Advances and Challenges with Rechargeable Lithium-Air Batteries

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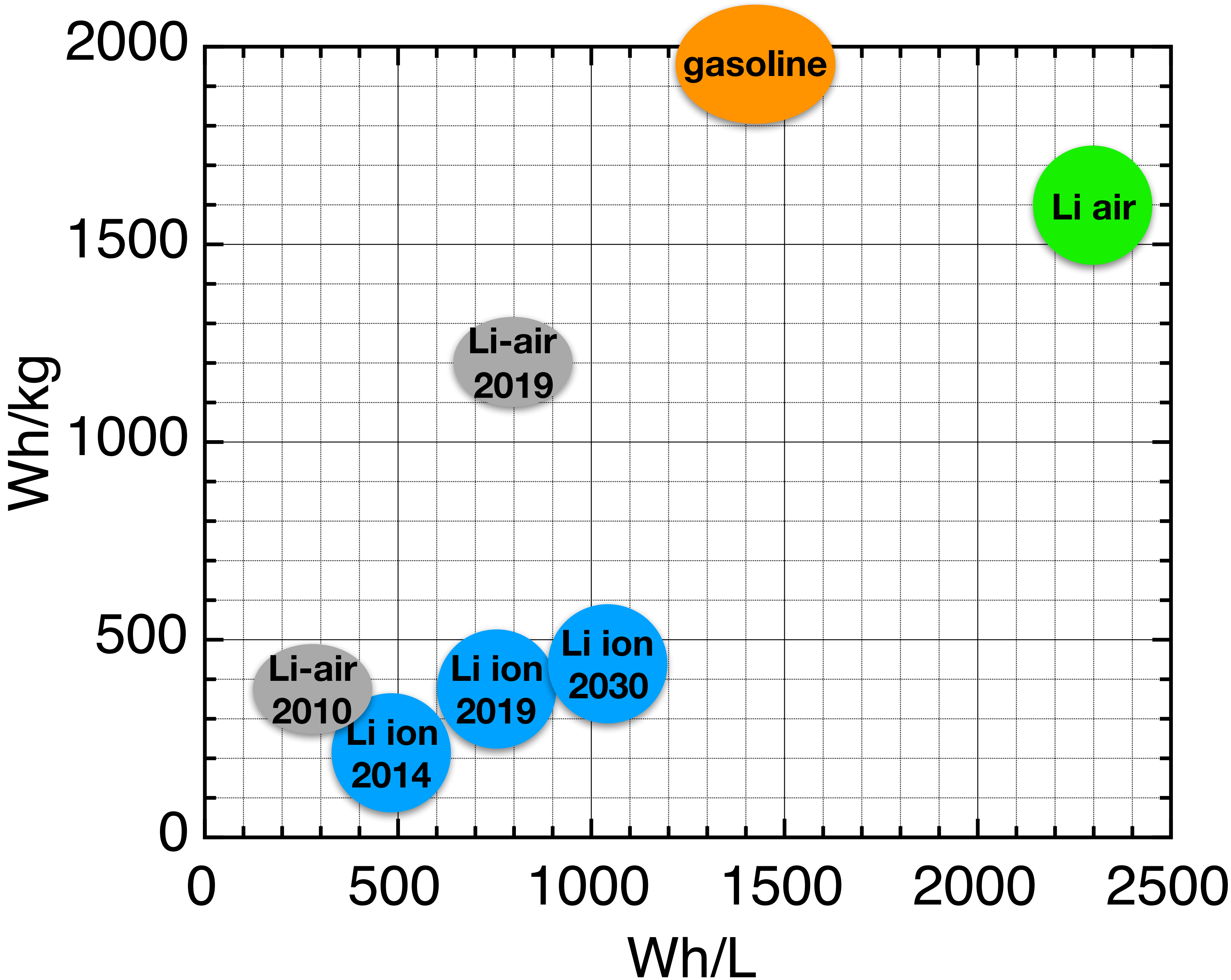
What do we want from a battery?

