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Recent Developments in Thin-Film Lithium and Lithium-Ion Batteries

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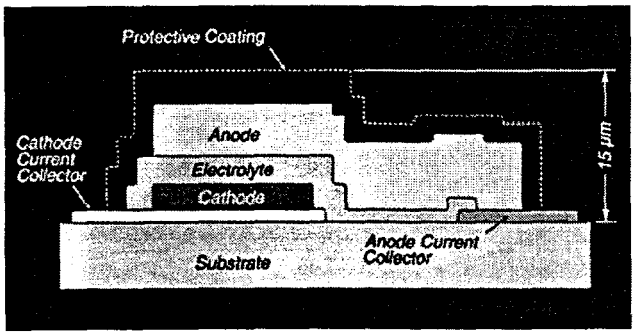
Outline

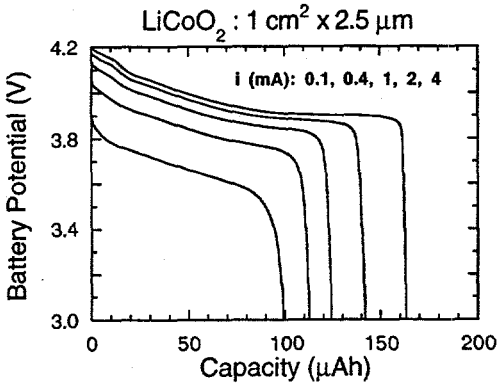
- Processing, materials, and performance
  - High rate deposition and annealing
  - Metal foil substrates
  - Tin and zinc nitride anodes
  - Lithium plating ("lithium free" lithium cells)
- Manufacturing and applications
- Challenges and future work

Thin-Film Battery Construction

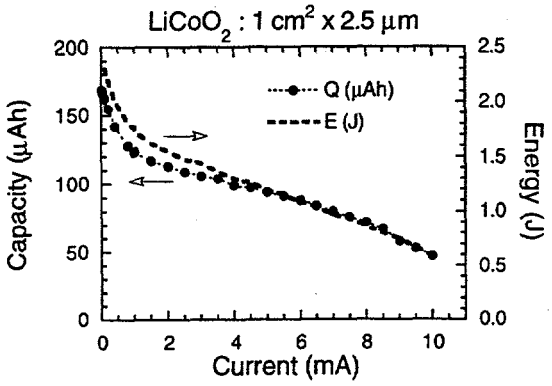


A thin-film battery is fabricated on a substrate that can be a ceramic, metal, semiconductor, or, depending on subsequent film processing, a plastic. The current collectors are deposited first followed by the cathode, electrolyte, and anode films. Finally the battery is covered with a thin protective coating. Except for lithium metal anodes which are deposited by evaporation, the metal current collector and inorganic films are deposited by sputtering.

Batteries Fabricated at High Rates



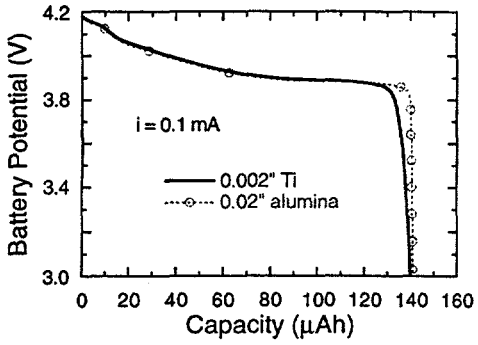
Discharge curves at 25°C of a Li-$LiCoO_2$ cell with the Lipon electrolyte and polycrystalline textured cathode films deposited at 70 A/min.



Capacity and energy of a Li-$LiCoO_2$ battery vs. discharge current. Cathode and electrolyte films deposited at 70 A/min.

