**These solid-state battery thingies have all been a bit of a disappointment so far, haven’t they? You’ve been listening to YouTubers like me going on about them for years and years – in my case since twenty-eighteen. But every time we think we’ve found a company on the cusp of the all-important breakthrough, they either go bankrupt or put out a press release admitting that it had all turned out to be just a bit more tricky than they had anticipated and they would now be reverting back to a traditional lithium-ion battery instead.**

**And here’s where I’m reminded of an anecdote that I once heard from none other than Jeremy Clarkson. On one of his many laddish adventures around the world he was on a small single propeller plane coming into land on a notoriously difficult and dangerous airstrip somewhere in the wilds of Southeast Asia. Clarkson recounted that ‘having made several attempts to land on the actual runway, the pilot eventually gave up and elected to land somewhere near it instead.’**

**And that’s kind of where we seem to be right now with the whole solid-state thing, because the new buzzword that it looks like we’ll all be getting used to in the coming months is not ‘SOLID state’, but ‘SEMI-solid state’**

**So, what’s the difference and, frankly, what’s the point?**

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

**Before we get stuck in, I thought I’d just let you know that we’re starting to approach our next YouTube landmark of six hundred thousand subscribers here at Just Have a Think and it would be amazing to get there during the second half of twenty-twenty-four. So, if you haven’t already done so, you really would be hugely supporting me and the channel if you hit that free subscribe button and click on all notifications. Getting noticed on YouTube is becoming more difficult as every day goes by, so your support will be massively appreciated.**

**Right then, let’s kick off with a quick recap of the three basic lithium-based battery configurations.**

**We’ve looked at traditional liquid electrolyte lithium-ion batteries loads of times on the channel, of course, but it never hurts to do a little bit of a reminder, does it?.**

**We’ve got two electrodes - an anode over here and a cathode over here, sitting on either side of an electrolyte containing lithium salts dissolved in a fairly nasty solvent either in liquid or gel form. Sitting in the middle there’s a separator membrane to stop electrons flowing from one electrode to the other. The cathode is typically made of a lithium metal oxide and the anode is typically made of graphite. And then we’ve got a copper current collector at the anode and an aluminium current collector at the cathode. During charging lithium ions move from the cathode, through the electrolyte and over to the anode where they intercalate in the graphite structure. Then, when a load is connected and switched on, the lithium ions flow back through the electrolyte and electrons flow out through the circuit to do their useful work.**

**The basic idea of a solid-state battery is to replace the liquid or gel electrolyte with a solid electrolyte, typically made of some sort of ceramic or polymer. No need for a separator here because the solid electrolyte does that job too. Lithium-ions and electrons flow in just the same way as they do in a normal lithium-ion battery, but you save a bunch of space by using a solid electrolyte, which means you get higher energy density, and in theory have a much safer set up by losing the flammable solvent.**

**There are variations on the theme, like the infamous Quantumscape battery, which doesn’t have an anode at all to start with and only builds one up as a solid lithium metal layer during charging. That improves energy density even more – IN THEORY!**

**All sounds great, doesn’t it? The slight wrinkle is that solid-state batteries are proving to be a bit of a nightmare to get into commercial reality, for various reasons. One of the biggest challenges is finding suitable solid electrolyte materials that can allow enough lithium ions to flow through at a fast enough pace to be useful, while also being stable enough to last a long time and be compatible with all the other components of the cell.**

**Then there’s the interfaces between the solid electrolyte and the electrodes, which are crucial for ionic transfer. They apparently often suffer from poor contact and high resistance, which can impede battery performance.**

**In some solid-state batteries, particularly those using lithium metal anodes, you can get the formation of the dreaded lithium dendrites that can pierce through the solid electrolyte, causing short circuits and battery failure.**

**The materials used in solid-state batteries, like ceramics or sulphides for the electrolyte, can be expensive and difficult to get hold of in sufficient volume and at the right level of purity, and manufacturing solid-state batteries at scale is no walk in the park either.**

**Processes like high-temperature sintering and deposition techniques, are energy-intensive and costly and require high precision and control to achieve uniform and defect-free solid electrolyte layers. If those layers are not perfect, then the overall quality and performance of the batteries is adversely affected.**

**Plus, production lines for conventional lithium-ion batteries are not easily adaptable to solid-state technologies, which means big capital outlay in new equipment and processes.**

**All of which brings us nicely to SEMI-solid-state batteries, which as you’ve no doubt already worked out, are an attempt to find a sort of middle ground between the two technologies we’ve just looked at.**

**And sure enough, they have a configuration and working system that looks very similar to the other two. The semi-solid electrolyte is generally a very viscous, gel-like substance that developers hope will provide enhanced ionic conductivity and safety all in one neat little package.**

**The clever battery bods tell us that semi-solid electrolytes can reduce the risk of leakage and thermal runaway, which means they’re inherently safer than liquid electrolytes. They can also achieve higher energy densities than traditional lithium-ion batteries, and the manufacturing process for semi-solid-state batteries can be more straightforward and scalable compared to fully solid-state batteries, potentially reducing costs.**

**Having said that, you’ve still production challenges in terms of consistency and scalability, and that stability issue is still a challenge.**

**Balancing ionic conductivity and mechanical stability in the semi-solid electrolyte is still a key research and development area for many companies.**

