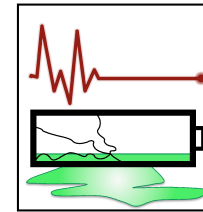




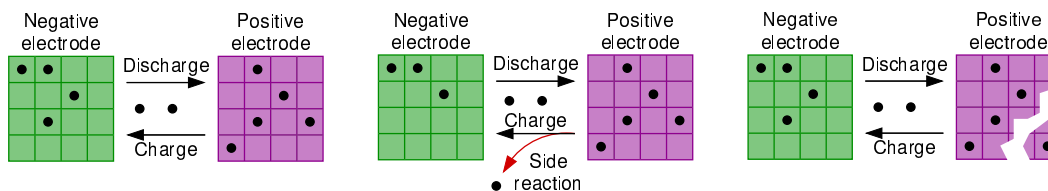
Performance changes as cells age

- We know that a BMS must estimate certain quantities indicative of its cells' states and parameters
- We have now seen a number of ways to estimate battery cell state—the quickly changing quantities
- Now, we turn our attention toward estimating battery cell parameters—the slowly changing, pseudo-static quantities
- In particular, we are most interested in those quantities that reflect a change in the performance that the pack can deliver
- These are indicators of battery pack “state-of-health” (SOH)
- SOH most often summarized by estimating present total capacity, series resistance



Loss in total capacity versus time

- As a battery cell ages, its total capacity decreases, primarily due to unwanted side reactions, structural deterioration

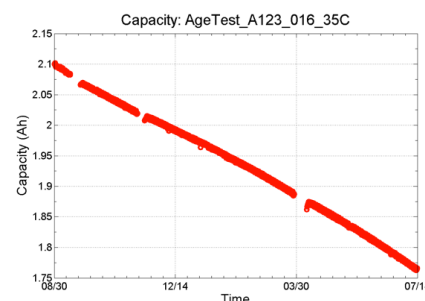


- Ideally, lithium moves back and forth between electrodes; none is lost
- Side reactions can consume lithium, primarily when charging cell
- Structural deterioration can remove storage sites for lithium from one or both electrodes



Capacity fade

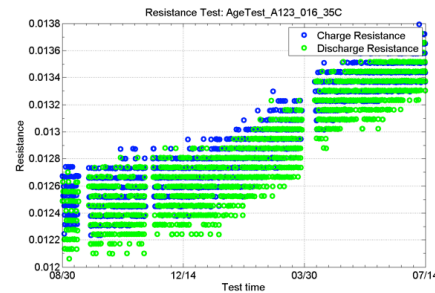
- Phenomena often referred to as capacity fade
- Knowing present value of total capacity important because it is:
 - Major contributing factor to energy calculation
 - Major contributing factor to SOC estimation if coulomb counting is used (else, minor contributing factor)
 - (Insignificant in power estimation)





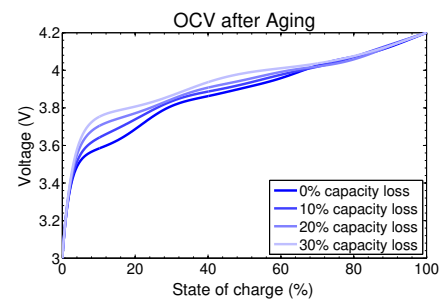
Power fade

- As a cell ages, its series resistance increases, also primarily due to unwanted side reactions and structural deterioration
- Knowing present ESR is important because:
 - Major contributing factor to power calculation
 - Major contributing factor to SOC estimation for some voltage-based methods (else, it is a minor factor)
 - (Insignificant role in energy estimation)
- Since resistance and power are so tightly coupled, resistance rise in a cell is commonly referred to as power fade



Other cell parameter values

- The OCV relationship changes as the electrodes lose capacity
 - For most chemistries in common use, unlikely that this change is large enough to be readily detectable
- Other cell parameters almost certainly change as well; however, I'm not aware of BMS that make efforts to estimate them
 - ESR, total capacity have dominant impact
 - KF-based methods in this course could be used to estimate the others, if application demands it



Summary and next steps

- Cell parameter values change over time as cell ages
 - Total capacity and ESR are the most important to track
- In this course, we first look at some qualitative explanations for cell aging
- Next, we explore a simple method to estimate ESR
- We then look at ways to estimate total capacity
- We finally look at KF-based methods to estimate up-to-date values for any desired set of cell parameters (honors)