	energy,	power,	cycles,	safety
Li-ion	✓	✓	1000	✓
Li-air	✓	✓	< 50	✓



Source: Li-ion: Volkswagen, Li-air: 2010: PNNL, 2019: Samsung lab prototype, mature Li-air and gasoline,;own work

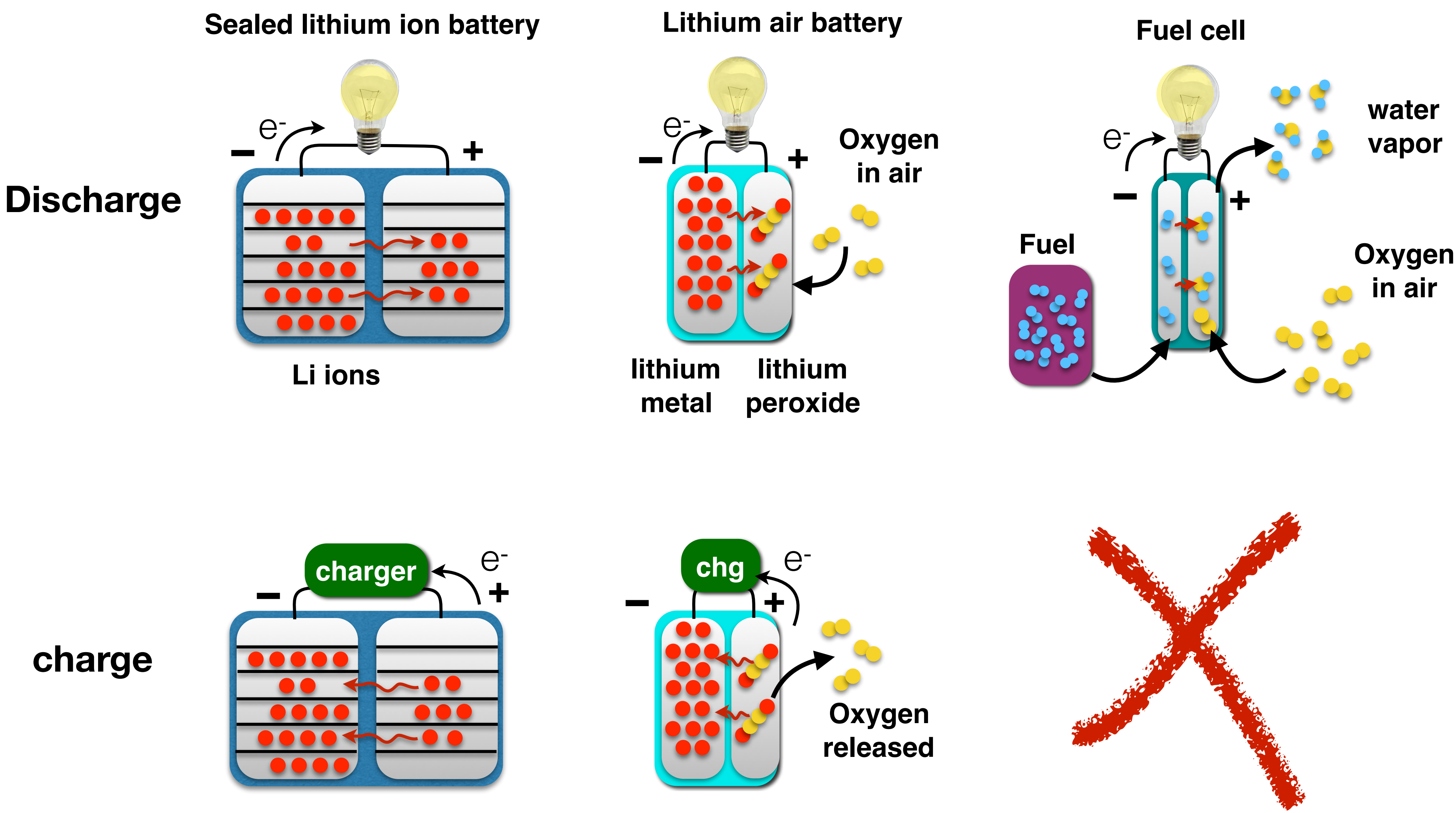
Doing less with more

Lithium air doesn't need any cobalt, rare or conflict materials.

