The University of Texas at Austin
Cockrell School of Engineering

DESIGNING LITHIUM-ION BATTERY CATHODES

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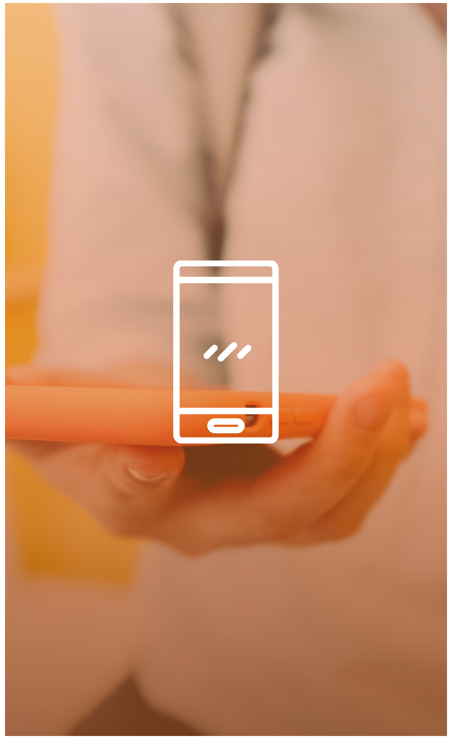
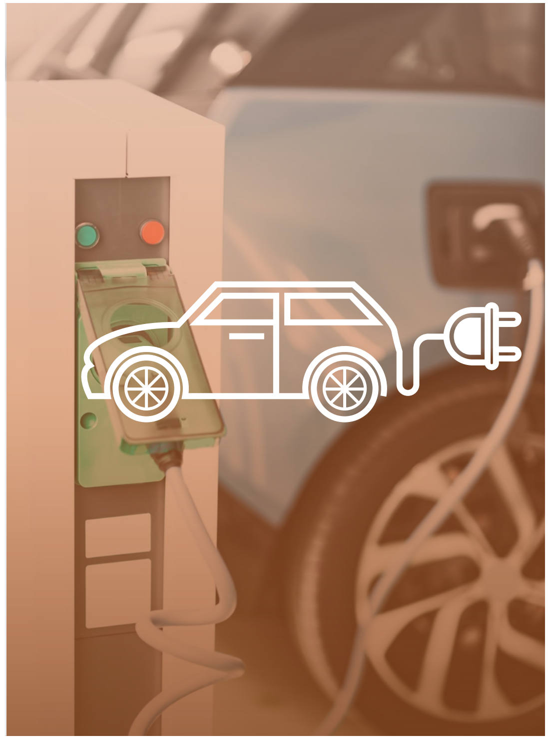
LITHIUM-ION BATTERY

