Not so fast!

Are LFP batteries really better at fast charging?

Response to “Ironclad: Lithium Iron Phosphate’s Economic Advantage for Frequently Fast Charging Electric Vehicles” by Hannah Morin (CMU)

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Hannah has shown that the commercial LFP batteries she tested can perform more fast charging cycles than the commercial NCA batteries. This results in better outcomes for consumers, potentially cheaper EVs, more access to EVs for people who don't own homes, and safer electric vehicles, though the LFP packs may never offer the range of NMC/NCA packs.

But we must be careful to understand *why* those LFP cells are better for this example to extrapolate policy implications from lab-scale testing results.

We often describe lithium-ion batteries by their positive electrode material, because it is the most expensive component of 'traditional' cells (LCO, NMC, NCA). Hence, 'LFP' versus 'NCA'.

So, it's easy to think that 'LFP' cells are more tolerant to fast charging *because of the LFP.* But we need to consider the entire system carefully to understand if this implicit assumption is true.

Usually, when traditional lithium-ion batteries (NMC-Gr, LFP-Gr) fail during fast charge, it is because lithium, instead of intercalating into graphite, plates on the graphite surface (and lithium metal is an awful electrode material in standard lithium-ion electrolytes, on top of being more reactive, i.e., less safe).

So why would using LFP in the positive electrode improve fast-charging durability?

When we compare lithium-ion battery materials, we need to consider overall cell and system design implications, driven by the properties of the electrode materials.

	NCA	LFP	NCA/LFP
Format	21700	26650	
Volume (mL)	24	35	
Mass (g)	69	90	
Charge Capacity (Ah)	5	3.3	
Energy Capacity (Wh)	18	11	
Volumetric Energy Density (Wh/L)	740	316	234%
Specific Energy (Wh/kg)	260	121	215%

The NCA cells have *more capacity* in a *smaller volume*, that is, there is more graphite in the smaller NCA cell than there is the larger LFP cell.

This means that the NCA cells have thicker much negative electrodes than the LFP cells. This makes the cell more likely to plate graphite at the negative electrode surface during fast charging events.

You can just make NCA cells with thinner graphite electrodes (e.g., a power cell) but this costs you in energy density…. Which maybe you'd want to do to make a better fast-charging cell.

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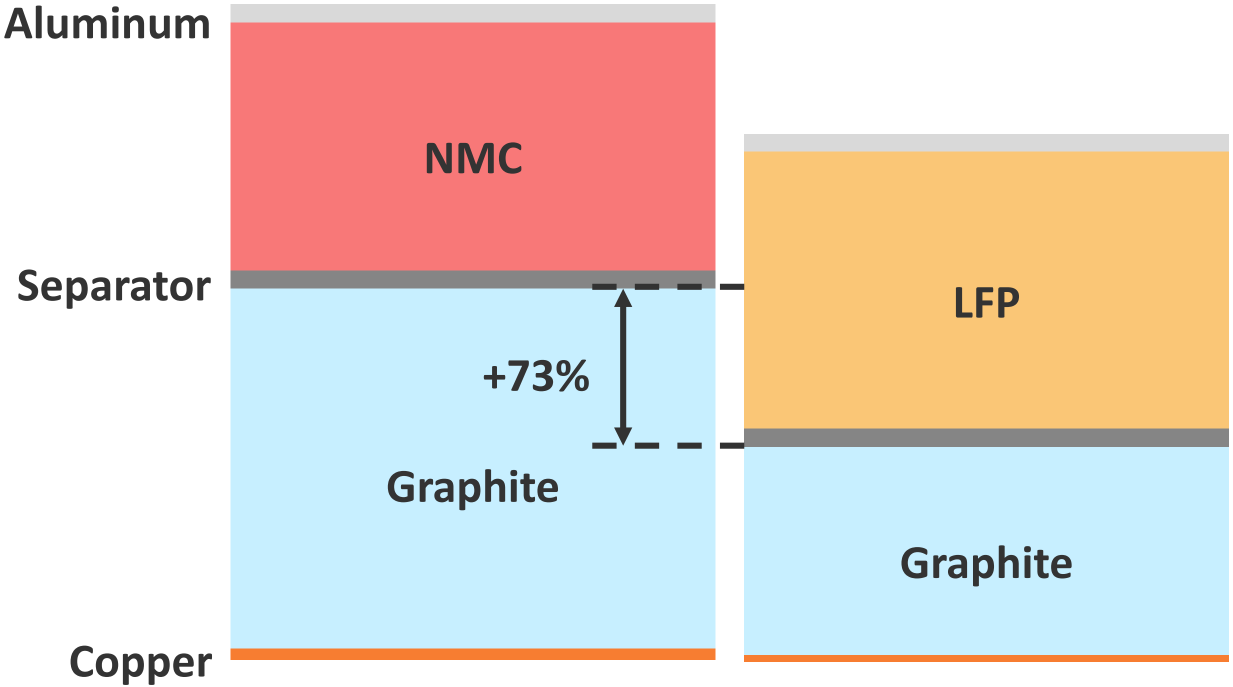
High energy NMC: 4.3 mAh/cm^2, 90 µm PE, 130 µm NE
High energy LFP: 3.4 mAh/cm^2, 100 µm PE, 75 µm NE

