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Introductory Jingle
Connecting for positive change.

Juan Maria
Welcome everyone to this episode of the Battery Caffe, where we'll be discussing different chemistries for anodes and challenges for scale up manufacturing. I'm Juan Maria Gonzalez Carballo, a member of the Chemistry and Industrial Technology Team, Innovate UK, KTN. I'm hosting today's episode, alongside my colleague Debra Jones. Hello, Debra.

Debra
Hi, Juan Maria. It's lovely to be joining you for this. This is my first episode of Battery Caffe Podcast and I also sit in the Innovate UK, KTN's Chemistry and Industrial biotech team.

Juan Maria
Hi, Debra, Thank you for joining me today. For those of you who haven't listened to our previous episodes, the Battery Caffe is an initiative of the Cross-Sector Battery Systems Innovation Network. A community funded by Innovate UK KTN and the Faraday Battery Challenge. The Innovation Network aims to open new markets for the battery industry, promote innovation in batteries, and help decarbonize a wide range of end users. If you haven't already, go check out our online platform at ukbatteriesnetwork.org. You will find lots of useful material and our previous episodes on investment in batteries, battery recycling, market trends for solid-state batteries, electric vehicle fire safety and batteries for highway vehicles. Our special guest today is Alex Groombridge. Hi, Alex, please could you introduce yourself?

Alex
Hi guys. It's great to be here. Thanks for the invitation. I'm Alex Groombridge. I'm the CTO and one of the Co-Founders of Echion Technologies, which is a company commercialising new battery anode materials, focused on safer, faster and longer lasting lithium-ion batteries for generally industrial technologies and installations.

Juan Maria
Thank you, Alex, for joining us today. Please everyone, make yourself a coffee and join us. As I mentioned at the beginning, today's topic is Anode. Alex, we hear a lot about the UK's cathode and catalysts experience, but not much about our anode capabilities. We know that the anode plays an equally important part in the design of a battery. Could you tell us which materials are currently used and commercialised and what are the desired properties of these materials?

Alex
Of course, yes. So and as you say, cathodes have been the biggest focus so far for quite a long time, normally because of the cost and sustainability implications of materials such as cobalt, and anodes have started to become a little bit more popular, especially recently. The main three materials which you'll sort of come across in a standard lithium-ion battery are graphite and carbon based materials, silicon or silicon oxides and hybrids with graphite, and

a material called lithium titanate, often shortened to LTO. With graphite based technologies, this is your, shall we say standard, technology is the cheapest. It's used in most devices, sort of 90-95% of devices out there use a form of graphite, to store lithium-ions. And it's often used for sort of low cost or high energy applications, really your standard lithium-ion battery uses this technology and then it's paired with various cathode materials that you may have heard about before - NMCs, your LFPS which are becoming popular as well. They're all covered there. Silicon, silicon oxides and hybrids with graphite and then focus more on the higher energy style of batteries. These are commercial today, with mixtures with graphite and there are some companies who are trying to look at them as 100% silicon anode materials. Now they're really interesting because they have such a high potential capacity to store lithium-ions. So you can have energy densities that are a huge step change compared to what we have today. And they do suffer for some limitations, which I think we'll get on to later on. Finally, you've got lithium titanate LTO base material, which is really exciting for high power, long life batteries, but it is quite a niche material today. So it's used in things like, some industrial applications, it's used for fast charging batteries, you can fast charge it in a few minutes. You can last for sort of 10 times longer than you would with a graphite or silicon battery, that it has limitations as well which we can come back to later on. That's kind of the main three technologies that you'll find the lithium-ion batteries. When you consider things like sodium-ion or solid state. It's all quite different. So I'll stick to these ones for now and we can always come back to the others.

Debra
Thanks, Alex. You mentioned some limitations. Obviously, most materials have some limitations and you often enhance one property at the expense of another. And when you're doing any sort of modification, do any of these materials have particular challenges that are critical to overcome as we move to a sort of more electrified energy system?

