Development of Advanced Materials for Li-ion Cells

Julia Weaving

(AEA, England)

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Accentus plc

a Wholly owned subsidiary of AEA Technology plc

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AEA TECHNOLOGY BATTERIES

Introducing Accentus

At Accentus, we develop Intellectual Property and technology, which we license to manufacturers

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AEA TECHNOLOGY BATTERIES

Overview

- Advanced polymer technology
  - development of porous polymer films
- Strategies for higher energy density Li-ion cell designs
  - introduce higher capacity (mA h g^{-1}) cathode material - $LiNi_{1-x-y}Co_xAl_yO_2$
  - cell packaging/design
- Optimisation of electrolyte
  - increased efficiency with existing materials
  - improved overcharge characteristics

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Advanced Polymer Technology

- Accentus's polymer technology is not the same as the Bellcore technology

- Accentus's polymer technology includes:
  - homopolymers
  - copolymers
  - terpolymers
  - grafted polymers

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Advanced Polymer Technology

- Development of porous polymer films
  - as separator materials
- Development of polymer-based bonding technology
- New polymers in cathode and anode
  - improved overcharge performance

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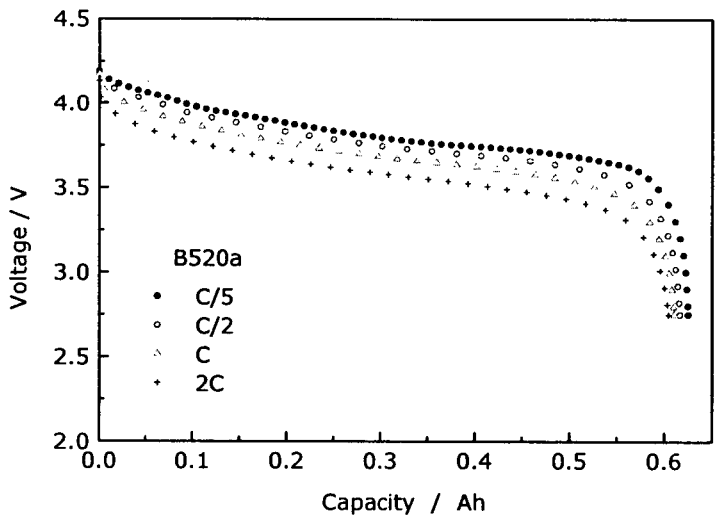
AEA TECHNOLOGY BATTERIES

Graphite - $LiCoO_2$ Rate Performance

- Porous polymer separator and EMC-based electrolyte
  - achieved 96.6% of 0.2 capacity at 2C



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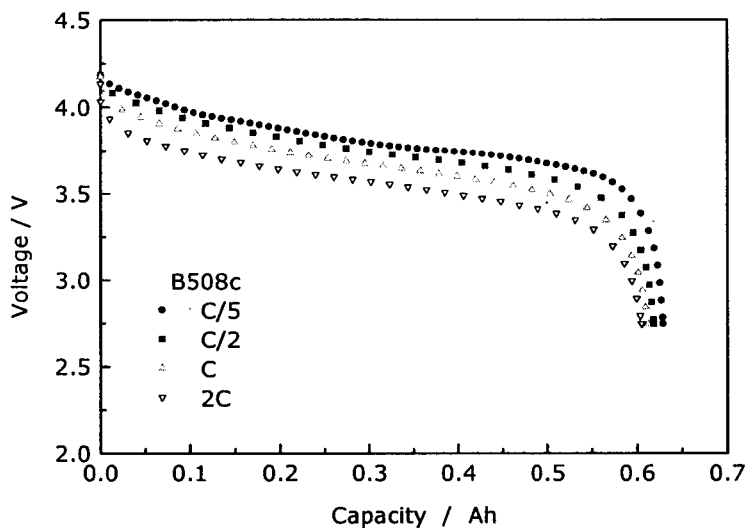
AEA TECHNOLOGY BATTERIES

