Sulfur-Graphene Oxide Nanocomposite Electrodes for Next-Generation Lithium/Sulfur Batteries

Min-Kyu Song[1,3], David N. Fronczek[2], Caiyun Nan[2], Zhan Lin[2], Seong E. Choi[3], Yuegang Zhang[1] and Elton J. Cairns[2,3]

[1] The Molecular Foundry, Lawrence Berkeley National Laboratory

[2] Environmental Energy Technology Division, Lawrence Berkeley National Laboratory

[3] Department of Chemical and Biomolecular Engineering, University of California, Berkeley

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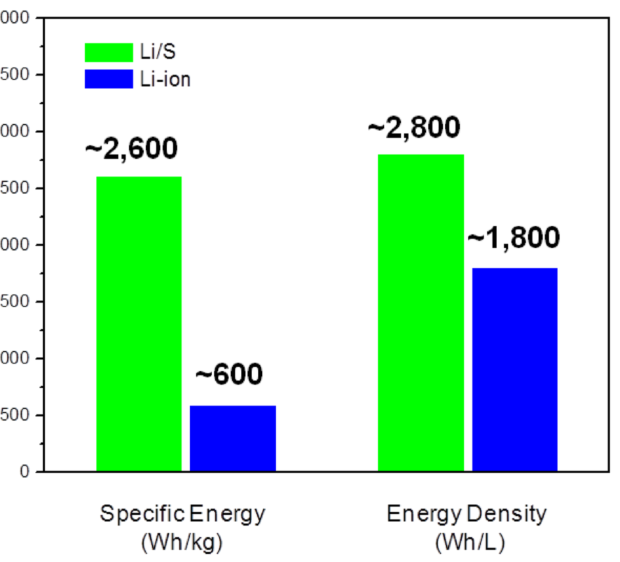
Introduction

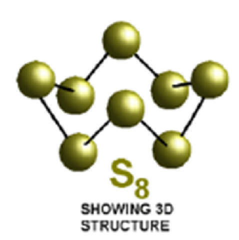
1 Why Lithium-Sulfur batteries?



- High theoretical specific energy : Advanced Li/S batteries could provide >300 mile range for electric vehicles.
- Low cost
- Abundance of sulfur on earth
- Environmentally benign

$S + 2Li^+ + 2e^- \leftrightarrow Li_2S$

2 electron reaction



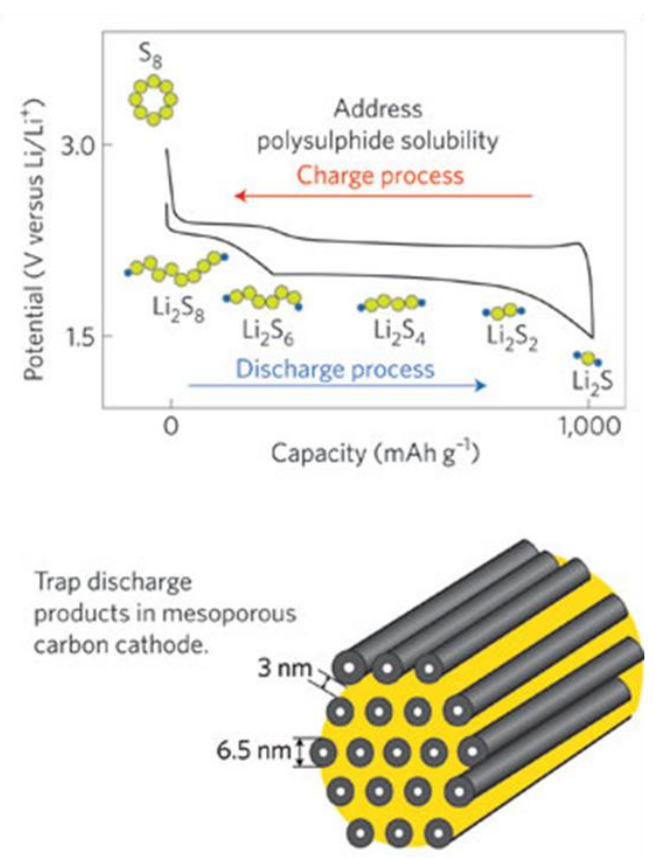
Theoretical specific capacity: 1,675 mAh/g