A DISCOVERY THAT CHANGED THE WORLD





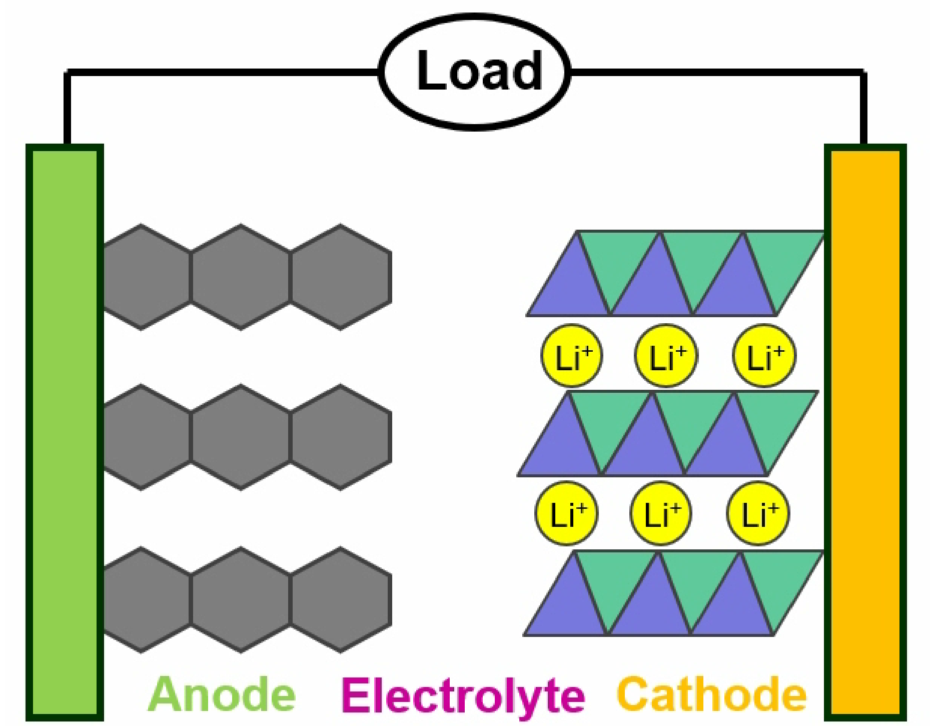
EARLY WORK

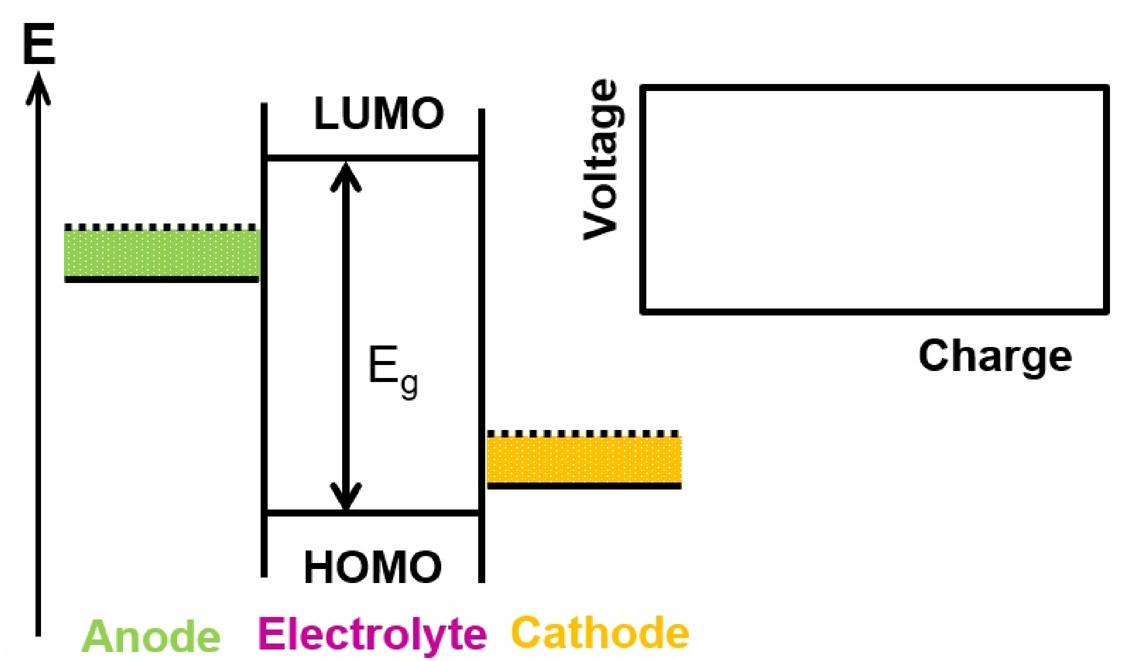
1950-1980

- Magnetic materials for first RAM memory
- Cooperative atomic orbital ordering
- Rules for sign of magnetic interactions
- Solid sodium-ion electrolyte: NASICON