Graphite - $LiCoO_2$ Rate Performance

- PE separator and EMC-based electrolyte
  - achieved 96.2% of 0.2 capacity at 2C



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High Capacity Cathode Material $LiNi_{1-x-y}Co_xAl_yO_2$

- Key characteristics of $LiNi_{1-x-y}Co_xAl_yO_2$
  - x ~0.15
  - high reversible capacity: 184 mA h g^{-1} to 4.2 V
    - ~ 30% higher than $LiCoO_2$
    - allows charging to 4.2 V (4 V for $LiNiO_2$)
  - improved cycling behaviour at high capacity compared with $LiNiO_2$ material
  - role of Al to increase chemical and cycle life stability compared to $LiNi_{1-x}Co_xO_2$
  - safety OK in 600 mA h class cell

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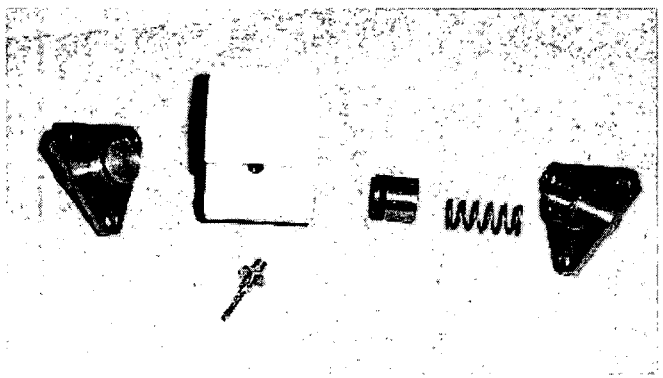
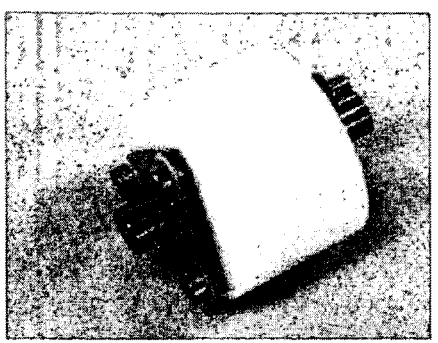
$LiNi_{1-x-y}Co_xAl_yO_2$ Electrochemical Characterisation

- Three terminal cell
  - RE: lithium metal
  - CE: lithium metal
  - WE: 12.46 mm diameter disc of -ve or +ve electrode
  - glass felt separator
  - 100 μl electrolyte
- Spring mounted assembly





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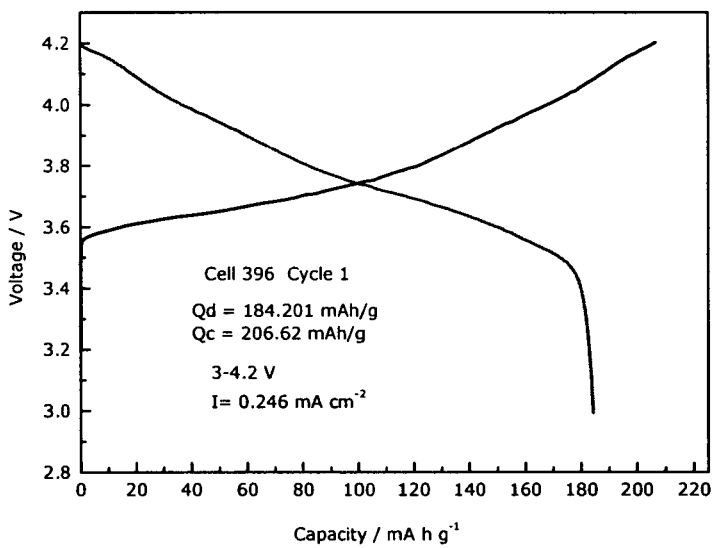
$LiNi_{1-x-y}Co_xAl_yO_2$ Electrochemical Evaluation