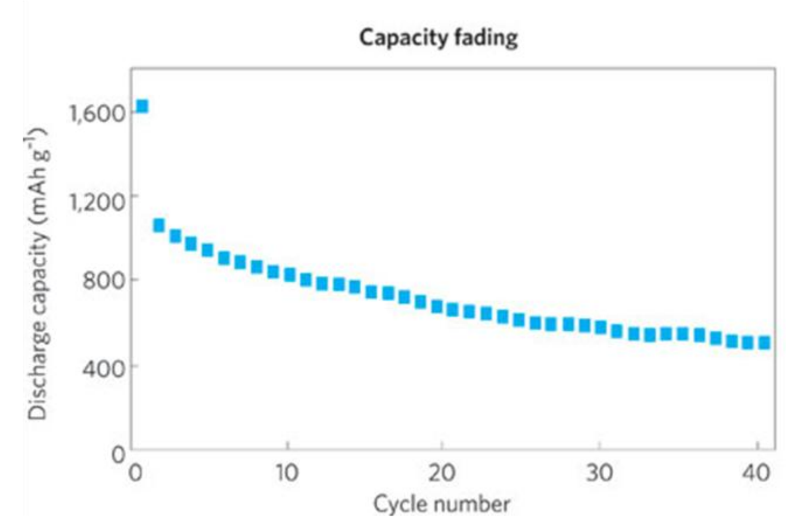
Capacities of current cathodes: 130 ~200 mAh/g (e.g. $LiCoO_2$)

M.-K. Song et al, Nanoscale, 2013, 5, 2186-2204

The Lithium/Sulfur battery could provide up to 4 times the specific energy of current lithium-ion batteries.

2 Critical challenges of sulfur cathodes





"Physical Absorption Approach"

P. Bruce et al, Nature Materials, 2012, 11, 19-29

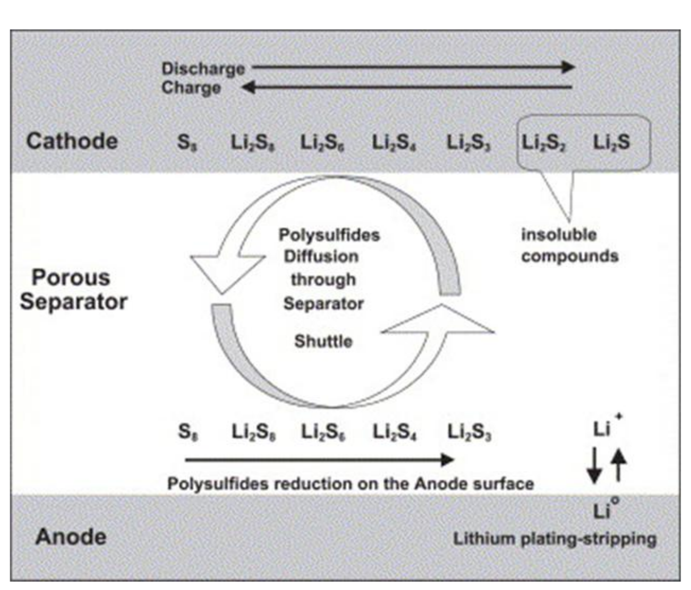
3 Factors limiting the performance of Li/S cells

(1) Loss of Sulfur: Formation/dissolution of lithium polysulfide

(2) Polysulfide shuttle between negative and positive electrodes during cycling

(3) Mechanical degradation by volume change (~76%) of the sulfur electrode during cycling

