Low Cost Sodium-ion Battery to Enable Grid Scale Energy Storage: Prussian Blue-Derived Cathode and Complete Battery Integration

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R&D Aim

- Develop a sodium-ion battery (NIB) that will dramatically increase battery cycle life at a low cost, while maintaining high-energy capacity. Successful battery development will exceed US Government Department of Energy (USDOE) 2015 cost targets for stationary energy storage and facilitate adoption and deployment of renewable energy.
- This SIB technology uses low-cost Prussian Blue (PB) as active cathode material. PB crystals have large interstitial spaces that allow easy intercalation of sodium ions.

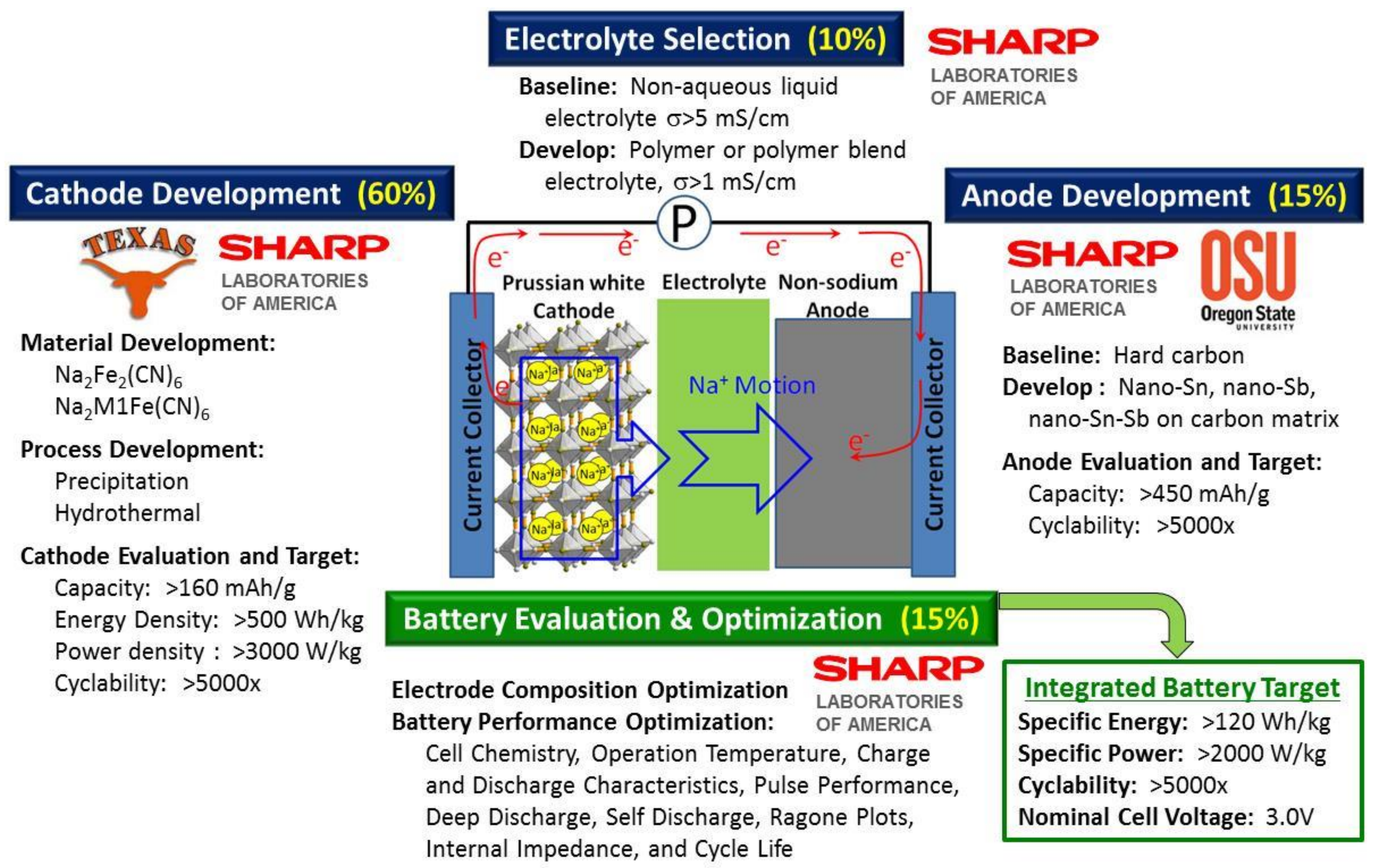
Target Products

Small System

Large System

Development Overview

Development Period: March 2013 to March 2016

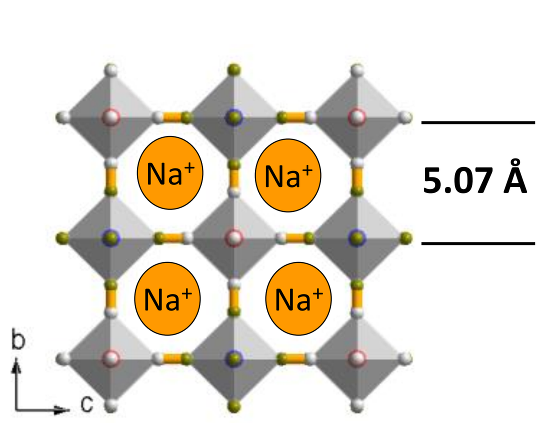


Prussian White and Low Cost Synthesis

Open Structure

Prussian Blue (PB):
$Na_2M1M2(CN)_6$

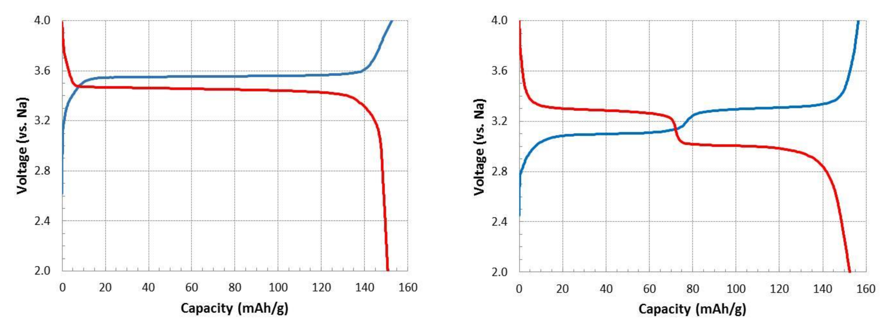
M1 and M2:
Fe, Ni, Mn, Cu, Ni, Co, Mg, Zn, Ca, Cr, Ti, V, etc.