- Electrochemical evaluation
  - 3.0 - 4.2 V, I=0.246 mA cm^{-2}



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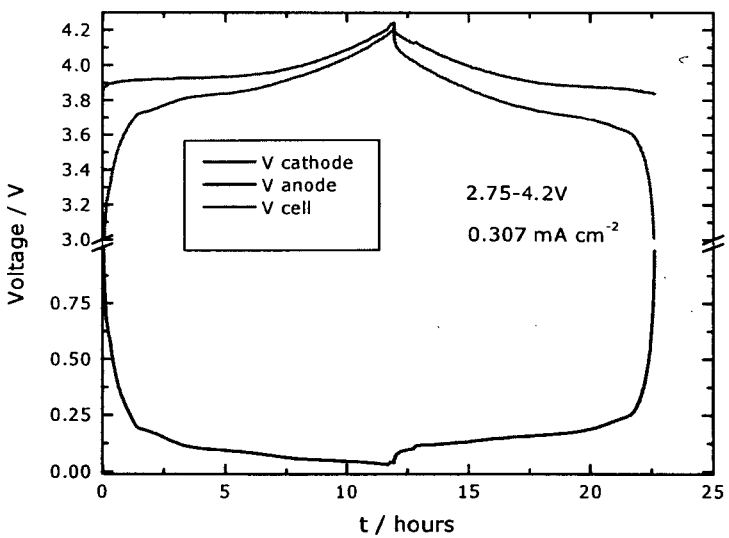
Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ Cell Balancing Experiments

- Voltage characteristics with graphite anode
  - 3 terminal cell



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Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ Cell Performance

- Stable cycle performance demonstrated
  - EMC-based electrolyte
  - % retained capacity 0.2C rate
    - 87% @ 500 cycles & 82% @ 1000 cycles
  - % retained capacity C rate
    - 85% @ 500 cycles & 77% @ 1000 cycles
- Rate performance
  - achieved ~92% at 2C
- Safety - Passed C rate overcharge
  - no fire/no explosion

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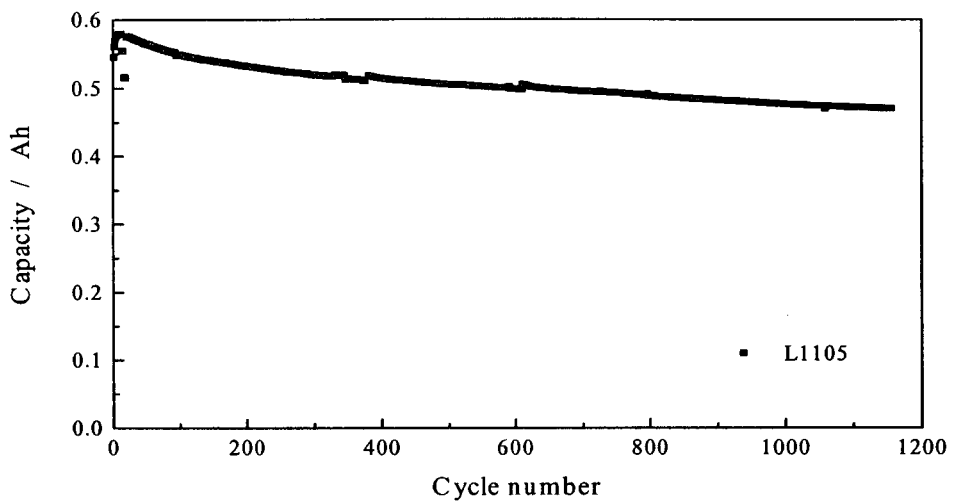
AEA TECHNOLOGY BATTERIES

Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ C/5 Rate Cycle Performance

- 600 mA h, standard PE separator
  - 87% @ 500 cycles & 82% @ 1000 cycles



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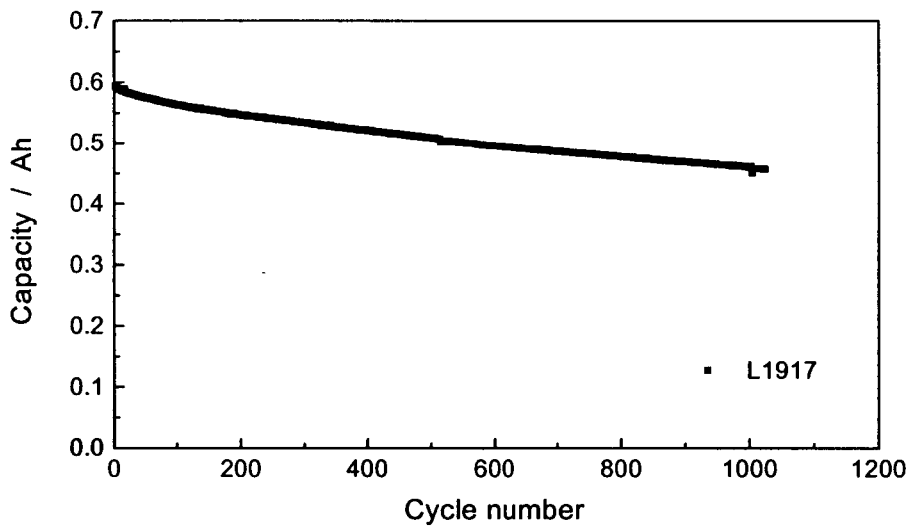
AEA TECHNOLOGY BATTERIES

Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ C Rate Cycle Performance

- 600 mA h, porous polymer separator
  - 85% @ 500 cycles & 77% @ 1000 cycles



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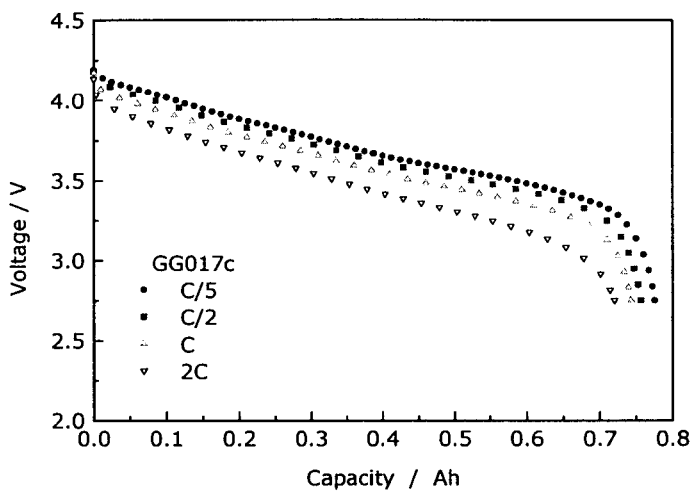
AEA TECHNOLOGY BATTERIES

Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ Rate Performance

- Standard PE separator and EMC-based electrolyte
  - achieved 92.8% of 0.2 capacity at 2C



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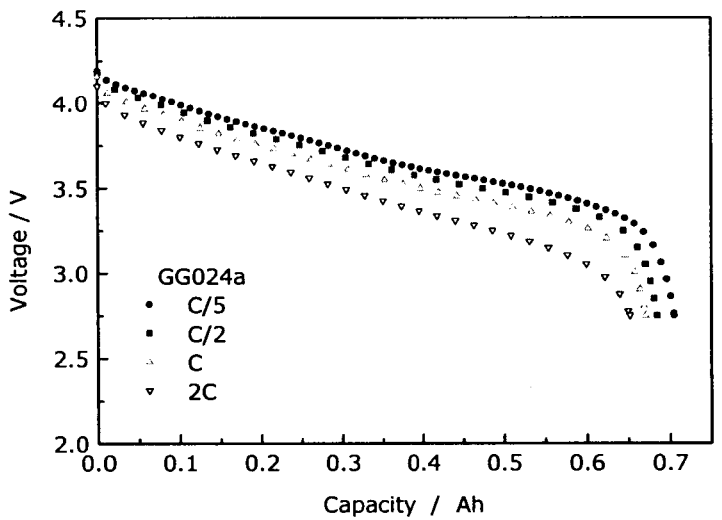
AEA TECHNOLOGY BATTERIES