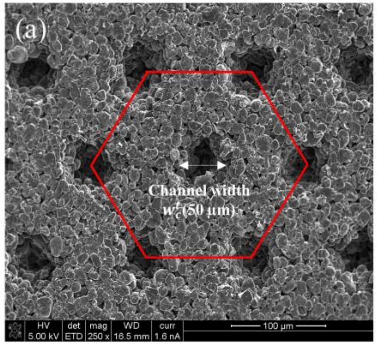
Ank et al, Journal of the Electrochemical Society (2023) 170 120536
Stock et al, Electrochimica Acta 471 (2023) 143341

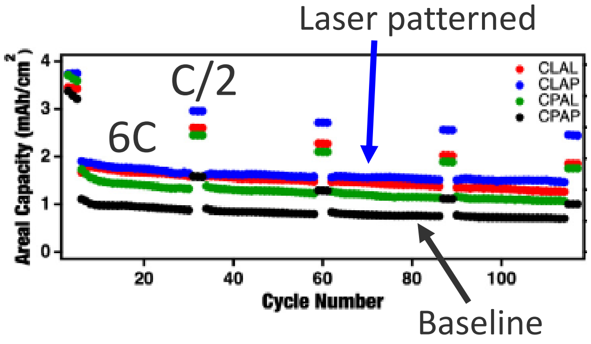


~30% increase in areal capacity requires ~70% increase in graphite electrode thickness; thicker graphite electrode may need to be more porous to enable > 1C charging.

Just print a thicker LFP electrode for better energy density!
… you try tape casting a 300 µm electrode (counterpoint: 24M).

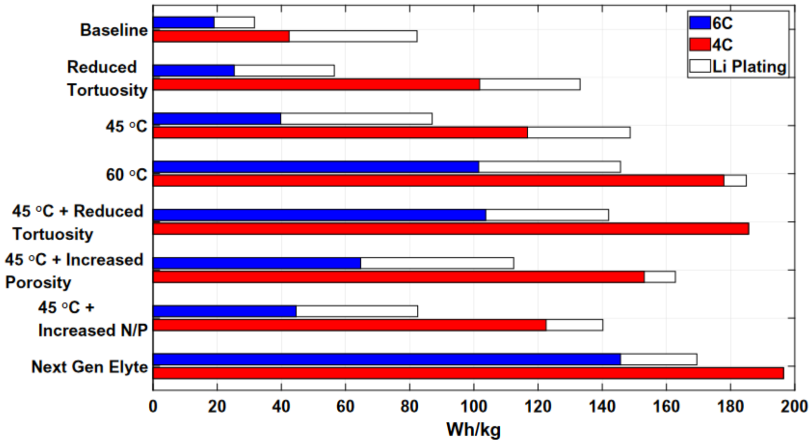
We can improve fast-charging capabilities of high loading electrodes with material changes or microstructural modifications.





