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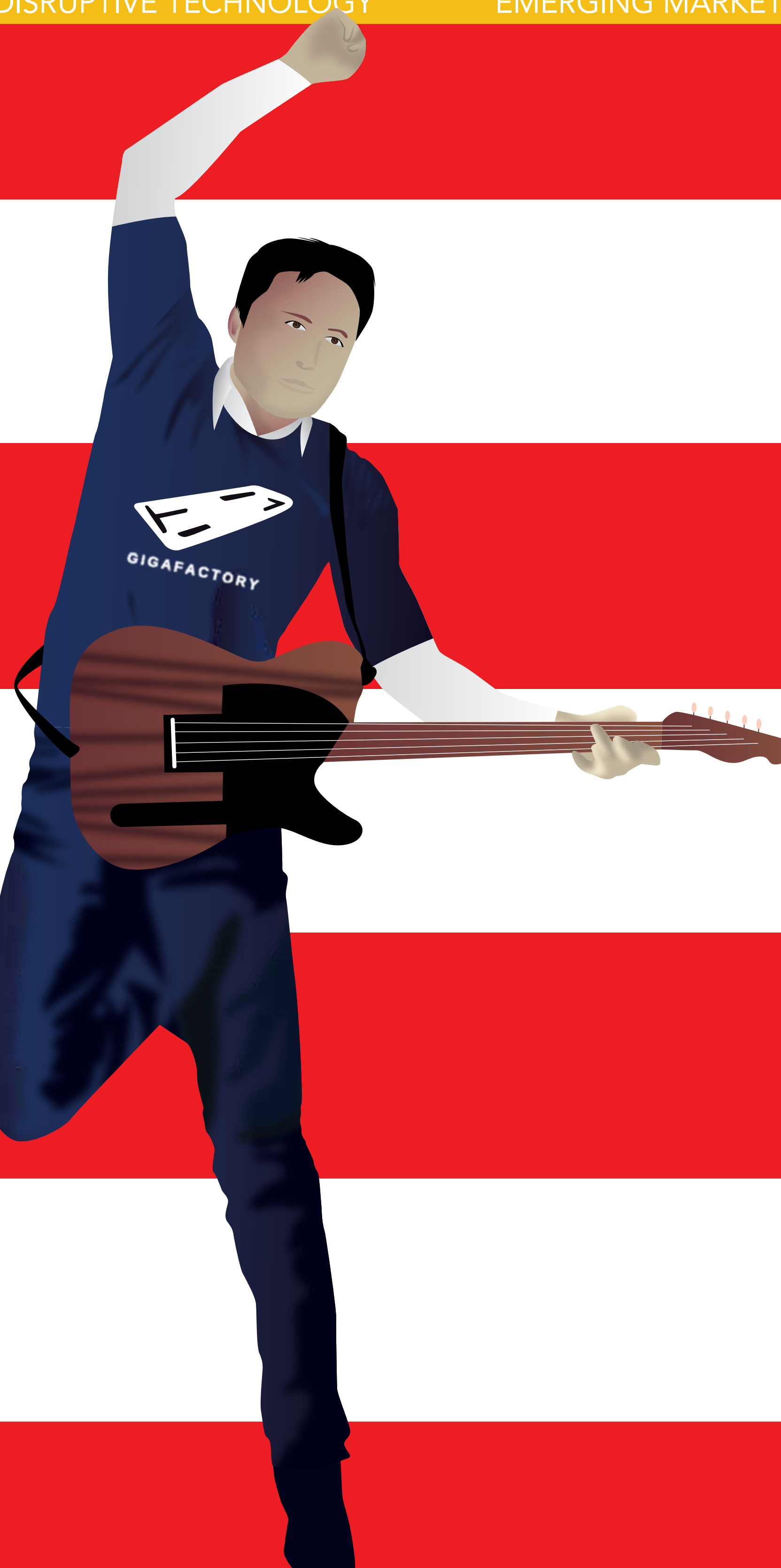

Benchmark Mineral Intelligence Q3 REVIEW 2020
Tesla enters lithium | OEMs' battery ambitions | Lithium ion's unsung hero

23

THE ANODE EVOLUTION

OneD Material CEO Vincent Pluvinage, PhD (left) and CTO Yimin Zhu, PhD

Benchmark speaks with **Vincent Pluvinage**, CEO, and **Yimin Zhu**, CTO, of **OneD Material** on the growing use of silicon in anodes, and how the company is positioning itself in the anode supply chain and more

Benchmark: Could you let our readers know about the history of OneD Material and what role the company intends to play in today's lithium ion supply chain?

