Science AMA Series: I'm Gerbrand Ceder, a battery scientist at Berkeley Lab, and I research new ways to improve energy storage technologies. Ask Me Anything!

Gerbrand$_{C}eder^{1}andr/ScienceAMAs^{1}$

[1]Affiliation not available

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Abstract

Hi Reddit! I'm Gerbrand Ceder, though I go by "Gerd" as my first name. I'm the lead scientist for multi-valent batteries at the Joint Center for Energy Storage at Berkeley Lab, and a faculty scientist in the Materials Sciences Division at Berkeley Lab. I am also the Chancellor's Professor of Materials Science and Engineering at UC Berkeley. I look forward to answering your questions about building better batteries for a better future. Recently, my team and I shed light on how lithium-rich cathodes work, which could lead to higher capacity batteries. You can read about that here. And here is my website. I received an engineering degree from the University of Leuven, Belgium, and a Ph.D. in Materials Science from the University of California at Berkeley in 1991. Between 1991 and 2015, I was a Professor in Materials Science at the Massachusetts Institute of Technology and braved the hard Massachusetts winters. As a college student in engineering I was fascinated by the tremendous impact novel materials could have on society, and decided to make it my career to come up with more rational methods to design novel materials, rather than just "try and see." I rode the wave of computing growth and became one of the first "computational materials designers." In the early 90's I got involved with Li-ion batteries, at the time a very nascent technology. It has been a wild ride since then, seeing the multiple waves of impact this technology is having as it moves from portable electronics to vehicles, and now to grid. The little time I am not working I enjoy listening to loud music, baking bread (preferably at the same time), or doing a good hike. I look forward to your questions. Edit: I'm live and answering your questions. Thanks to everyone who has submitted thus far. I'll be answering until 3p ET/12p PT. Here we go... Edit: It's noon and my laptop battery is at 2%... So, I must go! Thanks for joining me today. Be sure to check out the links above and below for more on battery research and stay tuned for more science reddit AMAs from Berkeley Lab. Cheers! Berkeley Lab Joint Center for Energy Storage

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REDDIT

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GERBRAND_CEDER R/SCIENCE

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Berkeley Lab
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There have been many (obviously overhyped) articles claiming that researchers have achieved various "breakthroughs" in battery tech, from longevity to capacity to rapid charging, etc.

What, in your opinion, is the closest-to-market significant improvement in battery tech? How long do you think it will take to get it to the point of mass manufacture?

Also, do you have a sourdough starter you like?

ArchitectofAges

According to Thomas Edison (1883) "The storage battery is, in my opinion, a catchpenny, a sensation, a mechanism for swindling the public by stock companies. The storage battery is one of those peculiar

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things which appeals to the imagination, and no more perfect thing could be desired by stock swindlers than that very selfsame thing. ... Just as soon as a man gets working on the secondary battery it brings out his latent capacity for lying."

So yes, overhyping batteries is nothing new. I am most bullish on things like Solid-state batteries and Sodium, mainly because they are technically achievable and there is a real need for them. Solid state would deal with the safety problem of Lithium-ion and sodium systems have potential for very high charge/discharge rate capability and very low cost. Further out is Mg-based technology, which as of today is really unproven, but can be a real game changer.

And I try to make my own sour-dough starter, though it is frustratingly difficult

How far away do you think we are from phones/electronics that can charge in a really short amount of time, like less than five minutes?

yrfavtrash

Great question. Fast charging is a very rapidly developing field. In many applications such as phones cars we are often limited by the power rate the charging device can give out. For example, when you charge a phone through a USB connection it charges rather slowly as the USB port cannot provide much power. This is being improved by new USB standards and by the idea of using dual USB ports to charge. So phone charging in 5 minutes is well within reach. For electric cars the problem is similar but more difficult. To charge a 100kWh Tesla battery in 6 minutes one would need a 1Mega-watt power supply. That is serious stuff ! Todays chargers supply in the range of 7kW (level 2) or 50kW and higher for the various "fast charging technologies". But there are plans to raise the fast charging standard to 300kW. That would charge a 100kWh Tesla in about 20 minutes (from totally empty) and my BMW-i3 in less than 5 minutes. Fast charging will be facilitated by the move to higher voltage (e.g. Porsche is suggesting an 800V charging standard). So fast charging is becoming mainly an infrastructure question

