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DESIGN OF ORGANIC MATERIALS FOR ELECTROCHEMICAL ENERGY STORAGE

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ORGANIC MATERIALS FOR ELECTROCHEMICAL ENERGY STORAGE

-XVW VR HDV\ Z
KHOS RI \
WRROV RQH FDQ
ZKLWHUUUD
%5($'LQWR D
752//(<%8ž6

%87 :+$7)25"

Electrochemical power sources: formal requirements

$$\nu_1 Red_1 + \nu_2 Ox_2 \rightarrow \nu_1 Ox_1 + \nu_2 Red_2, \quad \Delta G^0$$

$$\nu_1 Red_1 - ne^- \rightarrow \nu_1 Ox_1 \qquad \nu_2 Ox_2 + ne^- \rightarrow \nu_2 Red_2$$

$$E = \frac{\Delta G}{nF}$$

Formal: any redox pair

Limitation:

1) Fundamental (kinetics, reversibility, reliability)

2) Practical (Cycle and shell life, Form factor)

Numbers:

Cell:

Energy density $W_{max} = nFU/m$ or $W_{max} = nFU/V$

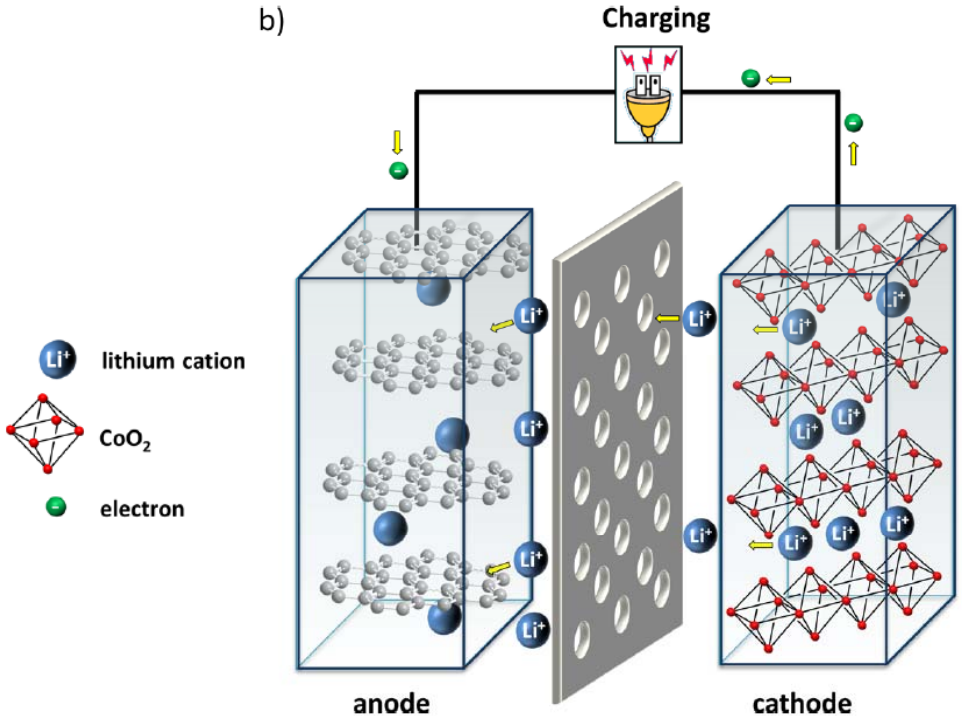
Power density $P = UI/m$ or $P = UI/V$

Electrode:

