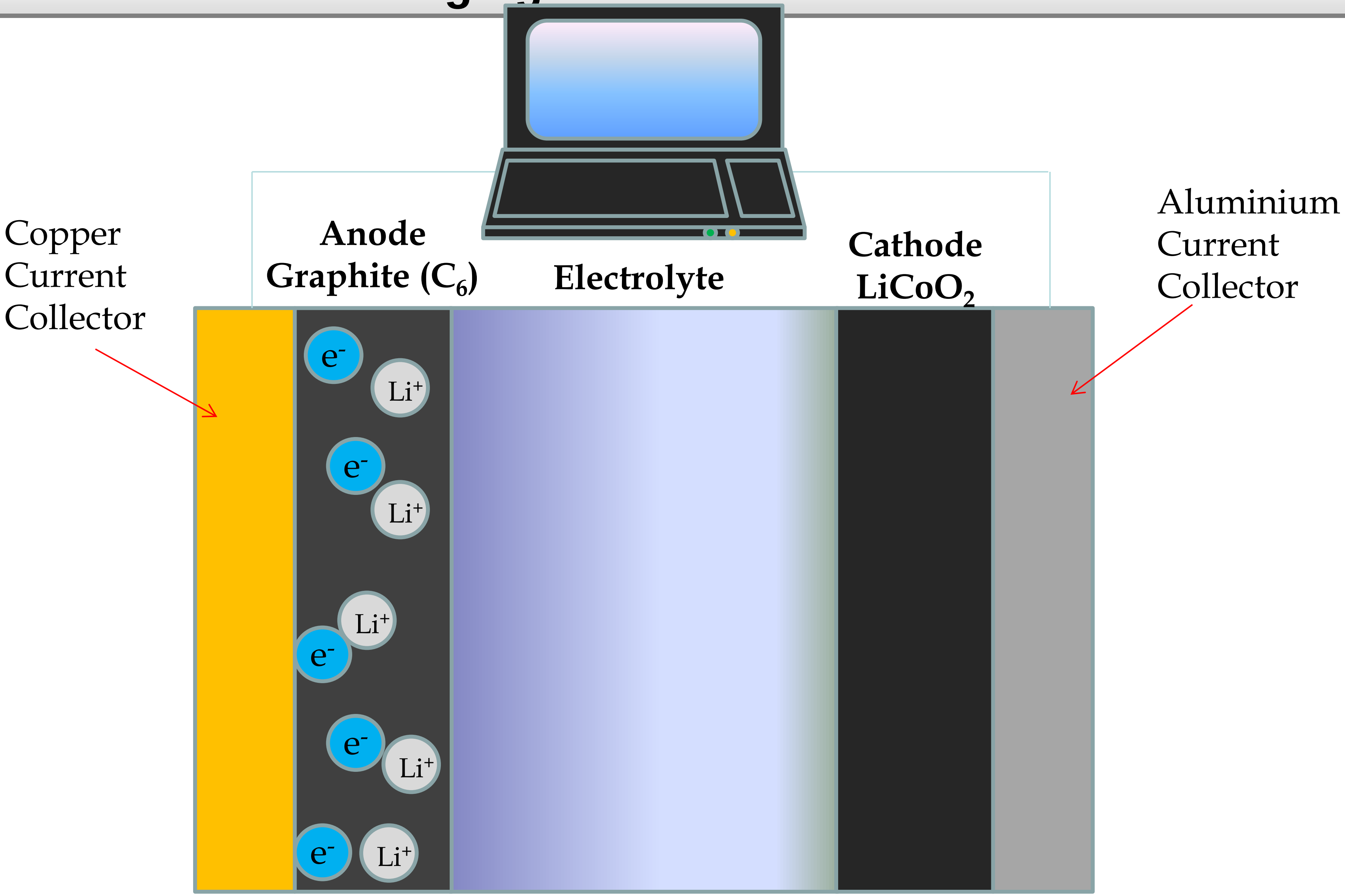


PbA - £150/KWh

Li-ion Assumptions:
Current Cell Prices, Mass Manufacture of Batteries

Li-ion Batteries

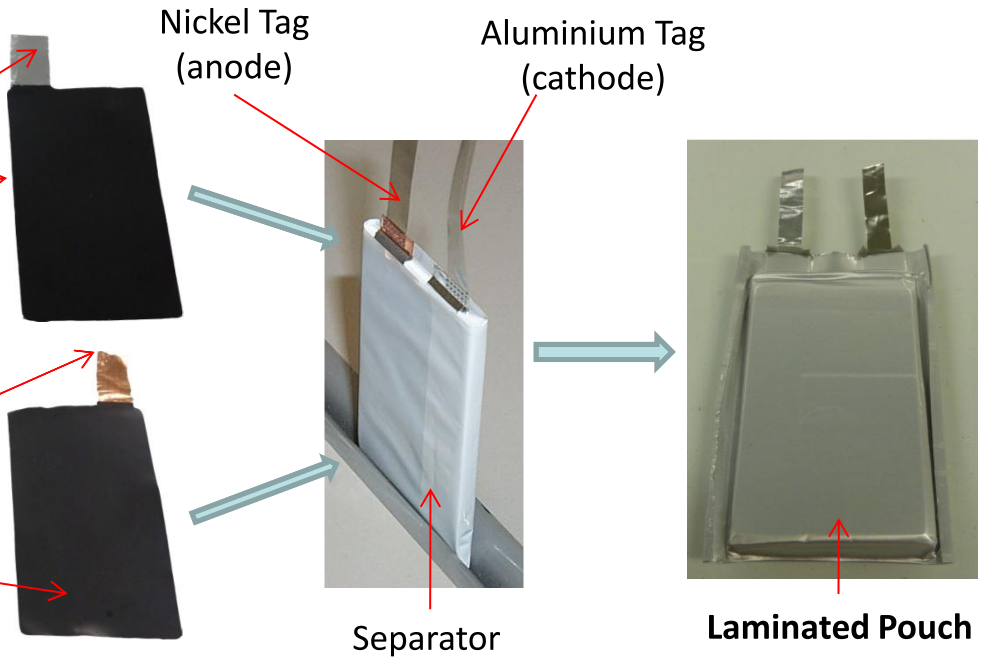
Li-ion Cell - Discharging

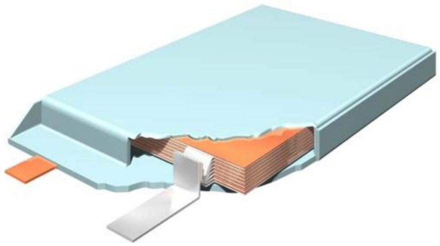


$C_6Li \rightarrow C_6 + Li^+ + e^-$ $2Li_{0.5}CoO_2 + Li^+ + e^- \rightarrow 2\ LiCoO_2$