THE LITHIUM-ION BATTERY

HOW IT WORKS





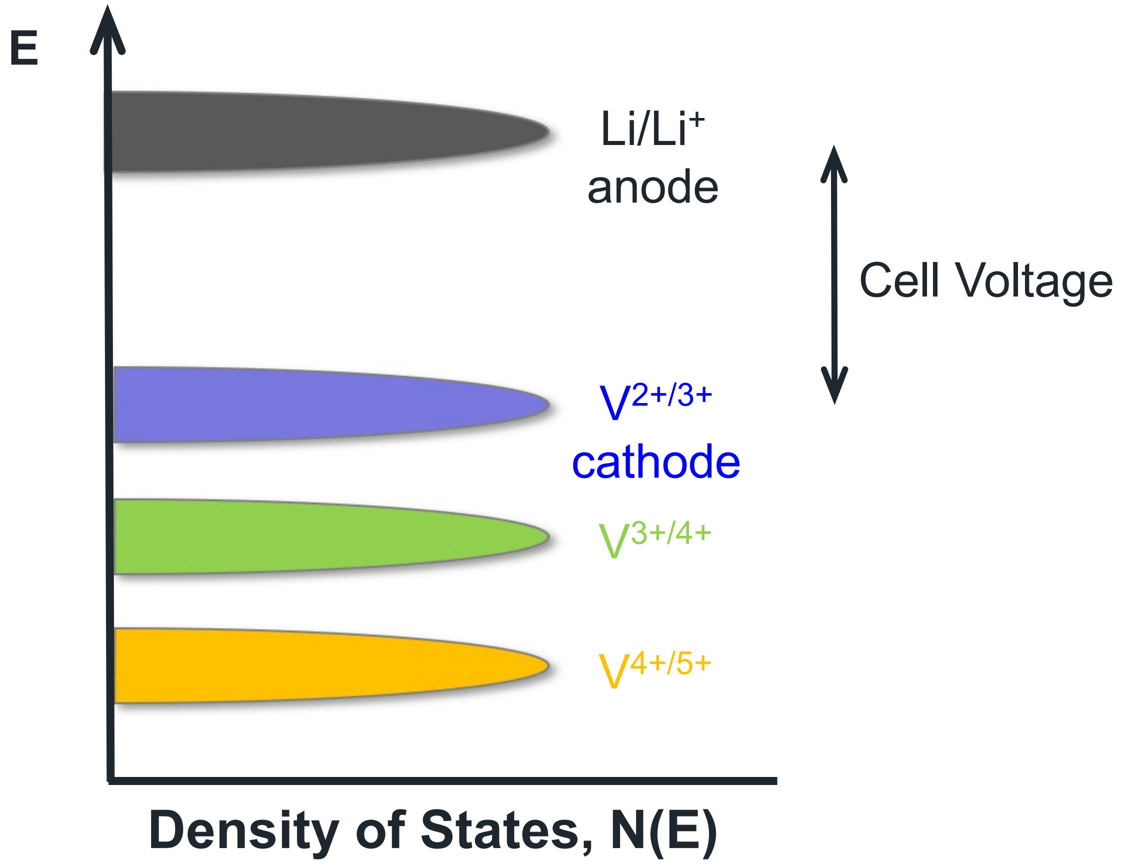
WHAT FACTORS DETERMINE CHOICES FOR NEW BATTERY CHEMISTRY?

