Factors to Consider in the Design and Applications of High Power Lithium Ion (Li-Ion) Batteries

High Power Li-ion batteries capable of being fully discharged and charged in several seconds to a few minutes are needed for hybrid electric vehicles, directed energy weapons, power tools and many other high power applications. The selection of appropriate electrode and electrolytes materials and porous separator, and the design of optimum electrodes, current collectors, cell stacks and battery packs with low resistances and polarization losses in order to sustain the very high current drains are key to the successful development of such batteries.

The power, P, of a Li-ion cell is given by $P=V^2/R$, where V is the cell's load voltage and R is its internal resistance, high voltage cells with low internal resistances are the most desirable for high power batteries. In additional to the polarization losses associated with the resistances of the various cell components, mass transport in the solid electrode lattice and in the electrolyte solution/separator phase have to be understood and optimized to obtain the highest continuous power output from the cell. A pragmatic methodology to design such batteries is needed. It can be shown that an electrode material with a relatively high solid-state Li diffusion coefficient of the order of 10^{-10} cm^2/sec (e.g., $LiCoO_2$ and $Li_2Mn_2O_4$) can be fully discharged in 100 seconds using about one micron size particles. On the other hand, if the diffusion coefficient of the electrode material is a much lower 10^{-14} cm^2 /sec, (e.g., $LiFePO_4$) approximately ten nanometer size particles are needed to achieve full discharge in the same time period. The use of very small electrode particles having the latter dimensions may introduce potential issues such as difficulty to fabricate low impedance electrodes, enhanced electrode surface reactions with the electrolyte leading to the loss of active material and increases internal resistances, and penetration of particles through the separator pores to cause high rates of self-discharge. An awareness of the latter problem is especially important as separator porosity and electrolyte conductivity show a direct relationship to the discharge rate capability of high power Li-ion cells (1). Rationally selecting both active and inactive materials and incorporating them in optimally designed electrodes, and building cell stacks with minimal internal resistances and optimal ion transport profiles to produce high power Li- ion batteries are key to the development of high power Li-ion batteries (1-3).

Small high power Li-ion cells with $LiMn_2O_4$, $LiFePO_4$ and LiMn-Ni-oxide cathode materials are commercially available. Interestingly, high power Li-ion batteries are not fabricated with $LiCoO_2$. What is the reason?

References:

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