In a power utility context, what is the biggest challenge preventing good energy storage? I keep hearing that storage is the key to unlocking the potential of renewable sources like wind and solar, but I don't think I quite understand what the technical challenge is. Is it not currently possible to make a battery large enough? Can our current batteries not be accessed fast enough to be useful when needed? Thanks in advanced! What you guys do is amazing!

afroman555

Great question. Lots of pricing that is thrown around is based on old cost models. Within a few years Li-ion cells will sell at $100/kWh. This estimate is based on some of the forward pricing we see in the automotive industry. At such a price the system level costs (power electronics, site prep, etc.) start to dominate. But as more grid level systems are built one can expect that to come down through more standardization.
One issue that remains for Li-ion is safety. The larger the installation, the larger the potential for catastrophic scenarios. Hence, improving safety at the cell and system level is an important target today. Solid state Li-ion would be perfectly safe, but is still at the scale of lab development today.
As you point out, hydro is very inexpensive and makes up a large fraction of our current storage inventory, but is difficult to grow. Also dams cannot just release water at any time that is convenient for the grid due to environmental concerns. With respect to pricing, it is important to understand that there are opportunities for storage at almost all price levels in the grid, depending on whether the storage is used for load deferral, frequency regulation, or short-time leveling.

Hi Professor Ceder,

First off, I've noticed that all consumer rechargeable battery technology is based off of lithium ion tech. With the cost of lithium projected to skyrocket in the next decade or so, is there any interest in adapting the same technology to less expensive, more easily available cations?

Secondly, I'm currently an undergrad chemistry major at the University of Pittsburgh and I know that I want to go into the materials science field. Do you have any advice for people looking to get into materials science?

Thanks for taking the time to do this AMA!

Airstew

Do it ! Materials Science is a cool field !
Yes, lithium prices have gone up a lot, but it is not likely that they will stay this high. There are fairly large supplies of lithium in the world. At this point we are only mining the easy ones. Other metals in the Li-ion battery such as cobalt are much more of an issue as they are scarce and rather expensive. But definitely, for the longer turn we need to think about other working ions: Sodium is particularly interesting IMO. Long-term would be great if we could use divalent ions such as Ca and Mg as they will solve the resource problem and give us potentially much higher energy density than Li-ion

Is Li-on pretty much the peak as far as battery materials go, or are there promising alternatives?

Curious for science reasons, not because I want to buy a bunch of that material and sell it to Elon Musk in a few years.

Pile_Of_Atoms

Li-ion is definitely very good and it is the 10,000 lbs gorilla in the room when doing "new" stuff. As such it is hard to beat. But potential long-term challengers are 1) Solid state Li (really another form of Li) 2) Na: for low cost and very high rate capability 3) Multi-valent ions (Mg, Ca etc.) -> this can dethrone Li-ion in terms of energy density by a factor of 2x, but it is a hard problem. Not even fully lab ready now

Is it possible to get a definitive answer regarding "conditioning" batteries? Is the best method for optimal battery life to let it drain completely and recharge? Constantly topping off no matter what? Will leaving a battery recharging overnight cause its lifespan to shorten? Do batteries have "memories", i.e. will they ever show that they're fully charged when they're not?

pandafoxshark

Li-ion has no memory. (This was a problem with old Ni-Cd technology). After production Li-ion cells are run for a few cycles in the factory to condition them. There is very little else you should afterwards. But since the battery is most sensitive when fully charged it is not a bad idea to not fully top it off when leaving it for a long time. And high temperature is never good.
There is no reason to drain and recharge again, unless you want to reset the electronics that keeps track of the charge level

In theory, what is the biggest battery we could build? and where do you see batteries and energy storage in 20 years?

SirSeabass1

Not really any limit. Batteries are really modular. Large batteries are made up out of smaller "cells" – just like there are 6 cells in your car's lead acid battery -. So in principle we can put as many cells together as we want, and as you can afford. In some technologies we might become limited by resources.