1. Cost
2. Energy
3. Power
4. Cycle Life
5. Safety
6. Environment

MATERIALS

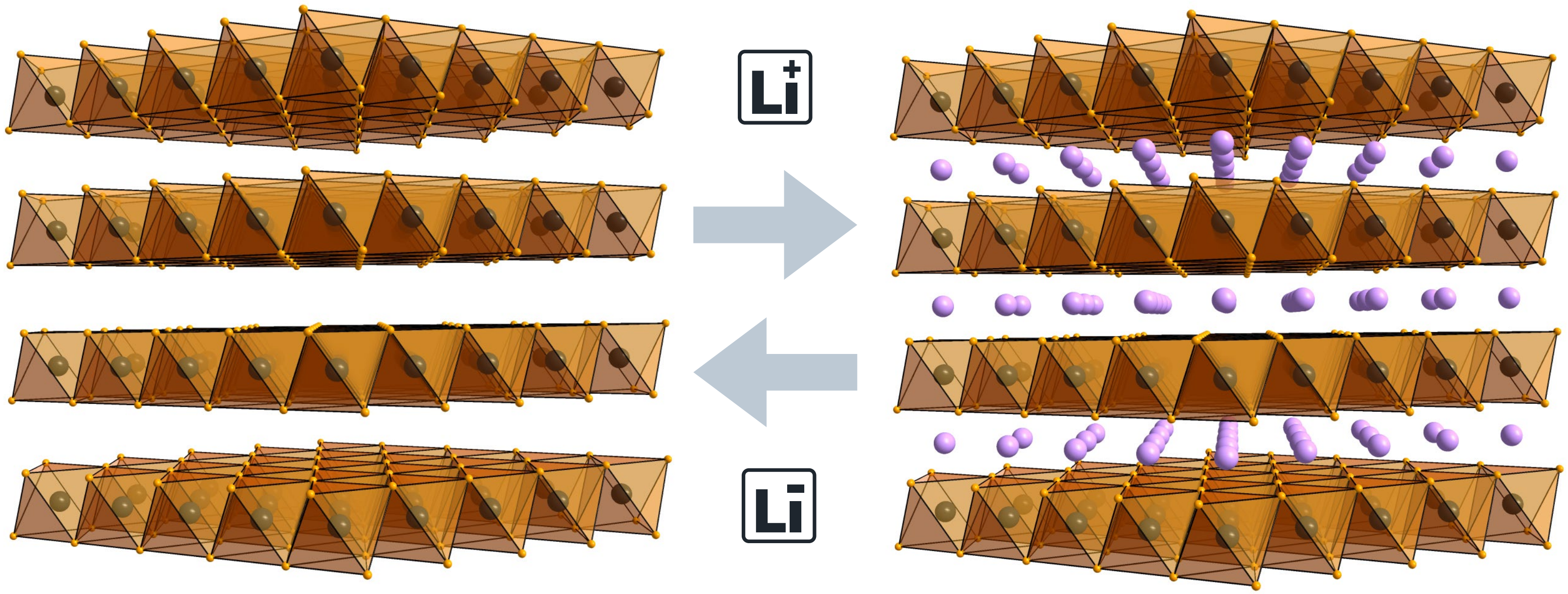
ENERGY DENSITY

User Time = (Cell Voltage) x (Amount of Lithium ions Stored)



