**One of the most mind-bending technological developments that I’ve had to apply my somewhat limited brain to while I’ve been making videos for this channel, has been the painfully complicated process of attempting to combine lithium with sulphur inside a battery cell in order to derive a very significant increase in performance. Sulphur is an abundant element. In fact, according to the Encyclopaedia of Analytical Science, it’s the tenth most abundant material on earth. So, in that respect it represents a very compelling option.**

**But there are so many technical barriers and challenges in the chemistry that making it work at any kind of commercially viable scale has until fairly recently been regarded as an unobtainable goal.**

**But time marches relentlessly on, doesn’t it? And while I’ve been distracted with other subject matter, lithium-sulphur battery technology has been quietly moving up the Technology Readiness Level, or TRL ladder, taking it from the hypothetical laboratory concept that I first looked at more than three years ago to a market ready product today that is attracting a great deal of interest from some of the world’s largest car manufacturers.**

**So, as part of our twenty-twenty-four sustainable technology review series, now seems as good a time as any to dive back in, remind ourselves how it all works, and find out if lithium-sulphur batteries really could be a potential success story.**

**Hello and welcome to Just Have a Think.**

**We’ve checked out progress on sodium-ion batteries and solid-state batteries in the past couple of videos, both of which look like playing an important role in the green transition.**

**Lithium-sulphur is an alternative that offers some potentially very big advantages over standard lithium-ion battery chemistry, but it also comes with the inevitable raft of technical challenges that scientists love to explain in peer reviewed research papers, using the full range of their slightly impenetrable language, which I’ll do my best to deconstruct as we go through the video.**

**According to those science bods, lithium-sulphur chemistry could theoretically store five times as much energy as la standard lithium-ion battery, which would be nice, wouldn’t it? Trouble is, when they first started building cells to test that theory, researchers found them to be inherently unstable with very slow power delivery and a useful operational lifetime of only a few charging cycles. Which was disappointing. So why was that then?**

**Well, sulphur itself is an electrical insulator, which is not ideal for a battery material. So, to make it work at all, it has to be highly distributed on some kind of conductive scaffold like carbon nanofibres, or exfoliated graphite to produce a very thin, very regular and very repeatable pattern over a very large surface area that enables the sulphur to interact with ions and electrons.**

**As the battery discharges, lithium ions arrive at the sulphur electrode, and rather than intercalating inside it, like they do inside the graphite anode of a standard lithium-ion battery, they react with the surface sulphur to create what are known as polysulphides, which are soluble in the liquid electrolyte and are therefore free to float across the separator to the other side. Those polysulphides physically remove sulphur from the electrode, and that causes it to shrink a bit. Then when the battery is charged back up, the sulphur is returned back into its host scaffold structure, causing it to swell back up again. That constant expansion and contraction quite quickly distorts and cracks the structure which is why early versions of the system only managed about fifty charge cycles.**

**As we discovered in our previous videos on the subject, there are ways and means to get around that problem by creating what are known as ‘expansion tolerant architectures’ like the one developed by researchers at Monash University in Australia, using what they describe as a ‘springy matrix of carbon and sulphur compounds’. That matrix like structure also has the advantage of allowing more space for lithium ions to interact with the sulphur, resulting in a claimed overall GRAVIMETRIC ENERGY DENSITY of five hundred watt-hours per kilogram, and an operational lifetime of about a thousand charge cycles. But we’re not out of the woods just yet. There’s a thing called polysulphide shuttle, which would have been a great name for a nineteen sixties dance craze, but which is actually a phenomenon that can cause a lithium-sulphur battery to become effectively useless if it’s not managed properly. As those soluble polysulphides arrive at the negative electrode, rather than being held there, they can break down and float back over to the positive side where they recombine again, kicking off a continuous back and forth movement. That’s your polysulphide shuttle, and it causes a phenomenon the science bods call ‘infinite charge’ where a battery charges up once and then won’t charge anymore because these polysulphides just keep bouncing between the two electrodes. And another not very helpful reaction can take place at the negative electrode, depending on what it’s made of. This one has the elegantly scientific title of Surface Electrolyte Interphase or SEI, which in plain English is a kind of unwelcome mossy like growth that builds up over time and eventually causes the electrode to act more like an electrical insulator. We looked at how that works in a bit more detail in our previous video on the subject, so if you’re keen to get the technical low down then you can click up there somewhere to jump back to that one.**

**Now I’ve made all that technical development stuff sound like no more than a couple of weeks’ worth of laboratory work, haven’t I? But in reality, it’s been many years of spirit crushing trial and error, mostly error, by scientific research teams all over the world to achieve anything that has even the remotest chance of competing with the uber dominant incumbent lithium-ion chemistries that now provide the energy for just about every electrical device and machine on the planet. So why keep plugging away at something that looks a bit of a hopeless cause? Well, as usual, because the prize for the outfit that gets there first is potentially very attractive indeed. A properly resolved and engineered lithium-sulphur battery could potentially deliver a very cheap, very safe and relatively sustainable solution with several times the energy density of current lithium-ion technology. So, if someone call really nail it, so to speak, then it would certainly put a serious turbo boost into the acceleration of the electric vehicle industry and may even open up the possibility of electrically powered medium haul passenger planes in the coming decades, something that until now has been generally regarded as a delusional pipe dream.**