Outline

- Similarities and differences between Li-ion, Li-air and fuel cells.
- Details of Li-air batteries
- Challenges in bringing Li-air to commercialization
- Successes in bringing this technology closer to market.

Li ion, Li air, fuel cell

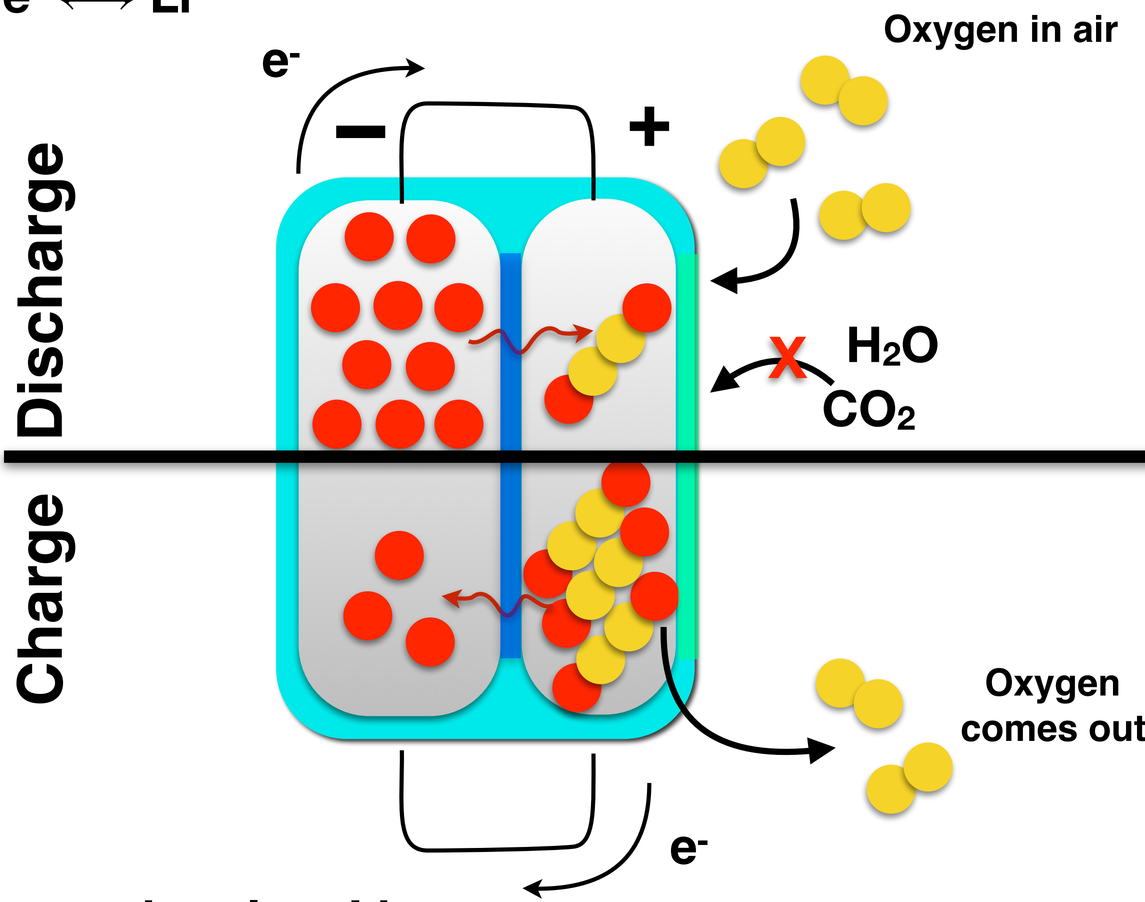


Rechargeable lithium air batteries- basic science

$O_2 + 2\,Li^+ + 2e^- \longleftrightarrow Li_2O_2$

$E°$ 3.6V vs Li^+/Li

$Li^+ + e^- \longleftrightarrow Li$



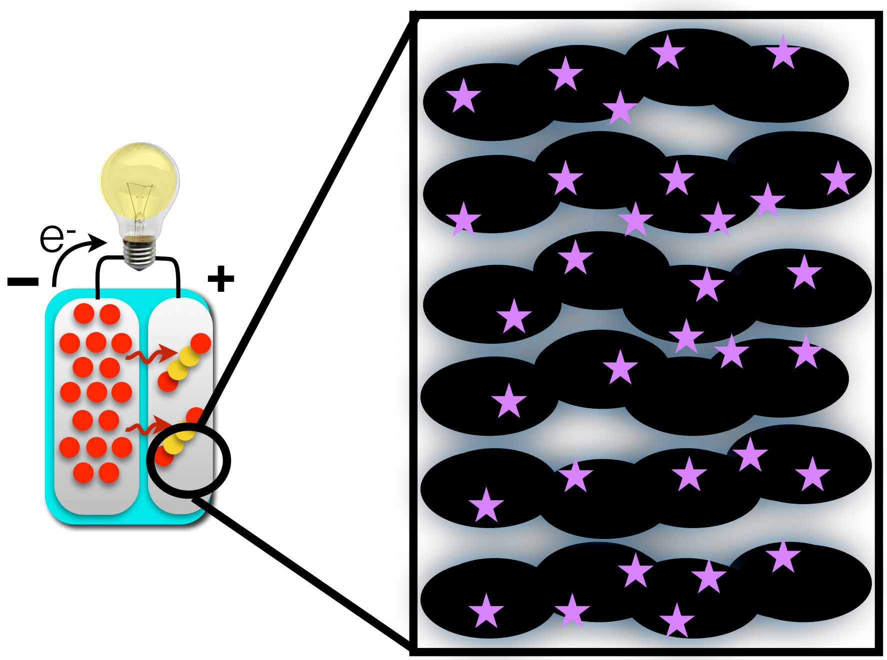
Oxygen reduction improved with catalyst, cell potential ~2.2V

Oxidize Li_2O_2 -
***don't oxidize anything else*.**

Li electrode- plate Li, avoid dendrites

Electrolyte can be aprotic/organic, solid or both

Details of the air electrode: land/sea/air



- Land: porous, conductive electrode with catalyst particles
- Sea: electrolyte to catalyst sites (wet but not flooded)
- Air: gas access to catalyst sites throughout the volume of the electrode

The ideal gas diffusion electrode has a triple point of gas, electronic and ionic access throughout its volume