Vincent Pluvinage: OneD was founded in 2013 after the acquisition of all energy storage assets, facilities and team from Nanosys, a Silicon Valley leader in nanotechnologies, to continue the work started a decade earlier on silicon anode technologies, under the direction of Dr. Yimin Zhu, OneD's Chief Technology Officer (CTO).

Since then, OneD perfected new anode materials and manufacturing processes to fit within the technical and business road maps of the leading suppliers of lithium-ion batteries (LIB). These novel anode materials and their manufacturing processes are described as the SiNANOde technologies.

Our investors backed Yimin's vision to leverage the established LIB battery supply chain by offering a highly scalable and cost-effective manufacturing process to add nano-silicon onto any type of commercial graphite already produced at scale and qualified by the leading cell makers.

OneD's goal is to integrate seamlessly with the existing EV (electric vehicle) supply chain to enable an immediate, low-risk and cost-efficient transition to more silicon in the anode electrodes of LIB during the 2020 to 2030 decade.

Yimin Zhu: OneD's platform is 100% compatible with the large investments of the leading industry participants, from both technical and business point of views, to enable better, faster, cheaper EV batteries rather than requiring the risky adoption of expensive new materials and manufacturing methods. The increase in silicon in anodes must decrease risks and costs: for more than a decade, we worked very closely with the industry leaders to understand their needs and constraints and designed our technology platform and our solutions accordingly.

Benchmark: What are the main benefits of using silicon materials in anodes?

YZ: Technically, for the same weight of anode material, nano-scale silicon can store ten times more energy than graphite, and if the electrical path between the electrode and the silicon presents low resistance, the charging is faster and more power can be delivered during discharge.
VP: Business-wise, silicon can increase range of EVs, shorten charging time and reduce both battery cost ($ per kWh) and carbon footprint (CO_2 per kWh). In fact, a small amount of silicon is already used in the cells of two leading EVs: the Tesla 3 and Tesla Y models. In the future, all EV cells will contain silicon and the percentage of silicon will increase progressively during the rest of the decade.

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> Yimin Zhu, CTO, OneD Material

Benchmark: Despite the energy density benefits of silicon in anodes, there are a number of obstacles associated with increasing silicon content. Please, could you provide our readers with an overview of this?

YZ: We see three major obstacles which have slowed the adoption of silicon, despite many large companies, universities and R&D teams working on this problem around the world.

The first hurdle is the difficulty of increasing energy density and power density without sacrificing battery cycle life. At the atomic level, silicon expands and contracts during each charge and discharge cycle, and both lithium ions and electrons must simultaneously penetrate the silicon during charging and exit the silicon during discharging.

Almost all of the silicon anode solutions proposed today to EV cell makers exhibit serious trade-offs: they either slow the movement of lithium ions into silicon or increase over time the electrical resistance for electrons to travel in and out of the silicon. This reduces charging speed, power, and capacity retention during the life of the battery.

The second hurdle is production scale-up: the fast-growing demand in EVs requires enormous quantities of anode and cathode materials. Most silicon anode solutions proposed today rely on new manufacturing equipment and/or require changes in the electrode manufacturing processes which are disruptive for the supply chain.
VP: The third hurdle is cost, i.e. any new silicon solution must decrease the $ per kWh of existing EV cells. To achieve the right cost level at large scale, it is necessary to leverage the existing investments in materials supply and battery cells production rather than seek to displace the relationships between the existing EV supply chain participants. For example, single sourcing a new material from one company seeking to displace leading graphite suppliers is not a viable option.

Just to exemplify the economies of scale required, the most successful wearable in the world today, the Apple Watch, sells about 30 million units per year. The battery cells in those 30 million watches store less energy than the cells in 500 EVs. Not only the total annual anode energy storage for EVs is many orders of magnitudes greater, but the cost target is an order of magnitude smaller in $ per kWh compared to other battery applications. There is simply no economically viable path to reach the required economies of scale by starting from wearable batteries and "growing into" the scale required for EVs batteries.

