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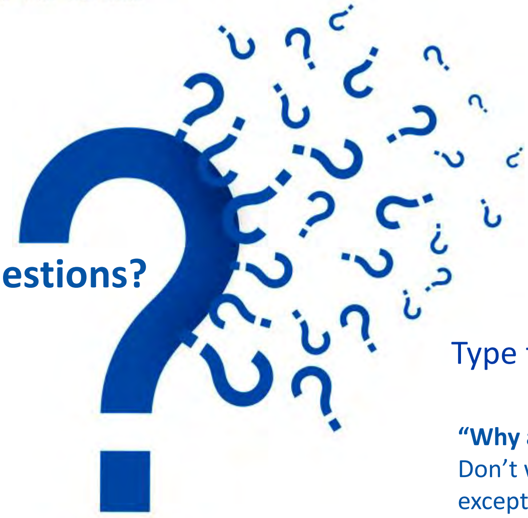

Have Questions?

Type them into questions box!

"Why am I muted?"
Don't worry. Everyone is muted except the presenter and host. Thank you and enjoy the show.

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Learn how to write better abstracts, deliver more engaging presentations, and network to your next dream job. Brush up on your soft skills and set a new career path by mastering what can not be taught in the lab.

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From renewable fuels to creating the materials for the technology of tomorrow, chemistry plays a pivotal role in advancing our world. Meet the chemists that are building a better world and see how their science is making it happen.

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The Drug Design Delivery Series has built a collection of the top minds in the field to explain the mechanics of drug discovery. Discover the latest research, receive an overview on different fields of study, and gain insight on how to possibly overcome your own med chem roadblocks.

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Why does food taste better when it is grilled or what molecular compounds make a great wine? Discover the delectable science of your favorite food and drink and don't forget to come back for a second helping.

Popular Chemistry

▶ View the Collection

Feeling burdened by all that molecular weight? Listen to experts expound on the amazing side of current hot science topics. Discover the chemistry of rockets, how viruses have affected human history, or the molecular breakdown of a hangover.

Business & Entrepreneurship

▶ View the Collection

How do ideas make it from the lab to the real world? Discover the ins and outs of the chemical industry whether you are looking to start a business or desire a priceless industry-wide perspective.

https://www.acs.org/content/acs/en/acs-webinars/videos.html

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Whether you are just starting your journey, transitioning jobs, or looking to brush up or learn new skills, the **ACS Career Navigator** has the resources to point you in the right direction.

We have a collection of career resources to support you during this global pandemic:

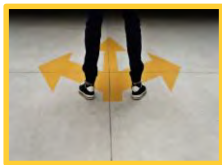

Professional Education


Virtual Career Consultants

ACS Leadership Development System


Career Navigator LIVE!


ChemIDP


College to Career

ACS Webinars

Virtual Classrooms

Visit www.ACS.org/COVID19-Network to learn more!

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Join us in our efforts to increase the diversity of chemistry.

Valued donors like you have sustained ACS educational programs that are welcoming students from diverse backgrounds into our profession.

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ACS Office of Philanthropy
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A Career Planning Tool For Chemical Scientists

ChemIDP is an Individual Development Plan designed specifically for graduate students and postdoctoral scholars in the chemical sciences. Through immersive, self-paced activities, users explore potential careers, determine specific skills needed for success, and develop plans to achieve professional goals. **ChemIDP** tracks user progress and input, providing tips and strategies to complete goals and guide career exploration.

https://chemidp.acs.org

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ACS Bridge Program

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- Resources to help write competitive grad school applications and connect you with mentors, students, and industry partners!

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ACS Department of Diversity Programs

Advancing ACS's Core Value of Diversity, Inclusion & Respect

We believe in the strength of diversity in all its forms, because inclusion of and respect for diverse people, experiences, and ideas lead to superior solutions to world challenges and advances chemistry as a global, multidisciplinary science.

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acsvoices.podbean.com/

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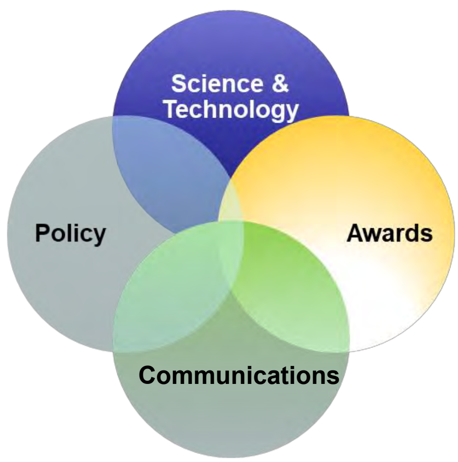
ACS Committee on Science (COMSCI)

"The ACS Committee on Science aims to ***engage the global chemistry enterprise to build a better tomorrow*** by identifying new frontiers of chemistry, examining the scientific basis of, and formulate public policies related to, the chemical sciences, and recognizing outstanding chemical scientists."



https://www.acs.org/content/acs/en/about/governance/committees/science.html

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Date: Wednesday, June 16, 2021 @ 2-3:30pm ET
Speakers: Michael Schulz, Virginia Tech and Emilie Rexeisen, 3M
Moderator: Tomonori Saito of Oak Ridge National Laboratory (ORNL) and the University of Tennessee, Knoxville

Register for Free!

What You Will Learn:

- How antiviral polymers were discovered, how the field has developed and what the future may hold for the field of antiviral materials
- What structural features give a polymer antiviral properties
- How four key aspects contribute to successful decontamination (decontamination efficacy, safety for the wearer, filtration efficiency, and respirator fit)
- How different respirator makes and models use different materials making it essential that each model is tested separately for each method

Co-produced with: ACS Division of Polymer Chemistry

Date: Thursday, June 17, 2021 @ 2-3pm ET
Speaker: Lee Polite, Axion Analytical Labs, Inc.
Moderator: Bryan Tweedy, American Chemical Society

Register for Free!

What You Will Learn:

- How to develop an HPLC method from scratch
- How to cut your analysis time in half, while preserving the quality of the results
- What are all those buttons for on your HPLC

Co-produced with: ACS Professional Education

Date: Wednesday, June 23, 2021 @ 2-3pm ET
Speakers: Carlonda Reilly, Kennametal / Serban Cantacuzene, AirLiquide / Kathleen Shelton, FMC
Moderator: Rebekah Paul, American Chemical Society

Register for Free!

What You Will Learn:

- Lessons learned from three executives' rise to the top
- Insights on how you can succeed in today's changing job market
- Advice for charting your own career in the chemical enterprise

Co-produced with: ACS Industry Member Programs

www.acs.org/acswebinars

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THIS ACS WEBINAR WILL BEGIN SHORTLY...

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ACS Webinars
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ACS Chemistry for Life®

Lithium-ion Batteries: The Road to Sustainable Energy Storage

AMY LUCÍA PRIETO
Professor, Department of Chemistry, Colorado State University and Founder, Prieto Battery, Inc.