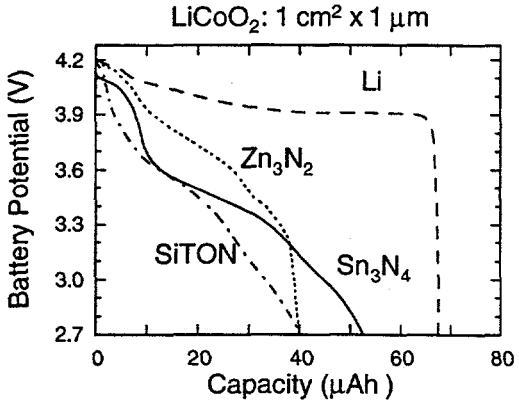
Metal Foil Substrates

- > Thinner batteries: reduced inactive volume and mass
- > Flexible batteries



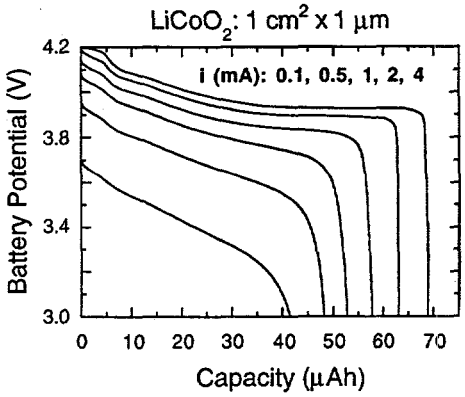
Discharge curves of Li-$LiCoO_2$ cells on Ti and alumina substrates. Cathodes 1 cm^2 x ~ 2 μm thick. A battery on 1 mil Ti could be rolled in to a 1" cylinder and flexed repeatedly.

Lithium-Ion Batteries

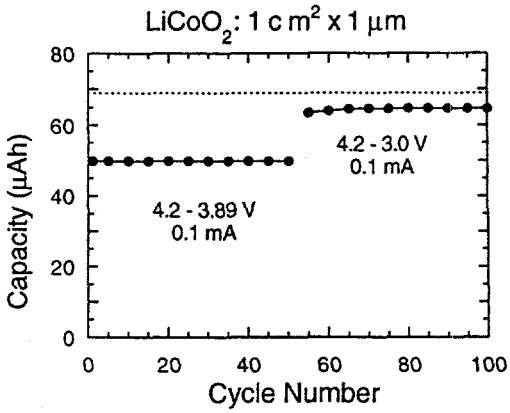


Comparison of discharge curves for cells with $LiCoO_2$ cathodes and SiTON, Sn_3N_4, Zn_3N_2, and lithium anodes.

"Lithium Free" Lithium Batteries



Discharge curves for a "lithium free" lithium battery. The anode was formed in-situ by plating lithium between the electrolyte and a metal film on the charge cycles.

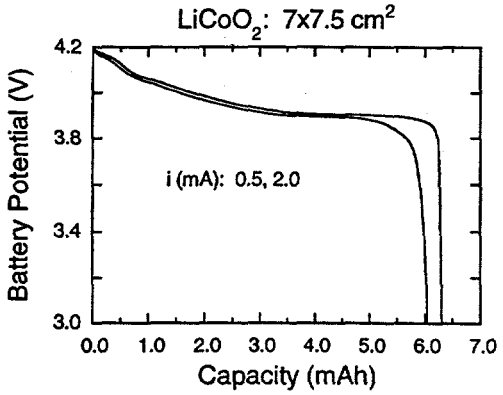


Discharge capacity vs. cycle number for a "lithium free" lithium battery. For cycles 1 to 50, the lower cutoff voltage was set above the potential for complete stripping of lithium. For cycles 51 - 100, complete stripping of lithium occurred at the lower cutoff potential. The dashed line indicates the theoretical maximum capacity for reversible cycling of 0.5 Li per CoO_2.

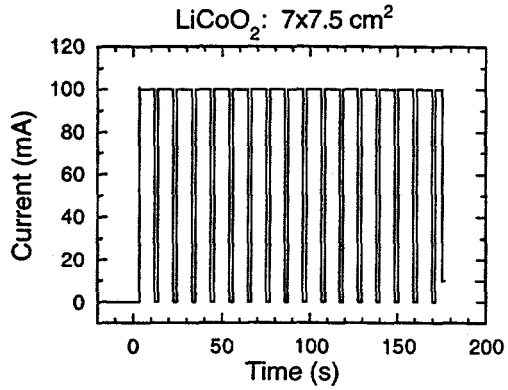
Manufacturing and Applications

> Large area industrial batch deposition: film quality equivalent to ORNL's

> Scaling demonstrated through performance of large area cells connected in parallel.



Discharge of a Li-$LiCoO_2$ battery consisting of a parallel connection of seven cells of 7.5 cm^2 active area each. The average cathode thickness was 1.7 μm.



Pulse discharge of a Li-$LiCoO_2$ battery consisting of seven 7.5 cm^2 cells connected in parallel.

Pulse: 100 mA, 8.5 s; repeat every 2s

Average energy/pulse: 3 J

Challenges and Future Work

> Improve yield of batteries on metal foils: electrical isolation of anode current collector from substrate

> Lower manufacturing costs: increase deposition and processing rates of electrolyte and cathode films

Acknowledgements

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