(4) Insulating nature of S and discharged product, Li_2S

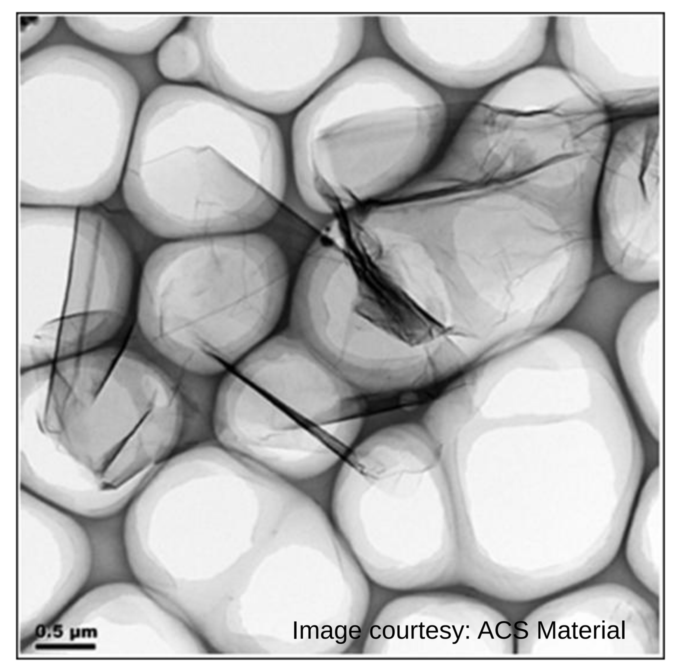


Cycle life is controlled by coupled 'chemical' and 'mechanical' degradation!