Graphite - $LiNi_{1-x-y}Co_xAl_yO_2$ Rate Performance

- Porous polymer separator and EMC-based electrolyte
  - achieved 92.4% of 0.2 capacity at 2C



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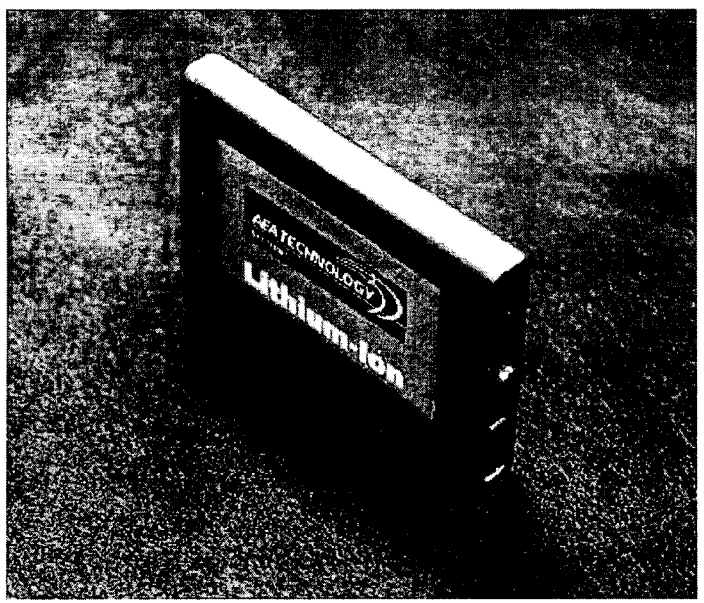
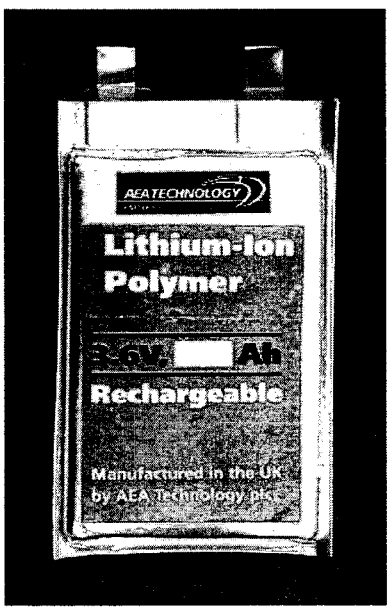
Increasing Energy Density

- Cell packaging/case design
  - metal case versus soft pack





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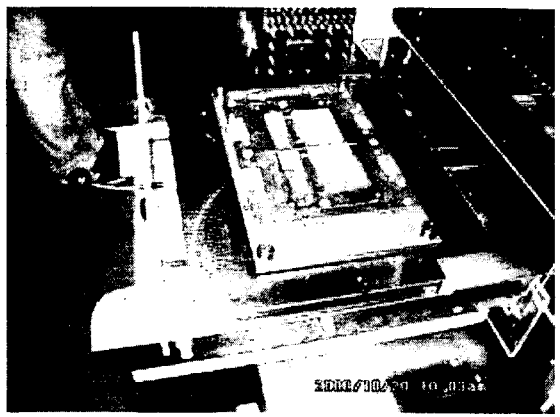
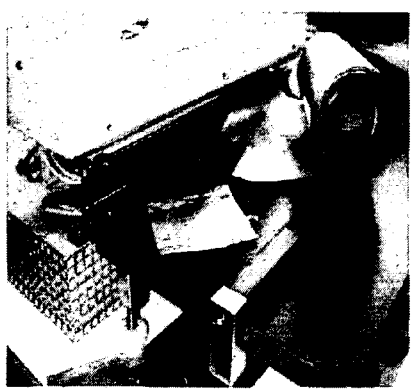
Flexible Package Material Selection