Li-ion Cell Construction

- ☐ **Cathode:**
  - Aluminium current collector
  - Double-sided composite: $LiCoO_2$/carbon/PVDF
- ☐ **Anode**
  - Copper current collector
  - Double-sided composite: Graphite/carbon/PVDF
- ☐ **Separator (porous PE)**
- ☐ **Electrolyte**
  - Salt ($LiPF_6$) + solvent



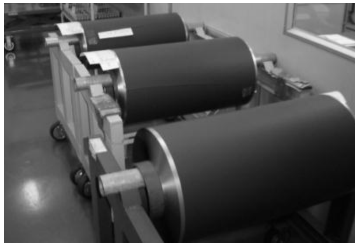


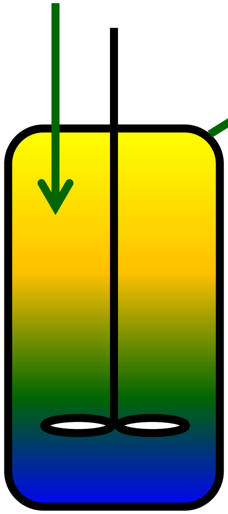
Electrode Manufacture

Composite Mix

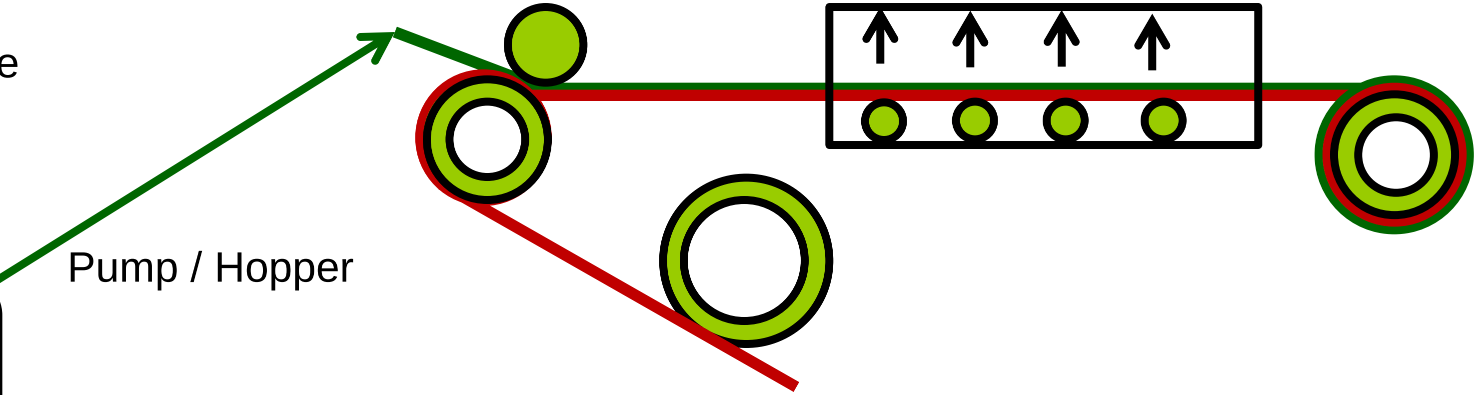
Coating

Drying





Active Material
Binder Solution
Conductive Additive



Pump / Hopper

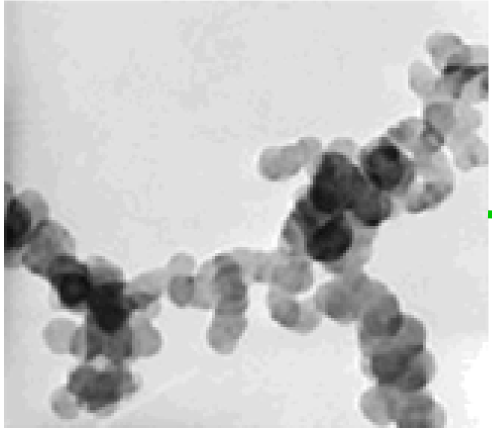
USE OF CARBON IN BATTERIES

Considerations during Formulation Optimisation

- 3-D electronic conductivity
- 3-D ionic conductivity
- Porosity
- Gravimetric and Volumetric Energy Densities
- Adhesion to Current Collector