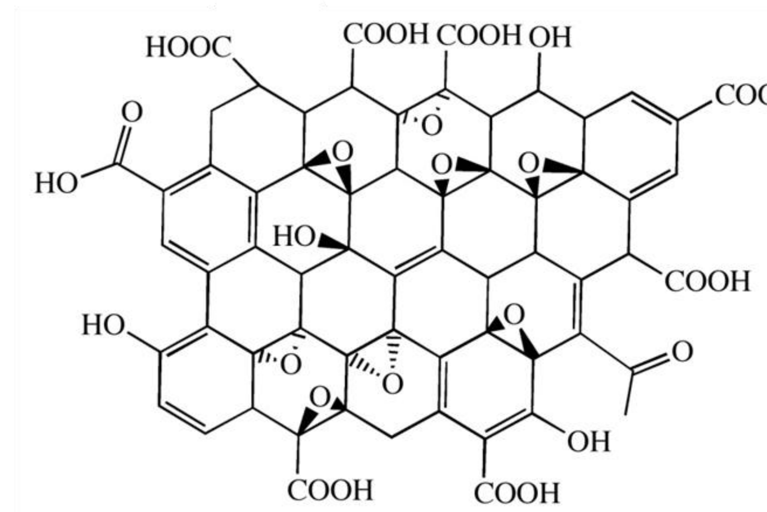
Results & Discussion

1 Graphene oxide (GO) as a sulfur immobilizer

Synthesis of Graphene Oxide: modified Hummer's method

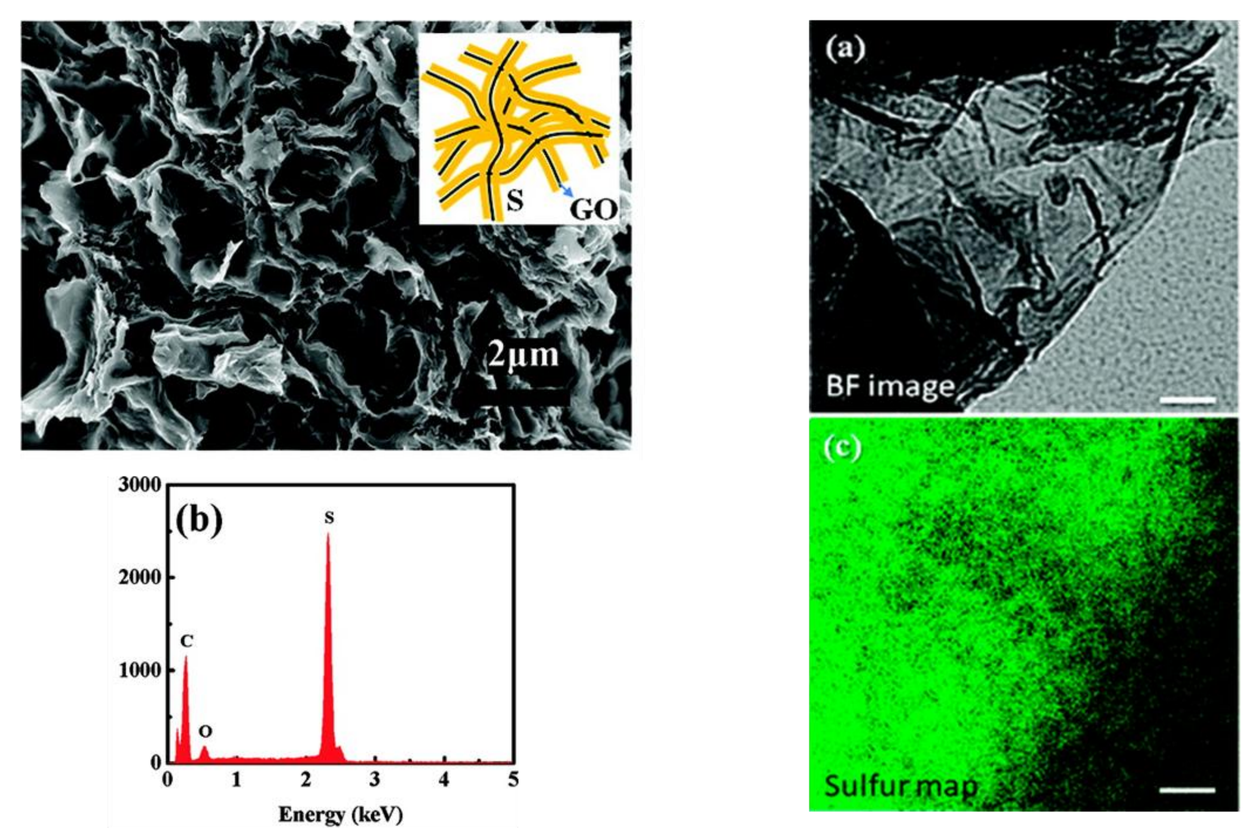


Chemical Approach



C 1s and O 1S XPS spectra showed the presence of sp^2 carbon (C=C), hydroxyl (C-OH), epoxide (C-O-C), carbonyl (> C=O) and carboxyl (HO-C=O).

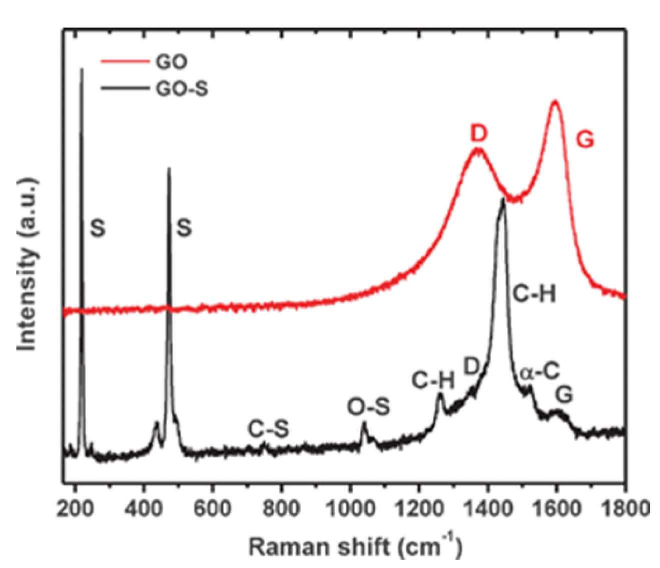
2 Conformal, thin coating of sulfur onto GO



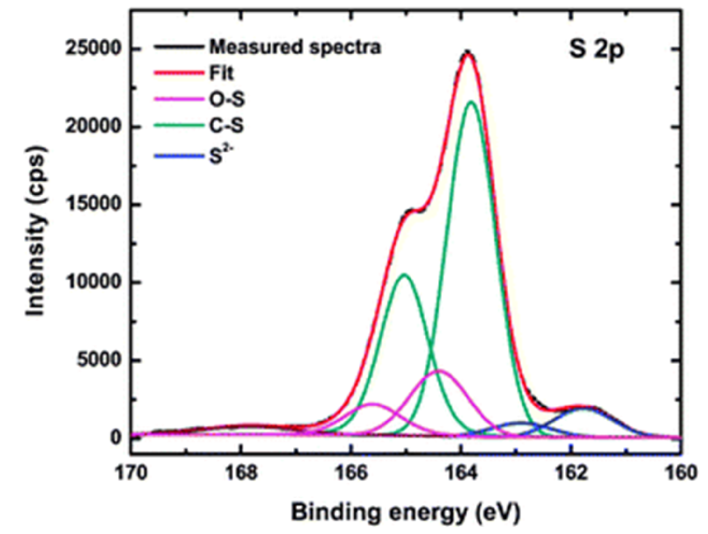
Uniform and thin (around tens of nanometers) sulfur coating on Graphene oxide + heat treatment (155°C x 12h, Ar) process

