Overcharge Protection for High Voltage Lithium Batteries

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Lithium batteries are prone to energetic venting, ignition, and even explosion following severe overcharging [1]. A reliable overcharge protection mechanism is, therefore, an indispensable requirement for large cell assemblies. Ideally, this would be achieved with a minimum of added weight, volume, and cost. We have shown [2,3] that electroactive polymers whose conductivity depends upon their state of charge can provide overcharge protection in lithium batteries by means of a reversible, self-actuating, low resistance internal shunt that allows overcharge currents to pass harmlessly through a cell while maintaining its discharge capacity (Fig. 1). In a high voltage cell stack, this would allow the rest of the cells to continue to charge normally.

The feasibility of this approach was first demonstrated in low-voltage Li-TiS_2 cells using a poly(3-butylthiophene)-coated separator that shorted the cells at around 3.2 V. Increases in the shorting potential, achieved by the use of other polymers and by combinations of two or more polymer layers, enabled protection in $LiFePO_4$ cells, which are charged at 3.6 V [4]. We have now developed polymer systems that operate above 4.0 V (Fig. 2) and can be used to protect cells containing $LiCoO_2$, $LiMn_2O_4$, and substituted Ni oxides such as $LiNi_{1-x-y}Co_xAl_yO_2$.

Details of the polymers used, the coating of separators to maintain porosity, and their performance as overcharge protection agents will be presented. Design issues, including loading and distribution of the polymers, overall cell configuration, and temperature effects will also be discussed.

1. K. M. Abraham and S. B. Brummer, in *Lithium Batteries*, J. P. Gabano, Editor, Academic Press, New York (1983).
2. G. Chen and T. J. Richardson, *Electrochem. Solid State Lett.*, **7**, 23 (2004).
3. G. Chen, K. E. Thomas-Alyea, J. Newman and T. J. Richardson, *J. Electrochem. Soc.*, **151**, A509 (2004).
4. G. Chen and T. J. Richardson, 205th Meeting of the Electrochemical Society, San Antonio, TX, May 10, 2004.

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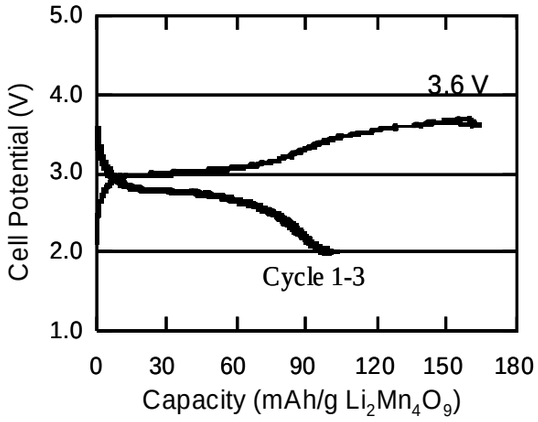

Fig. 1. Constant current charge/discharge curves for $Li_2Mn_4O_9$-Li cell protected by composite separator.

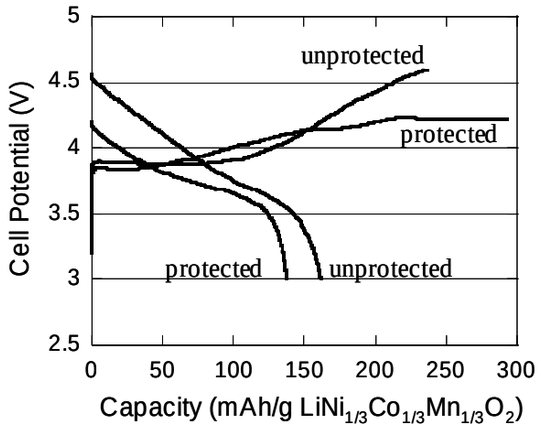

Fig. 2. Constant current charge/discharge curves for protected and unprotected $LiNi_{1/3}Co_{1/3}Mn_{1/3}O_9$-Li cells.