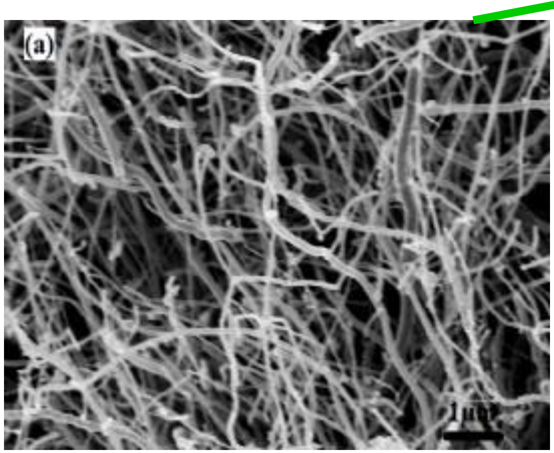
Composite Cathodes

Carbon Black

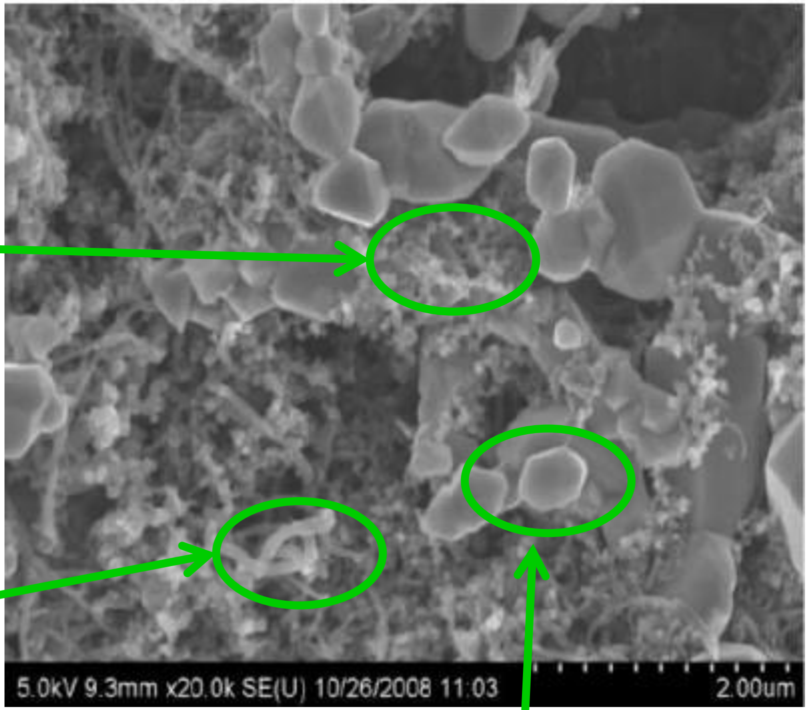


Timcal SuperP

Carbon Fibres



Composite Cathode



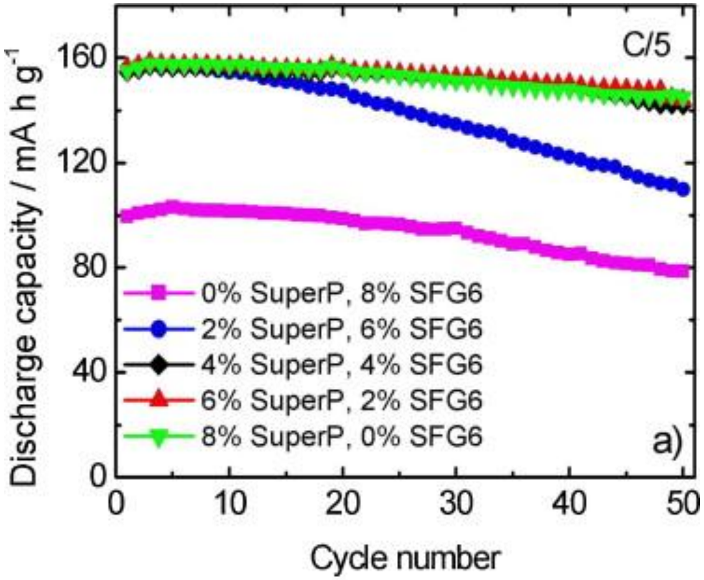
http://www.azonano.com/article.aspx?ArticleID=2315

Active Cathode Material

Effect of Formulation

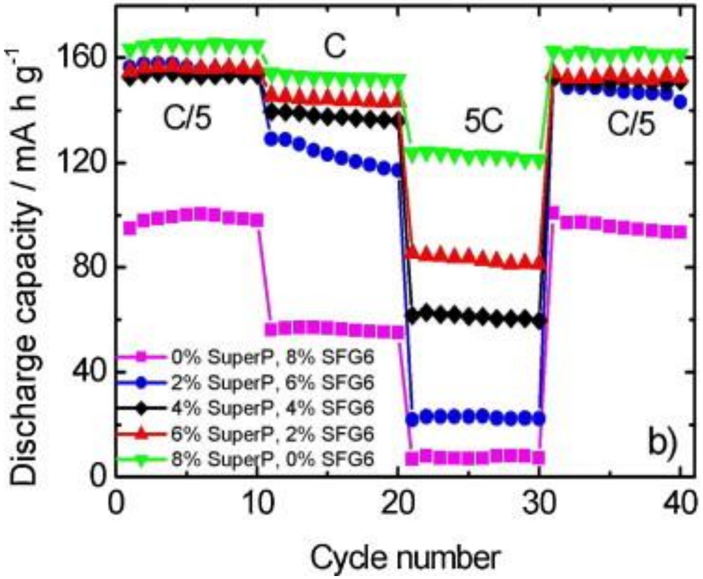
Table 3. Composite slurries with different content of conductive agents.

Composition ratio	1	2	3	4	5
NCA [wt. %]	84	84	84	84	84
Super P [wt. %]	0	2	4	6	8
SFG6 [wt. %]	8	6	4	2	0
PVdF [wt. %]	8	8	8	8	8



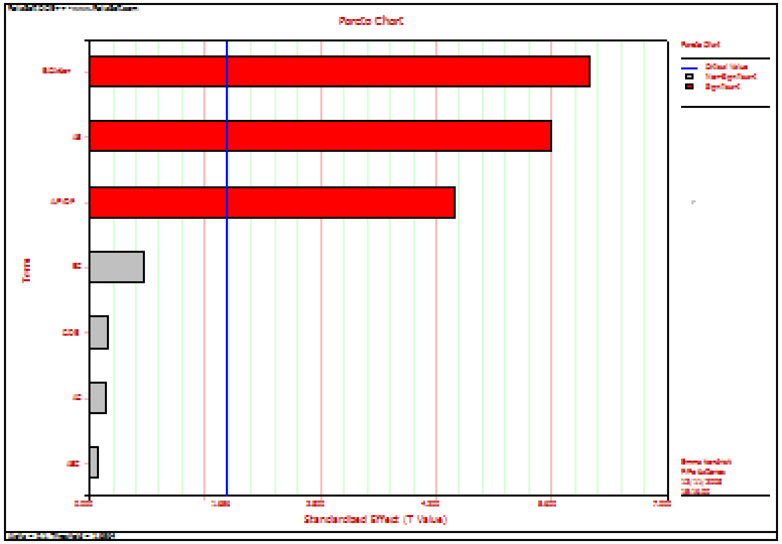
- ➢ Improve Electronic conductivity of electrode
- ➢ Increase porosity

- ➢ Optimise Performance
- ➢ Capacity and Rate
- ➢ Improve Life time



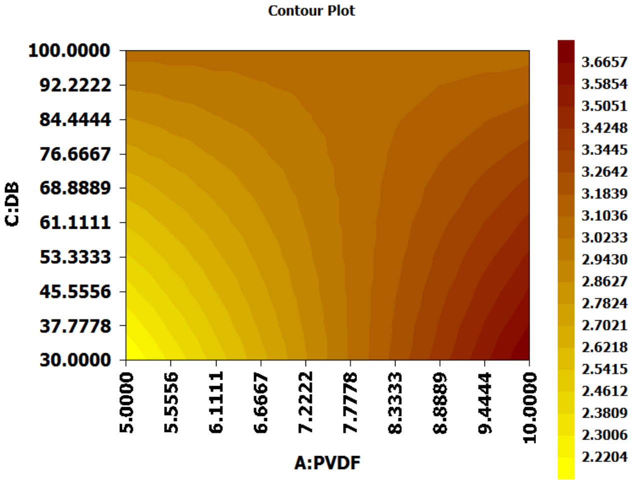
Influence of Electrode Preparation on the Electrochemical Performance of $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ Composite Electrodes for Lithium-Ion Batteries | *Journal of Power Sources*, ***In Press,*** *Available online 21 March 2012,* H.Tran, G. Greco, C. Täubert, M. Wohlfahrt-Mehrens, W. Haselrieder, A. Kwade