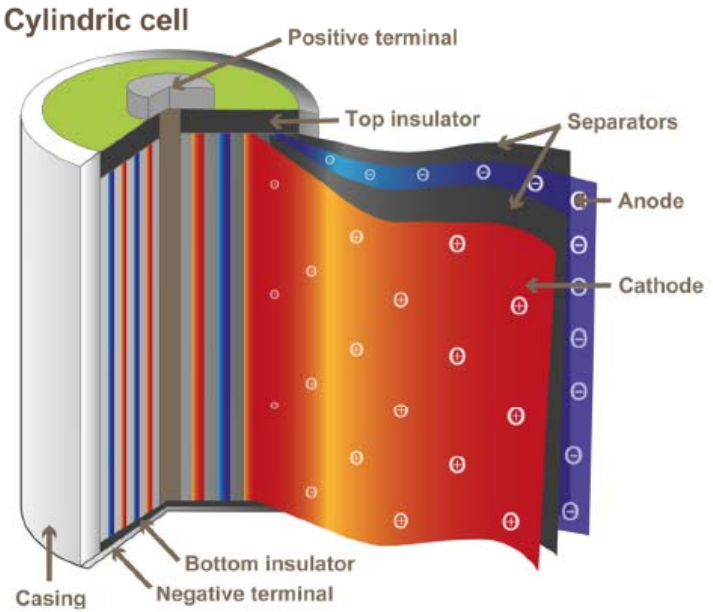
Capacity $Q_{max} = nF/m$

EMF $E = \Delta G/nF$

Current status

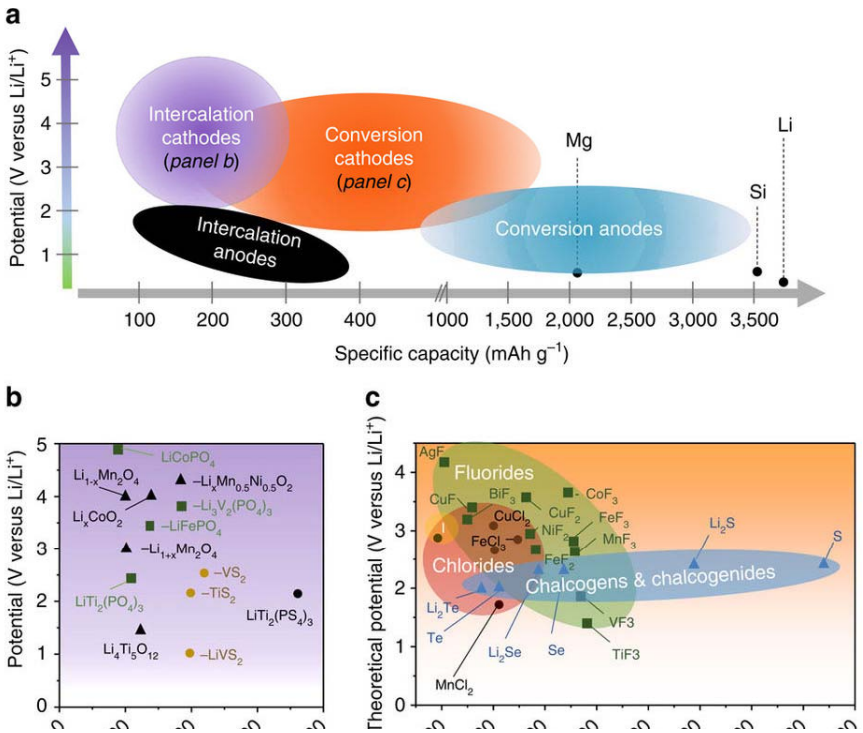


Metal ion battery: low electrolyte content → W!



Current status

Ragone chart for capacitors, supercapacitors, batteries and fuel cells

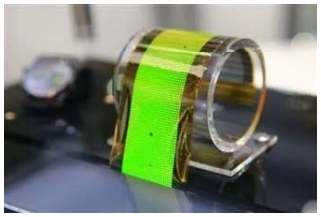


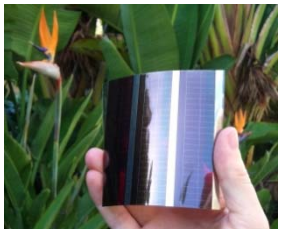
Sensors 2008, 8(12), 8037-8066; doi:10.3390/s8128037

Nature Communications **7**, Article number: 12647 (2016)