In addition, many silicon solutions have a lower first cycle efficiency than graphite, which forces an increase in expensive cathode material. That is simply not acceptable to EV cell makers: the addition of silicon to the anode must match the performance and cost characteristics of the cell makers' chosen cathode materials, because cathode material are several times more expensive than anode materials.

Benchmark: What do you make of Elon Musk's announcements regarding the use of silicon anodes during Tesla's Battery Day? He hinted that Tesla might be moving towards pure silicon anodes.

VP: Our first takeaway from the Tesla's

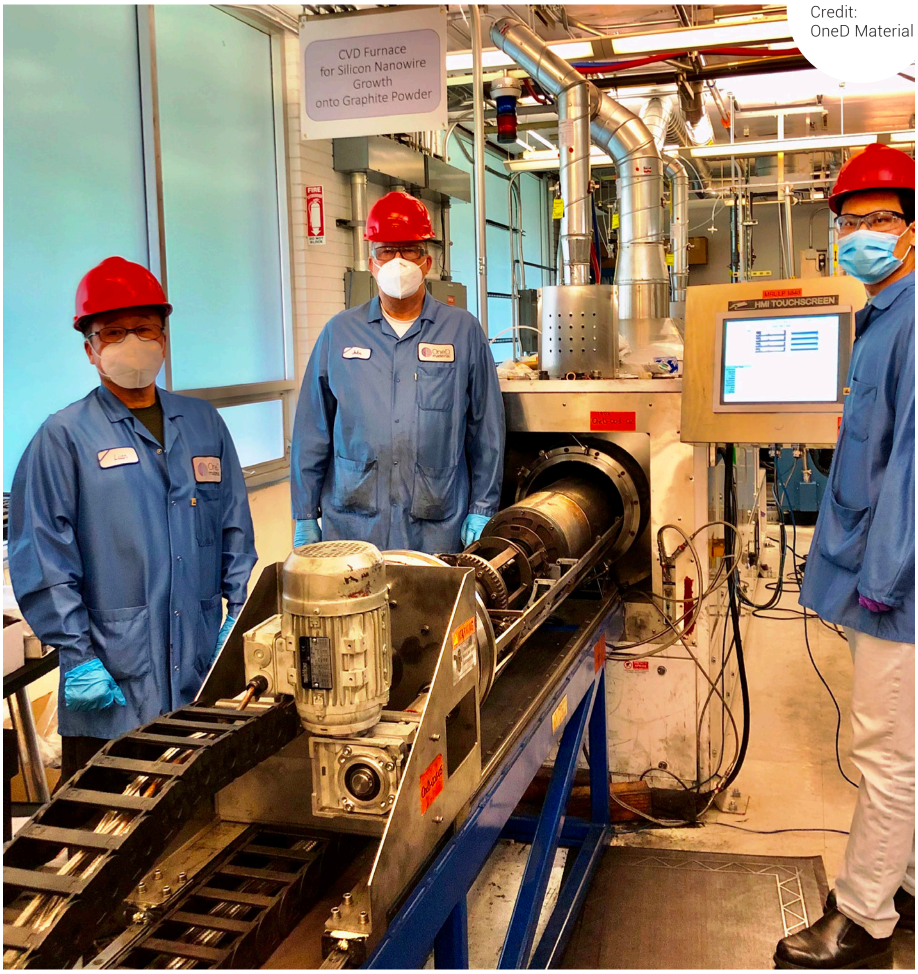
Battery Day is that it confirmed once more that EV cells will contain growing percentage of silicon in the LIB anodes for the rest of the decade.

However, we do not believe that the active material in LIB anodes will transition to 100% silicon for several technical and business reasons which we do not need to cover here. Let me just say that there have been several publications looking at the reasonable and/or optimum amount of silicon weight percentage in the anode with respect to the cathode and all other cell elements and the consensus is for silicon content in EV anodes to increase progressively, but to likely peak around 50% of total anode weight.

Our second takeaway from the Tesla's Battery Day is the strong emphasis on cost and scalability. The only chance for a new anode material technology to be adopted by EV cell makers and OEMs is to be cost competitive and available at industrial scale. I also would like to add an additional comment on some of the costs data given during the Tesla presentation which suggested a cost of $100 per kWh for silicon nanowires. Those estimates are not related to the cost of SiNANOde powders, which are much more cost competitive and can provide a lower $/kAh or $/kWh than the current graphite-based anodes in EV cells (with or without silicon oxide additives). Since day one our focus has been not just to improve performance but also cost and scalability, and that's well aligned with what was presented during Battery Day.

