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POLARIS BATTERY LABS

#FREEOFCHARGE

The data looks good, but it "secretly" not practical.

- Our anode material cycled 1000 times in a half cell.
- (insert material here) has achieved 3000 mAh/g and has 100's of cycles.
- The first lithiation capacity we achieved is 175mAh. Our cell cycled for 800 cycles with less than 10% fade.

How to Identify Skewed Battery Data Pt. 2

Any papers or news releases you come across will have information they are and are not telling you. This does not mean the paper or article has bad information, but it does mean identifying what they are not telling you is often just as important as what they are telling you. Here we detail a few tips we have come across when looking at data which can be applicable to investors and researchers alike!

1.) Using half cells for cycling data

Half cells are a useful part of research, and are used to isolate the material you are working with typically by placing your electrode of interest vs. lithium metal. Half cells are typically used in research to validate a material and gain information such as first charge/discharge capacity, first cycle loss, initial fade rate, first cycle loss, impedance, and coulombic efficiency. It is a vital first step before transitioning to a full cell, and one we highly recommend. So why are they so bad when looking at cycling data? Essentially when you cycle against lithium you typically have a theoretically unlimited supply of lithium. This oversized lithium supply reacts much different than a graphite, or other anodes which result in a lithium-limited electrode. An oversized lithium supply can hide lithium losses in the cell as processes that consume lithium (i.e SEI) will not cause a loss of capacity. In addition, half cells do not indicate how a cell will do in a practical cell. Half cell data should be used to determine how to model your full cell, but is the full cell interactions in which can help you determine practical cycle life values. Half cells are nearly always done in coin cells. Coin cells typically have an extreme excess of electrolyte, do not allow for degassing, and have variable pressue. Sparators and electrolyte could also be different from what is manufacturable and show different wetting characteristics than commercial materials would. It is also true that when using a half cell, it can also make the data look worse. This is especially true for c-rate testing. Half cells can look much worse in c-rate testing because one of the electrodes is

Polaris Pro Tip: Use half cells to validate electrodes and don't look to them to extrapolate the data to full cell performance. If you want cycle life data look at full cells.

2.) Using low loadings

The loading of electrodes (mg/cm^2) has a significant impact on battery results. The more mg of material per square centimeter the more potential capacity you have. It is important to remember that when scaling, loadings do not show linear performance capabilities. Firstly, cells at a lower capacity will require a lower current to achieve 1C, or in other words, require a lower areal current density. Low areal current densities can be very advantageous when it comes to battery safety as they can reduce dendrite formation which is one of the big appeals to high surface area electrodes. Another thing to remember is that to achieve higher loadings you will likely need to increase the thickness of the electrode itself which can cause separate issues. Low loadings also hide any conductivity issues that may be present in the electrodes. Because electrons have such a short distance to travel to the current collector, conductive aid is less important. This means that often for higher loadings, the slurry formulation will need to be reconsidered to allow for this. High loadings also have more difficulty with adhesion to the foil and can be much more difficult to process through to an actual cell with the coating intact. Thus, even if you theoretically say that you can just go to a higher loading, it may actually not be possible to coat or process and it will require some time to reconsider the slurry recipe to try to combat some of those issues which may or may not be possible to solve.

Polaris Pro Tip: To understand if a electrode has reasonable loadings, look for mAh/cm2 as it is easy to see what they really have and will prevent you from being tricked by a high theoretical capacity (We are looking at you Sulfur and Silicon). At Polaris our rule of thumb is that <1=not usually very practical 1.5-2=practical >2= great. Of course this is very application specific, if you know your requirements you can come up with your own parameters.

3.) Cycling in a Narrow Voltage Range

Cycling a battery in a narrow voltage range is an easy way to skew cycling results to look as though they have a high capacity and long cycle life What is often done is that a battery is charged to its maximum voltage, for lithium ion ~4.25 at a low c-rate around C/20. This makes the capacity look great as you are using up most of the cells available capacity. However, when you look at cycling protocol, you will often see that the full voltage range is not being used, the battery may have done 1000 cycles but only to 4 or 4.1V. This in itself is not necessarily bad, it is often done to both speed up cycling as well as allow for the longer cycle life to be achieved. What can be misleading is thinking you are going to get that full capacity and low fade rate for the 1000 cycles that was promised. Cycling to the max voltage (or close to it) can significantly shorten the life of the battery. Over time, resistance builds up in the cell and can push the electrode potentials to the point of degredation. For NMC, this degredation can begin to occur at 4.3V so cycling to 4.1V instead of 4.25 will give you significantly more cycles until the resistance increases to a point in which it will cause electrode damage.

Polaris Pro Tip: Don't take a capacity value for granted. Be sure you know how they achieved that capacity and compare it against cycling results so you can verify that the capacity corresponds to that voltage range.