

American Chemical Society AMA: My name is Dee Strand, and I am the Chief Scientific Officer at Wildcat Discovery Technologies. Ask me your lithium ion battery questions!

AmerChemSocietyAMA<sup>1</sup> and r/Science AMAs<sup>1</sup>

<sup>1</sup>Affiliation not available

April 17, 2023

### Abstract

Hi Reddit! Lithium ion batteries are complex combinations of components that we increasingly depend upon for our phones, our computers, our entertainment, and our vehicles. At Wildcat Discovery Technologies, we apply high throughput/combinatorial research tools and techniques into the discovery and development of materials to improve lithium ion batteries. New active materials can enable lighter, smaller batteries that can provide better range for electric vehicles. Longer lifetime, improved safety, and better wide temperature performance can be achieved through development of new electrolytes. You can read more about our discoveries at [www.wildcatdiscovery.com](http://www.wildcatdiscovery.com). I have a background in electrochemistry and material science, and having been working on lithium ion battery materials for over 10 years in industrial settings. Tune in to the ACS Webinar on Thursday, 3/10 at 2pm ET to hear more details how your cell phone battery works, and also how it fails. Register for free at <http://www.acs.org/content/acs/en/acs-webinars/technology-innovation/batteries.html>. I'll be online from 9:00 a.m. to 11:00 a.m. PST to answer your questions. Ask me anything! EDIT: Hi - I'm live and look forward to answering your questions! DAS EDIT: I am signing off now. What a wonderful discussion I have had with many of you! Thank you so much for all the good questions and comments. Check out our website at [www.wildcatdiscovery.com](http://www.wildcatdiscovery.com) if you want to learn more about our research. Or reach me at LinkedIn if you want to talk more! DAS

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## American Chemical Society AMA: My name is Dee Strand, and I am the Chief Scientific Officer at Wildcat Discovery Technologies. Ask me your lithium ion battery questions!

AMERCHEMSOCIETYAMA [R/SCIENCE](#)

Hi Reddit!

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I have a background in electrochemistry and material science, and having been working on lithium ion battery materials for over 10 years in industrial settings. Tune in to the ACS Webinar on Thursday, 3/10 at 2pm ET to hear more details how your cell phone battery works, and also how it fails. Register for free at <http://www.acs.org/content/acs/en/acs-webinars/technology-innovation/batteries.html>.

I'll be online from 9:00 a.m. to 11:00 a.m. PST to answer your questions. Ask me anything!

EDIT: Hi - I'm live and look forward to answering your questions! DAS

EDIT: I am signing off now. What a wonderful discussion I have had with many of you! Thank you so much for all the good questions and comments. Check out our website at [www.wildcatdiscovery.com](http://www.wildcatdiscovery.com) if you want to learn more about our research. Or reach me at LinkedIn if you want to talk more! DAS

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Hi Dee!

A little bit off the beaten track this one...

I wrote my undergraduate dissertation, very broadly, on the topic of graphene micro-super capacitors. I was astounded at the achievements of some researchers who were able to manufacture devices which were of comparable performance to some L-Ion batteries. Why do you think that we are still pursuing chemical battery technologies, as opposed to making the logical (some would argue) step towards a next-generation technology which has many far reaching implications, not just in power generation/storage?

Thanks for your time!

[toolemeister](#)

Good question. I think these may fill a niche, but for high energy density applications - lithium ion batteries are necessary. I have not seen system based volumetric energy densities that compare well between the two technologies. But we definitely need to explore alternative technologies such as these for those applications where ultracaps meet performance and cost targets. DAS

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Honestly, all I want to *really* know is when do you think my iPhone will be able to go a good 2-3 days of actually heavy daily use days before needing to be charged.

[ecib](#)

I love this question. The answer is never. With every improvement in the battery, the cell phone company wants to add more features (and so do you). Bigger screen, brighter display, more apps, touch screen features, etc. All those features are designed to work such that your phone can (hopefully) last a day with recharge overnight. The batteries will continue to get better, but the phone will continue to get even better. DAS

When should you recharge if you want to optimise the lifetime of your battery? From what I've read you should probably recharge when you have around 50% power remaining.

[Col\\_Shenanigans](#)

Here are a few things I would do to optimize the life of a battery. 1) Don't leave it in your hot car. 2) Don't charge it if the battery is very cold. 3) If you are not using the device for a long period - leave it around 50% charged. Other than that, the battery management system is designed to charge/discharge the battery to achieve the specified cycle life of the battery. DAS

Hello, Thanks for taking the time to do this! Do you think it is important to start transitioning away from Lithium ion batteries to other types like Sodium ion which are made of more abundant resources? What do you think is the biggest reason why a transition away from lithium ion batteries is not critical? Thank you.