H.N. CHENG
President,
American Chemical Society

YOUNG-SHIN JUN
Professor, Depart. of Energy, Environmental & Chemical Engineering, Washington University in St. Louis

Presentation slides are available now! The edited recording will be made available as soon as possible.

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This ACS Webinar is co-produced with the ACS Committee on Science.

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Presidential Theme – Growth, Collaboration and Advocacy

ACS Chemistry for Life®

- **Chemistry is a central science.** A strong and growing global chemistry enterprise is good for the profession and its members
- **Some possible actions:**
  - Innovation, new frontiers, new applications
    - Entrepreneurship, industrial engagement
  - Sustainability and green chemistry
  - International partnership and mutual assistance
  - Collaboration
- **Need continued public and government support**

American Chemical Society 16

New Frontiers and Opportunities for Chemistry

- Chemistry continues to be a productive field, with new or expanded areas where future chemists and chemical engineers can find exciting opportunities
- Chemistry is also becoming multidisciplinary, and many innovations are found at the interfaces of two or more disciplines
- The goal of the Presidential – Committee on Science Webinar Series and Symposium is to highlight some of the major growth and emerging areas of chemistry, to provide the opportunity to meet the foremost leaders in these areas, and to inform our members and students as to the future directions of chemistry
- Thanks are due to Professor Amy Prieto, ACS Committee on Science (particularly Young-Shin Jun, Michael Morello, Martin Kociolek, and Mary Kirchhoff) and the ACS webinar team for their critical role in making these webinars possible.

New Frontiers and Opportunities for Chemistry

ACS New Frontiers Symposium at ACS National Meeting on August 22-24

34 speakers in **9** sessions (all virtual) covering advanced materials, catalysis, nanotechnology, biotechnology, biomedical, electronics, environmental chemistry, advanced food technology, and sustainability.

The first session will start on **Sunday, August 22, at 2:00pm EDT**, and will run continuously until Tuesday, **August 24 at 6:30pm EDT.**

New Frontiers and Opportunities for Chemistry

ACS Chemistry for Life®

ACS **"Frontier Friday"** Webinars in May and June

5/28/2021: **Dr. Zhenan Bao**, Stanford University,
"Skin-Inspired Organic Electronics"

6/11/2021: **Dr. Amy Prieto**, Colorado State University,
"Lithium-ion Batteries: The Road to Sustainable Energy Storage"

6/25/2021: **Sir Fraser Stoddart**, Northwestern University,
"Artificial Molecular Machines: Going from Solution to Surfaces"

Amy Lucía Prieto, Featured Speaker

ACS Chemistry for Life®

- B.S. Williams College, 1996; Ph.D. UC Berkeley, 2001; postdoc Harvard, 2002-2005
- Professor, Chemistry Department, Colorado State University
- Founder, past Chief Executive Officer, and current Chief Technology Officer (6/09 – present), Prieto Battery, Inc., Fort Collins, CO
- Recipients of many awards and recognition, including Fellow of Royal Society of Chemistry (FRSC) (2017), Agnes Fay Morgan Research Award (2014), Presidential Early Career Award (PECASE) (2012), Margaret B. Hazaleus Award (CSU, 2012), Colorado Cleantech Industry Association award for Excellence in Storage Technology Commercialization (2011), ExxonMobil Solid State Chemistry Faculty Fellowship (2011), NSF CAREER award (2010-2015), Best Teacher Award Nominee, CSU Alumni Association (2008), ACS/PROGRESS Dreyfus Lectureship Award (2007)

Energy Storage is a Critical Piece of Any Renewable Energy Strategy

https://www.scientificamerican.com/article/giant-turbines-propel-boom-in-wind-energy/
https://www.coloradoan.com/story/news/local/colorado/2018/02/11/arapahoe-county-oks-permit-colorados-second-largest-solar-farm/327956002/
https://miro.medium.com/max/1250/1*aB76P-E7QsE0VYD17aXZ1g.jpeg

A Brief History of the Battery

Alessandro Volta’s battery (circa 1800 A.D.): copper and zinc separated by cardboard soaked in brine

However, jars have been discovered outside Baghdad dating to ***200 B.C.***:
iron rod, encased in copper, and soaked in vinegar or wine (0.78 V)

Rechargeable Batteries

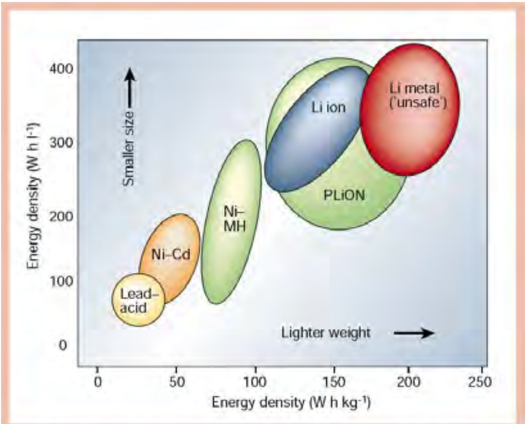


Figure 1 Comparison of the different battery technologies in terms of volumetric and gravimetric energy density. The share of worldwide sales for Ni–Cd, Ni–MeH and Li-ion portable batteries is 23, 14 and 63%, respectively. The use of Pb–acid batteries is restricted mainly to SLI (starting, lighting, ignition) in automobiles or standby applications, whereas Ni–Cd batteries remain the most suitable technologies for high-power applications (for example, power tools).

Tarascon & Armand, *Nature* **2001**, *414*, 359

Li-ion Batteries: Electric Cars

Older models, circa 2012

Tesla Roadster

- 0-60 MPH in 3.9 seconds
- "244 miles" on a single charge
- 6,831 Li-ion cells = $36,000 replacement cost
- ***Challenges:*** *driving range, charging time, cost, and safety*

ELECTRIC VEHICLE RANGE AND COST

On the left is the distance electric vehicles can travel on a single charge, as shown on three real-world routes between major cities.

Vehicle	Range Miles	Range KM	List Price	Cost/Mile
Fiat 500e	84	135	$33,460	$398
MINI Cooper SE	110	177	$29,900	$272
Nissan LEAF	149	240	$31,600	$212
BMW i3	153	246	$44,450	$291
Hyundai IONIQ EV	170	274	$33,045	$194
Porsche Taycan Turbo S	192	309	$187,610	$977
Porsche Taycan Turbo	201	323	$153,510	$764
Porsche Taycan 4S Perf Battery Plus	203	327	$112,990	$557
Audi e-tron	204	328	$65,900	$323
Nissan LEAF e+ SV SL	215	346	$39,750	$185
Audi e-tron Sportback	218	351	$69,100	$317
Nissan LEAF e+ S	226	364	$38,200	$169
Jaguar I-PACE	234	377	$69,850	$299
Kia Niro EV	239	385	$39,090	$164
Tesla Model 3 Standard Range Plus	250	402	$37,990	$152
Hyundai Kona EV	258	415	$37,190	$144
Chevrolet Bolt EV	259	417	$36,620	$141
Polestar 2	275	443	$59,900	$218
Tesla Model Y Performance	291	468	$59,990	$206
Tesla Model 3 LR Performance	299	481	$54,990	$184
Tesla Model X Performance	305	491	$99,990	$328
Tesla Model Y Long Range	316	509	$49,990	$158
Tesla Model 3 Long Range	322	518	$46,990	$146
Tesla Model S Performance	348	560	$94,990	$273
Tesla Model X Long Range Plus	351	565	$79,990	$228
Tesla Model S Long Range Plus	402	647	$74,990	$187