Electrode Optimisation

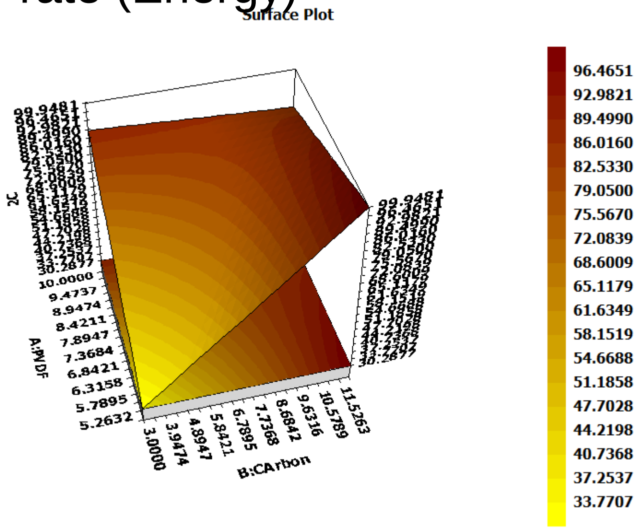


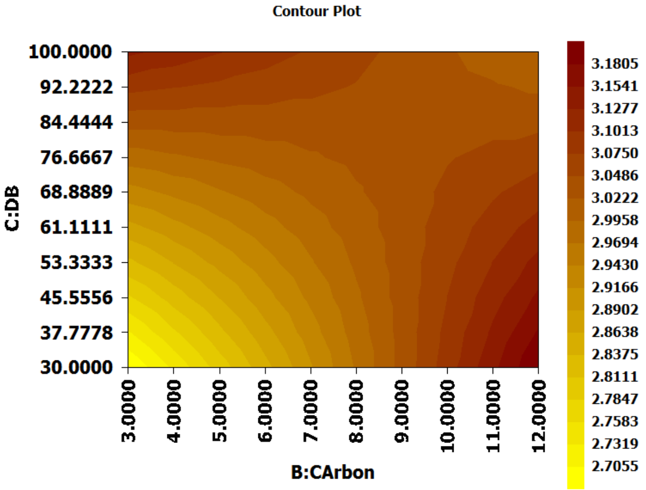
A - Carbon
AB
B - PVDF

1st Cycle Loss



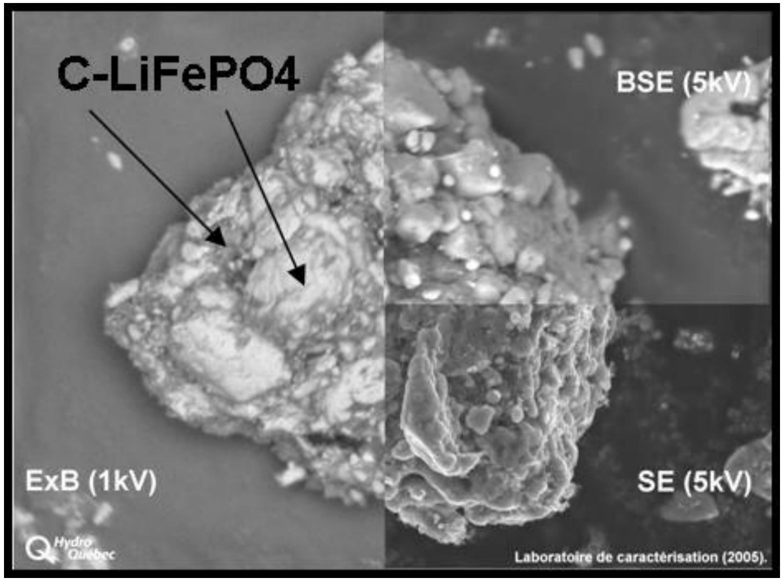
2C rate (Energy)

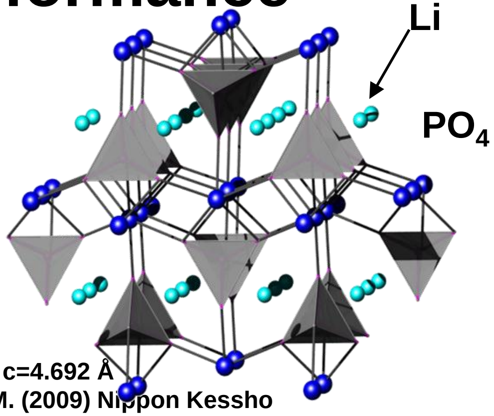




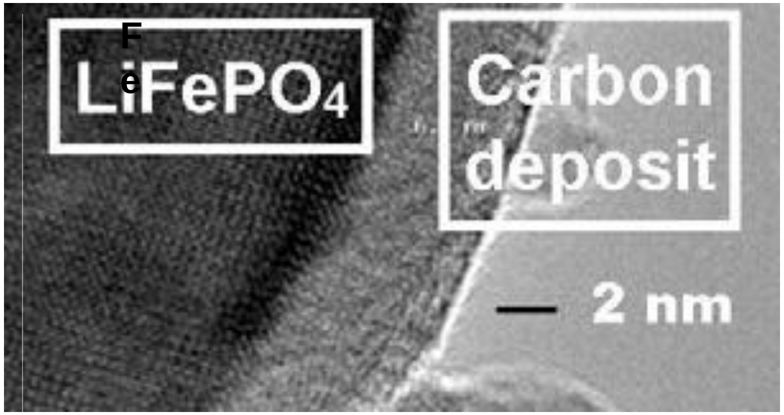
Lithium Iron Phosphate $LiFePO_4$

- **Electronic conductivity lower than those of mixed metal oxides**
- **Modification**
  - **Reduction in particle size**
  - **Pyrolytic carbon deposit**
- **Improved performance**
- **Cost**