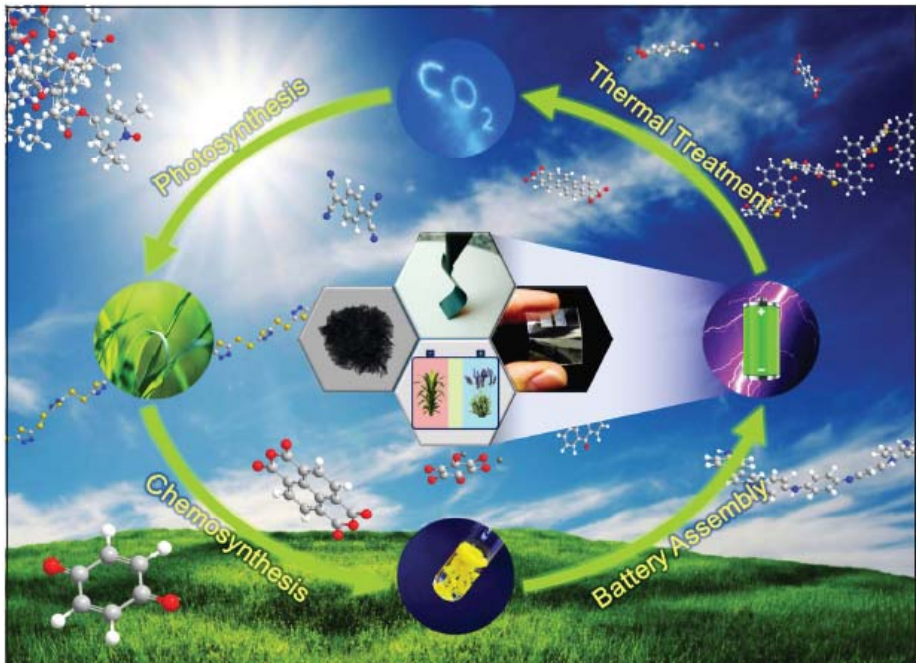
Technology trends

- Inorganic W Organic
  - steel W plastic
  - LED W OLED
  - Si W DSSC, Organic PV
- Batteries?





Organic material advantages



- Ltght weight, flexible, thin film processable
- Less energy consuming wet fabrication process
- Less limited organic resources
- Easy disposability. Burnable away without toxic gas and ash formation
- Less toxic, no ignition non fuming ..... Safe & environmentally benign

Song & Zhou, Energy Environ. Sci., 2013, 6, 2280.

BATTERIES – PRESENT AND FUTURE CHALLENGES

Emerging battery technologies towards 2025

Helena Berg, AB Libergreen
Aleksandar Matic, Chalmers
Patrik Johansson, Chalmers

Goteborg, May 2015.

Table 7. Cost trend estimates (cost/storage capacity) for emerging battery technologies, compared to the improved Li-ion technology (- refers to relative cost reduction, + refers to relative cost increase).

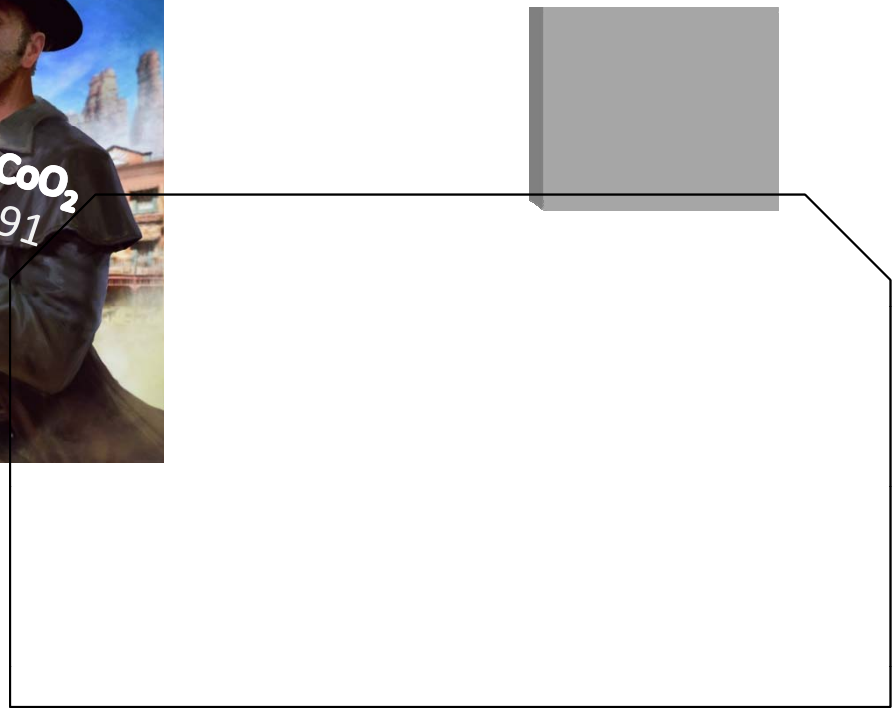
Technology	Cost – cell	Cost – pack*	Cost driver
Solid Li-metal	- 8%	- 6%	Anode cost 1/3 of Li-ion, no Cu used
Na-ion	- 13%	- 10%	20% lower cell material cost
Mg	± 10%	+ 75%	Low cell voltage
Li-S	- 40%	> 100%	Low-cost raw materials. High pack cost due to low cell voltage and poor rate capabilities
Li-O_2	± 0%	+ 250%	Low electrode cost, high electrolyte cost, low cell voltage and poor rate capabilities, extra components for air/oxygen handling not included.
Organic	- 50%	- 35%	Low cell voltage
Asymmetric super capacitors**	± 0%	± 0%	High rate capabilities, low energy density

*The same cost for electronics, control, and management are assumed for all technologies. **HEV application only.

ɔrgotten ?

