High-power alternative-ion batteries via co-intercalation

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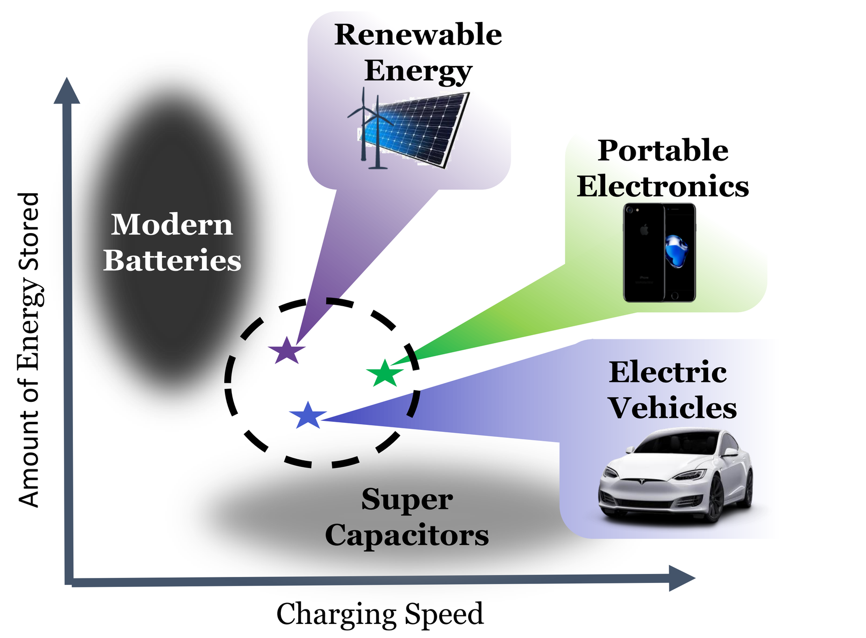
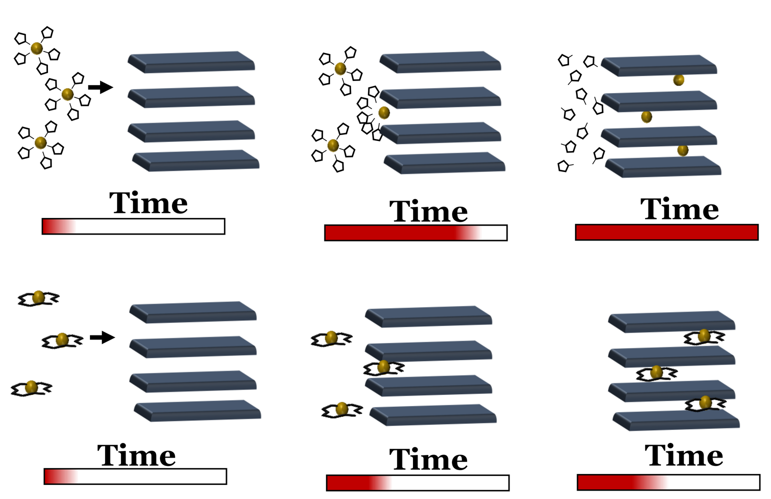
Background

Why is there a need for high-rate batteries?

- Modern energy storage cannot meet demand for **affordable technology with high power & ultrafast charging**



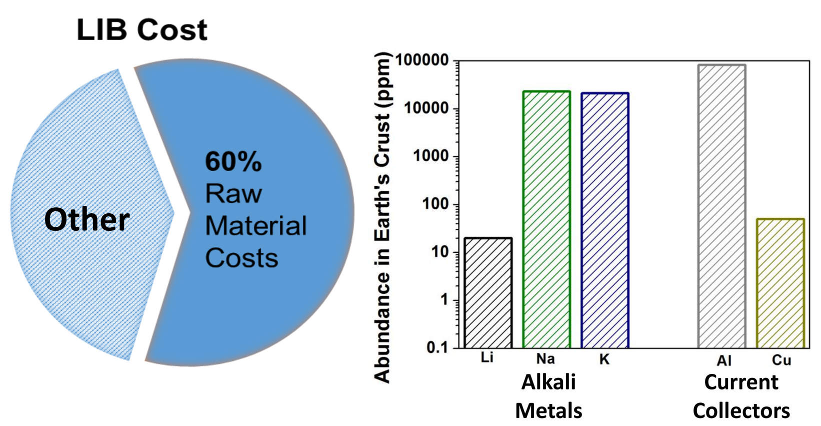
Why is co-solvate intercalation the answer?



