**I saw this article in the online journal Popular Mechanics the other day and I thought ooh that looks interesting. And, then I thought hang on a minute, capacitors and batteries are two completely different animals, aren’t they? I mean everything I’ve learnt about capacitors in the past tells me we can never use them to replace batteries – they just don’t have any useful energy density.**

**So, I downloaded the actual research paper to see if I could summarise its findings, so you don’t have to. And, oh my goodness! This one’s a DOOZY! It’s got ALL the clever scientific words!**

**Hello and welcome to Just have a think,**

**I like capacitors as a rule. In fact, I’d probably struggle to live without them, and arguably so would you.**

**That’s because they’re pretty much essential to the way just about every conceivable modern gadget works. In fact, other than resistors, there are apparently more capacitors in a typical electronic circuit than any other passive component, by which I mean a component that doesn’t require an external power source and doesn’t amplify electrical signals.**

**What I really like about them is the elegant simplicity of their design.**

**Essentially, a typical capacitor is just two strips of metal stuck to either side of a bit of insulating material that the science bods call a dielectric. Some sort of ceramic material usually does that job quite nicely.**

**In something like a phone or a laptop, capacitors can provide short bursts of high power for occasional tasks like the flash on your phone camera but they can also take the edge off that initial surge of electrons that you get when you flick the on switch, because they absorb some of that tsunami to fill themselves up with charge. That results in a ‘soft start’ that protects your very expensive equipment. And it performs the same very useful task when the power is switched off as well. So, all those little lights on various electronic gizmos that don’t go out instantly but sort of fade out gradually? Well what you’re essentially watching there is the equalisation of a capacitor.**

**The simplicity of the structure in capacitors means they last for ever, or at least for millions of cycles anyway, which is of course a feature that developers would dearly love to see in batteries as well.**

**There are lots of other useful applications for capacitors that would take too long to go through here, but one application that IS probably worth mentioning is in the regenerative braking systems of modern electric vehicles. You are no doubt familiar with regen braking by now – if you want to slow an EV down, instead of pressing the brake pedal you can scrub off the vehicles momentum by using that kinetic energy to make the electric motor work like a generator to put some charge back into your batteries. BUT, rather than allowing those electrons to flood into the battery pack all at once, potentially causing a bit of unwanted extra degradation, capacitors absorb that high power and deliver it back into the batteries more gradually.**

**The downside with capacitors is that, although they have high power density, they have very low energy density, typically in the range of microjoules or millijoules per cubic centimetre. Even modern supercapacitors, which are an attempt at a sort of hybrid structure between a capacitor and a battery, only generally reach a few watt-hours per kilogram, compared to, say, a lithium-ion battery that can provide upwards of two-hundred and fifty-watt hours per kilogram.**

**And that’s frustrating for developers because if you could combine the almost instant charging capability of a capacitor with the high energy density of a battery, you’d have a laptop that charged up in seconds and a car that went from zero to a hundred percent charge in about the same time it takes to fill up an equivalent fossil fuel powered vehicle.**

**The performance of a typical capacitor tends to be limited by the ability of the dielectric material between the two metal plates to hold an electric charge.**

**It’s what the science bods call low polarization. There are some exotic sounding ferroelectric materials like Hafnium Dioxide, Zirconium dioxide and Barium Titanate that offer higher polarization, but they also have what’s known as ‘high remnant polarization’, which means they hold onto some charge when they should be releasing it, making them less efficient for energy storage.**

**To solve that annoying wrinkle, the science bods have been developing what they call ‘relaxor-ferroelectric materials’ that have tiny little defects engineered into them to produce so-called ‘nano-domains’ that enable high energy storage with LOW remnant polarization.**

**Trouble is, the process of creating those nano-domains often reduces the material's overall quality and ability to achieve maximum polarization, plus some methods result in a phenomenon known as ‘polarization saturation’ at LOW electric fields, which also limits the amount of energy the capacitor can store.**

**And that’s where the researchers at Washington University reckon they’ve made a major leap forward.**

**They tell us that their approach controls the relaxation time using two-dimensional materials while minimizing energy loss by using 2D/3D/2D heterostructures and preserving the crystallinity of ferroelectric 3D materials.**

**And good for them… what does that mean though?**

**Well, in terms that I can just about get my head around, it means they’ve come up with a method to improve energy storage in capacitors by using super-thin, two-dimensional materials created using a specially developed technique that splits them into single layers. Those 2D layers are then combined with a single-crystal layer of barium titanate (BaTiO3), which is one of those ferroelectric materials I mentioned earlier that’s very good at holding an electric charge. Unlike other methods that degrade the quality of ferroelectric materials, sandwiching the barium titanate between the 2D outer layers preserves its single-crystal nature without altering its structure. Interactions between the layers at the point where they meet helps control the relaxation time of polarization, which, as we saw earlier, is the time it takes for the material to return to its normal state after being charged. And that helps maintain a high charge capacity while reducing unwanted residual charges.**

**So, that’s the method – or at least it’s an extremely limited attempt by yours truly to summarise the incredibly complicated workings set out in the paper – but what about the results?**

**Well, according to the Washington University team, their lab tests produced a capacitor with an energy density of a hundred and ninety-one-point-seven joules per cubic centimetre with an efficiency of over ninety percent. In other words, they’ve got something that can store a large amount of energy, lose far less energy, and maintain high performance with minimal degradation.**

**Sounds great, right? So, when can we expect to see it powering all our cars then?**

**Yeah…its; never quite that simple, is it? According to people far smarter than me, the density of barium titanate is about six thousand kilograms per cubic metre, and that one-hundred and ninety-one-point-seven joules per cubic centimetre that I just mentioned equates to fifty-three-thousand two-hundred and fifty watt-hours per cubic metre. now we’ve got units that are the same, which means we can divide that number by the density of the barium titanate to give us eight point eight-seven-five-watt hours per kilogram.**

**That’s not going to be challenging the supremacy of a two-hundred and fifty-watt hour per kilogram lithium-ion battery any time soon, is it?**

**But that’s not really the point here, to be honest. The goal is not to replace batteries but to produce something that can enhance their performance and increase their longevity. What the Washington University bods have managed to do is retain the extremely simple structure of a capacitor while increasing its ability to capture, retain and release electric charge by a factor of nineteen X.**

**That potentially means much faster charge times and a significant reduction in the amount of stress and strain on the batteries of electronic devices and electric vehicles. It also means significantly improved flexibility in utility scale energy storage systems.**

**The research team are now putting their heterostructure capacitor through its paces in extended testing to ensure it can keep working its magic without losing storage capacity over repeated cycles, but if the results of that work come out clean then we could be looking at one of those ‘transformational gamechangers’ that YouTubers like me are always banging on about.**

**And that’d be nice, wouldn’t it?**

**So, what do you think? Could this be one of those breakthroughs that results in a technological step change? Do you work in the industry and have additional insights you can share with us all? Or do you just have some observations and feedback that you want to add? Whatever it is, the place to leave your thoughts is in the comments section below here. And I’ll be interested to see what you say.**

**That’s it for this week though. Thanks as always to our fantastic Patreon supporters who help keep this channel completely independent AND keep ads and sponsorship messages out of your way, and I must just give a quick shout out to some fine folks who joined recently with pledges of ten dollars a month or more. They are**

**John Paterson, Tom Heung, William Graham, Phil Beauchamp, Richard McDonald Woods, Daniel Orme, Kenneth Kerr, Simon B, Farm Thompson, Tim Camilleri, Jerry Lyndrup, Alf Chamings, Joseph Mersnik and Robert B Alf.**

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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.**