A Novel Intrinsically Porous Separator for Self-Standing Lithium-Ion Batteries

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Lithium-ion rechargeable batteries with $LiCoO_2$ cathodes and carbon anodes are rapidly replacing other battery systems due to their high energy and power densities. Energy densities of about 120-130 Wh kg^{-1} are now available in cell using metal cans, with higher values of 160-170 Wh kg^{-1} estimated for cells with light weight packaging [1]. The concept suggested by Bellcore [2] to construct a light weight battery is based on the preparation of a free-standing battery stack that needs no external pressure to maintain contact between the electrodes. The electrodes and separator in the Bellcore system contain a platicizer that can be extracted after lamination, leaving a porous structure which is subsequently activated by filling the cell with a liquid electrolyte. Recently, PEO based composite polymer electrolyte prepared using nano-scale ceramic fillers such as SiO_2, Al_2O_3, TiO_2 and MgO [3-5] have shown enhanced ionic conductivities and improved mechanical and thermal stability over electrolyte without oxides. The effect of inorganic oxides such as SiO_2 [6], Al_2O_3 [7], CeO_2 [8] and TiO_2 [9] on the electrochemical properties of plasticized polymer electrolytes have also been studied. It has been shown that ceramic fillers greatly influence the characteristics and properties of polymer electrolytes by enhancing their mechanical stability and conductivity. Furthermore, the strong interaction of liquid electrolyte with these particles may help in holding the liquid component within the membrane structure.

In this presentation we will describe our results concerning the construction of self-standing plastic lithium-ion batteries based on the intrinsically porous separator concept [10]. γ–$LiAlO_2$, Al_2O_3 and MgO were used as fillers in a PVdF-HFP polymer matrix to form self-standing, intrinsically porous separators in which the inorganic oxide to PVdF-HFP ratio was 70:30.

The separators as well as the electrodes were produced by Ferrania. The separators were found to be intrinsically porous and able to swell with added liquid electrolyte. A specific conductivity of about 4 x 10^{-4} S cm^{-1} was determined for a MgO-based separator with a liquid electrolyte weight fraction of about 40%. The electrochemical compatibility of the separators was tested by cycling half-cells produced by hot-lamination of the separators with PVdF-HFP-based electrodes. The separators can be hot laminated with the electrodes without losing their capacity to swell with liquid electrolyte. Half-cells, filled with the liquid electrolyte, were tested versus a lithium electrode. We found that some fillers are not compatible with the electrodes; the separators based on MgO and γ–$LiAlO_2$ possessed good anode stability while separators based on MgO, $LiMn_2O_4$ and Al_2O_3 showed good stability with the cathode. The MgO-based separator showed the best anode and cathode compatibilities and was selected for the lithium-ion battery cells. Lithium-ion battery cells were assembled, hot laminated and activated by soaking in liquid electrolyte. Battery performance was then evaluated as a function of the discharge rate and cycle number. Prototype batteries showed reversible lithium cycling with good capacity retention. The charge/discharge ratio after a few cycles was 0.988. The battery performance was evaluated during discharge the cells at different rates. The energy density calculated at a C/4 rate was about 100 Wh kg^{-1} while the power density calculated at a 3C rate was higher than 280 W kg^{-1} (both of the values are based on the total battery weight without the current collectors weight). Improvements are expected in terms of a better cathode/anode capacity ratio and electrode porosity reduction.

In the presentation, the electrochemical characterization of the separator as well as the performance of optimized lithium-ion batteries will be reported.

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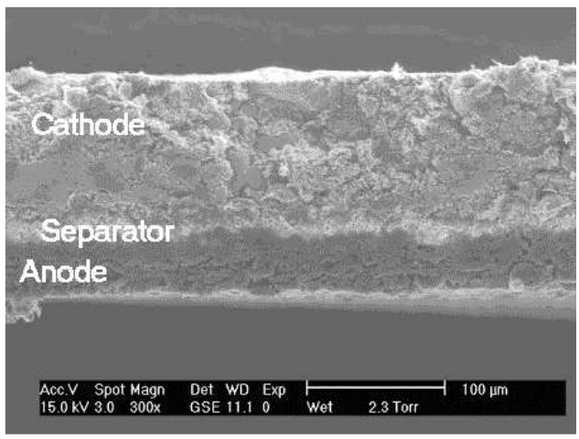

Figure 1. SEM micrograph cross-section of a anode/MgO-based separator/cathode hot laminated cell.