- Aluminium laminate materials
  - resistance to electrolyte
  - vapour barrier characteristics
  - high/low temperature storability
  - insulation characteristics
    - anti-pinhole





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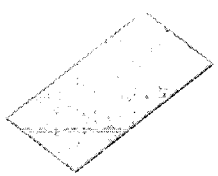
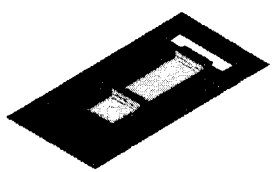
AEA TECHNOLOGY BATTERIES

Cell Packaging Designs

- Cold formed Al laminate blister packaging
- Variable cell footprint & cell thickness
- Thin <3.8 mm profile (600-650 mA h)
- Electrode tab sealing
- Development of novel stacking techniques



Aluminium laminate



Cold formed cavity

Heat sealed pack

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AEA TECHNOLOGY BATTERIES

Development of Novel Electrolytes

- Use of higher boiling/flash point solvents
  - PC-based electrolytes
    - improved efficiency with graphite anode
  - GBL-based electrolytes
    - improved overcharge performance
    - reduced bulging

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AEA TECHNOLOGY BATTERIES

Electrolyte Optimisation
PC-Based Electrolytes

- EC/PC solvent combination selected
  - both components have high boiling point and high flash point
  - PC has low freezing point
- Large first cycle irreversible capacity loss with graphite electrode in PC-based electrolyte
- Investigate use of additives to overcome first cycle capacity loss
- High efficiency achievable (D1/C1>90%)

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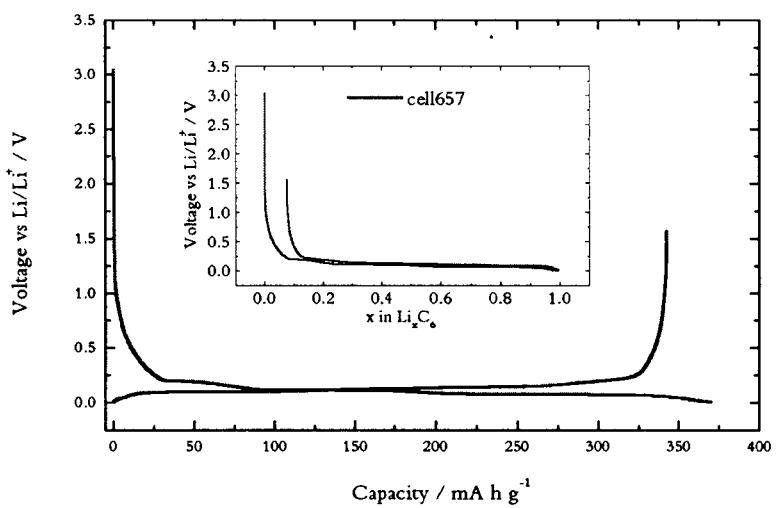
Graphite Anode Characteristics EMC-Based Electrolyte

- Typical high reversible charge capacity on graphite anode (small 3 terminal cell)
  - 0.164 mA cm^{-2}



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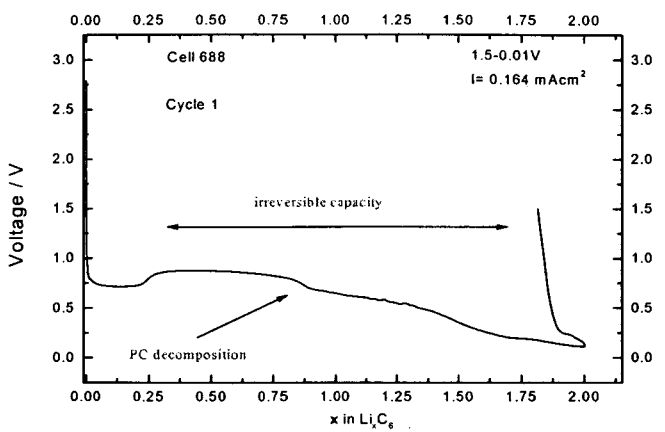
Graphite Anode Characteristics PC-Based Electrolyte