INSERTING LITHIUM

HOW THE CHEMISTRY WORKS

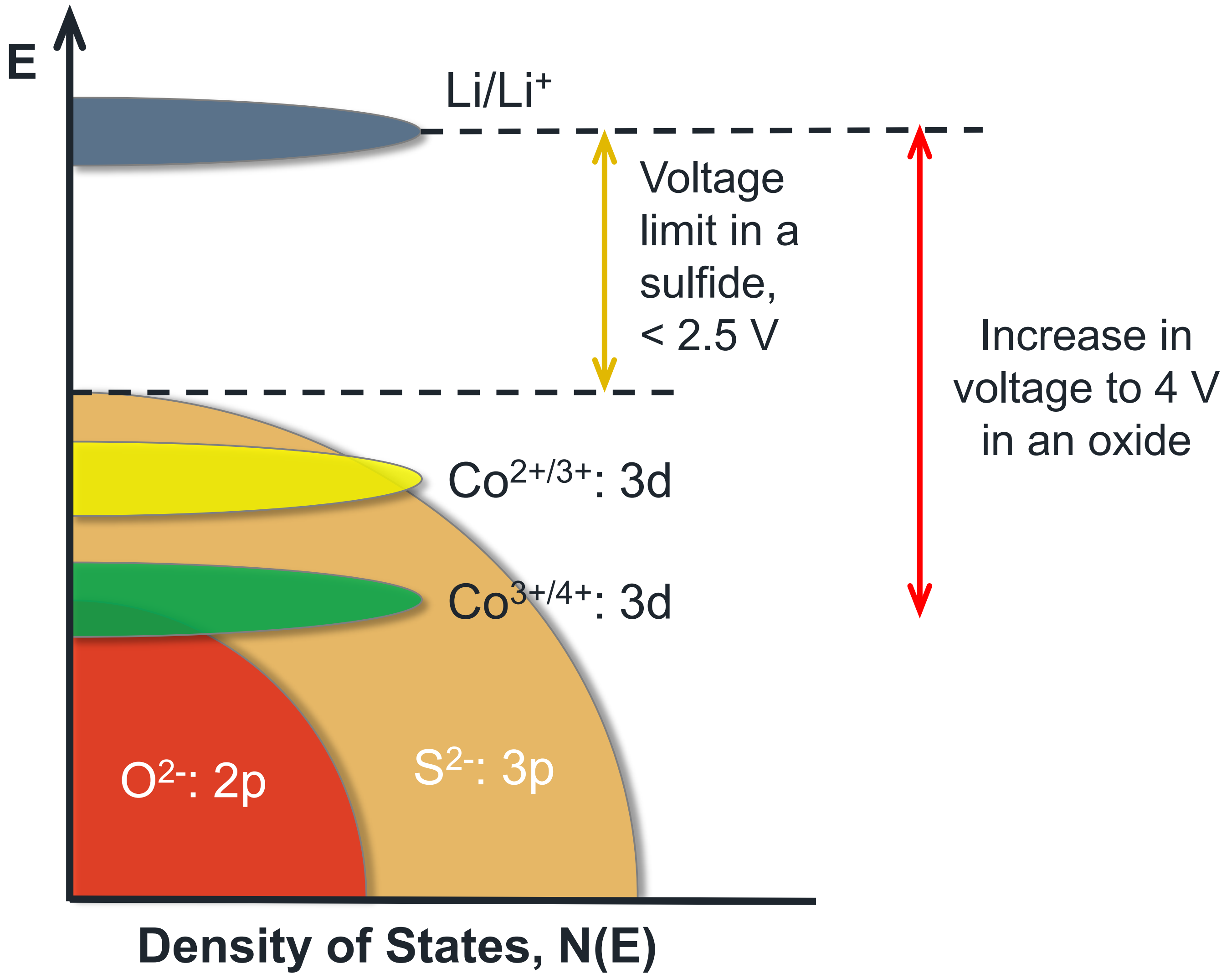


Titanium Sulfide
TiS_2

Lithium Titanium Sulfide
$LiTiS_2$

ENERGY DENSITY

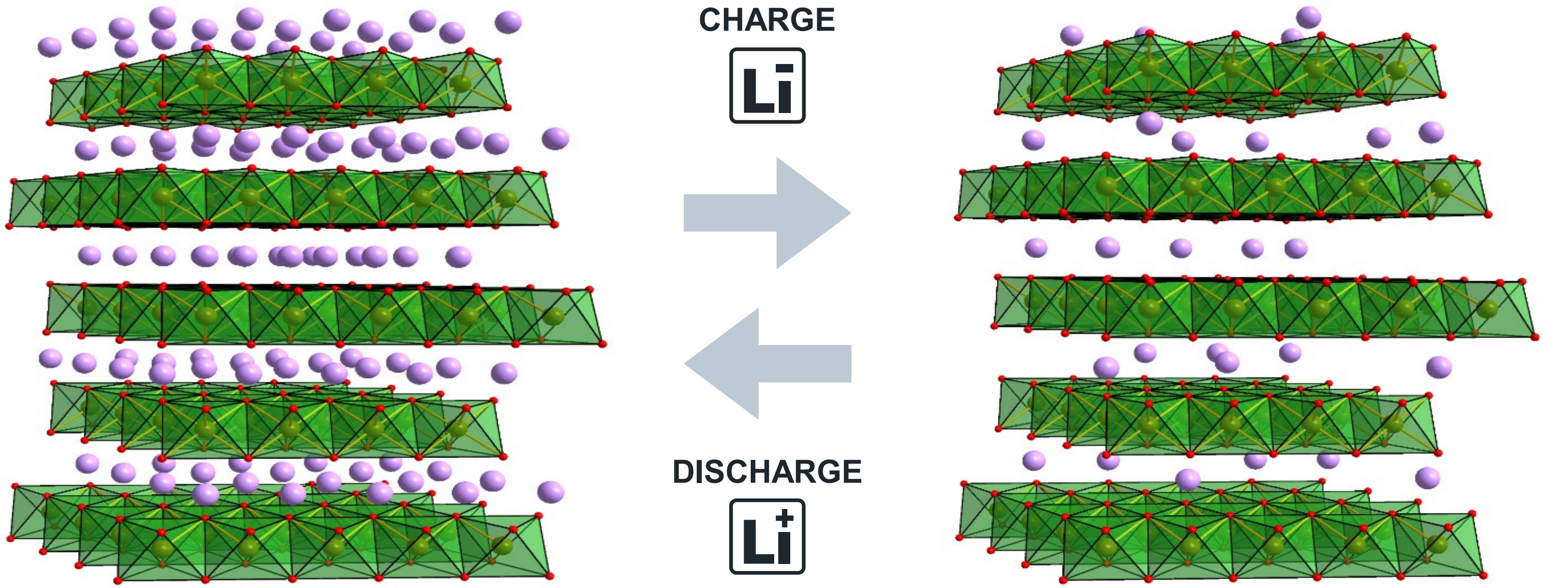
FROM SULFIDE TO AN OXIDE



MATERIALS CLASS 1

1980: LAYERED OXIDE

Citation: Mizushima, Jones, Wiseman, Goodenough — Materials Research Bulletin ***15,*** *783 (1980)*



