Current state and future of Li-Ion Battery technology

Projected Growth Will be Driven by Electric Vehicle Success

PARSA WIRELESS COMMUNICATIONS

State of the art in Lithium-Ion Technology

- Hand-held communication devices mostly utilize lithium cobaltate (LCO) cathodes
  - Good run time, long working life, defined mfg process
  - High cost limits use to smaller cells
  - Slowly being phased out by LCO modified by Ni and Mn
- Power applications – tools, hybrid vehicles – require a different chemistry allowing rapid discharge
  - Lithium manganate, lithium iron phosphate dominate
  - Latter is safest but also yields lowest energy cells
- Other cathode materials target niche markets, for now
- Electrolytes are very complex Li salt solutions, designed for specific operating conditions
- Graphite anodes are ubiquitous; strong push to upgrade
  - Many R&D projects on silicon, graphene; just touching market

PARSA WIRELESS COMMUNICATIONS

Overall trend in LIB technology

- Electric vehicles (EVs) seen as key to future growth
  - Perhaps 20%/year through 2030
  - New cell chemistries needed to meet consumer demands for greater driving range
- High-voltage cathode materials with 40+% greater energy output are in development phase
  - Combination of Ni-Co-Mn (low Co) will keep price down
  - Ceramic coatings will prevent electrolyte degradation and allow better power performance
- Non-graphitic anodes needed for greater Li storage
  - Early materials in market have limited working life
  - Silicon and decorated graphenes have superior capabilities, but must involve nanotechnology ($$)
  - Many other nanomaterials are candidates, all in various stages of R&D

PARSA WIRELESS COMMUNICATIONS

Future LIB Products and Specifications

- Next-generation LIBs will boost energy output >50%
  - Cathode materials will contain Ni & Mn, with little/no Co
  - Average voltage >4V, charge voltage >4.5V
  - Specs: 2500 charge/discharge cycles, high thermal tolerance, improved power capability
- Larger cells will be enabled with improved design
  - Ability to bleed off excess heat critical for safety, longevity
- Nano-enhanced anode materials with 3-5X the Li storage capacity of graphite
  - Metal/alloy whiskers, metal oxide-decorated graphenes
  - Nanotechnology will be the key, cost is the major hurdle

PARSA WIRELESS COMMUNICATIONS

Potential breakthroughs in LIB technology

- Stabilized non-stoichiometric Li-Ni-Mn-Co cathode materials providing substantial energy boost
  - Must establish production-scale process: >90% chance
  - Lab-scale preparation well defined
  - Inexpensive particle coatings to enhance stability and power capability
- Ionic liquid-based electrolytes with high thermal and voltage stability
  - Costs must drop substantially for consumer market
- Anode nanomaterials for high-energy LIBs
  - Must overcome 20% capacity loss during first charge-discharge cycle
  - Must establish less expensive manufacturing processes
- More robust, non-polyolefin separators in power cells

PARSA WIRELESS COMMUNICATIONS