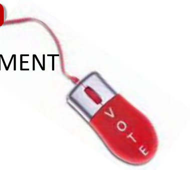
VISUAL CAPITALIST

Tesla Model Y Performance	291	468	$59,990	$206
Tesla Model 3 LR Performance	299	481	$54,990	$184
Tesla Model X Performance	305	491	$99,990	$328
Tesla Model Y Long Range	316	509	$49,990	$158
Tesla Model 3 Long Range	322	518	$46,990	$146
Tesla Model S Performance	348	560	$94,990	$273
Tesla Model X Long Range Plus	351	565	$79,990	$228
Tesla Model S Long Range Plus	402	647	$74,990	$187

Colorado State University · Prieto Battery

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

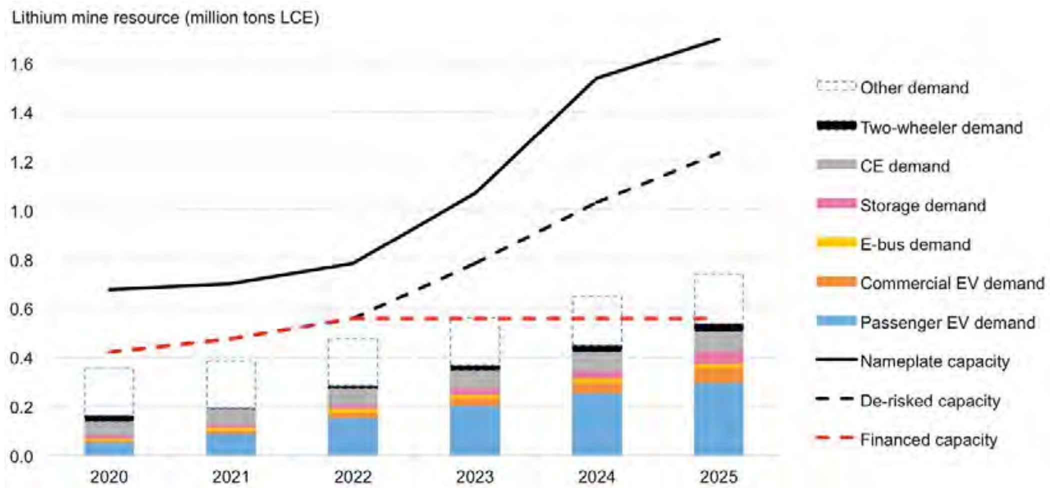


How much Lithium would we need to electrify transportation?

- 5 million kg of Li
- 20 million kg of Li
- 50 million kg of Li
- Greater than 100 million kg of Li

https://www.greentechmedia.com/articles/read/is-there-enough-lithium-to-maintain-the-growth-of-the-lithium-ion-battery-m

Rising Demand



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https://spectrum.ieee.org/energywise/energy/batteries-storage/evs-to-drive-a-lithium-supply-crunch

The History of the 'Modern' Li-ion Battery

1970's - **Stan Whittingham** (Exxon)
$LiAl/TiS_2$

1980's - Jeff Dahn (Moli Energy)
Li/MoS_2

1980's - **John Goodenough** (Oxford)
$LiCoO_2$ as the cathode

1980's - **Akira Yoshino** (Asahi Kasei)
C(coke) as the anode

1991 - Sony
$C/LiCoO_2$

2019 Nobel Prize in Chemistry

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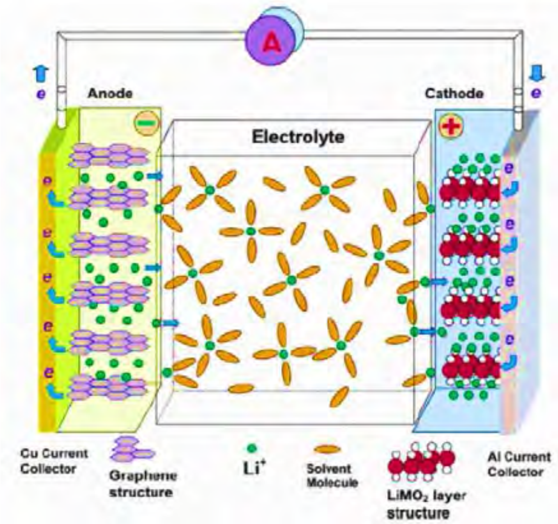
The Main Components of a Battery

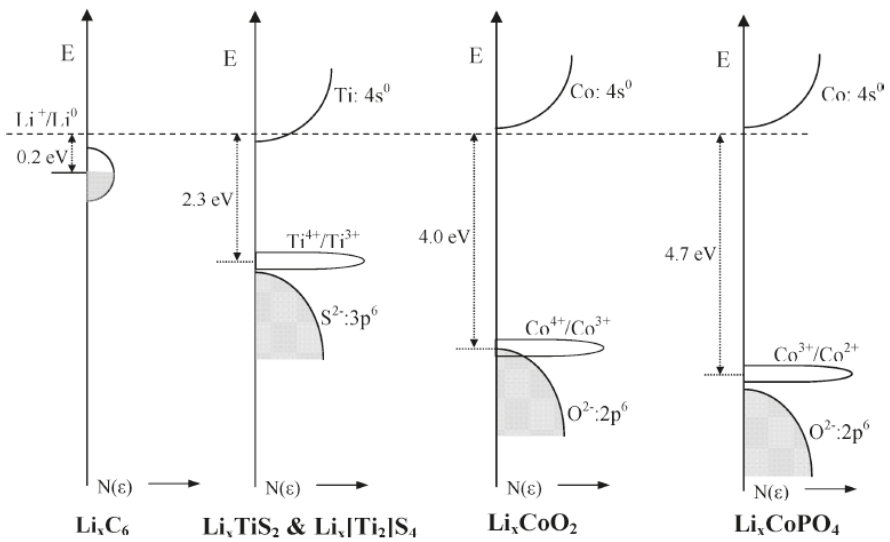


Components

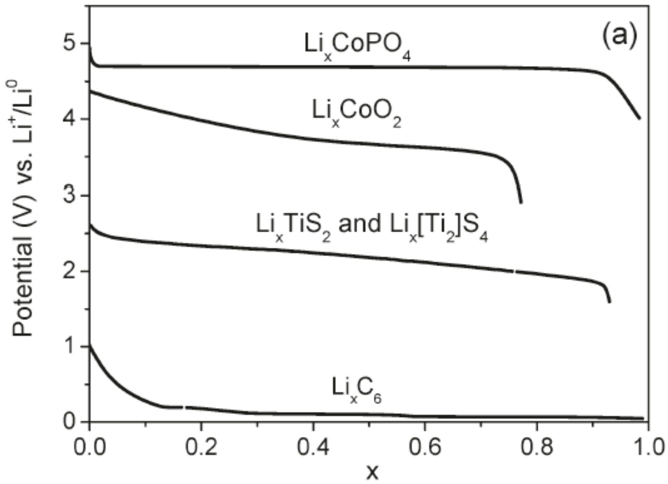
- Anode
  - Carbon
- Cathode
  - $LiCoO_2$
- Electrolyte
  - $LiPF_6$
- Separator
  - Polypropylene

Goodenough and Kim, "Challenges for Rechargeable Li Batteries" *Chemistry of Materials*, **2010**, *22*, 587-603.