1) If there is one thing you could change in the process of battery research, what would it be?

2) Which data is not readily available but would help battery R&D?

Specifically the second question is related to my project at openbatt.org. Thanks for AMA!

openbatt

Battery research should become more quantitative.
Also, academic researchers would benefit greatly from more details on how commercial cells are made and what issues they have. The bridge between manufacturing details and science is often too large

Hello! It is easy to see how more efficient batteries improve everything from cell phones to cars. A lot of technology used today rely on batteries in order to remain relevant. For as far as R&D companies have come I still feel like we're only seeing the tip of the iceberg when it comes to battery sciences.

What are your thoughts on where battery technology will be in 10 years?

Thanks!

QueforLife

You are probably right that great things are still to come. Having been around in the field for a while I have seen the lulls where everyone thinks noting new is to come and then someone comes up with a great new idea and the field jumps ahead. Something like that happened again in 2011 when researchers in Japan found that solid state electrolytes can have the same or better Li conductivity than liquids. This is HUGE as it removes the flammable component from the battery. This translates into safer and higher energy cells + less need for safety and cooling devices on cars etc. The industry is working very hard to make this new direction a reality and I am confident we will see solid state cells emerging within a few years

Professor Ceder,

Really excited to see you here on reddit!

Can you let us know what you think the next steps are in the Materials Genome Initiative?

thirdworldprobs

Thanks for the question. I think that as materials prediction is getting better we need to become more predictive on how materials are synthesized. This will allows to innovate much faster in the materials world

To make better use of solar energy do we need better solar panels or better batteries to store the

energy produced by the existing technology in solar panels?

konman96

Probably both. Nobody will dispute the benefits of higher efficiency solar cells, for sure. But storage is becoming really necessary to deal with the peak output of solar during the day. I believe storage on the grid is definitely happening

How much room for improvement remains for batteries? Some people suggest that lithium batteries are a matured technology, where only incremental improvements remain, rather than large advances.

maelstrom3

They are mature in the sense that they have a large industry behind them, but there is plenty of room for innovation. Today the best cells are around 700Wh/l energy density. Replacing carbon anode by Si or by lithium cell, and having some of the advanced cathode concepts work should bring us close to 1000Wh/l. If solid state electrolytes work, this will move even higher, probably reading 1200 Wh/l. Going out further on the horizon, using Multi-valent shuttling ions (rather than Li-ion), 2000Wh/l is not unreachable. But now we are talking 10+ years away

In fairbanks, alaska, as well as some other places in the world, temperatures can get down to 40 degrees below zero (fahrenheit), or colder. How is battery technology addressing this issue for electric cars in extreme climates?

cyoung-cs

I want to solve this problem since I like hanging out in Alaska. Todays electrolytes and electrodes are not good at handling 40 degrees below zero. So you will need to heat the battery. But in Alaska and northern Canada people already plug their cars in too prevent their engine blocks from freezing.

Why is everything always coming out in 5-7 years?

Stopher

Ha ha. Because we can't think any further ahead

What qualifies as "loud music"?

sashaminkh

As loud as possible until my neighbors complain or the music starts to distort

Dr. Ceder,

I am a grad student using density functional theory to model the performance of organic electrode materials for lithium/sodium ion batteries:

--- Do you think there is a market for DFT or computational "consulting", in regards to battery research and development? Maybe for designing new active materials or examining electrolyte stability?

--- Do you think computational tools could be playing a larger role in industry and industrial R+D?

I have been following your groups research for quite some time; thanks for doing this AMA!

energystorage

Thanks for the question. Yes there is definitely a market for computational consulting. There is lots of modeling being done in industry already I sued to do a lot of it but don't have the time anymore

How far are we from my phone's battery lasting all day long?

Punkupine

not far at all. Just turn off your apps, or be willing to live with a thicker phone. Battery size in the phone is limited by the size of the phone. Same with laptops. I think that super fast charging is a better option. What if we could top up your phone in just a minute ? You could stand by while it charges

How environment friendly are the batteries once they are disposed? There is no doubt that battery production is going to ramp up significantly in next few years, however, has the environmental impact been assessed for such case?

crudent

Large battery packs (such as EV's and grid) will not immediately get recycled. Rather they will be repurposed. When an EV is at the end of its life, the battery may still be good for 70-80% of its capacity. At that point it is likely to be repurposed for energy back storage (grid, critical facilities) etc. Once there is no use anymore, one will recycle the cells. Most Li-ions cells today are recycled for the metal content. In particular the Co content is valuable.