Alex
Yeah, they certainly do. As, as you say, in the battery world, everything's a trade off, depending what you're trying to get towards. Sort of four main metrics, which I'll focus on, are your energy, so how much energy you can store, energy density, how much energy you can store in a given mass or volume. Power, which can mean many things. So, like fast charging, fast discharging, or it could be pulse power, putting your foot on the accelerator, for example, or things like this. Cost, very important. You can make a wonderful, expensive battery but no-one will buy it. And lifetime, how long does it last? Of course, there are others, but those are the main ones, which I'll focus on. If we think about a graphite anode material and its use for a lithium-ion battery, it's definitely the cheapest technology out there in terms of sort of dollar per kilo cost of the material itself, but also how you put it together in a battery. Energy density, it's pretty good, it's sort of middle of the road, fairly reasonable power density, it's renowned for having great discharge power, you can discharge it very quickly. But it has severe safety limitations when you want to charge quite fast. And that's because, going into a bit of the technical detail, if you have lithium-ions, basically bombarding the graphite material at very high rates, you end up with lithium-ions transitioning to become lithium-metal, due to over potentials in the electrode itself. This causes lithium dendrites, which you may have heard of, which can cause short circuits, either in the least impactful way, this can just be shortened lifetime, and in the worst, this can lead to severe battery failure. Explosions and things like this can happen. So they're often fundamentally limited in terms of power, like your Tesla Supercharger at 4C charge, so once

in 20 minutes, but don't do it too often, because you'll damage the battery, and that comes because of this primarily. And lifetime graphite, sort of again, it's middle of the road, it's fine. It's alright, it's hundreds of cycles to a couple of thousand cycles, is what we typically think about. Silicon then is focused on higher energy density, it's a lot higher than what you would find for a graphite based system on its own. That's why people look at blends or 100% silicone based materials, very attractive for sort of driving your electric vehicle on a single charge halfway across the country, for example. And power silicone materials can be quite good. However, they have this severe limitation in terms of lifetime. This is due to when you lithiate these materials, they have a different mechanism, lithium is alloyed with silicone, causing a huge volume expansion where the whole material expands and contracts repeatedly to cycle the battery, which can lead to severe degradation of life. So normally, they only last for a few hundreds of cycles in use, which often is fine for a high energy style of application. Lithium titanate then, as I said, it's excellent in terms of power, you can charge, discharge, excellent terms of life after you've optimised it. To mitigate things like gassing taking place, you can have 10s of 1000s of cycles potentially from this material. However, energy and cost are its limitations. The material itself has a fundamental limit for how many lithium-ions you can store inside it, due to the nature of the material crystal structure, its composition is redox chemistry. That basically leads to higher cost as compared to the other materials when you want to use it in an application, it could work but then half of your vehicle would be a battery, for example.

Debra
So Alex, it sounds like we know that batteries are a reasonably well developed technology. However, they aren't without their challenges. So we understand that there are efforts going on to develop and improve the properties of these existing materials. But would you be able to tell us a little bit more about new families of materials being developed and what advantages they bring and challenges that they solve?

Alex
Of course, yes. So new chemistries that's where a lot of focus is from cathodes to anodes, solid-state, semi solid-state, the list goes on. For anode materials there are a lot of efforts to improve existing materials in intelligent, different ways, or change how they're actually used to mitigate some of these problems. For example, with graphite materials, there's a lot of work in how to mitigate the problem of lithium dendrites through how you use it, maybe operated at a different temperature, maybe have separated materials that prevent lithium dendrites from going through the material, maybe modify the material itself with various coating technologies or so on to try and stop this. So it's more sort of treating the problem, if you like. With silicone, these materials are still well under development, for sure, the volume expansion challenge is a real, real difficult one. But there's a lot of progress being made. There's a lot of startups that started sort of 20 years ago that are now some of the biggest companies out there in the battery materials world. Companies like Sila Nano in the US, I think, are one of the biggest. So the work continues there and how to mitigate that technology. It's challenging, particularly with regards to how you manufacture batteries made from it, because there are typically some changes you have to make if you want to go for full silicon based technology. Lithium titanate has been around for quite a reasonable amount of time, it's not in a huge amount of material development, so far, it's more around the system, then. So mitigating problems of generation of gas byproducts, and so on. When we think about new materials, there is a bit of interest in looking at hard carbon and soft carbon based

materials, for example, sort of higher voltage materials than graphite, so you can potentially get around dendrite formation and access higher charge based materials. But then you have challenges with side reactions and lithium loss, when you first charge and discharge hard carbon based materials. So there's a lot of activity there on people trying to explore slightly different carbon based materials and see how they could potentially be used. Otherwise, there's materials, particularly for my interest at Echion, based on materials like niobium. So we're looking at mixed niobium oxide based materials. Niobium base materials are quite interesting for these high power styles of batteries. So looking at providing the same benefits with the lithium titanate technology in terms of power and lifetime, but providing much more competitive energy density and cost. And there is where it's really a brand new development from the very beginning, looking at material formulations designs, rather than trying to mitigate a problem that exists with a new technology. But as compared to cathodes, there are less options out there today for sort of brand new materials discovery.