State of art Li-ion 2032 cell

Feature	LIR2032 battery can maintain 80% capacity after 500 cycles
Model	LIR2032
Nominal Voltage	3.6V
Nominal Capacity	40mAh
Max discharge current	12mA
Max pulse discharge current	75mA
Dimensions(Dia x H)	20mm (0.8") x 3.2mm(0.1")
Weight	3.1 grams (0.1Oz)



J.S. Miller, Advanced Materials, 5 (1993) 671 676
T. Matsunaga, H. Daifuku, T. Nakajima, T. Kawagoe, Polymers for Advanced Technologies, 1 (1990) 33 39

Charge balance in organic electrode materials

One-electron oxidation

$$M \underset{+e^-}{\overset{-e^-}{\rightleftharpoons}} M^{\bullet+}$$

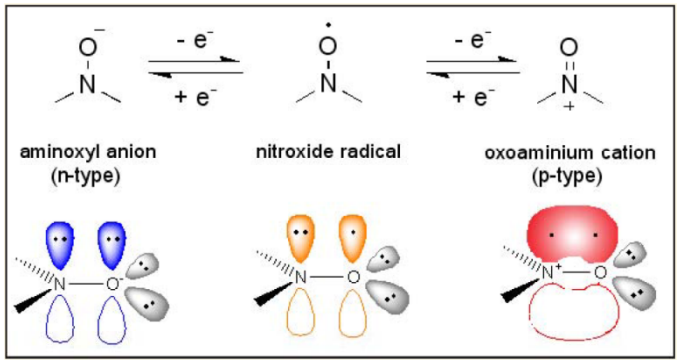
$$M^{-} \underset{+e^-}{\overset{-e^-}{\rightleftharpoons}} M^{\bullet}$$

One-electron reduction

$$M \underset{-e^-}{\overset{+e^-}{\rightleftharpoons}} M^{\bullet-}$$

$$M^{+} \underset{-e^-}{\overset{+e^-}{\rightleftharpoons}} M^{\bullet}$$

Example:



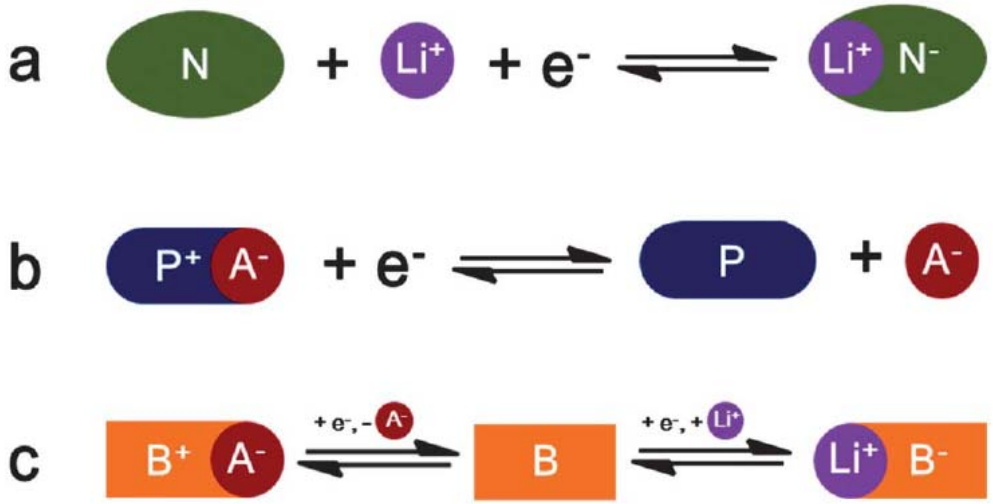
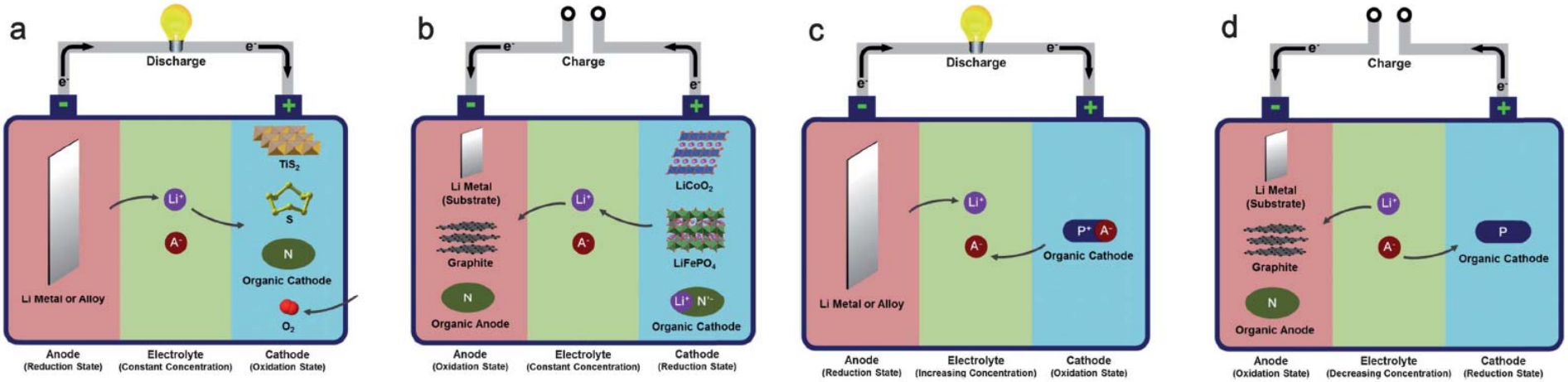