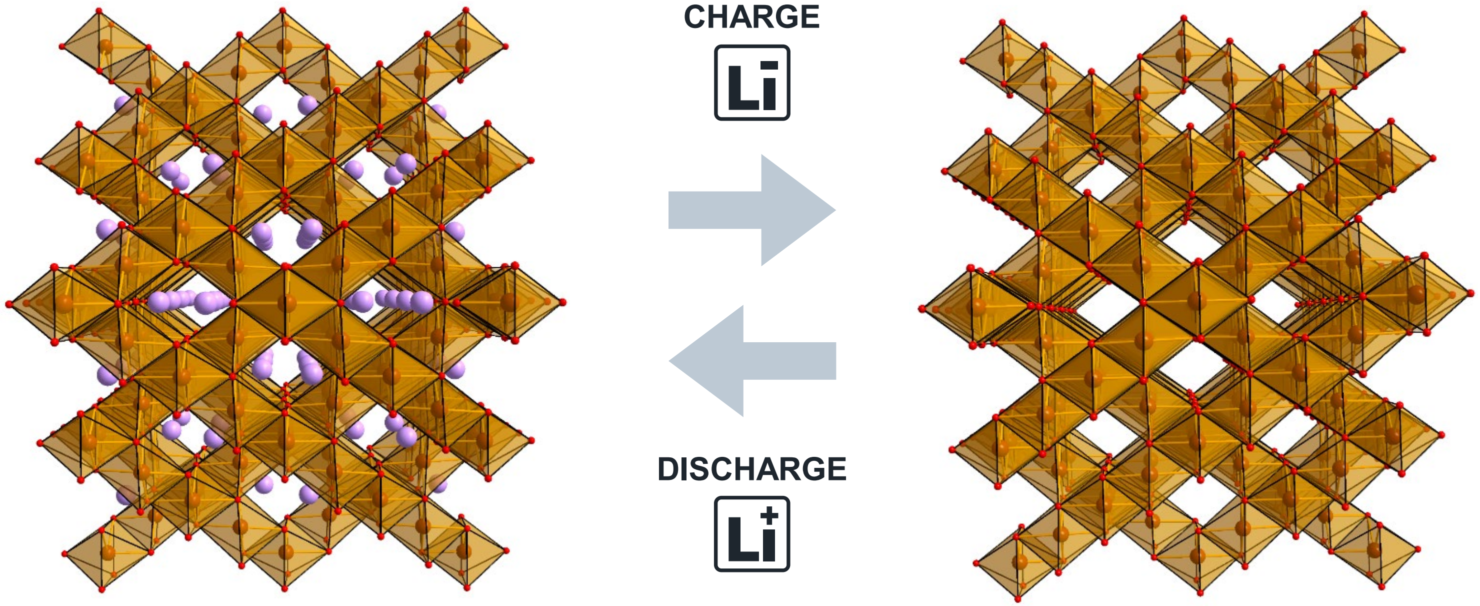
Lithium Cobalt Oxide
$LiCoO_2$

Lithium-deficient Cobalt Oxide
$Li_{0.5}CoO_2$

MATERIALS CLASS 2

1983: SPINEL OXIDE

Citation: Thackeray, David, Bruce, Goodenough — Materials Research Bulletin ***18,*** *461 (1983)*



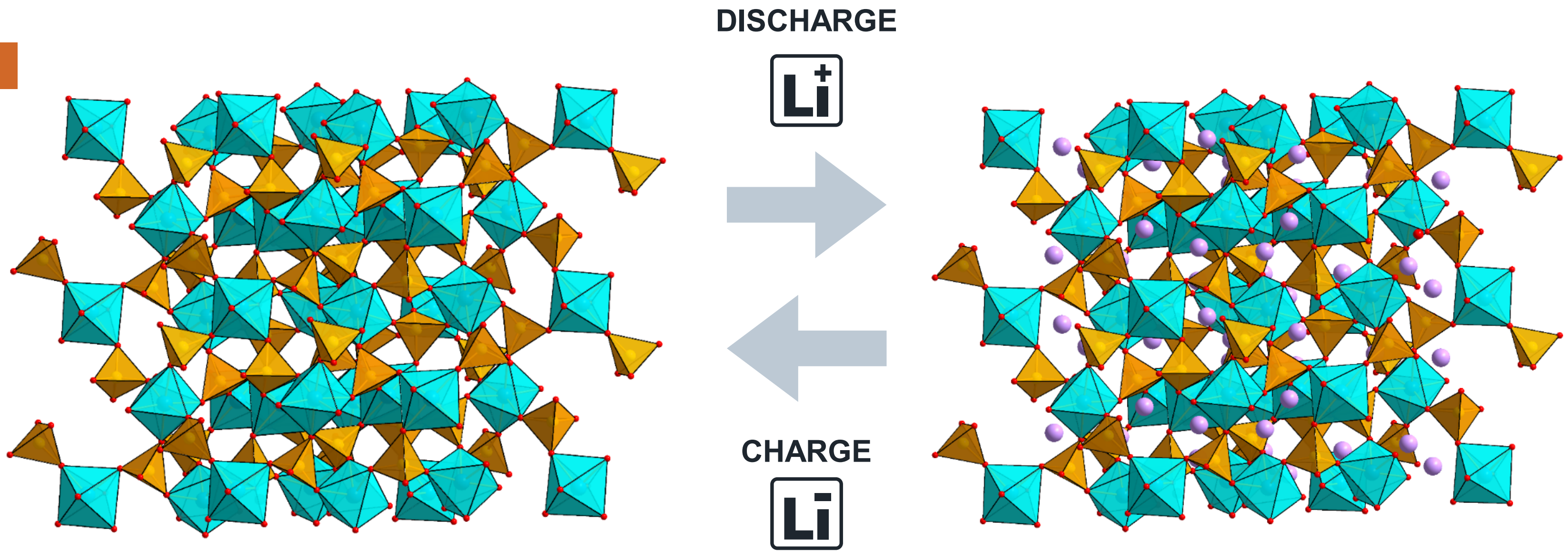
Lithium Manganese Oxide
$LiMn_2O_4$

Manganese Oxide
Mn_2O_4

MATERIALS CLASS 3

1987-89: POLYANION OXIDE

*Citation: Manthiram, Goodenough — Journal of Solid State Chemistry **71,** 349 (1987)*
*Manthiram, Goodenough — Journal of Power Sources **26,** 403 (1989)*



