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Development of High Energy Cathode Materials

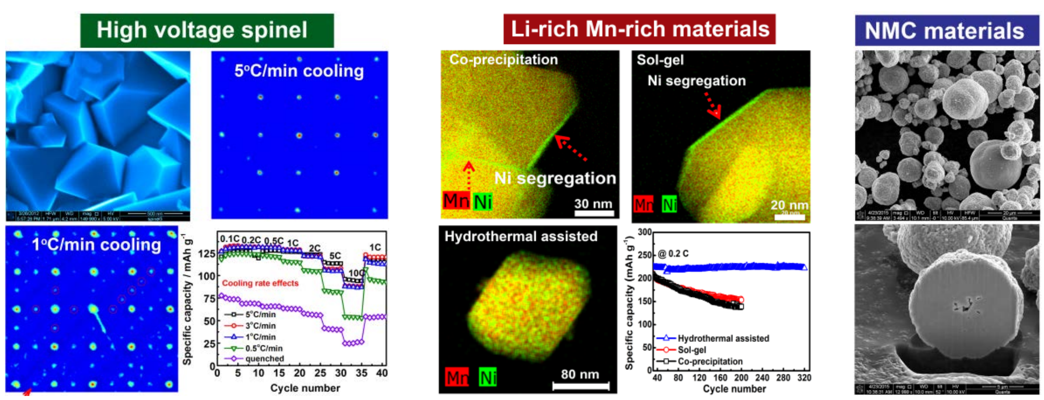
Introduction

Rechargeable lithium-ion batteries (LIBs) have become the dominant power sources not only for the consumer electronic devices but also for the pure electric vehicles (EVs) and plug-in electric vehicles (PHEVs) because of their high energy density, light weight and long cycle life. The increasing demands on minimizing global warming and environmental pollution have accelerated the development of EVs. With the state of the art LIBs used in automobile industry, the driving range of EVs is still far behind those of conventional vehicles using internal combustion engines. Therefore, there is an urgent need to further improve both energy density and power capability of LIBs, to improve the driving range and decrease the recharging time. To meet these requirements, significant effort has been devoted in the research of high energy density cathode materials.

Project Objective and Impact

The objective of this project is to develop low-cost, high-energy cathode materials with long cycle life. The success of this work will increase the energy density of LIBs and accelerate market acceptance of EVs, especially for PHEVs required by the EV Everywhere Grand Challenge proposed by DOE/EERE.

Key Achievements



- **High voltage spinel $LiM_xMn_{2-x}O_4$ (M = Ni, Co, Cr, Al, Mg)**
  Improve rate capability and cycling performance of high voltage spinel cathodes in both lithium half cells and in full cells by manipulating the Mn^{3+} concentration and site disorder.
- **Li-rich and Mn-rich (LMR) materials ($xLi_2MnO_3 \bullet (1-x)LiMO_2$ (M = Mn, Ni, Co)**
  Improve long-term cycling performance and mitigate voltage fade of LMR cathode materials through a variety of strategies, including electrolyte additives, controlled Ni segregation and surface coating/modifications.

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- **NMC materials ($LiNi_xMn_yCo_zO_2$ (x + y + z = 1))**
  (1) Achieve higher accessible capacities from traditional NMC cathodes by charging to moderately high cut-off voltages. (2) Synthesize NMC cathodes with higher Ni content to achieve higher energy density.

Contact: Dr. Ji-Guang Zhang, jiguang.zhang@pnnl.gov
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Selected Publications

1. ‘‘Structural and Chemical Evolution of Li- and Mn-rich Layered Cathode Material’’, Jianming Zheng, Pinghong Xu, Meng Gu, Jie Xiao, Nigel D. Browning, Pengfei Yan, Chongmin Wang, and Ji-Guang Zhang,Chemistry of Materials, 27(4), 1381–1390, 2015.
2. ‘‘Mitigating Voltage Fade in Cathode Materials by Improving the Atomic Level Uniformity of Elemental Distribution’’, Jianming Zheng, Meng Gu, Arda Genc, Jie Xiao, Pinghong Xu, Xilin Chen, Zihua Zhu, Wenbo Zhao, Lee Pullan, Chongmin Wang and Ji-Guang Zhang, Nano Letters, 14 (5), 2628–2635, 2014.
3. ‘‘Functioning Mechanism of AlF_3 coating on the Li- and Mn-rich cathode materials’’, Jianming Zheng, Meng Gu, Jie Xiao, Bryant J. Polzin, Pengfei Yan, Xilin Chen, Chongmin Wang, and Ji-Guang Zhang, Chemistry of Materials, 26 (22), 6320–6327, 2014.
4. ‘‘Corrosion/Fragmentation of Layered Composite Cathode and Related Capacity/Voltage Fading during Cycling Process’’, Jianming Zheng, Meng Gu, Jie Xiao, Pengjian Zuo, Chongmin Wang, Ji-Guang Zhang, Nano Letters, 13(8), 3824–3830, 2013.
5. ‘‘High-Performance $LiNi_{0.5}Mn_{1.5}O_4$ Spinel Controlled by Mn^{3+} Concentration and Site Disorder’’, J. Xiao, X. Chen, P.V. Sushko, M.L. Sushko, L. Kovarik, J. Feng, Z. Deng, J. M. Zheng, G.L. Graff, Z. Nie, D. Choi, J. Liu, J.-G. Zhang, M.S. Whittingham, Advanced Materials, 24, 2109–2116, 2012.