How do you stay in shape and look so good at your age?

HidingInYourPants

I each chocolate and drink beer

Are there any new materials you and your team are looking at to create next-generation batteries? How could the current (Li-Po) batteries be improved? Thanks for your time!

Sharpastic

Yes, we are looking into novel cathode materials for Li-ion that give about 50% higher capacity.

If you create something revolutionary, do you and your team have the option to massively profit from it? Can you start your own business with the idea?

Blix-

yes, in principle. What we do is usually owned by the place we work (University or lab) but there are options to license out the work. Most universities and labs are also willing to work with inventors if they want to build a start-up out of it.

What year do you believe we'll be able to hit 500 kWh per kg of battery?

Edit: This number is usually used as a ballpark for the energy capacity required to make domestic flight on electric planes feasible.

mmoustafa

In the year 20385 :-)
500 kWh/kg is a very large number. If you meant 500 Wh/kg that will be challenging but not impossible with Li-sulfur

What do you think about Tesla and the progress they have made increasing range of EVs?

hi_im_sefron

Tesla has done a wonderful thing in getting EV's to where they are now. They understood that electric drive trains can be used to create high performance cars and they started that innovation at the high end of the product line. This gave them enough budget to install a large battery leading to a large range. There challenge comes now that they are trying to move down into lower cost cars.

How fast do you think battery sites will ramp up in CA due to the extended renewable mandates and the improving outlook for storage?

I'm working on five 2MW projects and one 20MW storage project.

The 20MW project is one of many just mandated by SCE as an offset for the Alliso Canyon leak. For that project I'm helping bring 20MW of battery storage online in less than 5 months. Once CAISO figures out how they're going to make this work fluidly it will skyrocket.

Batteries are going to get cheaper and more efficient as time passes and once the process is in place for battery storage projects at CAISO, the physical medium of the battery won't matter.

It's your outlook as rosy as mine?

WcCannons

Yes. I think that battery prices have been coming down much faster than believe think. As I answered in another thread $100/kWh at the cell level will be a reality. At that point a lot more grid storage makes sense

Hi Dr. Ceder, I'm a huge fan behind the The Materials Project. What was the motivation behind this idea? And what do you see is the future of energy storage devices? Whether it will be Li-ion, Na-ion or solid state, or is it something that is beyond what we currently know of?

oneLove_-

Thank you. We had been doing high-throughput computing for industry for a while and thought it would be great to disseminate this information to the public. We also wanted to merge the 30-year effort in computational materials science with advances in computing power. That led us to the idea that once could calculate the properties of lots of compounds. Soo replies to some other questions on your "future of energy storage" question

Prof. Ceder:

Are there similar challenges being faced in energy storage r&d with mining and extraction for metals and rare earth elements as other industries are currently experiencing? Also, is it possible we will at some point see a paradigm shift with energy storage?

ImaLuckyChicken

There may be. Currently, the biggest concern is cobalt. Almost all good cathodes for Li-ion today contain a certain amount of Co (lots of it in portable electronics Li-ion, and smaller amounts in cells for automotive and grid). But today we are using almost half of all Co mined for the Li-ion industry. If we cannot develop "Co-free: cathodes, we will be in trouble when scaling Li-ion tenfold.
Na-ion and Mg batteries currently do not have these issues.

As someone who has just begun my Freshman year of college, what are some of the key classes you took that led you to where you are now, and how did you find your passion for your work?

inshaneindabrain

Thanks for the question. I always liked engineering, but after taking many materials engineering classes I got frustrated by the lack of quantitative approaches. So for a while I became "a theorist" so I could learn about and develop more quantitative approaches to materials science. I would say, try to take different classes in various flavors of science and engineering and see what attracts you. Don't be afraid to take stuff that is not considered mainstream as it may become mainstream soon.