Space group Pnma
a=10.329 Å, b=6.007 Å, c=4.692 Å
Yamada, A.;Yashima, M. (2009) Nippon Kessho Gakkai-Shi 51, 175-181



http://www.phostechlithium.com/prf_lifepower_e.php

Hard Carbon Anodes

- Higher Capacities
- Synthesis Routes
- Structure Optimisation

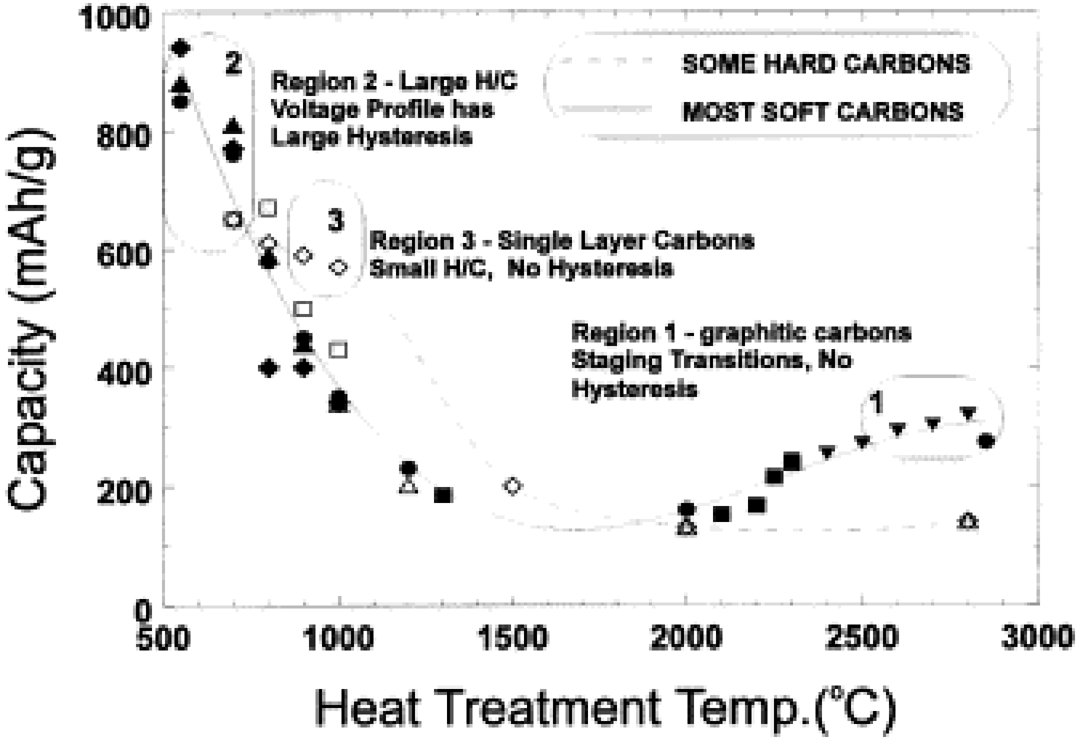
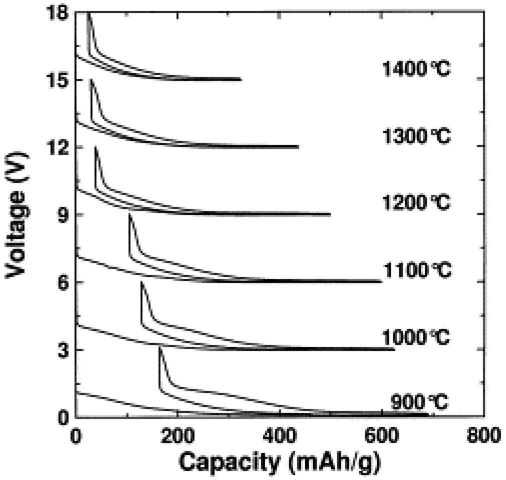


Fig. 1. Plot of reversible capacity for lithium vs heat treatment temperature for a variety of carbon samples (open symbols, hardcarbons; solid symbols, soft carbons). These data are for the second charge–discharge cycle of lithium–carbon test cells. The three regions of commercial relevance are shown. This graph has been taken from the work of Dahn et al.

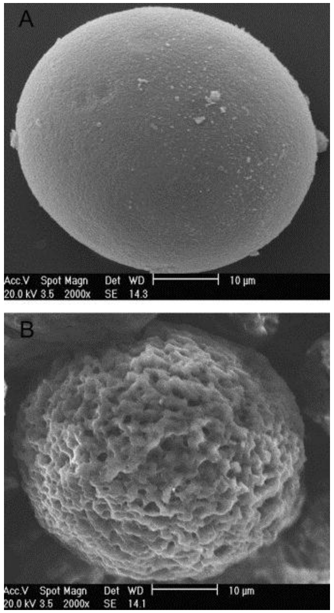


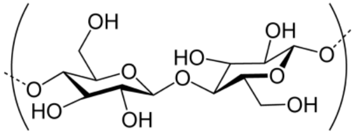
Voltage profiles of hard carbon prepared by pyrolysis of sucrose in argon gas. Heat treatment temperatures are indicated

SHARP LABS R&D EXAMPLES

Innovative Nanoporous Carbon Materials for Energy Storage Applications

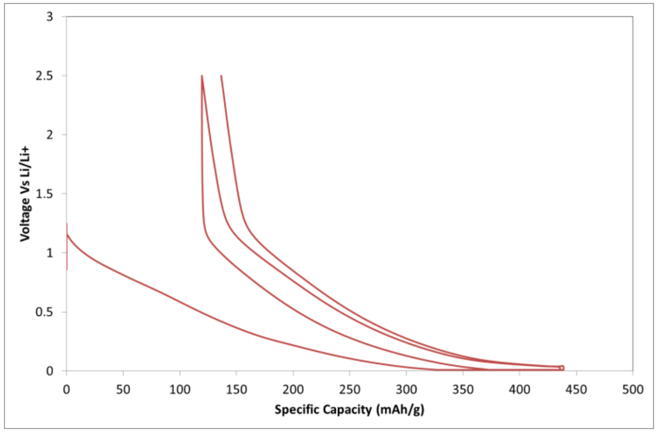
- Large Scale production of Carbon materials
- Renewable Low cost Precursors
- Controllable properties for Electrochemical energy applications