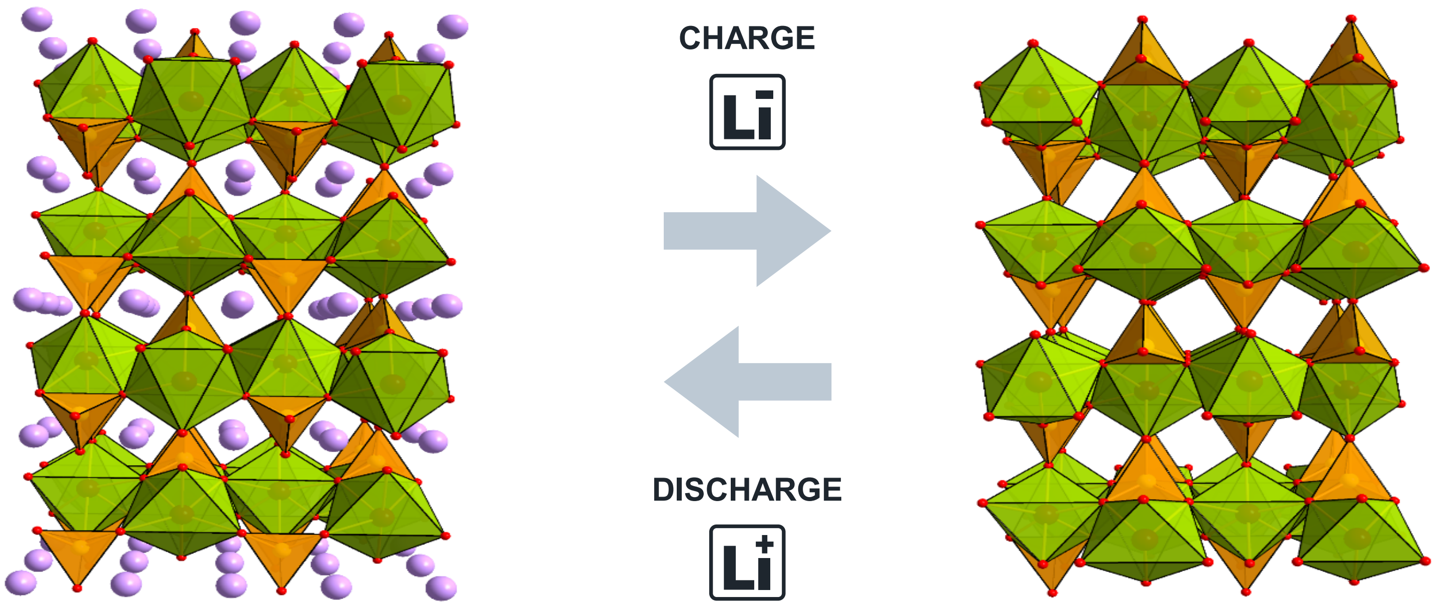
Iron Sulfate
$Fe_2(SO_4)_3$

Lithium Iron Sulfate
$Li_2Fe_2(SO_4)_3$

MATERIALS CLASS 3

1997: POLYANION (OLIVINE) OXIDE

*Citation: Padhi, Nanjundaswamy, Goodenough — Journal of the Electrochemical Society **144,** 1188 (1997)*



Lithium Iron Phosphate
$LiFePO_4$

Iron Phosphate
$FePO_4$

KEY FINDINGS

AND HISTORICAL SIGNIFICANCE

- A fundamental study of the properties of transition-metal oxides led to the identification of oxide cathodes

- Pushed boundaries at the intersection of solid-state chemistry and physics

- The three classes of materials discovered still remain the only viable cathodes — and the basis for future development
  - Layered oxide
  - Spinel oxide
  - Polyanion oxide

MOVING FORWARD

- Liberating society from fossil fuels
- Harvesting electric power from solar and wind energy
- Electricity storage as chemical energy is the key
- Affordable, safe battery technologies

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