EVS26
Los Angeles, California, May 6-9, 2012

Introduction to Dow Li-ion Battery Materials: Performance, Value Proposition, and Commercialization Status of the Dow Coated Anode and Coated Cathode Materials

Jamie L. Cohen[1], Mike Paquette, Tim Han, Dao Jin Hang[2], Guo Ji[2], Wayne Yao[2], Wanda Stringfield, Amber Wallace, Jia Liu, Andrew Horton

[1] Corresponding author, The Dow Chemical Company, Building 1702/Office 401C, Midland, MI 48674, jcohen@dow.com. [2]The Shanghai Dow Center, The Dow Chemical Company

Abstract

This talk will highlight The Dow Chemical Company's (Dow) lithium ion materials strategy and introduce Dow's capabilities. Two new coated products, a graphite-based anode and $LiNi_xMn_yCo_{1-x-y}O_2$-based cathode will be introduced that provide differentiated solutions for cycle life and safety improvement. Coated using a proprietary coating process, these materials, when combined, have been observed to provide cycle life improvements (up to >2x) over conventional uncoated systems in optimized cells without negatively impacting purity, physical properties, energy density and standard charge/discharge characteristics of core materials. The physical and electrochemical characteristics of these new materials will be presented and materials specifications will be discussed. 10 Ah full cell pouch cell Li-ion battery performance will be presented including charge/discharge rate capability, temperature performance, safety and cycle life performance. Commercialization of these materials will be underway early 2012. An update on commercialization status, including market development plant capacity, will be presented.

Keywords: lithium battery, cycle life, materials, safety

1 Introduction

The Dow Chemical Company (Dow) would like to introduce the Dow Energy Materials (DEM) business, the R&D program and the first two lithium ion battery electrode material product offerings from Dow. The lithium ion materials strategy of DEM and Dow's capabilities within this space will be highlighted. Two new products, a graphite-based anode and $LiNi_xMn_yCo_{1-x-y}O_2$-based cathode will be introduced and large-format cell data will be provided to support the value proposition of increased cycle life and enhanced safety of these coated Dow materials.

2 Results and Discussion

Dow Energy Materials (DEM) takes advantage of The Dow Chemical Company's material science, manufacturing, global marketing and R&D strengths to meet today's energy storage challenges. DEM offers an integrated portfolio of

Li-ion battery components to help cell manufacturers produce batteries with extended lifetimes, safer performance, and increased power and operational life. The DEM business has R&D capabilities in Midland, MI focusing on R&D-scale materials development, rapid materials synthesis scale-up using practical manufacturing methodologies, and materials-screening and optimization of Li-ion battery components in small-format batteries including button cells and small pouch cells. DEM business also has established an application development lab in Shanghai, China to produce large-format electrodes, batteries, and cell testing expertise to support customer needs.

The first two products presented by the DEM business are a coated graphite-based anode and coated $LiNi_xMn_yCo_{1-x-y}O_2$-based (NMC) cathode. Dow provides a differentiated solution for cycle life improvement by utilizing a proprietary coating process. Figure 1 and 2 provide SEM images of the coated cathode and coated anode materials made using this process. Figure 1
shows the coating material in red and the core material in green. In Figure 2, the coating material is observed as white and the core graphite is grey. This process produces a coated NMC cathode and coated graphite anode material that, when used in combination, provides improvements in cycle life (up to 2x) over conventional uncoated systems when placed in an optimized cell configuration. Dow is able to provide this enhancement in cycle life without negatively impacting the purity of the material, physical properties, excellent energy density and standard charge/discharge characteristics of the graphite electrode and NMC cathode materials.