- Typical low reversible charge capacity resulting from decomposition of PC-based electrolyte on graphite anode
  - small 3 terminal cell



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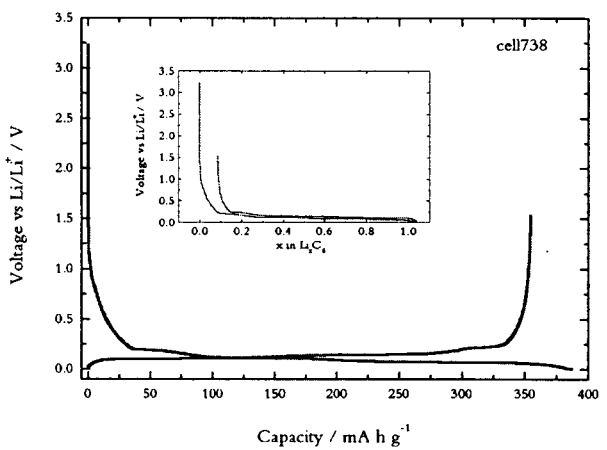
AEA TECHNOLOGY BATTERIES

Graphite Anode Characteristics PC-Based Electrolyte

- High reversible charge capacity on graphite anode using PC-based electrolyte containing chemical additive
  - small 3 terminal cell, 0.164 mA cm^{-2}



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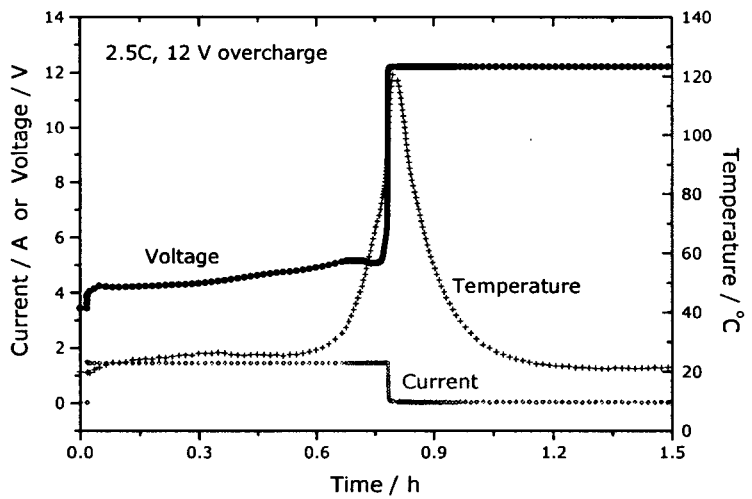
Electrolyte Optimisation
GBL-Based Electrolytes

- GBL-based electrolyte selected for high boiling point and high flash point
- Excellent overcharge performance achieved for cell containing GBL-based electrolyte
- Matching of electrolyte and separator important for good performance

GBL-Based Electrolytes Overcharge Characteristics

- 2.5C, 12 V overcharge
- Graphite - $LiCoO_2$ cell



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Summary

- $LiNi_{1-x-y}Co_xAl_yO_2$ cathode material demonstrates
  - high reversible capacity (>180 mA h g^{-1})
  - stable cycle performance
  - excellent rate performance
- Use of soft-pack laminate cell packaging materials
  - reduces cell mass & increases energy density
  - 183 W h kg^{-1} with PE separator
  - 174 W h kg^{-1} with porous polymer separator

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Summary 2

- Development of novel electrolytes
  - use of selective chemical additives in electrolyte
    - reduce first cycle irreversible capacity loss with PC-based electrolytes
    - increase solvent compatibility with graphite anode
  - high boiling/flash point electrolytes
    - improved overcharge performance
    - 2.5C, 12 V: no fire/no explosion

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