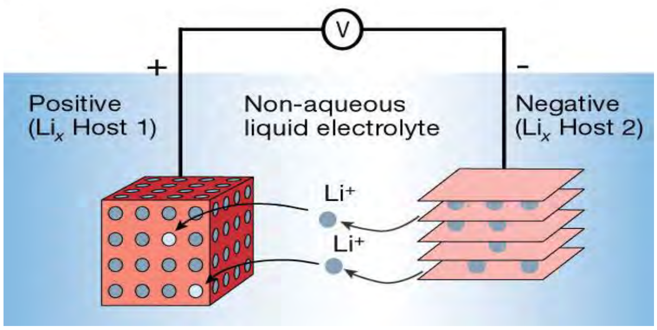
Fundamental Structure and Bonding



Voltage Profiles of Common Electrode Materials



Intercalation Chemistry



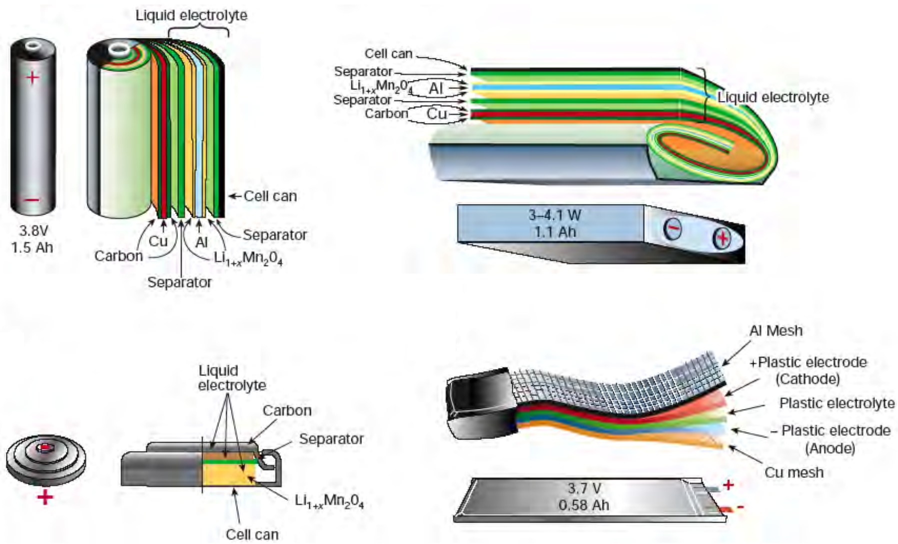
Limitation to Charging/Discharging Rates:

- diffusion of Li^+ into electrodes
- diffusion of Li^+ *between* electrodes

The problem of diffusion *between* the two electrodes would enable a new kind of device: a cross between a battery and a supercapacitor.

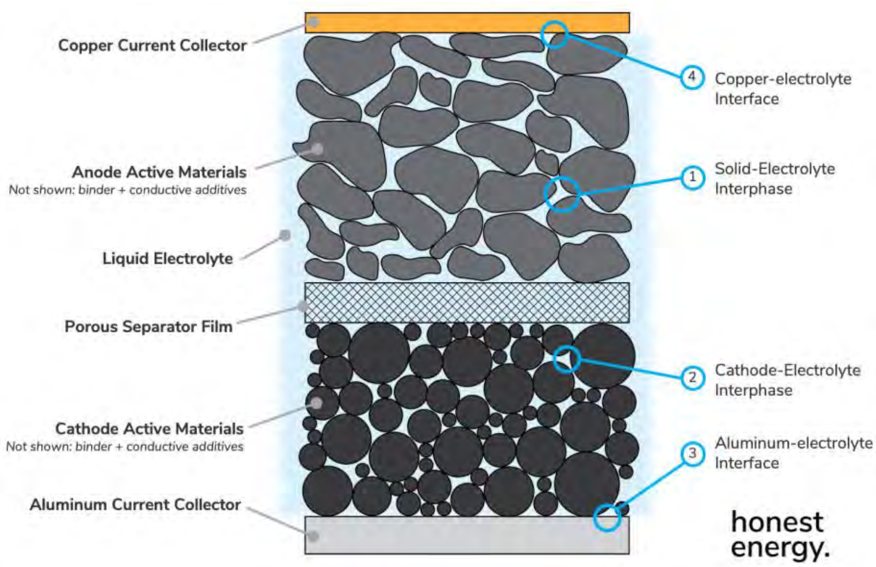
Tarascon, J.M. *et al. Nature*, **2001**, *414*, 359
Li, N., Martin, C.R., Scrosati, B. *J. Power Sources* **2001**, *97-98*, 240

Common Battery Architectures



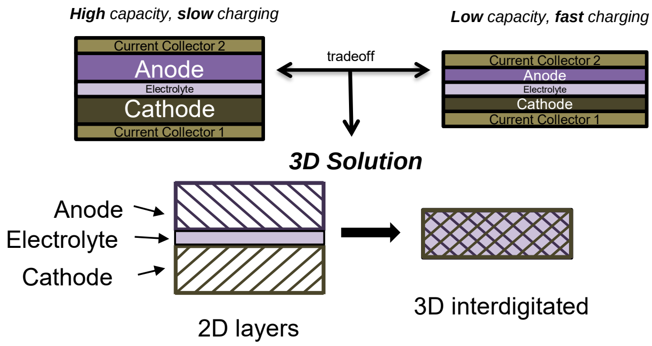
Tarascon, J.M., Armand, M. *Nature* **2001**, *414*, 359

Interfaces are Critical!



https://honestenergy.substack.com/p/the-little-ion-that-could

Better Batteries Require New Architectures

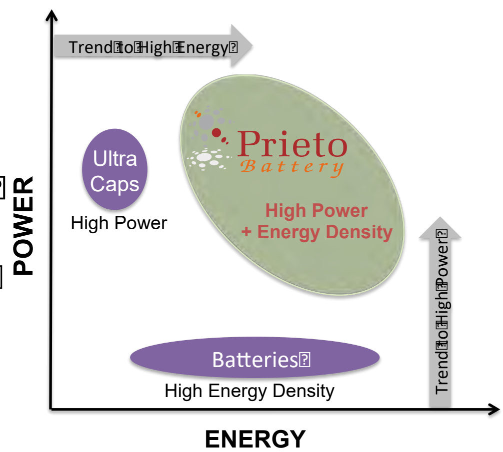


We are proposing that a 3D architecture provides ***high*** capacity, ***fast*** charging, and is safer