- **Eliminates the slow step** of ion de-solvation
- Significantly **increases** rate of charge storage vs traditional battery set up

Why alternative-ion?

- **Na and K are 1000 times more abundant** than Li in the earth's crust
- Na and K ion batteries utilize much cheaper current collectors than Li



Battery Fabrication

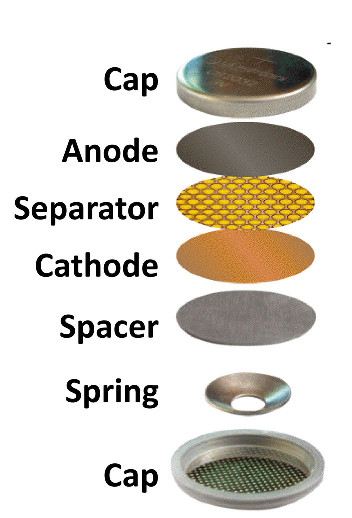


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Figure 1. Coin cell configuration

Cathode:
Prussian Blue was synthesized as shown

Anode:
Graphite with 2-15µm particle size

Electrolyte:
1 M $NaPF_6$/KPF_6 in DEGDME

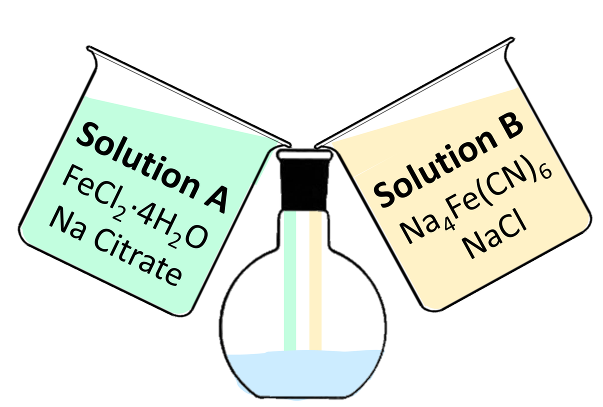


Figure 2. Prussian Blue synthesis schematic

Co-intercalation into Graphite

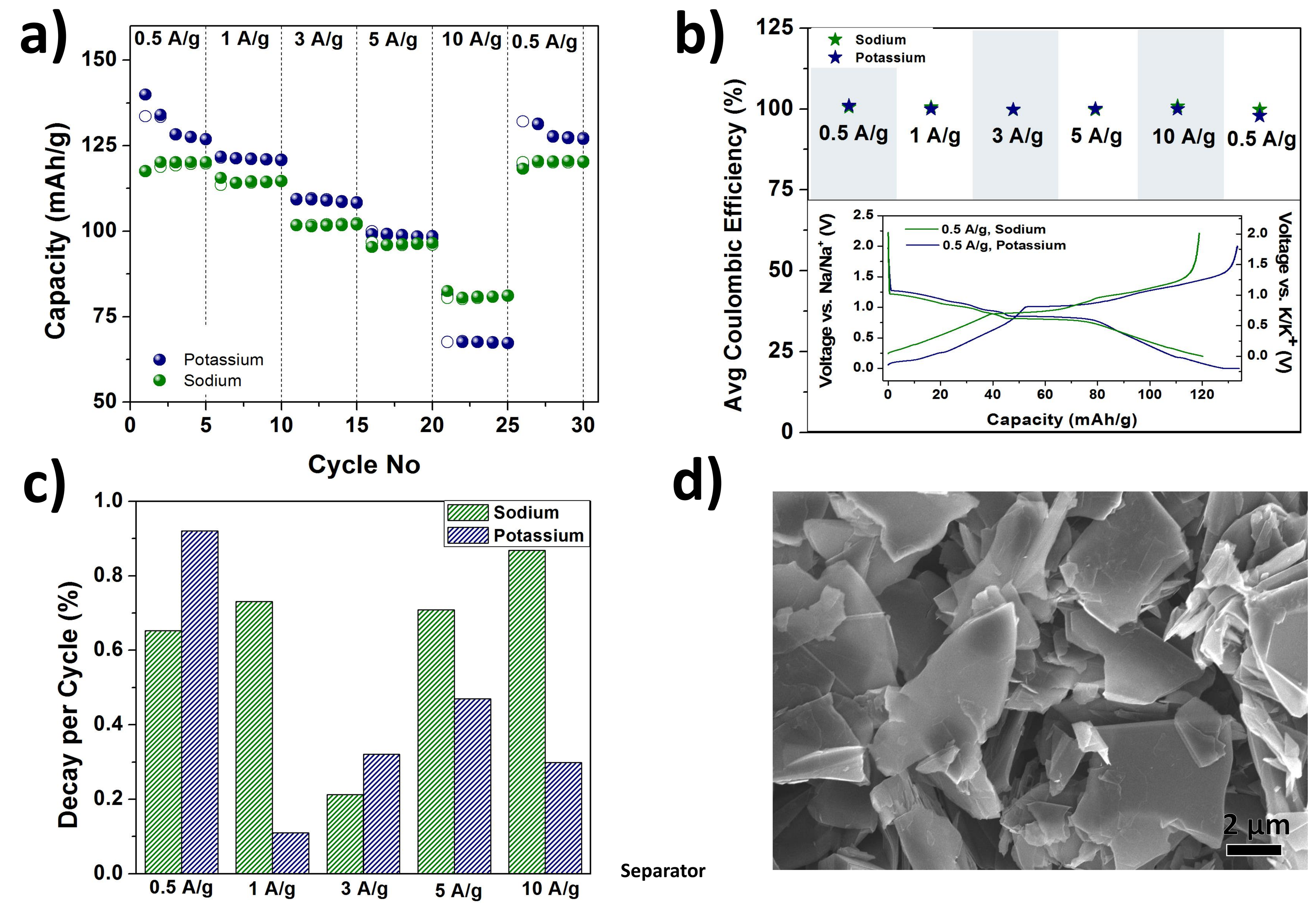


Figure 3. (a) Rate study of alternative ion co-intercalation into graphite (b) cyclic coulombic efficiency and charge-discharge curves (c) decay per cycle (d) graphite structure and SEM image

Potassium and Sodium both display capacities of >100mAh/g in under 2 minutes with coulombic efficiency of >99% and <1% average decay per cycle