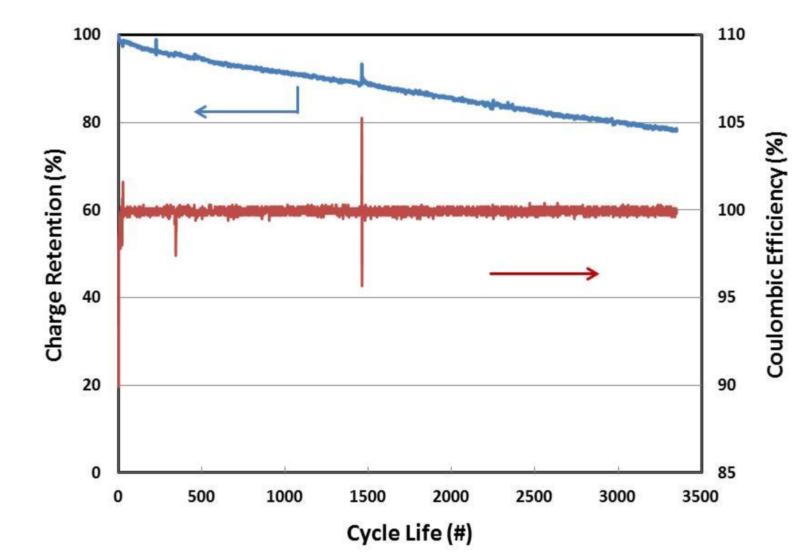


Low Cost Synthesis

Core Technology

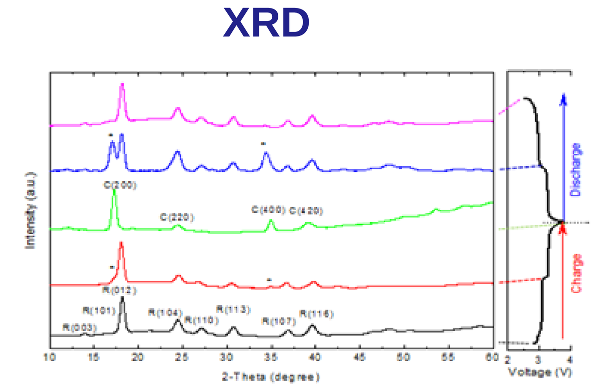
PB Cathode: High Capacity & Long Cycle Life