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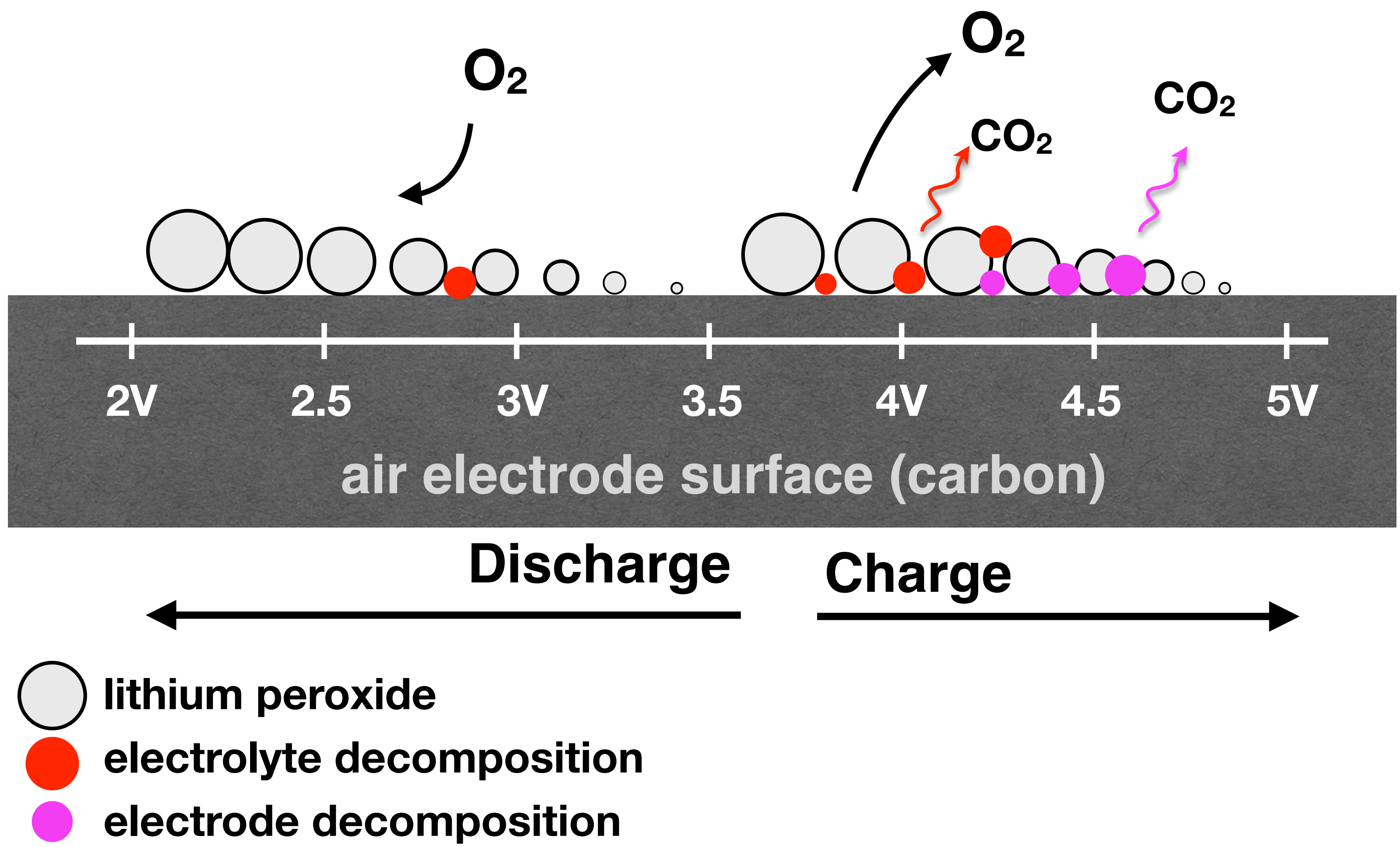
Air electrode reactions



Graphite catalyzes unwanted side reactions

Adapted from Bruce et. al., dx.doi.org/10.1021/ja310258x

Li-air: historical challenges

- Li metal electrodes are a challenge in any system.
- Fuel cell gas diffusion electrodes? Tried and true.
- Li-air gas diffusion electrodes? Brave new world.
- Exclusion of carbon dioxide and water vapor.