[FuzzyGold](#)

Great question! From what I've seen, lithium supply is adequate and there are recycle approaches that can be cost effective at volume. DAS

Hi there Dee! Thank you for your time and your answers! When you mention new active materials that will enable more of these batteries in electric vehicles, can you give certain examples? What exactly do you mean by active in this case?

As far as I understand it is the cathode material that is limiting in terms of performance for lithium ion batteries in large-scale applications, so what materials (lithium iron phosphates or Li-Mn, etc.) do you think are the most promising right now, and what makes them so (structure, property, etc.)?

Thank you once again for your time! Hope you enjoy the rest of this AMA enlightening us about all this!

[aduket2406](#)

Active materials - we need cathode materials that contain more lithium per unit weight or volume than today's cathodes. Or cathode materials, such as layered oxides, where we can access more of the lithium. Currently, if too much lithium is removed - the structure becomes unstable. Efforts to stabilize these materials (dopants, coatings, etc.) are vital to achieve steady progress in improving energy density without compromising cycle life. High Ni layered oxides are very popular right now - but we need chemistry solutions to stabilize those structures and identify electrolytes that are not oxidized at the surface.

Active materials can also mean higher capacity anodes, such as silicon. However, silicon progress is also slow due to the volumetric changes in this material during use. I think the intermetallic/alloy space would be a good area to explore more fully. DAS

Thanks for taking time to do this!! I have 3 questions. Fell free to answer some, all or none. 1) Lithium battery cycle life can be greatly improved by reducing the maximum charge voltage and increasing minimum discharge voltage. Is there an optimum window within which battery life impact is negligible? 2) Cycle degradation and calendar fade are the two main causes of battery performance decrease, with both strongly affected by temperature. Do they aggregate (i.e.  $cd+cf = \text{performance fade}$ ) or is it just whichever one is more apparent that limits the performance? (i.e.  $\max(cd, cf)$ ) 3) NMC and NCA seem to be the main Go-To chemistries right now. What's next on the horizon??

Thanks so much!!!

#### [The Beer Engineer](#)

You're welcome!! 1) yes - reducing the voltage window improves cycle life, but also reduces the energy density. Most devices have battery management systems that set the voltage limits to ensure the device hits the specified cycle life. A battery in a hybrid electric vehicle operates over a very shallow state of charge range - to yield hundreds of thousands of cycles. A plug-in hybrid operates over a wider state of charge, with a target cycle life of a few thousand. A full EV battery will need to use as wide a state of charge as possible and balance energy density (driving range) with the target cycle life. 2) Great question - with batteries, the answer is often "it depends." It depends on the source of the degradation. Think of it in terms of performance. You need a certain capacity out of the battery and you need a certain power from the battery across a range of states of charge. People are most familiar with capacity fade due to loss of lithium - when your 6 hour laptop battery now only lasts 2. However, power fade is also a big problem - and it can be caused during storage, particularly at higher temperature. As this occurs, your battery might be able to deliver the target power when fully charged - but when you are only 30% charged it can no longer do so. This is a real concern in vehicle applications. 3) We need new chemistries on the horizon!!! There aren't many in the pipeline. DAS

Hi there! I am curious undergraduate student who's working with supercapacitors with four questions for you.

- 1) What are the limitations of Li-ion batteries given it's power density and cyclic stability?
- 2) Any ideas on how to recycle the Li-ion battery after usage given that it has become so popular that people may tend to forget how to dispose of them properly (similarly with lead in the past)?
- 3) Are there any features that the Li-ion battery fails in that a composite material combining a battery and a supercapacitor can achieve that a Li-ion battery alone cannot?
- 4) What advice do you have for a student like me who is deeply interested in energy storage on applying for further studies and future research in the field?

:D

#### [dasleepyguy](#)

Glad you are interested in the field! 1) I think the ultimate limitation is cost. Materials and designs exist for many different performance targets - but currently are just too expensive. If lithium ion batteries were really cheap - we wouldn't worry so much about cycle life in an EV, we could just replace them on a regular basis. 2) I am not an expert on recycling, but there are several large companies that have

invested in recycle streams and (from what I hear) this is economically feasible at scale. 3) It depends on the target power/energy you want. There is probably a niche for the composite approach you mention. But there are good high power batteries out there if you need more energy than a supercap. 4) Go to grad school. Do R&D where you get exposure to making batteries and understand the complexities of combining the different materials/components. DAS

Hello there, I see you are in favour of liquid electrolytes. Is it because you don't see much potential for the solid electrolytes, or is it because the production and assembly methods are not suitable for upscaling? I took a look at your website, you make some really strong claims regarding the testing techniques. In what sense your testing assemblies are better than anything commercially available?