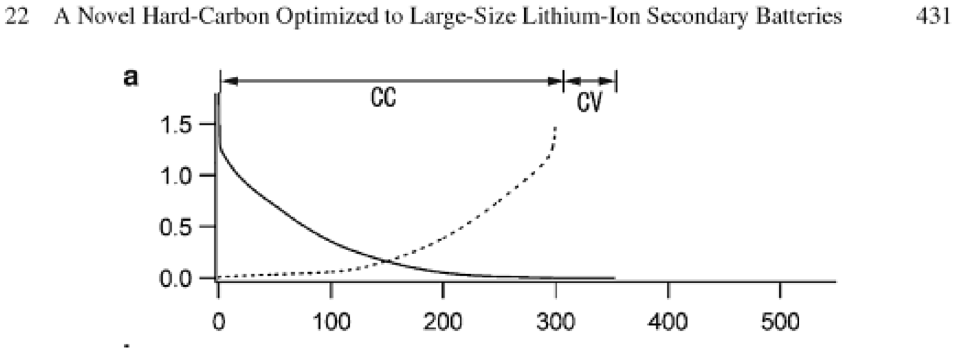




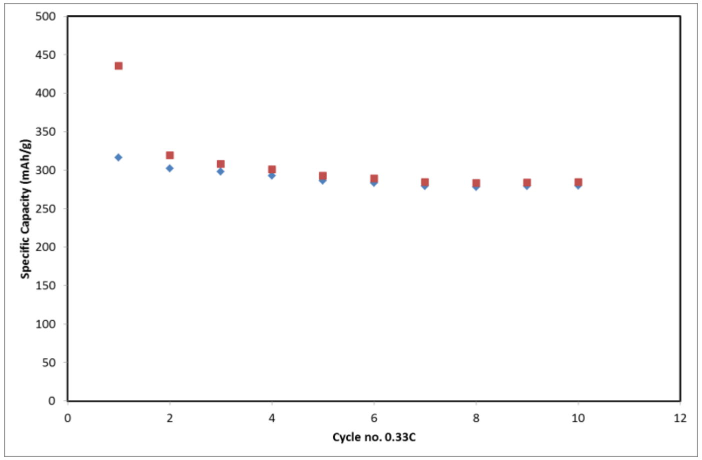
MAST Carbon will use their controlled carbonisation technology to convert the cellulose-based precursors to carbon materials for JM, Sharp and Axeon to evaluate.

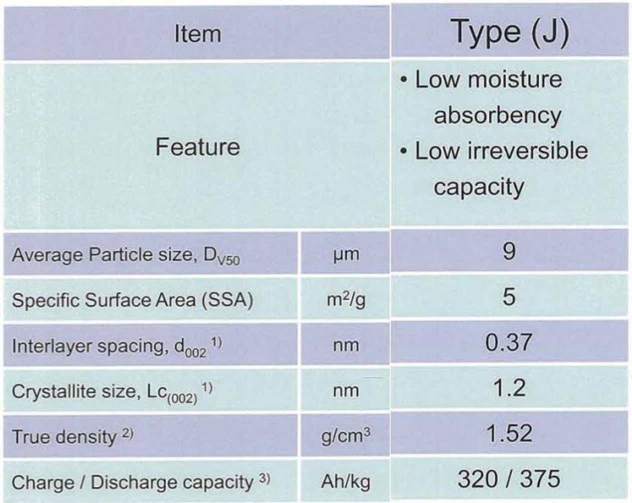
Carbon Anode – Commercial Material





22 A Novel Hard-Carbon Optimized to Large-Size Lithium-Ion Secondary Batteries 431

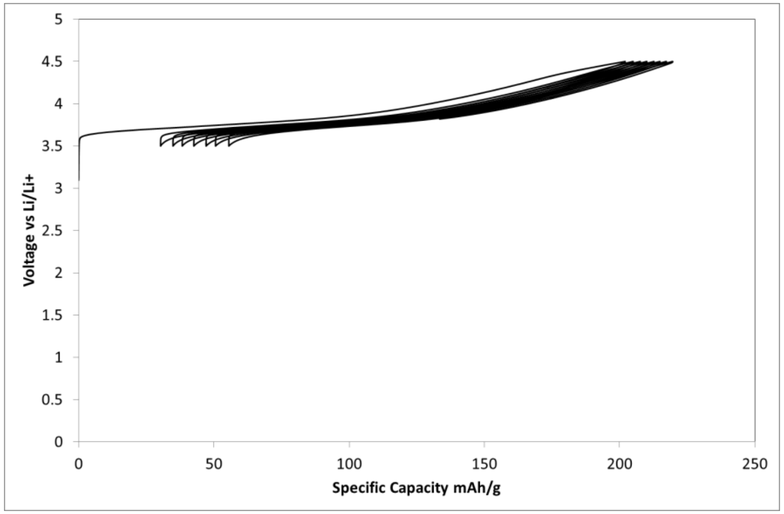


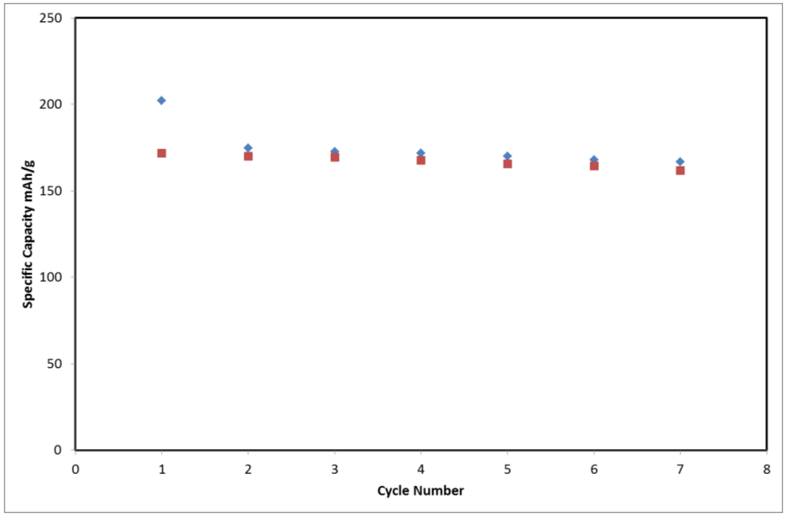


Item		Type (J)
Feature		• Low moisture absorbency • Low irreversible capacity
Average Particle size, D_{V50}	μm	9
Specific Surface Area (SSA)	m^2/g	5
Interlayer spacing, d_{002} 1)	nm	0.37
Crystallite size, $Lc_{(002)}$ 1)	nm	1.2
True density 2)	g/cm^3	1.52
Charge / Discharge capacity 3)	Ah/kg	320 / 375