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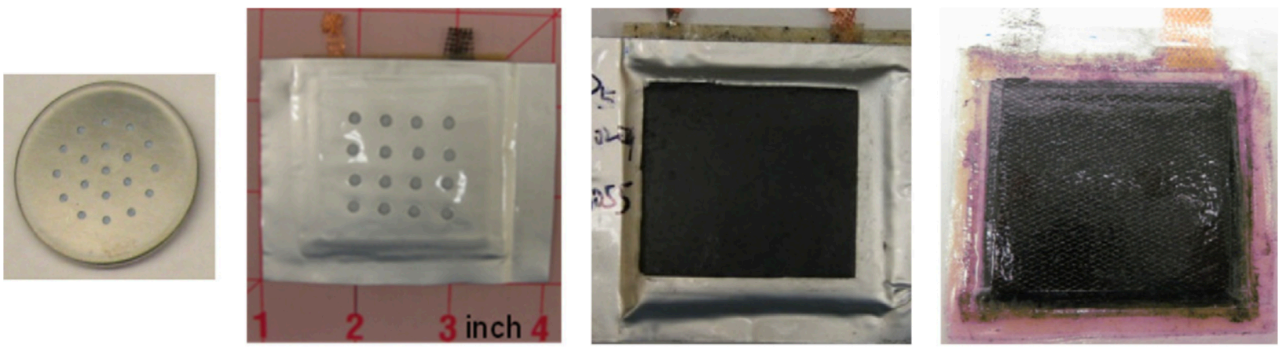
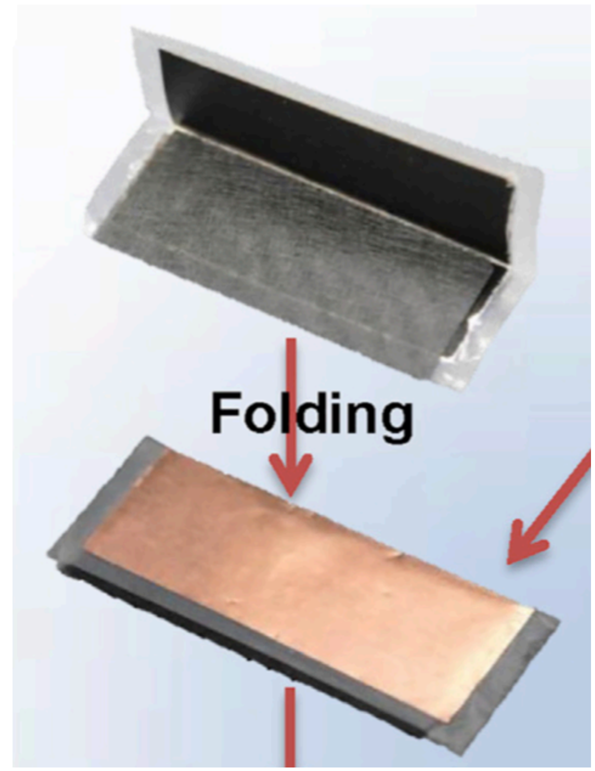
Towards a complete device

- fail early, fail often
- cut down on excess cell materials



Pacific Northwest National Laboratory (2010)

Zhang et. al., doi:10.1016/j.jpowsour.2010.01.022



800Wh/L, 1200 Wh/kg

Samsung

Lee et al., High-Energy-Density Li-O_2 Battery at Cell Scale with Folded Cell Structure, Joule (2018), https:// doi.org/10.1016/j.joule.2018.11.016

Not so fast!

- Li-air recharge chews up electrodes, solvents, electrolytes
- Some organics, solid electrolytes are OK
- Carbon black, CNTs, graphene electrodes don’t work
- Noble metals, carbides don’t stop side reactions

“It also requires the development of new materials that allow us to leverage desirable reactions and minimize or avoid undesirable ones…”