Third, it is clear that Tesla and other EV makers have both a global diversification strategy and a local sourcing strategy. Materials are sourced from multiple suppliers and cells are made by multiple cells makers, with distinct supply chains in China, US, and Europe. Therefore, any silicon technology must be compatible with these business strategies.

Our final takeaway from Tesla's Battery Day is the increasing involvement of the leading OEMs upstream in the value chain. The industry has shifted from a supply chain where OEMs would simply place orders with EV cell makers, and the cell makers would place orders with their material suppliers, to new supply chains where many OEMs are vertically integrating, investing and coordinating with EV cell makers to ensure the supply and pricing



Credit: OneD Material

Pilot production with a single CVD process tube at OneD Material's operation in Palo Alto

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> Vincent Pluvinage, CEO, OneD Material

of key raw materials and to control the new technology roadmaps. Therefore, any silicon technology must be compatible with these new business strategies.

In a sense, this is not a competitive race that will be won by anybody with one silver bullet. It's a relentless coupling of multiple material innovations and manufacturing process innovations to support the evolving business strategies of the EV supply chain participants.

YZ: Another interesting technical point in the Tesla presentation was the use of ionic polymers to stabilise silicon nanostructures, a problem that we tackled more than a decade ago. In addition, mixing various materials, whether for a dry electrode coating or a wet slurry electrode coating, is not a trivial problem, especially at large volume. We took this into account in designing the SiNANOde technology platform.

Benchmark: What is OneD's approach to using silicon in anode materials, and how does this differ from other companies on the scene?

VP: Since the very beginning, OneD's focus has been not only to use silicon to increase the performance of commercial graphite, but also to relentlessly pursue industrial production scalability at competitive cost and low adoption risks.

YZ: On the technical front, we focused on three basic principles: (1) availability of inexpensive proven precursors; (2) use of commercially available production equipment and (3) achieving high production yields. In addition, we always focused on technical solutions that fit with the industry's investments and road maps.

For the precursors, we start with commercial graphite powders produced at scale by leading suppliers, qualified by leading cells makers and proven suitable for use in EV cells. Then, we use commercial silane gas (SiH_4) made at large scale from metallurgical grade silicon, and nitrogen, which can be inexpensively extracted from air at the manufacturing site. Finally, we use clean energy (e.g. hydroelectricity or other renewables) during the manufacturing process. The amount of electricity required to transform silane into nanowires is smaller than most people speculate.

For the production, OneD leverages commercial CVD equipment that has been used by the solar cell industry for decades and our proprietary reactor and production software ensure that 99% of the silane is converted into silicon nanowires firmly attached to the particles of commercial graphite.

As to performance, silicon nanowires are superior to silicon nanoparticles because of the lower surface area and because each nanowire is electrically "plugged" into the graphite substrate particles, much like an extension cord is plugged into a wall outlet to allow electrons to move effortlessly. This reduces the capacity fading that plagues most of the other silicon anode materials, including silicon nanoparticles on or inside other porous carbons. We learned that directly from experimenting with various carbon substrates (for example carbon black or graphene), as attested by the some of the inventions in our IP portfolio which were filed more than a decade ago.

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> Vincent Pluvinage, CEO, OneD Material

OneD has worked for a decade with the large supply chain participants in various countries to grow silicon nanowires on commercial graphite chosen by leading battery makers and to ensure that the resulting powders can be easily mixed with all of the other anode materials using existing industrial equipment; can be coated into anode electrodes using existing large scale manufacturing processes; and finally can be matched with the newer cathode materials and formed into various EV cell formats using various types of advanced electrolytes.

Furthermore, OneD has successfully tested the SiNANOde platform with higher Si content using polymer electrolytes and other innovations in the EV cell technology stack which are likely to be adopted by the industry in the foreseeable future.

VP: Simply put, we are the only company to offer a manufacturing service to grow nano-silicon onto most of the commercial graphites already used in EV cells. Our business approach is not to compete with the existing material suppliers, but to enable EV cell makers and OEMs to leverage the materials and the suppliers that are part of their growth strategies in various continents, in order to transition to more silicon anode content cost effectively and with lower risks.