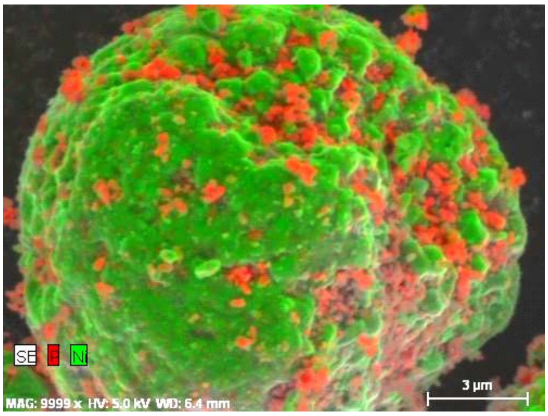

Figure1: SEM/EDS image of Dow coated NMC cathode product

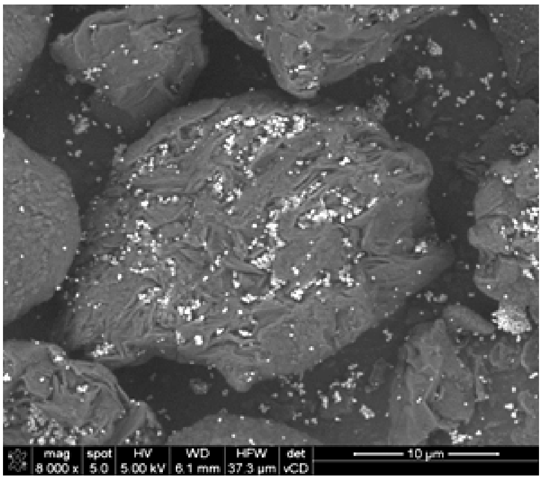

Figure2: SEM/BSE image of Dow coated graphite anode product

The physical properties and specification sheets for these materials will be reviewed. Tables 1 and 2 provide representative property data for the Dow coated cathode and Dow coated anode, respectively. Table 1 provides physical characteristics in parenthesis that are average values obtained from the scaled-up material produced in Dow's market development plant. The value proposition of the Dow anode and cathode materials are currently on test and demonstrated using 10 Ah cells. Data composed of both Dow coated anode and coated cathode, as well as systems composed of only one coated material are currently being obtained and include comparisons of charge rate, discharge rate, HPPC testing, discharge at temperature, cycle life at RT and 60°C and calendar life data. As an example of

Table 1: Dow Coated Cathode Material Representative Properties

Dow Coated Cathode Material Representative Properties	
Appearance	Black Powder
D_{10}	>1 µm (**5 µm**)
D_{50}	8-12 µm (**10 µm**)
D_{90}	< 40 µm (**16 µm**)
Surface Area	0.8 – 1.2 m^2 /g (**0.9 m^2/g**)
pH	10.5 – 11.5 (**11.1**)
Tap Density	2.2 – 2.4 g/cm^3 (**2.3 g/cm^3**)
Water Content	< 300 ppm (**230 ppm**)
First Charge Capacity @ 0.1C	> 175 mAh/g (**183 mAh/g**)
First Discharge Capacity @ 0.1C	> 155 mAh/g (**165 mAh/g**)
First cycle efficiency	> 87% (**89%**)

Table 2: Dow Coated Anode Material Representative Properties

Dow Coated Anode Material Representative Properties	
Appearance	Black Powder
D_{90}	>1 μm
D_{90}	20 - 25 μm
D_{90}	< 80 μm
Surface Area	2.2 – 4.4 m^2 /g
pH	8 - 9
Tap Density	1.2 – 1.4 g/cm^3
Water Content	< 400 ppm
First Lithiation Capacity @ 0.1C	> 360 mAh/g
First De-lithiation Capacity @ 0.1C	> 320 mAh/g
First cycle efficiency	> 87%

the data being collected, Figure 3 demonstrates elevated temperature cycle life data obtained using Dow coated cathode/bare anode compared to bare cathode/bare anode material. From these data, it can be observed that the coated cathode can impart improved 60^{o}C cycle life performance under the current Dow cell conditions. Overall, 10 Ah data will provide an understanding of the impact of a single coated cathode or coated anode material on overall battery performance, underlining that Dow coated anode and cathode materials can provide improved performance separately and when used together in a single cell. Choice safety testing will also be demonstrated for 2 Ah and 10 Ah cells. As an example of the 2 Ah cell testing, nail penetration results are provided in Figure 4. Cells that do not contain the Dow coated materials were tested alongside cells that contain Dow coated NMC cathode and Dow coated graphite anode. Both sets of cells are tested in exactly the same way and contain the same electrolytes, separators, and cell construction. It is clear that the Dow coated materials impart improved cell safety during the nail penetration testing.