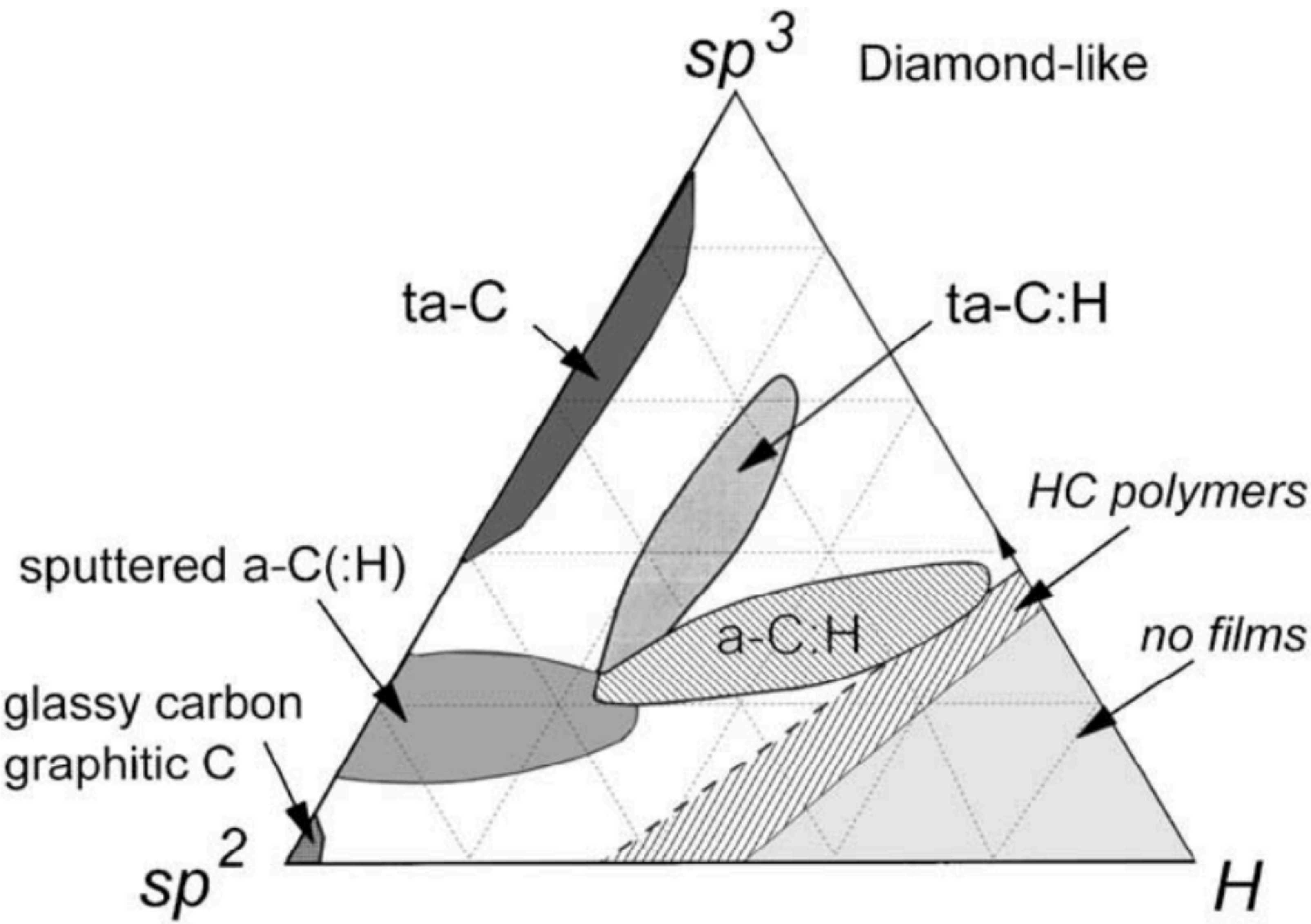
- Reuben Maciel Filho, director, New Energy Innovation Center, São Paulo, Brazil

Robust carbon

- Doped diamond-like carbon- (DLC)
- unparalleled electrochemical durability
- used for electrochemical generation of ozone and fluorine
- low catalytic activity- stays out of the way