We seek to reduce not only the cost of the silicon-graphite materials, but also the cost and the risks of adapting the EV cell designs and the cell manufacturing road maps to compete for better EV batteries.

Finally, since 2004 OneD has accumulated the leading and most extensive patent portfolio on silicon-carbon materials and manufacturing methods, with more than 200 granted patents worldwide. This offers our customers the protection and the freedom to operate that they need.

Benchmark: How does OneD's approach fit into today's anode supply chain?

VP: In our view, the notion that some companies will completely displace the graphite supply chain during the next decade with a new silicon anode material is an unrealistic proposition, both from technical and business perspectives. The ability to supply an anode active material consistently at a scale capable to meet the evolving technical requirements and growing commercial demands of EV makers is an extremely challenging task and existing large suppliers are in a dominant position.

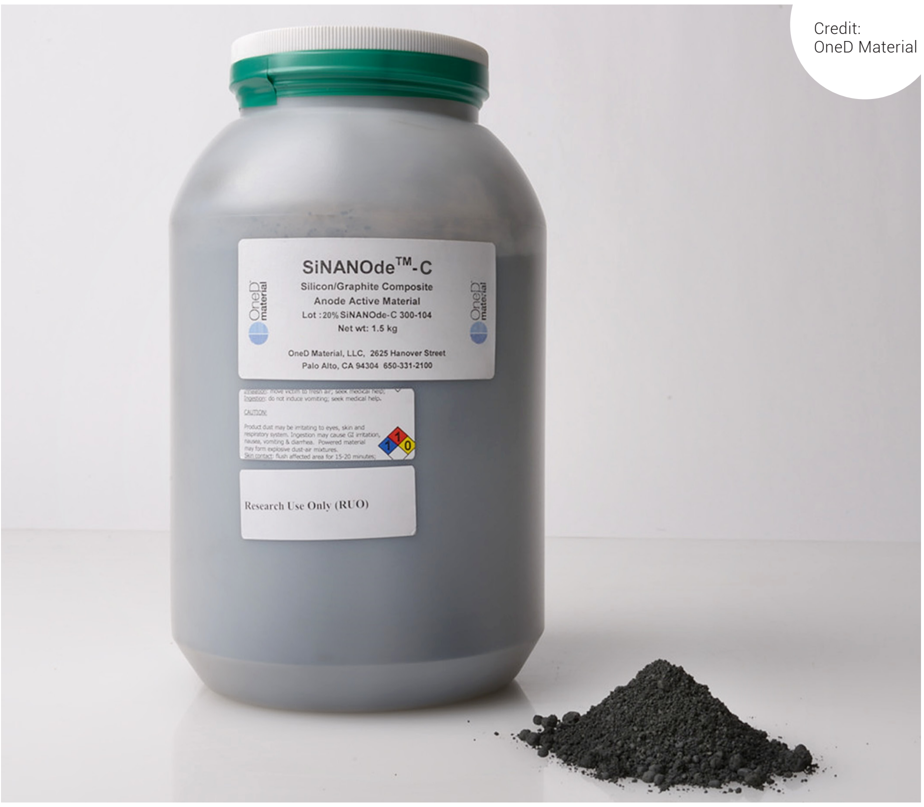
Yimin has proven that the existing SiNANOde manufacturing process can inexpensively grow silicon nanowires at scale on various commercial graphites and leading Tier 1 companies have verified the excellent electrochemical performance at the cell level. This approach offers a business flexibility that is un-matched.

Additionally, SiNANOde powder can be produced at various weight percentages of silicon (e.g. 20 wt. % silicon nanowires attached to 80 wt. % graphite particles triples the graphite specific energy storage). EV cell makers can then decide to use the SiNANOde powder pure or blended with pure graphite, to better match their chosen cathode material and cell design parameters. This blending capability offers a unique technical flexibility in anode design and in material sourcing.

For these reasons, OneD's SiNANOde manufacturing process integrates seamlessly within the existing supply chain and enables a faster, lower risk and more cost-efficient path to increasing silicon in anodes. This is opposite to other companies trying to displace or compete with the large participants in the existing EV supply chain.

Benchmark: What is OneD's roadmap or timeline for commercialising its technology, and what is your strategy for commercialisation?