According to Jeff Dahn, the only two ways to truly tell the lifetime of a battery is either High Precision Cycling (HPC) or through longevity tests (i.e. cycling normally over the course of many years). In other words, accelerated rate testing is not an accurate way to predict cell life. What are your thoughts on this?

The_Cantabrigian

Jeff Dahn is a very smart guy and he is pretty much correct on this one

Hi Profesor Ceder! Have you considered using nanotechnology in your batteries? Also, why do you go by "Gerd", when "Gerb" would be the more accurate abbreviation? Thanks!

ElysianDragon

Blame my mom

What future battery tech do you find most promising?

cogman10

Solid state Li-ion and Mg batteries

What would you say is a preferable academic background for developing new batteries and energy

storage options? Chemical engineer, electrical engineer, chemist, materials science...? Thanks in advance for the response!

BreezyMuffin

Interesting. The cool thing about the field is that you need a bit of everything. If you are going into the science side of it you definitely want to know chemistry and materials science. On the engineering and production side some mechanical engineering and electrical is also needed

Any hope for a battery with the energy density of a tank of gas?

Any hope for a battery that doesn't lose capacity as it ages? At least not so much that you need to replace it before the end of life of the product it's installed in?

capilot

Hmmm. Though. I did this calculation a long time ago. TO compete with the useable energy density of gasoline (not the hear of combustion) we would need to reach about 2000Wh/l That is near the upper limit of what we can envision with today's concepts. So not impossible in the very long term, but definitely not there yet today.

Professor Ceder,

A large majority of Li-ion battery research feels concentrated on improving cathode and anode materials, and the majority of current electrolyte study seems to be on developing solid-state electrolyte (I was at your talk at Stanford a few months back where you discussed this). Have liquid electrolytes reached the limit of their development? There seem to be many drawbacks to our current organic electrolytes in terms of safety and stability, can these not be overcome without a switch to solid electrolyte?

What technology do you believe will provide the next "big step" in battery development? For example I believe Silicon anode technology is close to being commercialized, will that realize a significant jump in performance?

Thanks for your time.

generic-user-name

Great question. As always, just as we think there is nothing interest left to do, someone comes up with an out of the box idea. That is true for the liquid electrolytes. Some of the highly concentrated electrolytes (solvent in salt) seem very intriguing. While not perfect yet, there is possibly interesting opportunity there !

What do you think about graphene batteries? Is it the next best storage technology?

HopTzop

graphene is used as an additive by some - and to get papers in Science. But is it no an active component

What about supercapacitors can they be the future of energy storage?

hiyawaffa

Supercaps will play a role as they can have very long lifetime and good cold weather performance, but there specific energy is too low to replace batteries for the main storage of energy. One can envision combined devices in which supercars buffer peaks in charge and discharge to give the battery an easier time.

Hi Doctor!

My company currently develops portable battery recharging products (power banks) and we have been using Lithium-Ion to do so for the last couple years, but I have been looking into using more commercially "new" technology but not sure if I should make the switch.

My question is this: Is there any reason as to why changing over from Lithium-Ion to Lithium Iron Phosphate (given the pretty clear advantages of safety, output consistency and recharge/discharge ability) hasn't been more widely used in mobile battery technology, and would it be a good idea to do so?

BobSagetBaseGod

LiFePO4 is very stable and good for high power and long life. But a bit lower in energy density than other Li-ion systems. So it depends on what your application is

What is the best way to maintain a typical smart phone lithium polymer battery? I know heat in general and especially while charging shortens the life. What is the ideal way to charge it? Try to keep the charge between 40% and 80%?

wasteland44

those are good ideas, but they seem like a pain to me though

Do you see the movement towards all-electric vehicles as being sustainable in the long term, given the resources that are required to create the batteries in the first place -- as well as all that goes into recycling/disposing of them once their useful life is through?

musicide

Great question. The automotive industry has an excellent track record of recycling (actually one of the best of any consumer product). Hence I am not worried about the recyling/reusing aspect of the EV trend. Battery packs will be repurposed after the life of an EV and go to other uses (back up power etc.) Only after that second life will they be recycled.