[l00rker](#)

I would love a great solid electrolyte. It could enable lithium metal anodes (better energy density) and improve safety and.... We're just a long way from a cost effective practical solution. But we currently are doing a lot of research in this area. Wildcat Discovery Technologies core competency is high throughput research. So we have high throughput tools that enable the synthesis of hundreds of materials (e.g., cathode powders) in parallel. We can then turn those hundreds of materials into electrodes with well defined thickness/porosity targets. We can formulate hundreds of electrolytes in parallel. Finally, we build and test thousands of cells containing those materials. The use of combinatorial approaches and high throughput research is extremely useful in battery research - as there are an infinite number of compositions, formulations, and combinations. DAS

I know nothing about batteries, except for their basic consumer applications. Do we simply have not enough elements that we know of to produce "better" batteries? Will we move away from lithium? What makes lithium so special? I hear battery nomenclature Ni-Cad and Li-Po thrown around but have no clue. What are the differences between them and lithium? Pros and cons? Thank you.

[kboi25](#)

You make me smile - sometimes I still ask the same questions! There are just a lot of constraints. For example, if we want good energy density - we need high material capacity (amount of lithium per unit weight) and high(er) voltage. But those higher voltages require stable electrolytes - and there aren't a lot of options currently. I recommend you get a copy of The Handbook of Batteries - it has lots of good information on different kinds of batteries and will answer many of your questions. An interesting point about batteries in general is that being an expert in (for example) lithium ion batteries, does not mean you know anything about other kinds of batteries. For example, lead acid chemistries have been around a long time - but there is still a lot of "art" in the pasting and forming of these batteries. A lithium ion expert might not know anything about this. DAS

Hey, Dee, thanks for the AMA topic. Lithium is primarily mined in Australia and Chile but assembled into batteries in Texas, China, India, etc. With that in mind and the transport vehicles in account, is driving an electric car or hybrid actually better for the environment as advertised? Is there any plan to transition into more localized battery materials like aluminum/air?

[XonikzD](#)

There are some good reports on the total life cycle impact of lithium ion compared to gasoline. (DOI 10.1007/s40518-015-0033-x) I am not such an expert in these areas, but acknowledge that a complete life cycle analysis must be done for fair comparison. DAS

I have a masters in electrochemistry, studied under some of the well known professors in the industry. (any more about my academic background would identify me to some other irl friends) But I've become disillusioned with the prospect and potential for lithium ion chemistries.

Why should I return to RnD for electrochemical energy storage? It's all incremental improvements with fuzzy, if any, practical mass production - ability.

#### [SketchBoard](#)

We all want better batteries - just think about what our phones could do if they weren't limited by the battery? Widespread adoption of vehicles with electrification can decrease GHG emissions. So this is a good problem to work on - and should be motivating to scientists/engineers. Furthermore, battery chemistry is fascinating. :) It's like a puzzle with many interconnecting pieces - resulting in great collaborations between organic chemists, inorganic chemists, electrochemists, analytical chemists, etc. If you want broad exposure to all these areas, battery research is a great place to get it. Remember, lithium ion batteries have not been around all that long - the industry is learning and growing. DAS

Will it damage my lithium ion battery, if I leave my Tesla parked on the street in cold weather?

I know the battery won't perform properly until it has been heated, but can freezing temperatures cause any permanent damage? If so, how cold does it have to be?

#### [kaspar42](#)

Well.... if I had a Tesla, I would park it in the garage (but that's for other reasons). No - cold weather won't hurt your battery if you're not using the battery. But don't charge it when it is cold - that can result in lithium plating on the anode. I would guess the battery management system on the Tesla might not allow charging below a certain temperature, so you wouldn't have to worry about this so much. DAS

In reference to specific battery cells, 18650, 18350, etc. have we reached a scientific plateau in capacity and discharge rate? It appears that we have been floating around 2500-3000mAh and 20-25A(continuous) for a while.

#### [Aspiring-AMWF](#)

I think 18650 capacity has been steadily increasing, and there are cells with greater than 3000 mAh out now. A lot of the progress has been on better electrode/cell design and increasing voltage. Introduction of small amounts of Si will also give a small improvement in energy density. Regarding discharge rate - that usually is less of a problem. There are some high power products on the market (of course, they have lower energy density). DAS

What do you think of Qualcomm's Quick Charge technology, is it damaging to a battery to charge at that higher currents?