**But there are plenty having a crack it that’s for sure. Too many to highlight in a single video in fact, but I’ve picked out a couple of promising contenders to do a bit of comparing and contrasting, starting with a US firm called Factorial Energy. They’re based in Massachusetts, and they’ve actually been on the go for about ten years with backing from some big auto makers like Stellantis, Mercedes-Benz and Hyundai.**

**They’ve got an acronym for their technology – because no self -respecting marketing department would be without an acronym, would it?**

**This one’s called FEST, which stands for Factorial Electrolyte System Technology. The set up is very much as we described earlier, with a lithium-metal anode and a high-capacity lithium-based cathode. The ‘FEST’ part is what the company describes as a ‘quasi-solid electrolyte’.**

**They don’t tell us what it’s made of course, but they do claim a cell energy density of three hundred and ninety-one watt-hours per kilogram, and a range of up to six hundred miles from a ninety-kilowatt-hour battery that’s forty percent lighter and thirty three percent smaller than a conventional lithium-ion pack. Plus, FEST batteries are designed to be made on the same production line as traditional lithium-ion batteries, with only minimal changes.**

**If all of that is true, then it’s extremely competitive indeed.**

**In October twenty-twenty-three, Factorial opened a factory in Boston which will have a two-hundred-megawatt capacity at full tilt. The company reckons that’ll make it the largest solid-state manufacturing plant in the US. In April twenty-twenty-four, Factorial signed a memorandum of understanding with the South Korean behemoth, LG Chem, which sounds very promising, and in June twenty-twenty-four it started providing a new round of B-samples to Mercedes-Benz, presumably with some tweaks and improvements for further testing and development.**

**Meanwhile, just down the road in Cambridge, Massachusetts, an MIT spin-out company called 24M Technologies has trade marked a Semi Solid technology with some brilliantly named components like “Impervio” and “Eternalyte”, based on the use of thick, clay-like electrodes which they say simplify the manufacturing process and improve safety and durability. The company is working with various partners including Kyocera. Most of us probably know Kyocera for their printers, but they are also a global market leader in industrial ceramics and semi-conductor components, so they’re a pretty useful partner to have on board. 24M are claiming a pack level energy density of three hundred and fifty watt-hours per kilogram, and they say they’ve achieved a test run of five hundred cycles at one full charge and discharge per hour, at the end of which the cell still had eighty-three-percent capacity remaining. Arguably even more importantly, the company have another trademark called Liforever™ which enables the reuse of nearly every part of the battery cell without the expensive and environmentally challenging processes of conventional cell recycling. Essentially, the Liforever process keeps active materials in their original form and doesn’t create the black mass typical of the existing lithium-ion recycling industry which then needs to be separated out into its constituent elements using quite nasty solvents. So, the Liforever process could prove to be a real gamechanger in the longer term.**

**Over in China there is of course a great deal of semi-solid battery development activity going on. Perhaps most notably from the Automaker NIO and their battery supplier WeLion. I had a quick look at them in a recent video when NIO’s CEO drove an ET7 sedan with a one-hundred and fifty kilowatt-hour battery more than six-hundred and fifty miles on a fourteen hour live streamed road trip.**

## **I guess the USP that NIO can claim for their semi-solid-state battery is that they are actually making them, at scale and putting them into real-world production vehicles.**

**WeLion began delivering cells to NIO in June twenty-twenty-three and has so far supplied more than sixteen-hundred megawatt hours-worth, which is about enough for more than ten thousand ET7 sedans.**

**China is of course determined to stay at the top of the tree in the EV battery market, spending more than eight hundred million US dollars on all sorts of solid-state battery research and development. And I haven’t forgotten about the two really big dogs either -** [**BYD**](https://electrek.co/guides/byd/) **and CATL. They’ll be receiving a good chunk of that financial support, and as you’ve no doubt seen in your news feeds, they’ve got some exciting products of their own that they want us all to be wowed by – so although I didn’t focus on them today, watch this space folks because I will be taking a close look at both of them very soon.**

**And as I mentioned earlier, there are plenty of other developers around the world vying for a share of what’ll be a very large and extremely lucrative market in the coming years as the energy transition rolls on.**

**If one of those others is a company you’ve got your eye on and you think they should have been featured in this video, or if you work in the industry and have some insights to share with us all, then as always the place to leave your thoughts is in the comments section below.**

**That’s it for this week though. A massive thank you, as always, to the channel’s Patreon supporters who help me stay independent and keep ads and sponsorship messages out of your way. And I must just give a quick shout out to some folks who’ve recently pledged ten dollars or more a month. They are Mark Chandler, Ursula Ambühl-Mettler, Marcus Hoy, Mahesh Shastry, Frank Zegler and Ewan McEwan.**

**If you find these videos useful and informative and you feel like you could support the channel for a dollar or more a month, then why not pop over to patreon.dot.com forward slash just have a think to see how you can get involved.**

**And of course, as I mentioned at the start of the video you can help us hit that six hundred thousand subscriber mark by hitting the like and subscribe buttons and clicking on all notifications, all of which you can do absolutely for free by clicking down there or on that icon there.**

**Most importantly though, thanks very much for watching! Have a great week, and remember to just have a think.**

**See you next week.**