3 Conclusions and Future Work

Overall, The Dow Chemical Company, through the Dow Energy Materials business, is rapidly building their cell testing capability to further demonstrate the value proposition of the newly commercialized coated graphite anode and coated NMC cathode materials. These capabilities will be leveraged across the Dow Energy Materials portfolio for next generation materials R&D, which will leverage Dow's materials science, analytical, and manufacturing expertise to rapidly scale and commercialize value-added Li-ion products for cell manufacturers, continuing to focus on improving lifetime, energy density, and safety.

The Dow Chemical Company is commercially producing both coated anode and coated cathode in a market development plant. The estimated

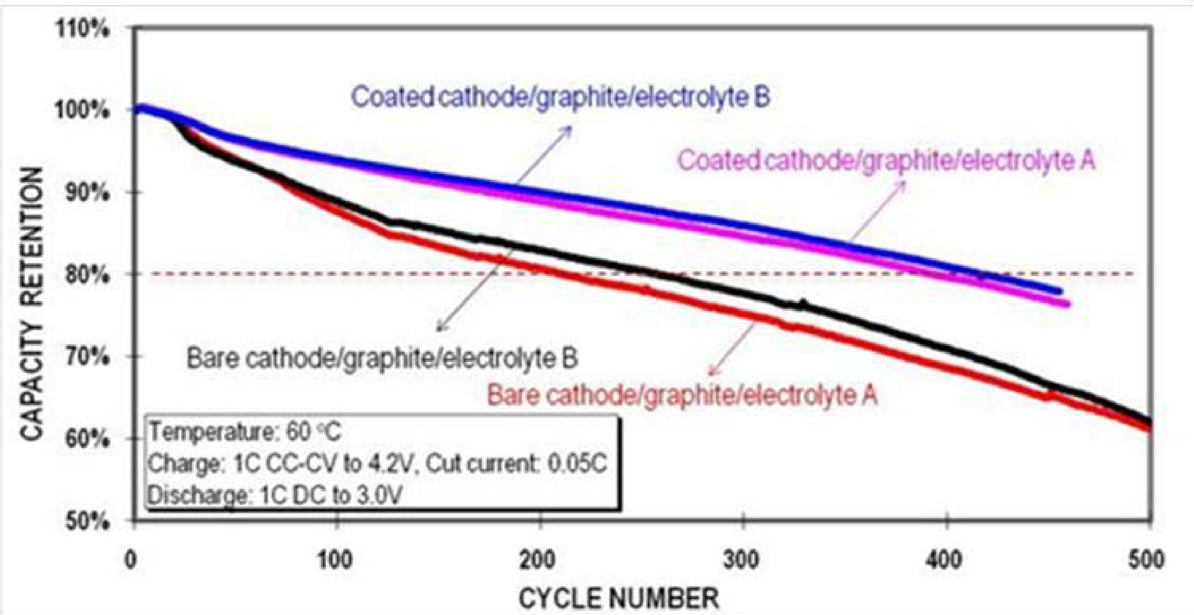

Figure 3: 60^{o}C cycle life data for bare cathode/bare anode 10 Ah cells compared to coated cathode/bare anode electrode materials and demonstrating improved cycle life for Dow coated NMC cathode material.

Nail Penetration	Test Condition	Sample 1	Sample 2	Sample 3
Coated (Dow's coated cathode/ coated anode), 2Ah pouch	Nail diameter: 3mm; Speed: 80mm/s; Completed penetration;	 pass	 pass	 pass
Bare (bare cathode/ bare anode), 2Ah pouch		 fail	 fail	 fail

Figure 4: Nail penetration results for 2 Ah cells containing Dow coated cathode/Dow coated anode materials compared to bare cathode/bare anode-containing cells demonstrating excellent performance of Dow coated materials.

capacity targets of the market development plant for coated cathode material is ~ 2 kta and the coated anode is ~ 1.5 kta per year, with manufacturing initially based in Midland, MI. Customer samples are currently available today.

Acknowledgments

The author would like to acknowledge Cliff Todd of the Dow Chemical Company Analytical Sciences Surface Microscopy Division for the SEM/EDS and BSE images provided in this paper.

Author

Jamie L. Cohen obtained a PhD in Electrochemistry from Cornell in Spring 2007 and began work at Dow Chemical in Summer 2007. She has worked for 4 of those years in Li-ion Battery research focusing on anode and cathode materials and some electrolyte activities. She is currently a project leader for Dow Coated Electrode Materials R&D