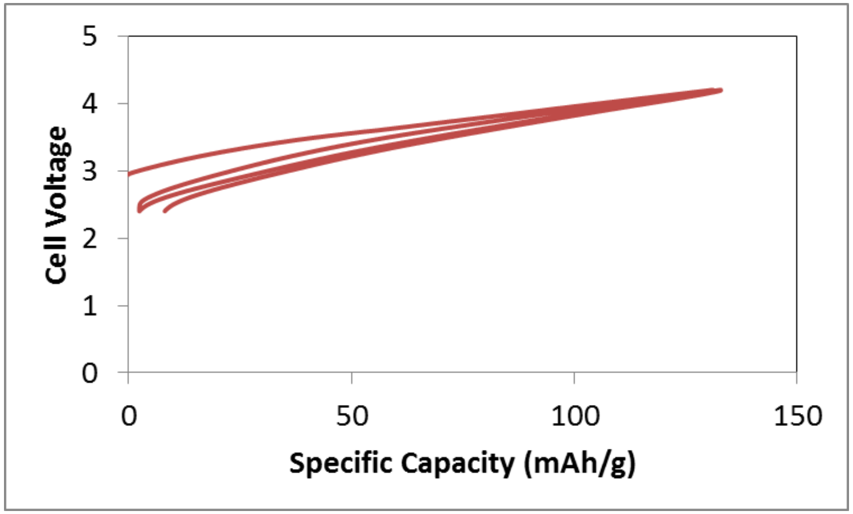
Commercial material base line

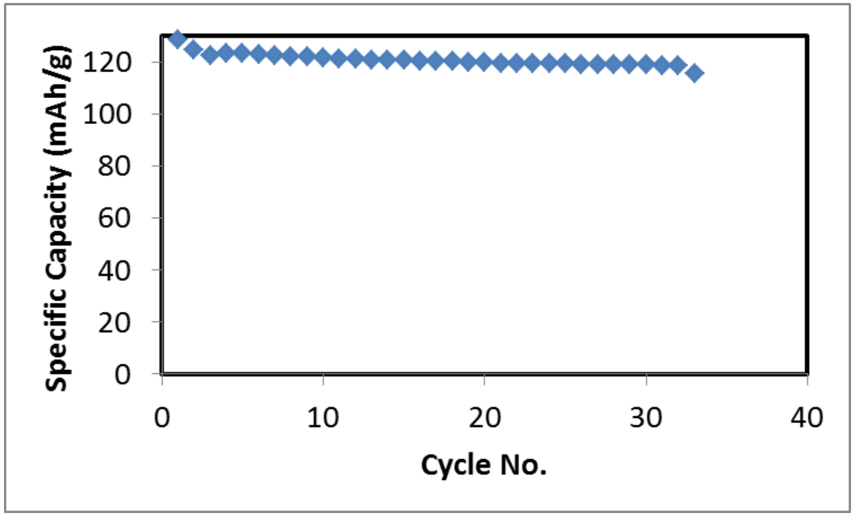
■Cathode





■Full Cell





LIB Replacement - Cost

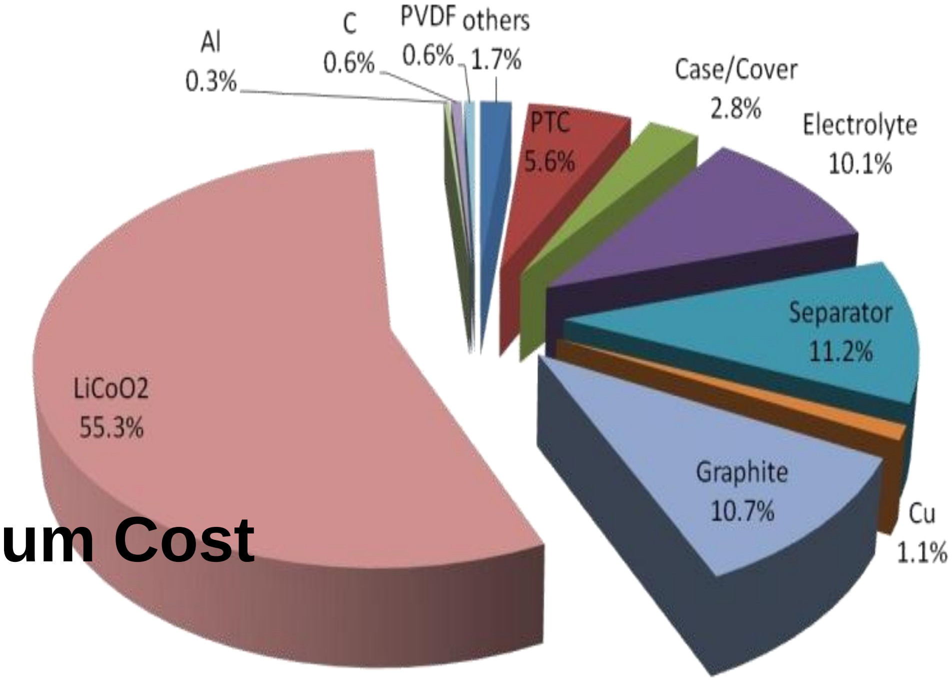
- **LiCoO$_2$ vs Graphite (battery chemistry)**

Replacement of Largest Cost Components of LIB with NIB alternatives

- Cathode (LiCoO$_2$)
- Anode (graphite)
- Electrolyte

Sodium Cost < Lithium Cost

Material cost analysis : 18650 (Standard cylindrical cell)



Takeshita Tutorial 2009 – Market Update on NiMH, Li Ion & Polymer Batteries

Co = $70/Kg - 2008

Lower Cost, Higher Energy Density, Drop-in Technology to existing LIB manufacturing lines

DECC : Low Cost Residential ES

Department of Energy & Climate Change

Advanced Energy Storage Solutions

Sodium ion Battery Development

NIB Full Cell Data

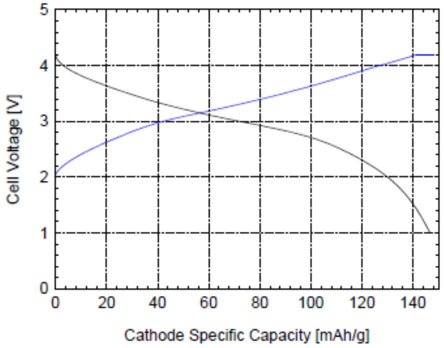


Figure 1: Cell Voltage Profile. Charge–discharge Behavior of a typical Hard Carbon//Layered Oxide Na-ion cell cycled between 4.2 and 1.0 V at a C/10 rate at 25°C.