L. Ji et al, Journal of The American Chemical Society, 2011, 133, 18522-18525

3 Chemical bonding between Sulfur and GO



Raman Spectra of GO and GO-S nanocomposite

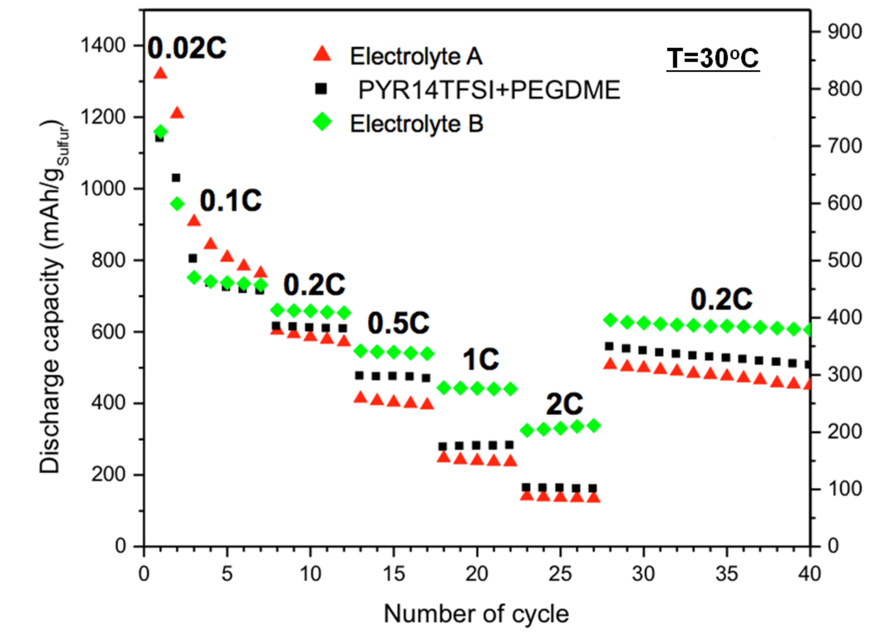


S 2p XPS spectrum of GO-S nanocomposite

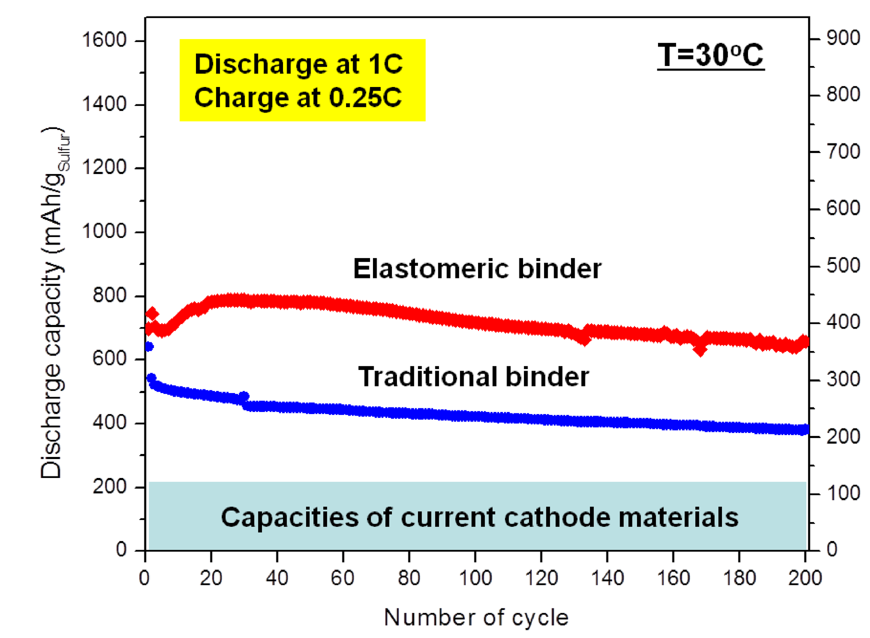
Raman and S 2p XPS showed the existence of chemical bonding between GO and S after coating S onto GO.