A High Rate Cathode

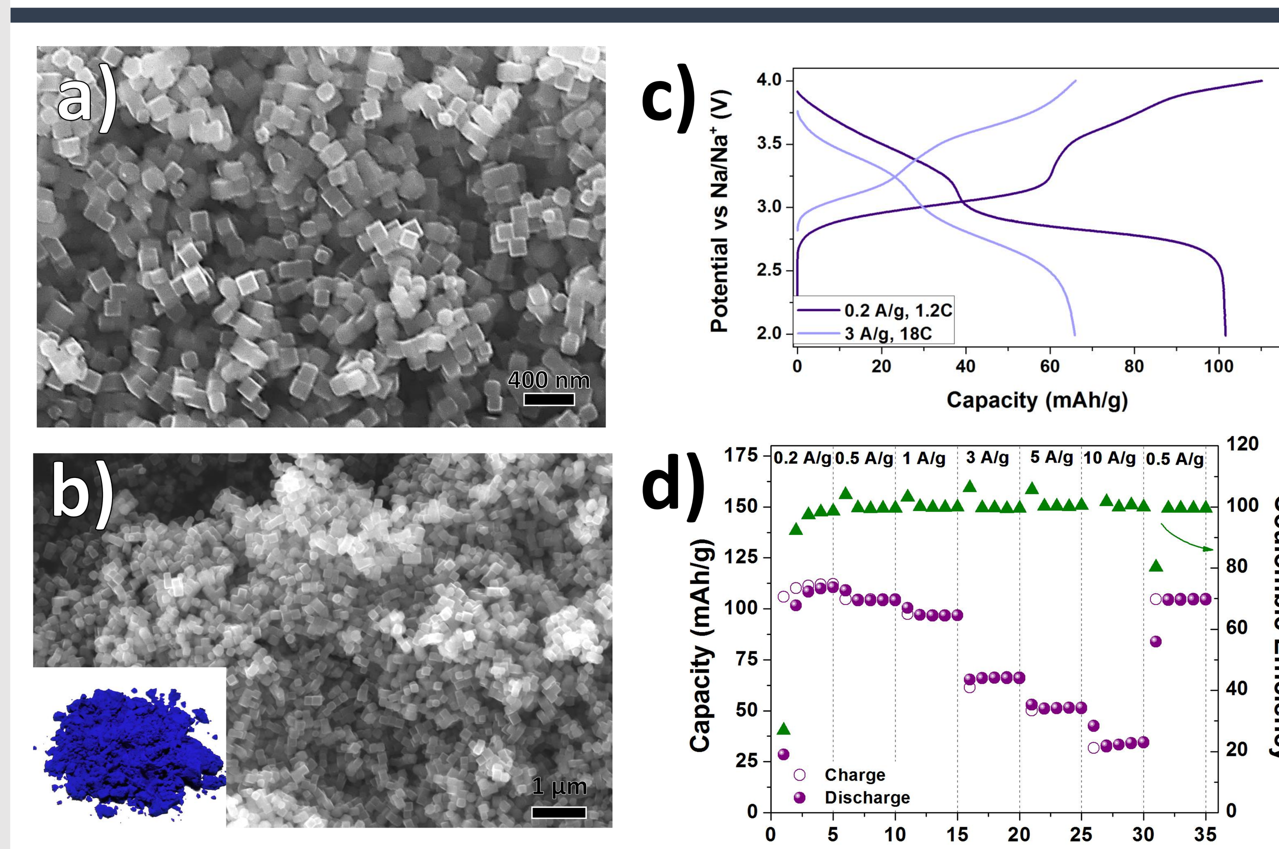


Figure 4. (a,b) SEM images of Sodiated Prussian Blue nanocrystals, (c) charge-discharge curves of cathode at varied rates (d) rate study of Prussian Blue

Sodiated Prussian Blue nanocrystals

1. **Non-Toxic**-in fact, it appears on the World Health Organization's list of essential medicines
2. **High Capacity**- theoretical capacity of 170 mAh/g
3. **High-Rate Capacity Retention-** exhibits capacities of ~100 mAh/g at 7C

Conclusions

- Alternative-ion graphite co-intercalation enables **charge >100 mAh/g in less than 2 minutes**
- Sodiated Prussian Blue exhibits **discharge >95 mAh/g in less than 5 minutes**
- A full device based on the co-intercalation phenomenon is designed to meet requirements for implementation in electric vehicles

	Super-Capacitors	Modern Batteries	Alternative-ion Co-Intercalation Devices
Low Cost	✓		✓
High Power	✓		✓
Energy Storage		✓	✓
Low Weight		✓	✓

Figure 5. Qualitative comparison of most common energy storage devices versus designed performance of full cell alternative ion co-intercalation devices