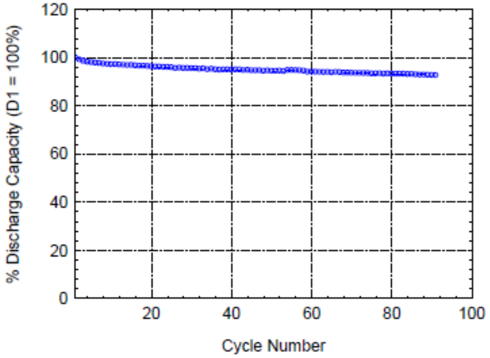
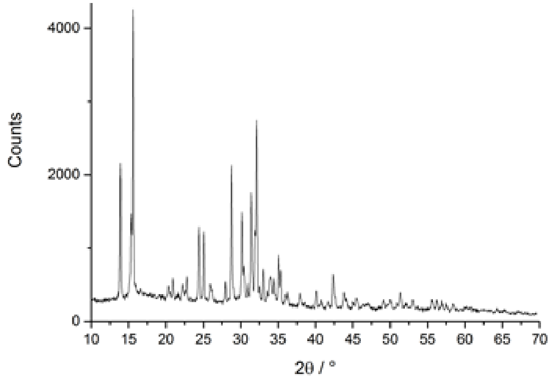
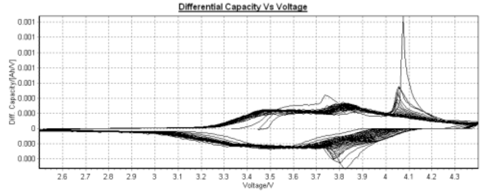


Figure 2: Cycle life profile of a typical Hard Carbon//Layered Oxide Na-ion cell cycled between 4.2 and 1.0 V at a C/10 rate at 25°C

Abstract #367, 224th ECS Meeting, © 2013 The Electrochemical Society

New Materials for Anode and Cathode



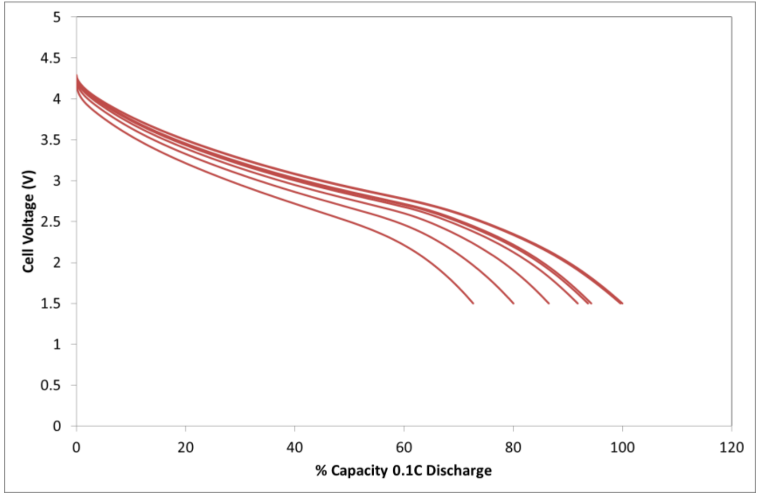


Na2Fe(SO4)2

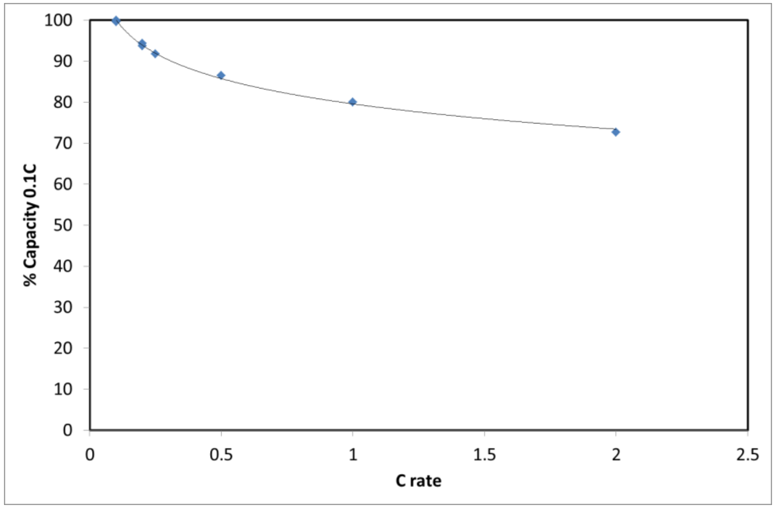
https://www.gov.uk/government/news/5-million-boost-for-energy-storage-innovation?utm_source=rss&utm_medium=rss&utm_campaign=press-release-5-million-boost-for-energy-storage-innovation

Electrode and Cell Optimisation

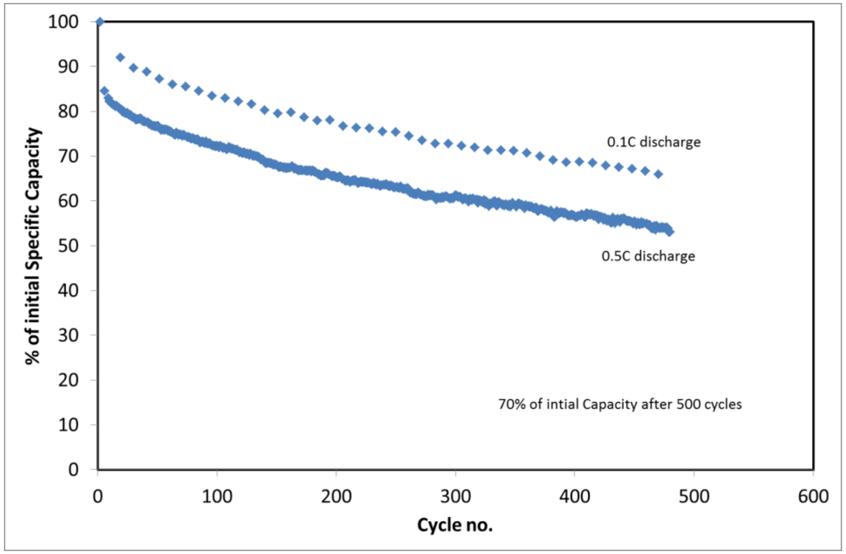
High Performance Full Cell LIB



- Cathode Electrode Optimisation
- Anode Electrode Optimisation
- Cell Construction
- Electrolyte type and Quantity
- Cell Balancing



Signature Curve



Cycling

Conclusions

- Energy Storage Markets
- Lithium ion battery manufacture
- Use of Carbon in Batteries
  - Conductive Additive
  - Active Materials
- SHARP Labs of Europe R&D

- Many types of carbon which offer different Benefits and Roles