Stein, A. *et al. Adv. Mater.* **2006**, *18*, 1750
Long, J. and Rolison, D. *Acc. Chem. Res.*, **2007**, *40*, 854

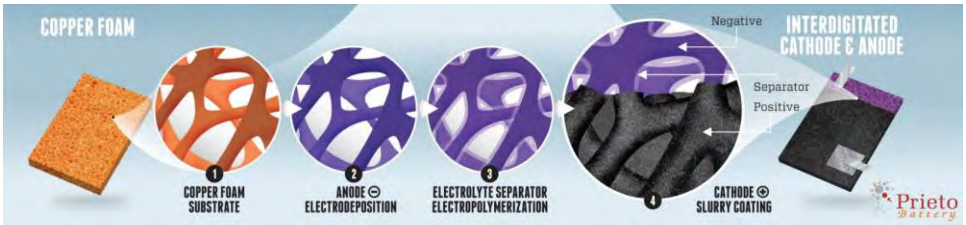
A New 3D Architecture

Developing unique 3D Li-ion cell, along with the materials and processes for the design



One device to combine ultra-capacitor power with Li-ion energy storage

Building a 3D Rechargeable Battery



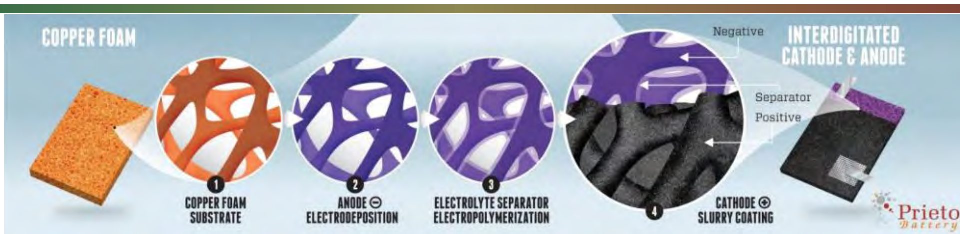
High electrode surface area + Shorter ion diffusion path = **5X High power density**	Cu_2Sb based anode = **3X increase in volumetric energy capacity** + Elimination of lithium dendrites	Solid polymer electrolyte = **Safer, non-flammable batteries** + Increased lifecycles	Standard industry available cathode materials = **Customizable** cell voltage & capacity

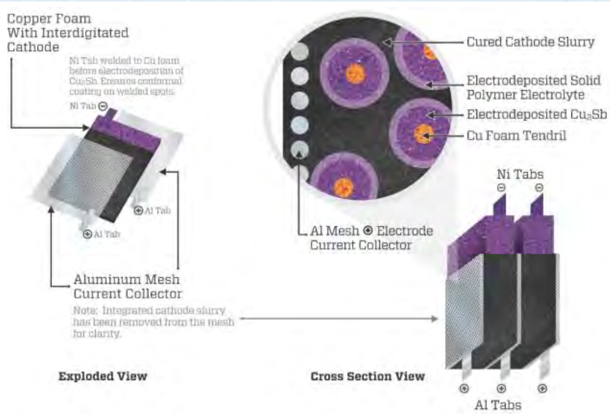
H_2O WATER BASED PROCESS Electroplating = **Low cost & Scalable**

In partnership with Stanley Black & Decker and Hercules Electric Vehicles

Prieto Battery

Building a 3D Rechargeable Battery

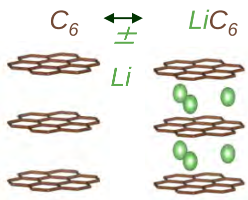




Prieto Battery

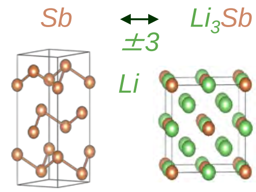
Seeking High Capacity Anodes

Intercalation material: graphite



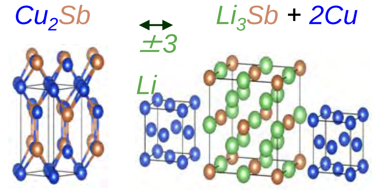
$Q_{gravimetric}$ = 372 mAh/g
$Q_{volumetric}$ = 800 mAh/cm^3
good conductivity
10% volume change

Alloy material: antimony

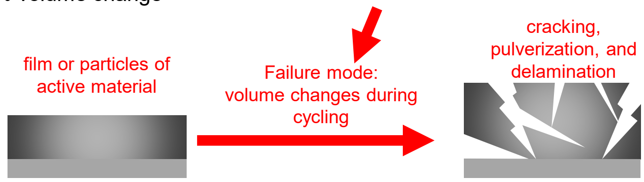


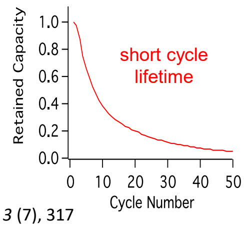
$Q_{gravimetric}$ = 660 mAh/g
$Q_{volumetric}$ = 4418 mAh/cm^3
Poor electronic conductivity
129% volume change

Conversion material: copper antimonide



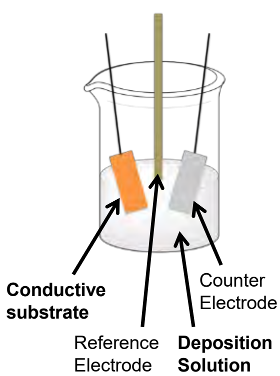
$Q_{gravimetric}$ = 323 mAh/g
$Q_{volumetric}$ = 2730 mAh/cm^3
improved conductivity
~90% volume change



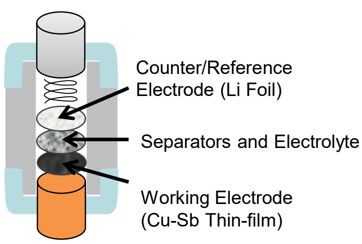


Fransson, L. and Thackeray, M. M. *Electrochem. Comm.* **2001**, *3* (7), 317
Matsuno, S. and Y.; Miyashiro, H. *J. Electrochem. Soc.* **2008**, *155* (2), A151
Applestone, D.; Yoon, S.; Manthiram, A. *J. Mater. Chem.* **2012**, *22* (7), 3242

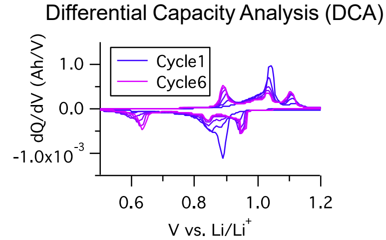
Direct Electrodeposition and Analysis by Cycling