**There are precious few commercial entities anywhere close to those sunlit uplands right now though. One company having a go is the South Korean behemoth LG, which has set up a subsidiary called LG Energy Solution to pursue the lithium-sulphur goal. They’ve set themselves the highly ambitious target of mass producing a commercially viable lithium-sulphur battery cell by twenty-twenty-seven, and they have apparently got their eye very firmly focussed on the aerospace industry. LG currently has a lot of working capital so they will no doubt be attacking this problem through the medium of brute force and lots of cash. But they’re also going after the solid-state battery market as well, so whether they really manage to stay focussed on lithium-sulphur remains to be seen.**

**A slightly more single-minded group of experts can be found at the offices and laboratories of Zeta Energy based in Houston, Texas and Munich, Germany. They’ve been plugging away at the challenge since twenty-fourteen and according to their own website, which I realise is, you know.. their website, not a peer reviewed scientific document, but anyway, according to their website they now have a commercially ready product based on sulphur, lithium and 3D carbon nanotube scaffold structure. They reckon they’ve found a lithium-based alternative to pure lithium metal for their anode, which they say eliminates polysulfide shuttle and eradicates the pesky dendrite problem that we’ve looked at many times in the past. The stated energy density is four-hundred- and fifty-watt hours per kilogram with a charge rate of 10C which, in theory at least, means a Zeta cell can be charged up in only six minutes. They also claim an operational lifetime of two thousand cycles, all of which, if true, makes their technology a potential market disruptor. You may have seen the automotive engineering guru Sandy Munro quiz their management team in a forty-five-minute interview back in March twenty-twenty-three but if you missed it, I’ve included a link to that video in the description section below. I suspect Zeta probably have some way to go before they become a household name, but by all accounts they do at least appear to be a genuine outfit with a real working chemistry that could prove to be very impactful in the fullness of time.**

**The name that I imagine most of you will already know though, and the one I’m sure many of you have been waiting for me to mention, is Lyten Inc. – a start up founded in twenty-fifteen in San Jose, California.**

**Lyten has enjoyed quite a lot of press coverage in recent months. In** **September twenty-twenty-three the company announced two hundred million dollars equity financing from multiple investors, including Prime Movers Lab, Honeywell, FedEx, and others, taking their total funding to four hundred and ten million dollars.**

**They tick many of the desirable boxes, like no nickel, manganese or cobalt ; lightweight cells with high energy density; a very wide operational temperature range right down to minus thirty-five degrees Celsius; resistance to thermal runaway, and a massively simplified supply chain using locally sourced materials, that keeps costs and environmental impacts to a minimum. Their superpower is apparently their own proprietary version of 3D graphene, which Lyten says can be engineered at atomic level to bond with other elements in a process they call tuning. They use it to provide the scaffold structure for their sulphur-based electrodes. As well as effectively eradicating the polysulfide shuffle problem that we looked at earlier, their so-called 3D graphene caging structure also gives the cells greater strength, hardness and electrical conductivity. As far as I can tell, Lyten hasn’t published specific performance numbers yet, but according to their CEO, Dan Cook, their cells have ‘the potential to deliver more than twice the energy density of lithium-ion’. In 2021, Lyten’s ‘LytCell’ prototype managed more than fourteen hundred charge cycles under US Department of Defense test protocols, which may by now have been improved upon, and Cook reckons they can commercialise all of that for about eighty dollars per kilowatt hour, which is well under the battery industry holy grail of one hundred dollars. All of that can of course be taken with a pinch of salt if you like, but what is undeniable is that Lyten’s technology has impressed the giant automotive group Stellantis – or at least the venture capital arm of Stellantis anyway. They recently announced a joint venture to develop applications for what they call ‘advanced Lithium-sulphur based EV batteries’. The two firms have been pretty cagey about how much money has actually changed hands in the deal, but the stated goal of Stellantis is that by twenty-thirty, one hundred percent of its European car sales and at least fifty percent of its US car sales will be fully electric, so if Lyten get a piece of that pie then they will be in very good shape indeed.**

**In June twenty-twenty-three Lyten opened its first Lithium-Sulphur Pilot Production Line, producing both cylindrical and pouch cells. Production cells are being sent to auto-manufacturers for testing now and the plan is to begin delivering commercial grade cells for non-EV applications this year.**

**So, there we are then folks. Once again I’m afraid I still can’t tell you that a silver bullet has finally been fired into the heart of the green transition challenge – I’m not sure there is such a thing to be honest, but I can say that real-world tangible progress is being made in lithium-sulphur technology, with the construction of actual factories and proper investment from hard-nosed car manufacturers desperate not to get left behind in the race for market dominance in the newly electrified transport sector. Despite the moans and groans and protestations of antiquated technology laggards, vehicle electrification is now an unstoppable market driven force that is taking us away from fossil fuels. And that gets my vote every time. You might not agree with that view of course, and you may now be feeling an irresistible urge to tell me that! So, whatever your opinion, why not jump down to the comments section below and leave you thoughts there.**

**That’s it for this week though. Thanks, as always, to our Patreon supporters, who enable me to keep ads and sponsorship messages out of all my videos.**

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**As always, thanks very much for watching! Have a great week, and remember to just have a think.**

**See you next week.**