Juan Maria
Thank you, Alex. It's been really interesting to hear. I mean, yeah, that's a comprehensive overview you're providing both on chemistries for anodes that are currently commercialised, but also those which are under development. For instance, the niobium you mentioned from Echion. Thinking about the different chemistries, I mean, batteries can be applied into different sectors. Are there specific formulations, which are probably more appropriate for batteries within specific applications?

Alex
Definitely, yes, definitely, for sure. When we think about the biggest market out there that's growing passenger car EVs, is primarily driven by cost and sustainability, for example. So it's really, it's a challenge, because everyone operates on quite a small margin for such a high volume application. So for those really the formulations people focus on are things like graphite based technologies, graphite mixed with silicon, try and improve their energy density, bring down the size of that battery pack that you need, such that it still fits what people need from a car. However, when you consider things like premium devices, like you know, wearable earphones or things like this, then people look for more performance. It's not really a race to the bottom in terms of cost and volume. And looking at things like raw materials supply chains, then that's all, I'd love a fast charging earbud or I'd like one that lasts for two weeks or something like this. So for sort of premium applications, it's more on what you're looking for, graphite, silicone, LTO, niobium base materials or otherwise. Then when we think in terms of more niche markets than passenger car EVs, these sort of industrial use cases, heavy goods vehicles, mining trucks, trains, marine if all of these need to be electrified, that's quite a substantial amount of battery out there. Still a drop in the ocean compared to passenger car EVs, but the power batteries at Echion we consider to be almost a 100 gigawatt hour market in the future, since it's quite substantial. And for these, there currently isn't a solution that works really, from an economic point of view. The energy batteries don't last long enough, can't charge fast enough, not safe enough. The power batteries are too expensive and can't have enough energy. So a new solution is needed for these types of applications where you need them to last for a long period of time. Then it gets even more complicated when you begin to think about raw materials where it's quite a hot topic at the moment, especially with conflicts going on as well. There's not enough raw materials around, it's a big competition over who can secure what, who can work with who, to get what they need for that application. So really, the answer is there's no one fits solution

for every application out there. There's a lot of opportunity for performance, differences, for different market requirements.

Debra
So we saw the exciting announcement back in December of Echion's new partnership to build a 2000 tonne per year manufacturing asset, to supply anode grade niobium oxides, we were just talking about earlier securing materials supplies, this is a really exciting announcement. However, as anyone who's ever tried to scale anything up, I know this is likely to be a pathway, is it fair to say there are some hurdles? Alex, would you be able to share what challenges you anticipate facing when you look at scaling up this material?

Alex
Yes. I would say it's not easy. For any new material out there, that's sort of not a modification of existing. When we started Echion, we were originally making milligrammes of material in a day, which if you imagine, is sort of a few grains of sugar, kind of that kind of size of material. Last year, we sort of made in excess of about 10 tonnes of our material, it's been quite a journey to go from a tiny, tiny lab scale, up to that sort of small pilot large lab. Now we're working on a 2000 ton per year supply by 2024. There's huge challenges here, where it goes from technical, money, financial, you know, risk and geography of where you put it, sustainability. And just making sure that there are people to buy the material at the other end, as well. And all of it has to match up in the middle. I would say, one of the biggest challenges in doing this, is that it takes a long time to build a facility. So you've got to do it at the right time scale with the right expertise in place. So for example, we partner with a company called CBMM in Brazil, who mined and refined niobium based products. And by doing so we cut down that timeline to get to the end result, because we can both work on our respective expertise points and at the same time, it gives huge confidence to our customers and to the market that the supply will be there. It's in line with our forecasts. So on the one hand, it's the technical challenge of, we've got to do a scale up of you know, a 100x from where we are today. It's been done before, we will certainly get there. But on the other side, we've got to make sure it happens in good time before the market changes. So lining all of that up is, I'd say, one of the biggest challenges, especially in such a global market.

Juan Maria
Alex, we wish you all the best, with the partnership and moving forward. I just wanted to thank you, Alex, for joining us today. It has been really, really interesting to hear your views on the different chemistries, that are both you know, developing and are under development for anodes for batteries, as well as the challenges for scaling up manufacturing. Thank you Debra for co-hosting this episode. And thank you all for listening. We hope you enjoyed the discussion as much as we did. Don't forget to visit our online hub on ukbatteriesnetwork.org and register to receive our news and updates. Our next episode will focus on battery storage. Until then, goodbye.

Outro Jingle
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