(Left) Usseglio-Viretta et al, Journal of The Electrochemical Society, 2023 170 120506
(Right) Dunlap et al, Journal of Power Sources 537 (2022) 231464

BatMan

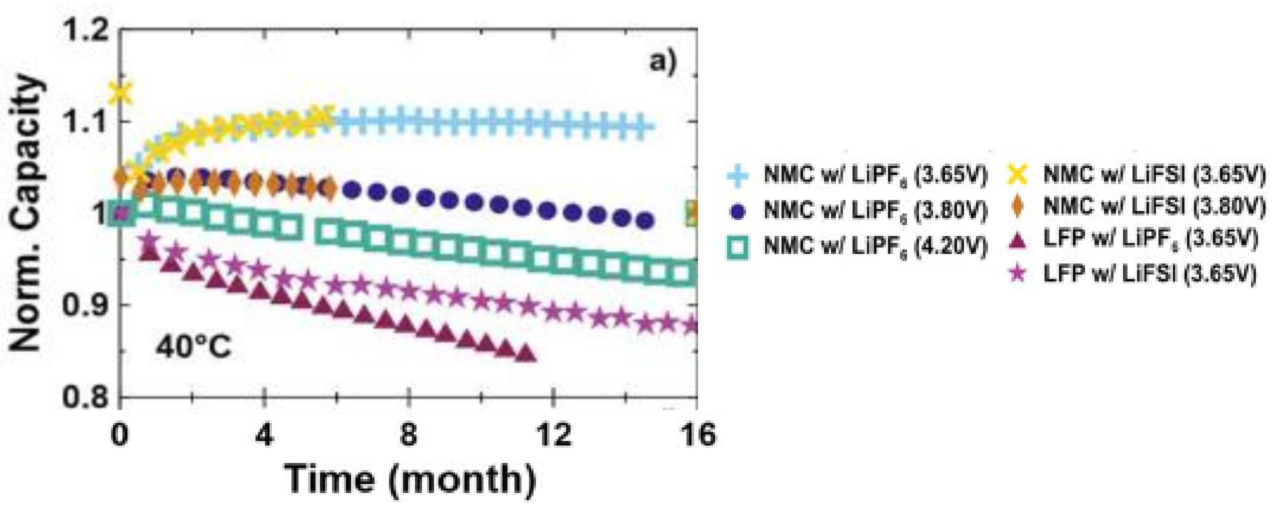


Colclasure et al, "Electrode scale and electrolyte transport effects on extreme fast charging of lithium-ion cells", Electrochimica Acta 337 (2020) 135854

XCEL
eXtreme Fast Charge Cell Evaluation of Lithium-ion Batteries

NREL Transforming ENERGY

NMC may be more chemically stable than LFP – the ‘best’ NMC cells are more durable than the ‘best’ LFP cells.



Aiken et al, “Li[Ni0.5Mn0.3Co0.2]O2 as a Superior Alternative to LiFePO4 for Long-Lived Low Voltage Li-Ion Cells”, Journal of The Electrochemical Society, 2022 169 050512

LFP versus NCA/NMC:

- ✓ Safer, so you can get away with making bigger cells (cheaper! Better cell-to-pack!)
- ✓ Generates less heat per unit volume / mass, so you can get away with less cooling system overhead (better cell-to-pack! Less range loss due to thermal management!)
- ✓ Your power electronics engineers like you more since there's a flat voltage profile
- ✓ Are often more tolerant to fast-charging
    - … until we get better at making thick graphite electrodes
    - … or just stop using graphite for the negative electrode (Si, Li metal)

… but …

- You will probably never be able to get the same range, even with cell-to-pack efficiency improvements
- You need ~12% more cells in series to hit pack voltage requirements (and use large, prismatic cells to reduce costs and gain back some energy density through better cell packing), increasing chance of pack failure due to single cell failure
- Your control engineers curse your name and can't sleep at night because there's a flat voltage profile (accurate state-of-charge/health/… estimation is much harder)