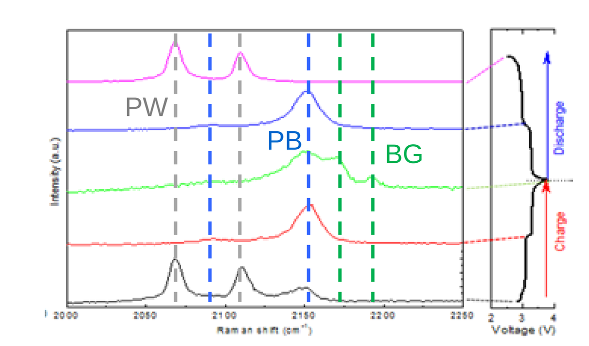


PB Cathode: Reversible Structure Change

XRD

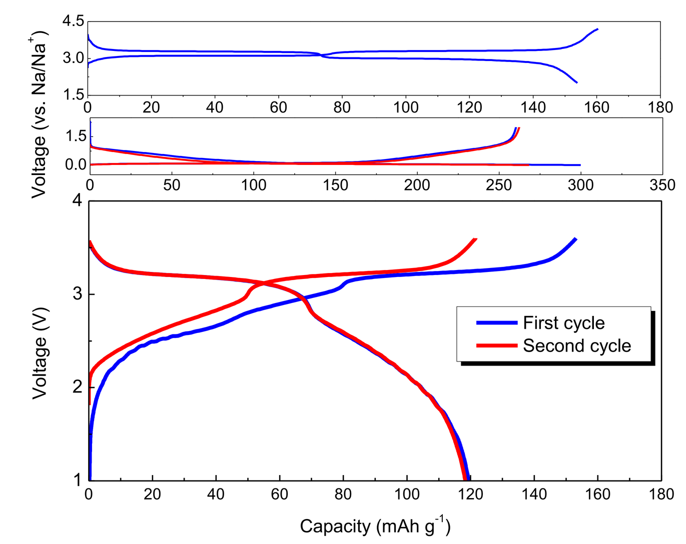


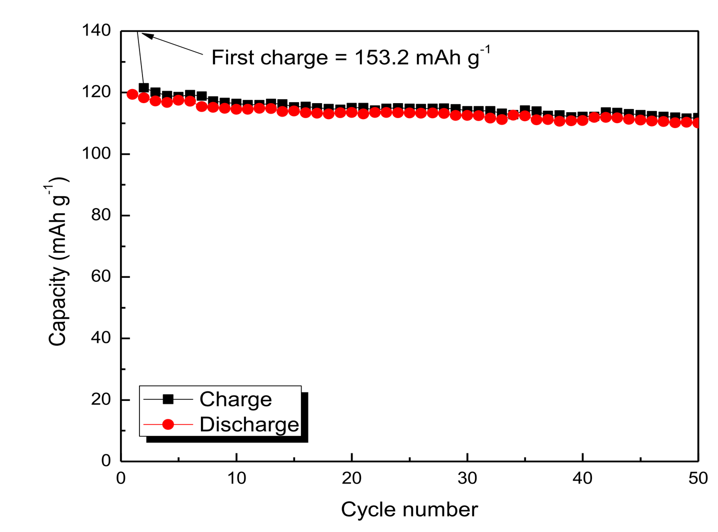
Raman

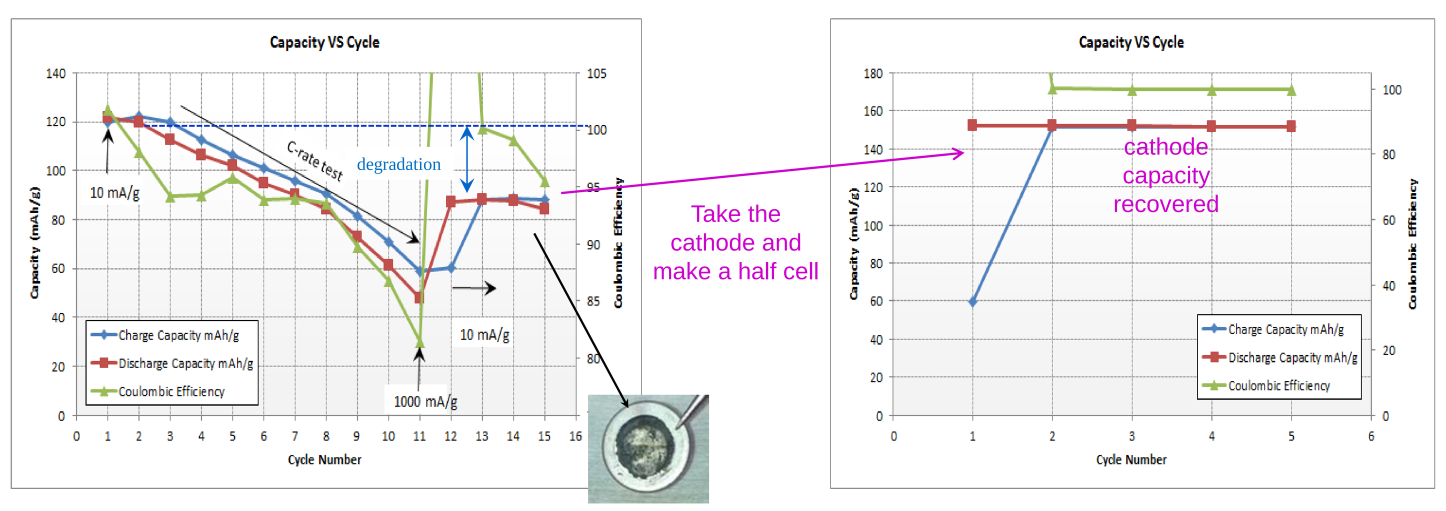


PW: $Na_2M1M2(CN)_6$
PB: $NaM1M2(CN)_6$
BG: $M1M2(CN)_6$

PB-HC Full Battery Analysis







Na plating at anode

Performance Comparison

	LiFePO$_4$ - Graphite		Prussian Blue Analogues (PBA) – Hard Carbon
Voltage (V)	~3.5V	≒	$Na_2MnFe(CN)_6$: ~ 3.43 V
Capacity	• 170 mAh/g (theatrical) • 160 mAh/g (actual)	≒	• 170 - 200 mAh/g (theoretical) • 150 mAh/g (actual, 0.1C) • 145 mAh/g (actual, 1C)
Material density	3.6 g/cm^3	>	1.9-2.3 g/cm^3
Cell energy density (Prismatic cell)	270 Wh/l	>	• 190 Wh/l (same electrode thickness as LFP) • 220 Wh/l (5 times thick electrode)
Material cost	20 US$/kg (High temperature (over 600 deg.) and inert atmosphere)	<	2.5-3.5 US$/kg (Room temperature and co-precipitate)
10 kWh Battery Pack	$3001 (1000 MWh annual production)	<	$2280 (based on Argonne National Lab: Modeling the Performance and Costof Lithium-Ion Batteries for Electric-Drive Vehicles)
Cycle life	80% ~ 90% after 1,000 cycle	≒	98% after 1200 cycle* (95% after 10,000 cycle, prospect)
High power density	95% (1.0C/0.1C)	<	87% (10C/1C) > 97% (1C/0.1C)
Safety	Hard oxygen generation	≒	No oxygen generation
Applications	• Stationary energy storage • Grid connected energy storage • Power source for home appliance • Plug-in electric vehicles (PEV)		• Grid connected energy storage (time-shift and frequency regulation) • Stationary energy storage • Plug-in hybrid electric vehicle (PHEV) or PEV for bus