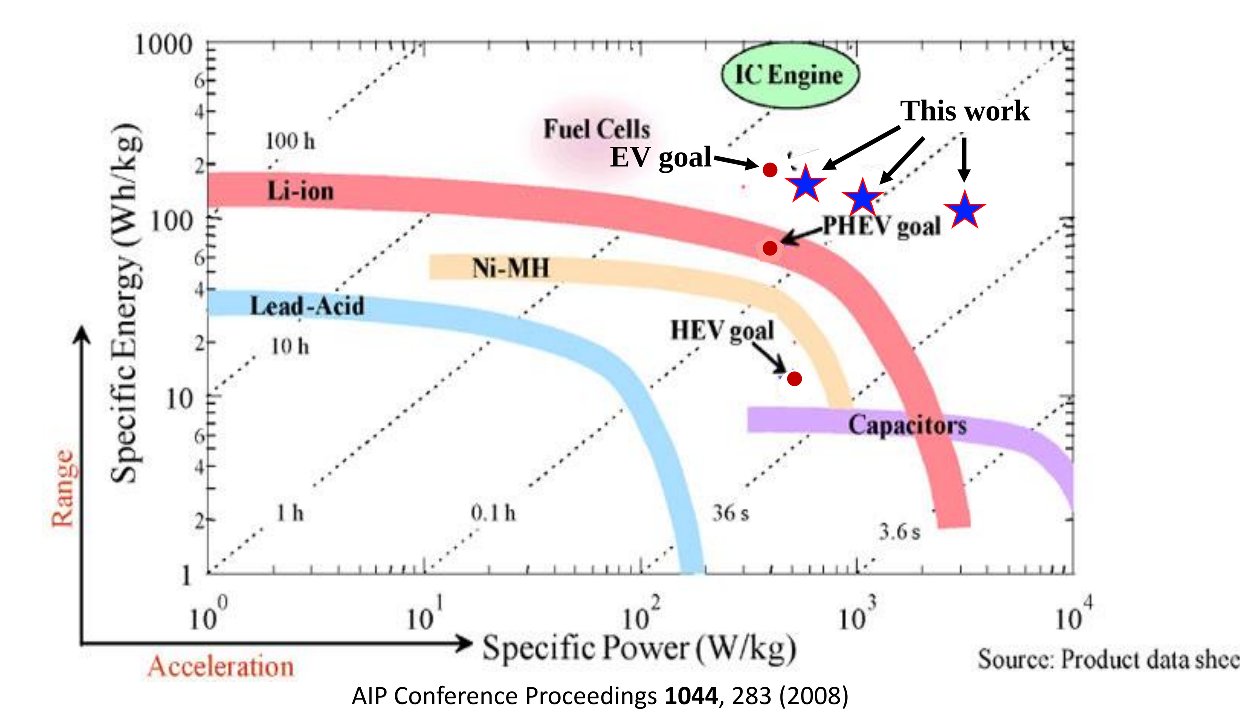
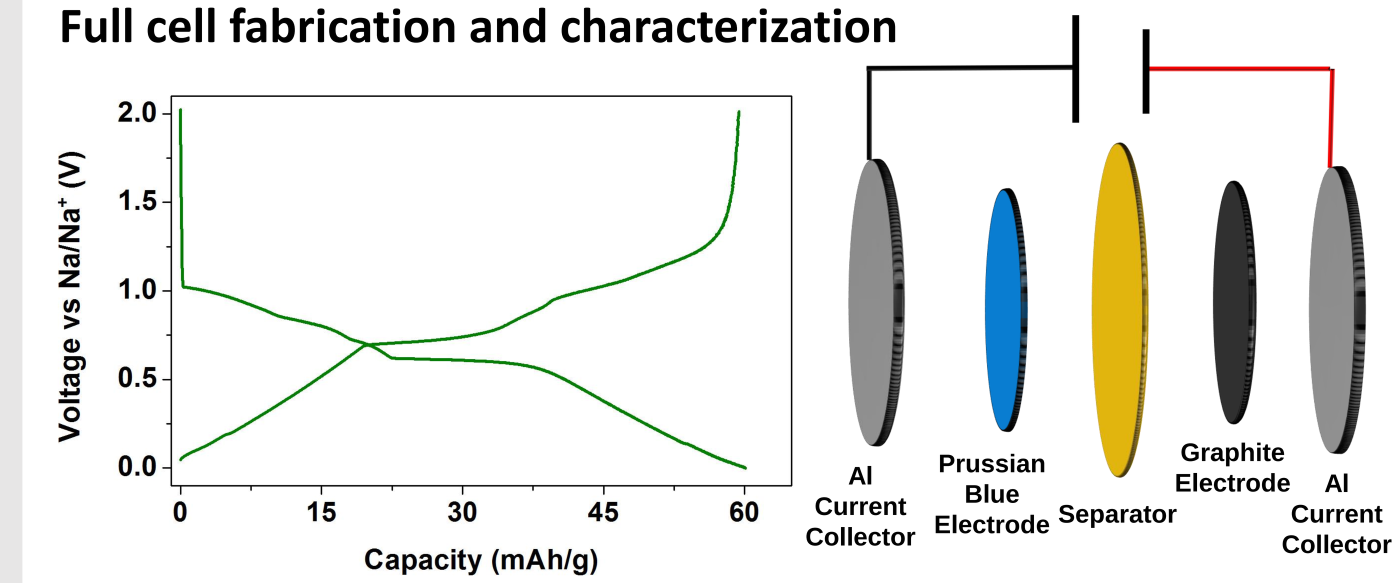


Figure 6. Ragone plot of modern energy storage methods, designed performance of this work, and the demands of emerging vehicle markets

Future Work

Full cell fabrication and characterization



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