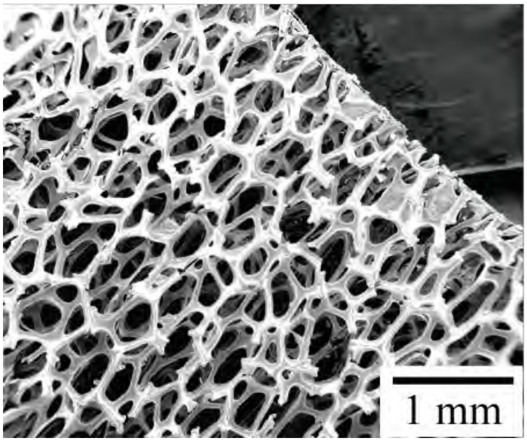
Characterize with ex-situ XRD and SEM before and after cycling

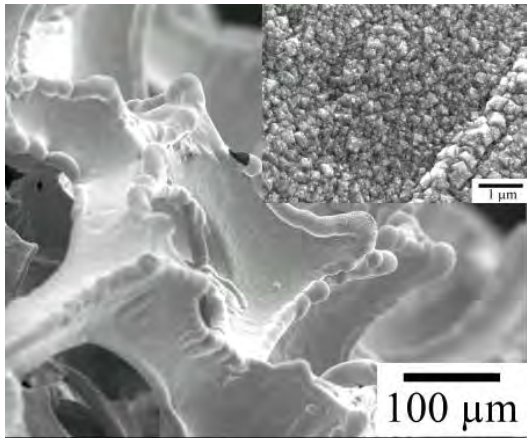


Differential Capacity Analysis (DCA)



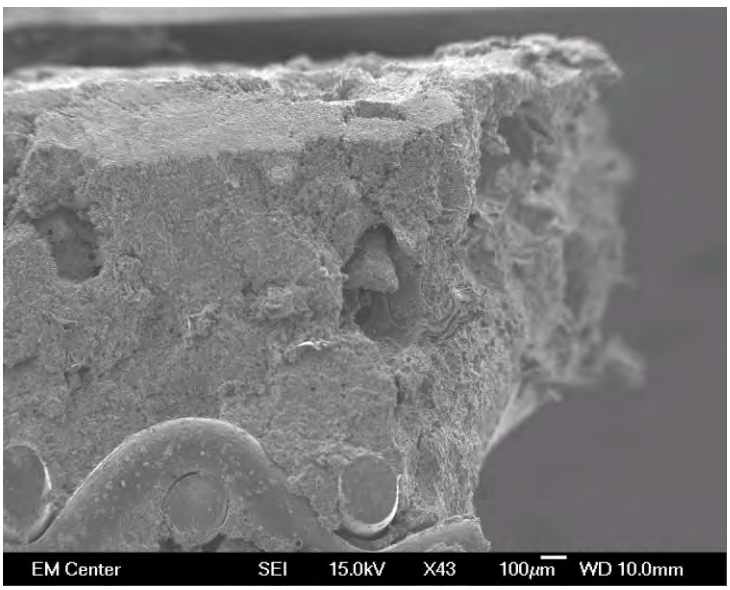
Conformal Deposition onto High Surface Area Structures



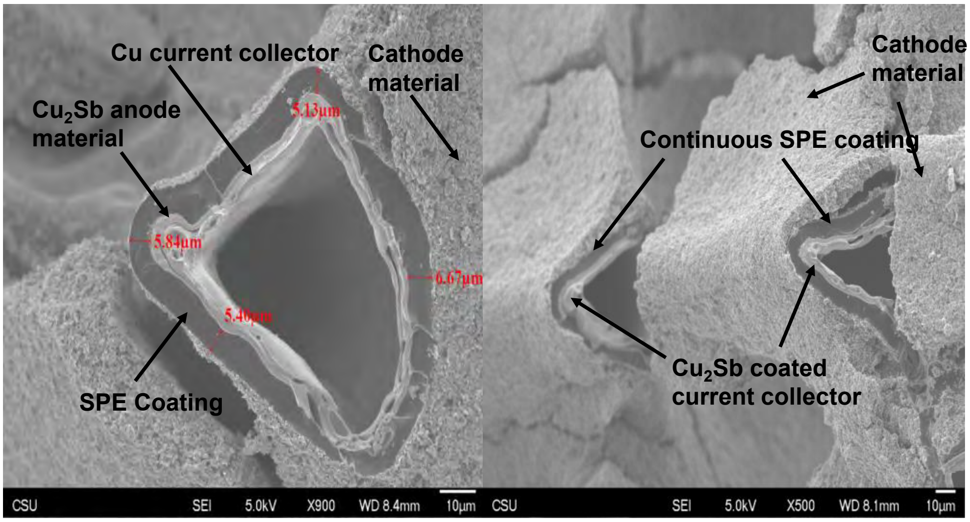


Short deposition times (2 minutes) result in a thin, conformal coating of Cu_2Sb on high surface area Cu foam