L. Zhang et al, Physical Chemistry Chemical Physics, 2012, 14, 13670-13675

4 Excellent rate capability by novel electrolytes

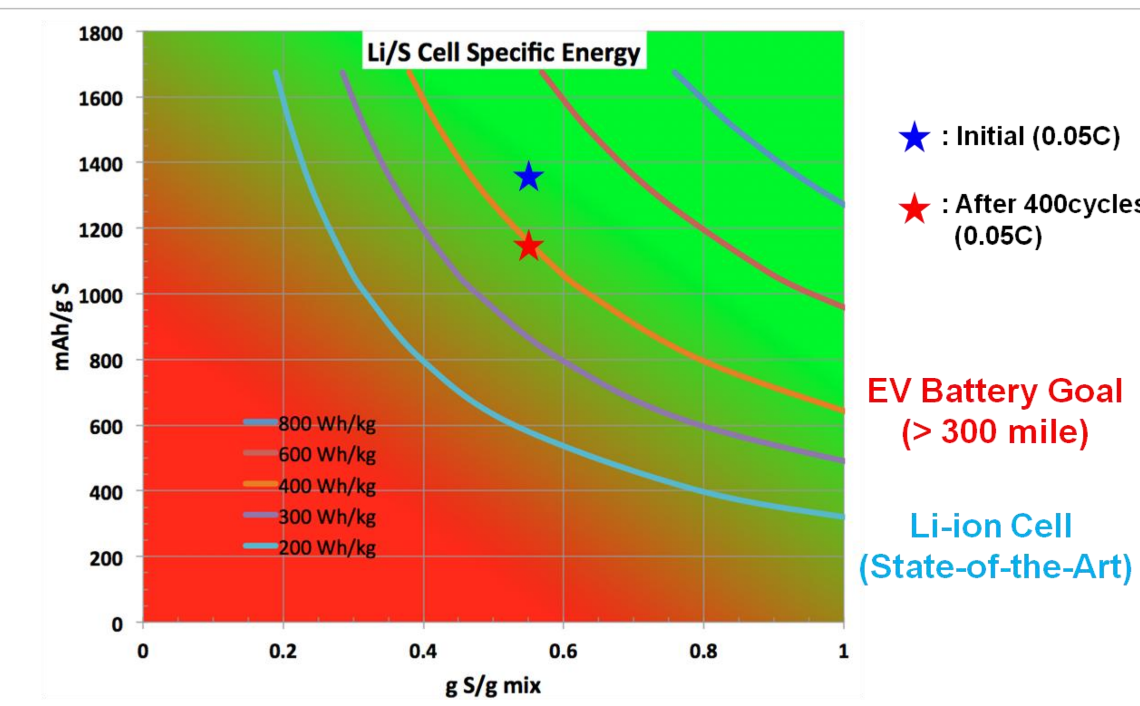


5 Effect of elastomeric binder on cycle life



Elastomeric binders played important roles in withstanding the volume expansion/contraction

6 Estimated cell-level specific energy



Summary

- Demonstrated 400 cycles for a Li/S battery with excellent specific capacity (above 1100 mAh/gS).

- Demonstrated 400 cycles for a Li metal electrode, enabled by the LBNL's safer ionic liquid based electrolyte.

- Novel electrolytes developed at LBNL have good properties for use in Li metal rechargeable cells, and offer safer operation than conventional, more flammable electrolytes.

"The strategy for improving a single component may not be able to address all of the issues that are interlinked."

From "Lithium/sulfur batteries with high specific energy: old challenges and new opportunities," M.-K. Song, E. J. Cairns, Y. Zhang, Nanoscale, 2013, 5, 2186-2204

Acknowledgement

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