#### [Gold\\_Diesel](#)

I don't really know what the technology is. However, there are many improvements that can be made with good algorithms in the battery management system. In general, it can be damaging to charge a battery too fast - as lithium plating will occur on the anode. Most BMS systems will operate to prevent this. DAS

If I don't charge my battery for a while it becomes dead. Where does all that potential energy go?

[kkehoe5](#)

Parasitic reactions result in self discharge of the battery. That usually isn't a problem for standard lithium ion at normal temperatures.

Hello and thank you for taking time to do this.

One of the security issues I have seen with Lithium is that once it meets with water there is a violent reaction.

My question is there a way to make lithium less dangerous if it comes in contact with air or water?

Reason if anyone was to pierce a lithium battery and flush it there could be a catastrophic outcome.

perhaps I am overthinking this but wanted your input on this as well.

[jabbo](#)

Rechargeable lithium ion batteries typically do not contain lithium metal - they are based on lithium containing cathode and a graphite anode. However, it would not be a great idea to pierce any battery as you will short it and generate a lot of heat. Remember, lots of energy packed into a small space should be treated with care. DAS

I am a Certified Hazardous Materials Manager currently working in Afghanistan on the only project of civilians charged with recycling, neutralizing, denaturing, etc of all of the hazardous materials produced or abandoned on US military bases during the now 15-year war. The project is now four years old and I've been with them for close to three. I've heard stories from the older colleagues that did this same project in Iraq of a very large lithium battery fire after a few guys pulled the tabs to discharge them and threw them back into the containment. I've personally amassed tens of thousands lithium batteries for shipment, separation and consolidation, and then shipment by air to Germany for recycling. The only fire that I've had to respond to was a small pallet sized fire that started the same way the 'hundred thousand lithium battery fire of Iraq' started (The fire department let it burn itself out). I have a few drums of lithium batteries currently in my hazardous waste yard with a Class-D fire extinguisher on-site. There were probably a few million of these batteries out here used by the Army before our year-long consolidation, shipment, and recycling effort finished last year. (They're in such supply because they're 30% lighter and last up to ten times longer than their Ni-Cd / NiMH counterparts).

As my research tells me, these batteries are just about 3% lithium, but they seem to have a (albeit VERY SMALL) chance of starting a fire if discharged or if they come into contact with water. Airlines have already banned them in cargo and (don't quote me) in the cabin as well.

[http://batteryuniversity.com/learn/article/battery\\_recycling\\_as\\_a\\_business](http://batteryuniversity.com/learn/article/battery_recycling_as_a_business)

What safety measures are currently in place inside the battery to protect them from being accidentally discharged or coming into accidental contact with water? What else could be done to make them safer? More containment?

[CouthDecay](#)

I don't know what might be in the specific batteries you handle. However, a battery pack or module should have safety features to limit the current from an external short. DAS

From everything I've read, the LiFePo4 chemistry has better stability than the Lithium Ion batteries. Is there a reason we don't see more of these commercially? It seems it would solve issues with a lot of consumer electronics catching fire.

[shit\\_eatin\\_grin](#)

There are a lot of LFP batteries on the market - particularly in Asia. However, they lack the energy density required for a lot of US consumer applications (like phones). LFP operates at a lower voltage than other cathode chemistries, reducing the energy density. DAS

I smoke an E-cigarette which uses a 18650 li-ion battery. My mom is constantly harassing me about it potentially exploding while I am using it. Even if something were to occur, wouldn't the battery just vent the lithium flare out from the top? Or would it actually explode?

[the\\_injury](#)

I'm not sure what would happen, but there's quite a lot of energy packed into a small volume - so the outcome depends a lot on the failure mechanism. A dead short on a fully charged battery will have different results than failure due to overcharge. Be sure your E-cigarette has a high quality battery management system. DAS

Greeting, and thank you for participating!

I'm interested in lithium ion battery technology for the purposes of standalone PV systems. Which particular lithium chemistry, in your judgment, would work best in an application like this? (Assuming that the batteries would be store in "room temperature" conditions.)

Could you also add a word on safety of these new batteries? There is a lot of (mis?)information out there that lithium technology still has not gotten over the fire risk issues.

Warm thanks!

[aintnocoffeeshop](#)

The nice thing about these types of system is that you can relax a little on the energy density - because you're not necessarily constrained to minimize weight or volume. That let's you choose lower energy density materials that can be safer and/or have longer cycle life. Safety is critically important for all types of energy storage, and concerns are not limited to just batteries. Flammable liquid fuel is a form of energy storage. Any type of stored energy (chemical, electrical, mechanical) can be dangerous, and the consumer needs to follow safety instructions. DAS

Hi and thank you for doing this!