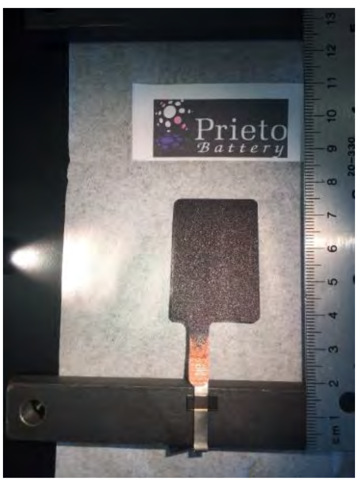
Near Ideal Slurry Chemistry

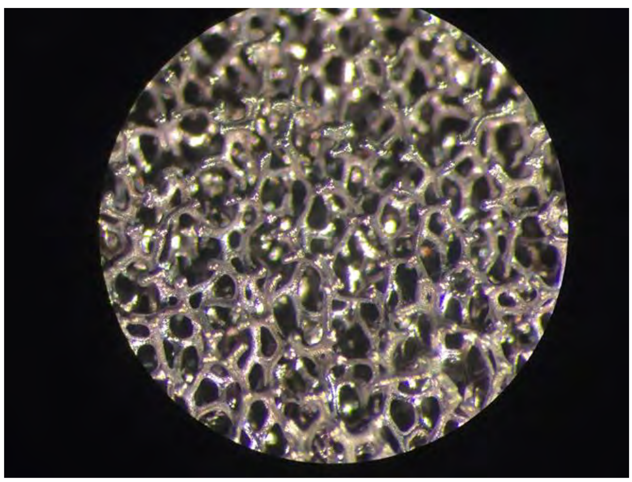


3D Cells Have Been Demonstrated



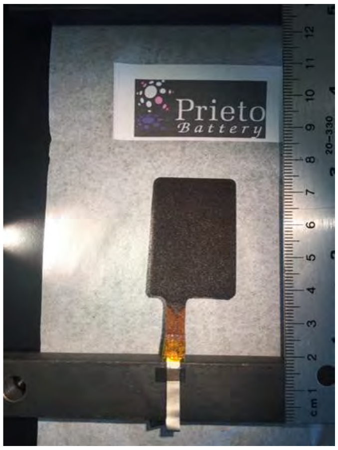
Anode – Cu$_2$Sb Coated Copper Foam

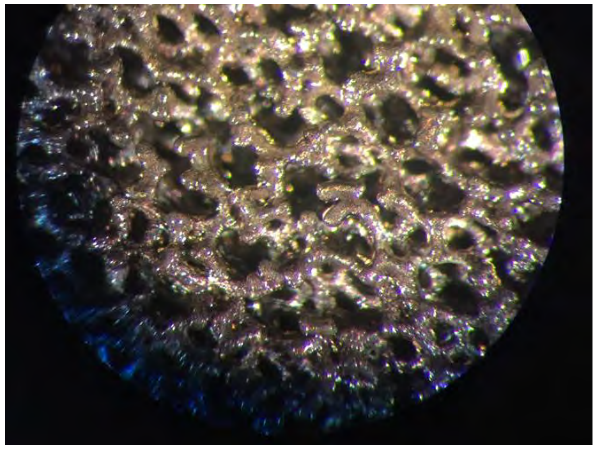




With our current process, we have fully functioning cells

SPE Coated Anode





Significant effort has been put into:

1) developing an SPE that is ionically conductive and
2) developing methods to coat it uniformly

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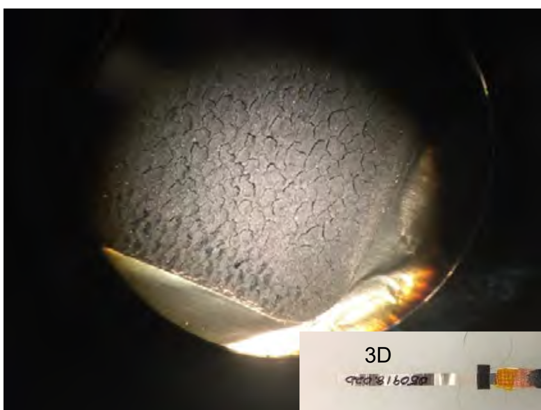
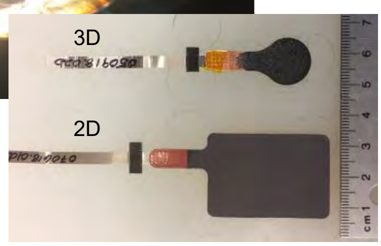
Cathode Backfilled 3D Cell





Same capacities, different footprints!

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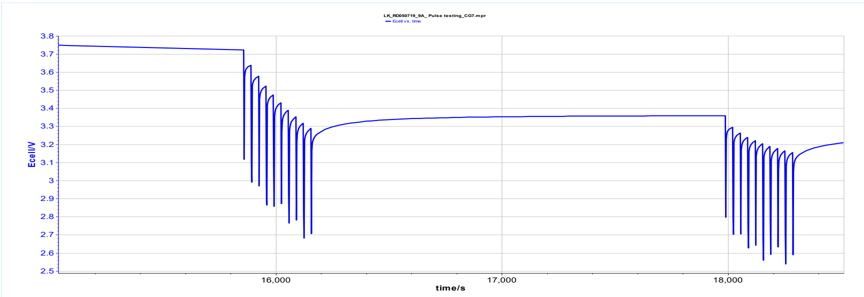
3D Solid State Battery Pulsing at High Discharge Rate

Cell: 20 mAh cell, Cu_2Sb/polymer electrolyte /NMC-811

Experiment: pulse discharging at 180 mA rate for 3 sec followed by a 30 sec rest, repeated 10 times. Pulsed current per FP = 42.8 mA/cm^2



Key Takeaway from Data Set:
Prieto's solid state battery performs well under high current/short time discharging (pulsing). This means Prieto has developed a solid state battery that can enable high power applications *at room temperature.*

Prieto Battery

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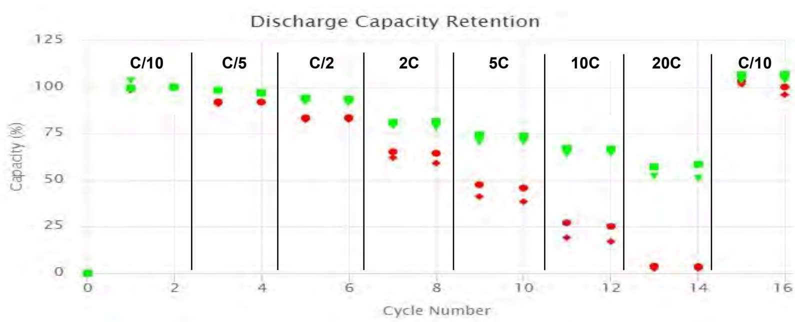
3D vs 2D Rate Performance Comparison

Green is for 3D interdigitated cells with gel polymer electrolyte

Red is for equivalent 2D cells with spray-coated cathode and gel polymer electrolyte



Key Takeaway from Data Set:
Prieto's solid state battery can achieve 20C discharge rates, with 50% capacity retention, at room temperature. These cells recover well at lower rates.

Prieto Battery

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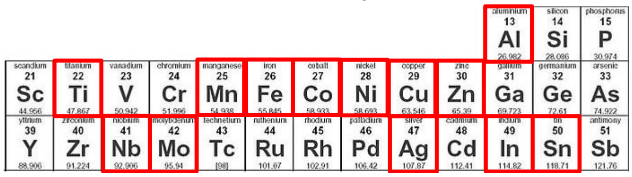
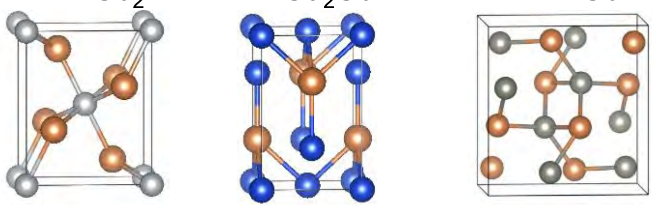
Expanding Our Toolbox

MSb + 3Li → Li_3Sb + M

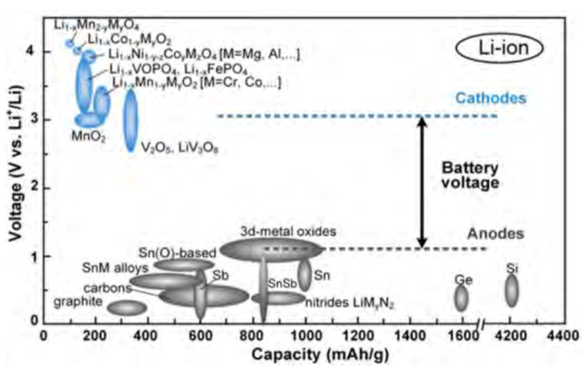


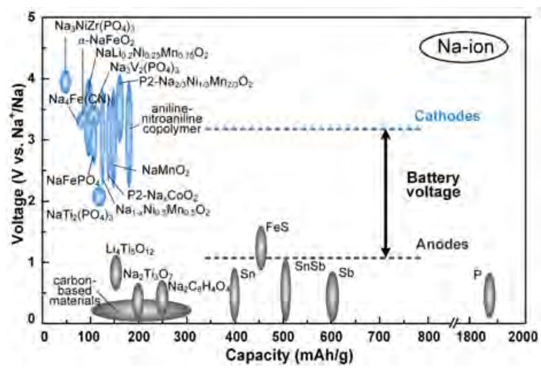
$NiSb_2$ | Cu_2Sb | ZnSb



Unique conversion chemistry | Strong structural relationship | Multiple lithium reactivities