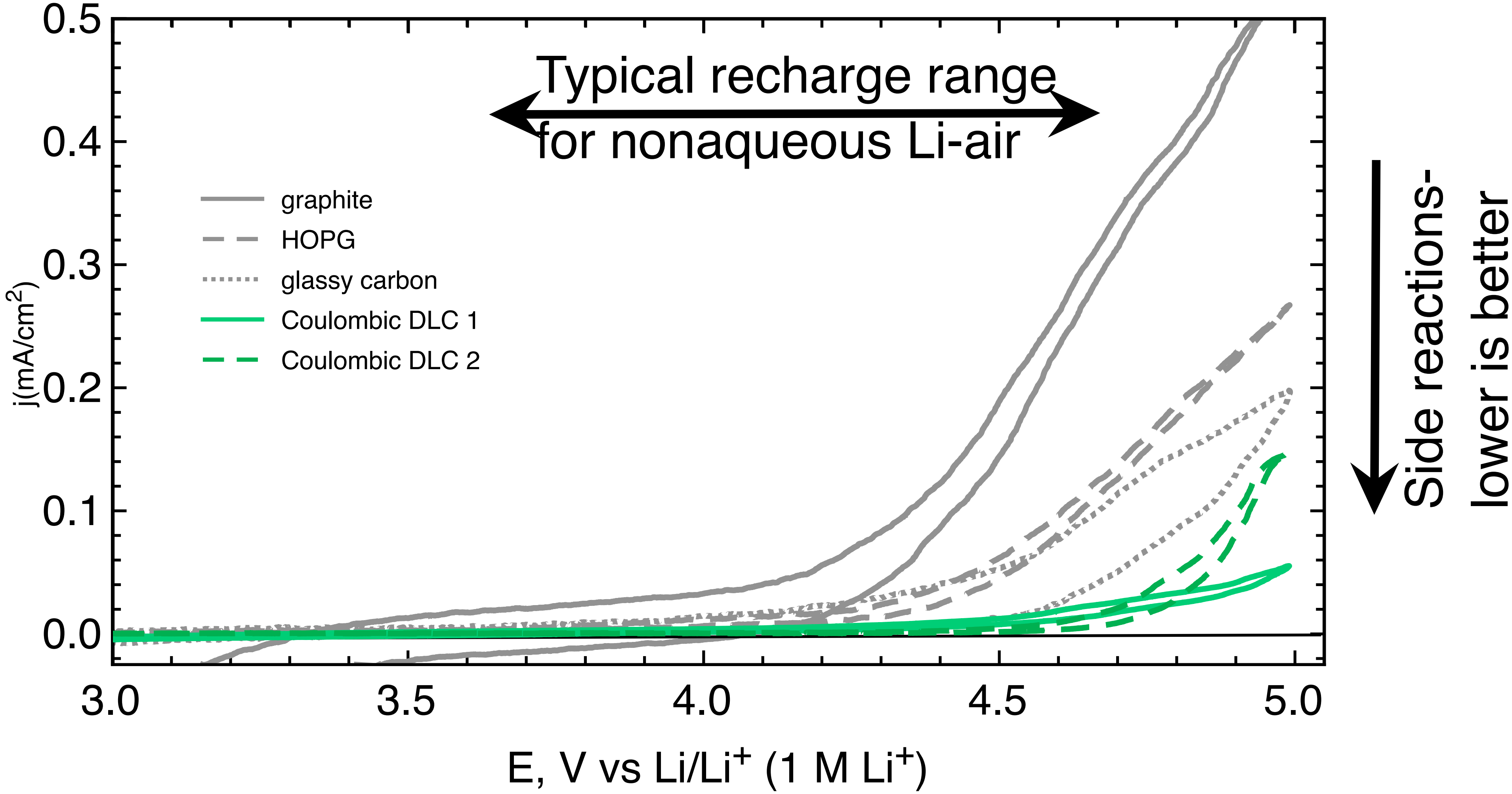
Coulombic's-
US Patent 9,831,503

DLC- many types



from J. Robertson, Materials Science and Engineering R 37 (2002) 129-281

DLC inhibits parasitic reactions



Cyclic voltammograms, 1M $LiNO_3$, TEGDME in dry air, 24C. Scan rate 10 mV/s

In summary

- The pieces for Li-air are coming together
- It’s not easy, but it’s quite possible
- More reasons to be optimistic now than ever

Thank you

Questions?