My question is this: Have you studied the battery failure on the Boeing 787 Dreamliner airplane and do you concur with the study that still says no root cause can be found as to why the battery cells vented in flight?

[tadius\\_maximus](#)

I have not seen reports on the final conclusions, and it feels wrong to speculate....

However, in general thermal runaway occurs anytime heat generation in the battery exceeds the heat dissipation. So I would look for reasons heat might be generated in the battery - shorts due to lithium dendrite formation, overcharge, ... DAS

A typical consumer grade lithium ion battery, from what I've heard, lasts for about 300 charge cycles before degrading significantly. Are there any advancements that could bring that number to, say, 1000 cycles for the same grade battery within the next few years?

Also, several months back there was discussion on Reddit about lithium-oxygen batteries with far greater potential safety, charge density, and longevity. Has further research brought this any closer to being market ready? Have there been any findings that would make this battery impractical to bring to consumer usage?

Thank you for your time. Also, if I'm completely wrong on everything here, don't be afraid to say so.

[tablesix](#)

Lithium ion batteries can be capable of thousands of cycles - such as those used in PHEV and EV applications. However, they cost more. The typical consumer grade lithium ion battery is designed for a performance and cost that is acceptable for the device. 300-500 cycles on a phone gives you 2 years, which most people find acceptable (as they want a new phone with improved features at that time).  
DAS

I work in a computer repair (Apple, specifically) shop, and often deal with the dreaded swollen battery once they hit the three to five year range. What causes this exactly? Along those lines, what's to prevent the same thing from happening to a Prius? For snowbirds that winter in Las Vegas, for instance, if they leave their Prius in the uncooled garage during the summer, are they going to come back to their Prius a few feet off the ground?

[ronh3](#)

The batteries swell due to gas formation. There can be a lot of mechanisms for this as batteries age. Batteries used in automotive applications have a little more space "built in" for this. However, they also use components (more expensive) that will help minimize this. For example, electrolyte purity is critical to give long cycle life and reduce gassing. Automotive batteries use EV grade electrolytes that can help with this. DAS

When lithium ion batteries get old and release gas, causing them to expand...what is actually happening in there?

Also thanks for doing this AMA, you rock!

[Pagetayl0r](#)

Thanks! Gas is generated by a few different mechanism. First, the organic electrolyte is not stable on the anode - resulting in formation of the solid electrolyte interphase layer which then protects the bulk electrolyte from the anode potential. That all sounds great - but gas is generated during the formation of the SEI. In large format batteries, this gas is removed by the cell maker after the first few cycles. However, the SEI is not 100% stable - so when it degrades, and more SEI is formed during the battery use, more gas will be formed. Likewise, parasitic reactions of the organic electrolyte on the cathode surface also will result in gas formation during the battery use. DAS

What has been the most Challenging part of your career so far?

Im really fan-girling because in my previous position your name was still on alot of samples and stuff here and there!! Though we've never met in person, I really admire your work.

[queenofthefreljord](#)

Awww thanks! And I'm really sorry that I didn't clean out all those old samples!

I think the most challenging part of my career was finally figuring out how much I just really liked to do science. There can be a lot of other aspects of a career (management, commercial, design) that come up over the years, and it can be difficult to figure out what you really want to be or do. Good luck with whatever you are currently working on! Try new things. Figure out what you really love to do. DAS

One biggest issue right now with lithium ion battery is charging time. Has there been any breakthrough in improving it?

[GodMode\\_Activated](#)

This is a challenging problem. More sophisticated algorithms in battery management systems can help. There are different anodes (e.g., lithium titanate) that allow fast charge, but the energy density is compromised. The industry needs some innovation on this one. DAS

With the latest advancements in production of Graphene, which is a highly conductive and high energy capacity storage material, when we see this start to be implemented into Li-Ion batteries? Do you think it is possible to create a Graphene based battery to create a Kilowatt hour battery for mobile devices?

[Liveonafarm](#)

Graphene has attractive properties in terms of capacity and conductivity. However, there is never a perfect material! High surface area materials are challenging in batteries - parasitic reactions of electrolyte on the anode become more of a problem with high surface area. High surface area anodes mean that lots of SEI needs to be made - which consumes lithium and reduces the specific energy of the cell. I'm not saying that graphene is not a good material, but there are challenges in implementation. That seems to be the case with many battery materials - there are always trade-offs. DAS