Moving Beyond Lithium

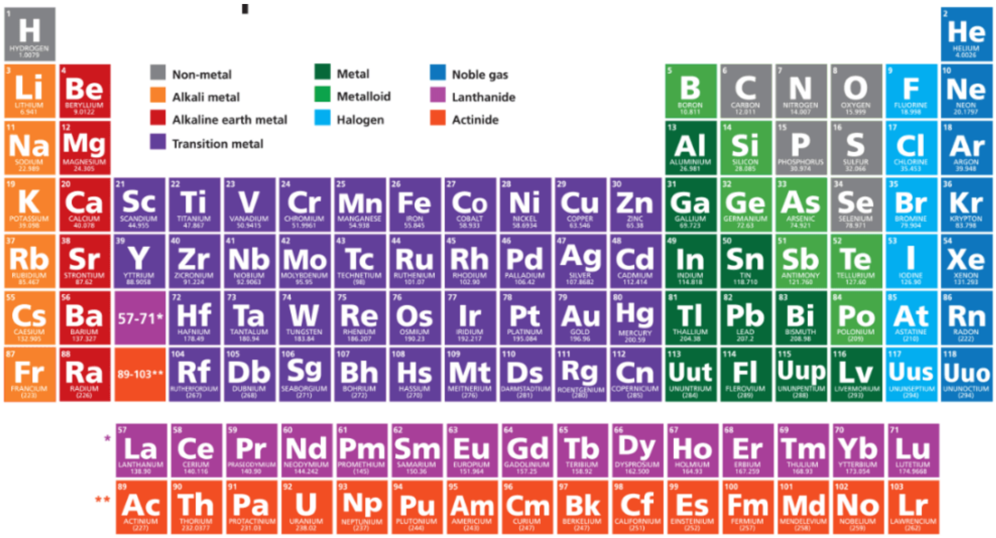




The translation from lithium to sodium is not trivial.

Oszajca, Bodnarchuk, Kovalenko. *Chem. Mater.*, **2014**, 26 (19), pp 5422–5432

Periodic Table of the Elements



https://magoosh.com/ged/ged-science-periodic-table

Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT

If you had US $1 billion to invest in new technology, would you invest in:

- New battery chemistry (beyond Li and Li-ion batteries)
- Advanced manufacturing facilities
- Supply chain stability
- Recycling
- Other (Let us know in the chat!)

https://www.greentechmedia.com/articles/read/is-there-enough-lithium-to-maintain-the-growth-of-the-lithium-ion-battery-m

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Prieto Battery

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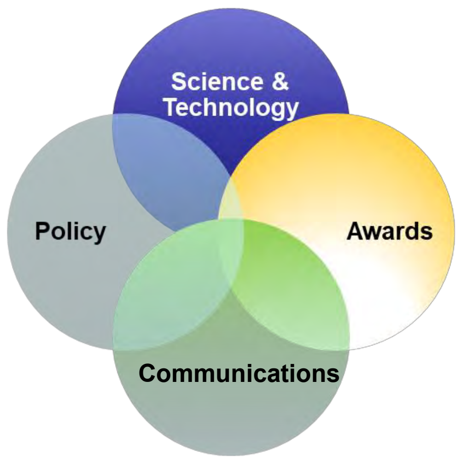

https://www.acs.org/content/acs/en/about/governance/committees/science.html

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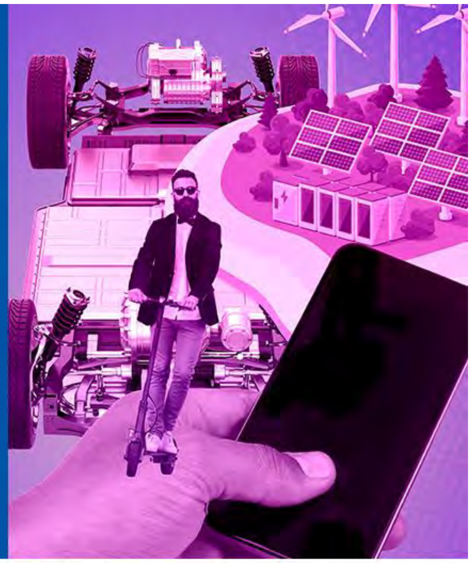
The Road to Sustainable Energy Storage



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Professor, Department of Chemistry, Colorado State University and Founder, Prieto Battery, Inc.

H.N. CHENG
President,
American Chemical Society

YOUNG-SHIN JUN
Professor, Depart. of Energy, Environmental & Chemical Engineering, Washington University in St. Louis

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Final Thoughts

1) There is ***no one perfect battery*** for every application.

2) Batteries are complex, ***dynamic*** devices, and major innovation will require sustained effort across the spectrum from fundamental science through innovative engineering and manufacturing.

3) We have a global ***responsibility*** to be mindful of resources and environmental impact of the technologies we develop.

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Polymers of the Pandemic
Antivirals and Decontaminating PPE

Date: Wednesday, June 16, 2021 @ 2-3:30pm ET
Speakers: Michael Schulz, Virginia Tech and Emilie Rexeisen, 3M
Moderator: Tomonori Saito of Oak Ridge National Laboratory (ORNL) and the University of Tennessee, Knoxville

Register for Free!

What You Will Learn:

- How antiviral polymers were discovered, how the field has developed and what the future may hold for the field of antiviral materials
- What structural features give a polymer antiviral properties
- How four key aspects contribute to successful decontamination (decontamination efficacy, safety for the wearer, filtration efficiency, and respirator fit)
- How different respirator makes and models use different materials making it essential that each model is tested separately for each method

Co-produced with: ACS Division of Polymer Chemistry

Mastering HPLC Method Development
What are all those buttons for?

Date: Thursday, June 17, 2021 @ 2-3pm ET
Speaker: Lee Polite, Axion Analytical Labs, Inc.
Moderator: Bryan Tweedy, American Chemical Society

Register for Free!

What You Will Learn:

- How to develop an HPLC method from scratch
- How to cut your analysis time in half, while preserving the quality of the results
- What are all those buttons for on your HPLC

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What I Wish I Knew Then
Advice from Chemical Industry Executives

Date: Wednesday, June 23, 2021 @ 2-3pm ET
Speakers: Carlonda Reilly, Kennametal / Serban Cantacuzene, AirLiquide / Kathleen Shelton, FMC
Moderator: Rebekah Paul, American Chemical Society

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What You Will Learn:

- Lessons learned from three executives' rise to the top
- Insights on how you can succeed in today's changing job market
- Advice for charting your own career in the chemical enterprise

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