Fig. 1 The redox reaction of three types of electroactive organics: (a) n-type; (b) p-type; (c) bipolar. A^- means anion of the electrolyte and Li^+ can be replaced by other alkali ions.

Energy Environ. Sci., 2013, 6, 2280–2301

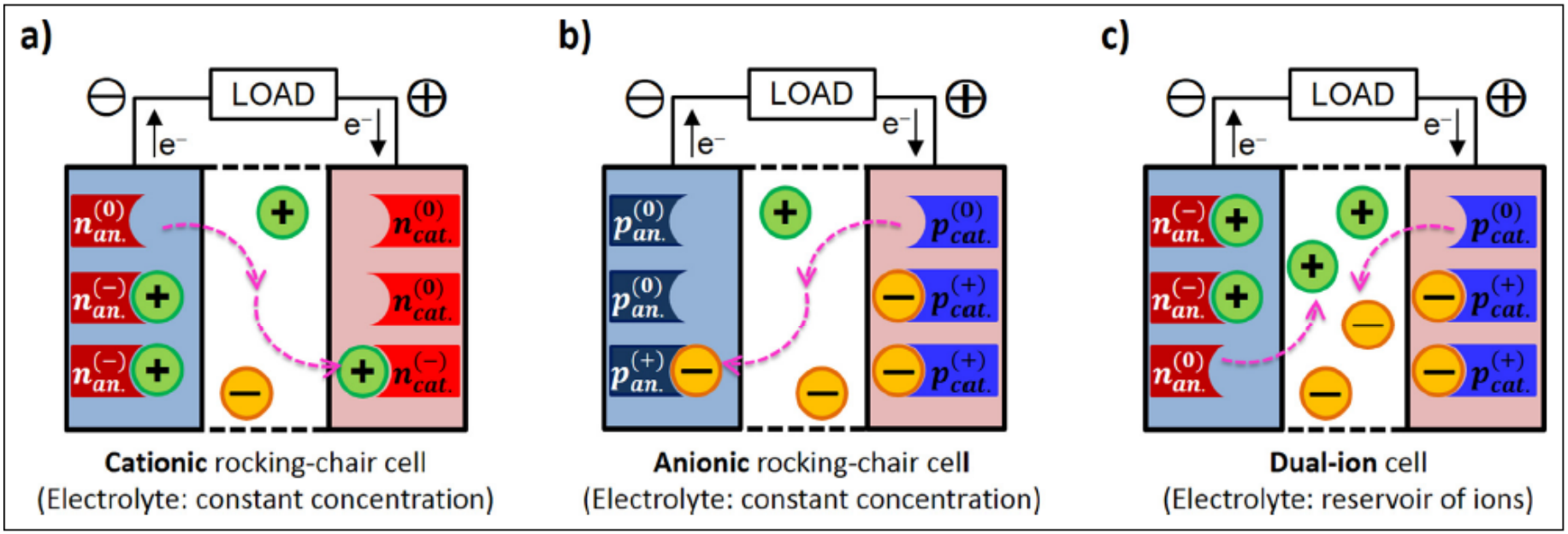
Cell configurations



- Cathode and anode balance
- Attention to initial states of electrodes
- Attention to doping mechanisms

Energy Environ. Sci., 2013, 6, 2280–2301

Organic materials – no selectivity to metal ion



Indeed, the shuttling ion can be either protons or ammonium type cations but also anions.

Current Opinion in Electrochemistry 2018, 9 :70–80

Remarkable example: Rocking chair Li ion cell

Zhao, Q., Wang, J., Chen, C. et al. Nano Res. (2017) 10: 4245. https://doi.org/10.1007/s12274-017-1580-9