How's the food at the Berkley Lab? Heard you have a great cafeteria up on the hill?

thesaltysquirrel

great ?? Clearly you have not been here ... Food down on campus is much better

How long does it typically take a new discovery you make to show up for consumers? I often hear

about new battery innovation but they "aren't manufacturable" how often do you take manufacturing concerns into account?

cybercuzco

Unfortunately rather long. The average time for materials to commercialization is 18 years. This is what the Materials Genome Initiative is trying to fix. In the battery field the average time to market is a bit better actually, but it can still take +5 years for any innovation to get to market. Part of that is just reality for testing scaling up, consumer acceptance and testing etc. But indeed a part of that is that sometimes the communication between industry and the science community is not perfect

Thinking 5-10 or more years out (I have no idea if that's a short or long time in the battery space), what do you think is the most significant improvement in our collective lives that's enabled by much better battery technology. Ie better demand shifting of utilities, electric cars, amazing hybrid cars, Mobile devices, things not yet imagined, cleaner environment, other? What's your biggest hope our dream of what's enabled by your work and the work in the battery industry?

areback

I think we really have the opportunity to clean up our transportation sector, which is responsible for about 1/3 of our CO2 emissions. We already see lots of busses being replaced by EV busses. Lower battery cost ad fast charging will make EVs more attractive for a larger fraction of the population. We really do not need to convince everyone for EV's t take hold. For vehicles that need much longer range PHEV is an ideal solution. I believe that EV may follow what we see in solar. The growth in solar has been tremendous to the point where its integration into the grid is not almost a problem w/o storage. I hope that through out work we can contribute to this and make materials that one day show up in these batteries !

Hi professor,

If storing electricity is so problematic, shouldn't we focus on efficiently transforming energy stored in other forms into electricity?

asmj

Great idea. Any specific thoughts ?

Hi Prof. Ceder,

What is your opinion on H2 fuel cells?

Also, which type space heater is more efficient, ceramic element or hot oil?

Thank you for all of your contributions, you've had a lasting positive impact on your field and on your students.

ajandl

All space heaters have the same efficiency. Basic laws of thermodynamics. But some are more pleasant

Not a fan of H2 fuel cells. Will aways be a technology of the future. the problem really is not the fuel cell but the fuel. H2 is not easy to make, transport, or store

Do you see any breakthroughs coming in lithium air batteries that might see them in autos or airplanes in less than 15 years? I would really love to see a reasonable electric aircraft. Thank you so much for your work!

gnetisis

No. I wish I could be more positive.
Electric aircraft might benefit more from lithium-sulfur technology as it is the highest energy per unit weight but suffers from cycle life issues. However if you are willing to replace batteries, Li-S is a good bet for anything that flies

Hi, I was wondering your general thoughts on li-air batteries. Specifically the possibility that they become a commonplace battery in ten or twenty years like how li-ion has emerged in the past ten years.

Thanks!

LD513

I am not particularly positive on them. But hey, I would love to be proven wrong on this one, as it would be a great advance.

I've recently heard of ceramic batteries possibly replacing lithium ion, what would be the benefits of switching to ceramic?

BigEarl1988

great safety.

How much money do you make?

wonderchin

Money ? I do science and work for the government

How do personally feel about flywheels? Or, indeed, fly wheels?

Will there be a place for more mechanical methods of energy storage in a decade, or will everything be... Chemical? (Is that the right word?)

Will capacitors and batteries merge into the same thing as the advantages of one come to the other?

wredditcrew

Interesting idea that has been around for a while. Even some companies built around it (like Beacon Power). Anything mechanical needs to run at very high speed in order to get the same energy density as chemistry/electrochemistry. So the engineering challenges are substantial. Currently, it does not seem economical, but who knows. Anyone designing future ideas for the grid should however plan for the 10,000lbs Li-ion gorilla which will come at you at $100/kWh

SCIENCE AMA SERIES: I'M GERBRAND CEDER, A BATTERY SCIENTIST AT BERKELEY LAB, AND I RESEARCH NEW WAYS TO IMPROVE ENERGY STORAGE TECHNOLOGIES. ASK ME ANYTHING! : **REDDIT**