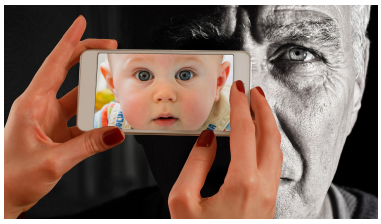
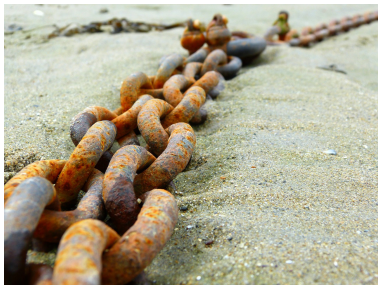
Cells change as they age

- This specialization doesn't study cell electrochemistry in detail
- But, understanding causes and effects of cell aging and failure has value (motivates need for SOH algorithms, power limits)
- Failures causes: cell design faults, poorly controlled manufacturing processes, aging, uncontrolled operations, and abuse
  - BMS algorithms can't do too much about the first two (too late!), but
  - Can respond to (even compensate for) the others



Aging processes (1)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Corrosion:*** (undesired chemical reaction with environment) consumes some of the active chemicals in the cell leading to increased impedance and capacity loss



Aging processes (2)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Crystal formation:*** Electrode particles evolve as larger crystals are formed. This reduces the effective surface area of the electrodes and hence their current carrying and energy storage capacity

Aging processes (3)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Dendritic growth:*** Formation of treelike structures on electrodes, which can ultimately pierce separator and cause short circuit

Aging processes (4)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Chemical loss through evaporation*:** Gaseous products resulting from over-charging are lost to atmosphere causing capacity loss

Aging processes (5)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Passivation:*** Growth of a resistive film layer that builds up on the electrodes, impeding the chemical action of the cell

Aging processes (6)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Shorted cells:*** Cells that were marginally acceptable when new may have contained latent defects that become apparent only as the aging process takes its toll: poor cell construction, contamination, burrs on metal parts leading to a short circuit

Aging processes (7)

- Cell performance gradually deteriorates due to unwanted chemical reactions, physical changes to the active chemicals
- Process is generally irreversible, and eventually results in cell failure
- The following are some examples of causes:
  - ***Electrode or electrolyte cracking*:** Some solid electrolyte cells such as lithium polymer can fail because of cracking of the electrolyte

Undesirable effects of aging

- ***Increased internal impedance:*** as larger crystals form, reducing effective surface area of electrodes; due to film, loss of electrolyte, corrosion of current collectors, etc.
- ***Reduced capacity:*** Deteriorated active materials, loss of charge carriers due to side reactions. In some chemistries, partially recoverable through reconditioning the cell by subjecting the cell to one or more deep discharges
- ***Increased self discharge:*** Electrodes can swell, increasing pressure on separator and, as a consequence, increasing the self-discharge rate of the cell
- Aging processes are generally accelerated by elevated temperatures but not necessarily noticed right away
  - “Battery dies in the summer but you hold the funeral in the winter”

Summary

- Valuable to understand causes of aging (motivates need for SOH algorithms, power limits)
- Some causes of cell aging (more detail in course 4)
  - Corrosion, crystal formation, dendrite growth, chemical loss via evaporation, passivation, shorted cell, electrode or electrolyte cracking
- Some effects of cell aging
  - Increased resistance
  - Decreased capacity
  - Increased self-discharge rate

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