VP: If I look at the work that Yimin and his team completed, I can basically say that there was a decade focused on improving the process technology to eliminate the use of expensive gases and gold nano-catalyst, and replace them with copper-based nano-catalyst, silane and nitrogen, to reduce costs and improve material performance. Then, during the last five years, the focus has been on scaling up the manufacturing process to achieve higher volumes at high yield; to decrease costs further and to increase manufacturing scalability to meet the fast-growing volumes required for EV cells. The manufacturing equipment installed and



Credit: OneD Material

OneD's SiNANOde powder can be used in dry or wet electrode slurries in industrial-scale electrode coating equipment, with both traditional and new advanced binders

> We are currently negotiating with a leading global company to build a SiNANOde processing plant capable of processing up to 10,000 tons per year
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> Vincent Pluvinage, CEO, OneD Material

in operation today at our Palo Alto facility has been designed for a nominal capacity of 25 tons per year per CVD process tube, with a 20% silicon nanowire to graphite weight ratio, which can then be used pure or blended with pure graphite, as desired by the cell makers.

The very same CVD equipment can be purchased in larger stacks (i.e. multiple identical process tubes) to produce thousands of tons per year in larger facilities without any process modification. This will not be done in Palo Alto, where we are limited by local city permits imposed on our pilot facility.

Thus, we are currently negotiating with a leading global company to build a SiNANOde processing plant capable of processing up to 10,000 tons per year. Once we have secured commitment from at least one of the EV makers we are in discussion with, we estimate that the building and commissioning of the plant can be completed in 24 months or less. In the meantime, we are progressively increasing material processing capacity to several hundreds of tons, to support the full pre-production material and cell qualification processes with EV makers.

Benchmark: Are there any specific applications or end markets that you will be targeting?

VP: Based on the positive feedback we have received so far from leading EV companies testing our material in their facilities in the last 18 months, we remain focused on EV cells as our main market segment. While there may be other segments that can offer shorter-term deals at higher prices and lower volumes, none of those segments can come close to EVs in terms of scale and growth opportunity.

Benchmark: Do you have any other comments for Benchmark's readers?

VP: One interesting observation is the magnitude of investments made by the anode material suppliers to meet the projected growth in EVs in the next years (15 million EVs expected globally by 2025). These suppliers have already started to invest in production capacity to meet the fast-growing demand of hundreds of EV cells gigafactories around the world.

Typically, the commitments between EV makers and suppliers involve multi-year agreements for very large number of batteries and for large quantities of key materials at a decreasing cost per kilogram.

OneD's technology adds nano-silicon onto any type of commercial graphite. The number one cost component for SiNANOde powders is the cost of graphite. OneD does not buy the graphite but just processes it to add the silicon nanowires. As a result, any cost reduction of graphite results in a cost reduction for SiNANOde and any increase in silicon weight percentage translates into an even greater cost reduction on a $ per kWh basis for the EV makers. This economic value proposition is unique to OneD's technology and business model, and a key differentiation compared to any other silicon anode material.

YZ: The one thing I just want to emphasise is that silicon-graphite is the future of EV anodes. As the percentage of silicon increases, other aspects of the cells will evolve. There is no plausible scenario where the anode electrodes in EV cells will be either pure silicon or pure lithium during this decade. The other thing is that any solution has to include nano-silicon of some dimension.

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Our solution certainly maintains both the "nano" features (the diameter of the nanowires) and the "micro" features (the length of the nanowires) of the silicon. So, our SiNANOde powders provide an ideal interface between the electrolyte (whether liquid or polymer or solid) and the silicon material. This is consistent with the future trends in electrolytes to support safer and faster charging EV cells.

There are three things that people do not often understand clearly.

First, if a graphite powder has a certain surface area, for example two- or three-square meters per gram, the addition of silicon nanowires does not increase the total surface area and can in fact result in a slightly lower total surface area (measured according to BET). So, the SiNANOde powders do not have the SEI problem that most other nano-silicon solutions have.

Second, the graphite particles not only provide a low resistance electrical path to the silicon, but also a mechanical framework for nanowires to expand and contract within the pores between graphite particles without damaging the anode electrode's integrity.

Third, several of our Tier 1 customers have already confirmed that the SiNANOde electrodes exhibit a high first cycle efficiency ("FCE"), which matches that of the best graphite electrodes, unlike the lower FCE of graphite/silicon oxide blended anodes. The benefit is significant cathode cost savings.

VP: In summary, the OneD's SiNANOde solution is sound from a technical and a business perspective and is uniquely suited to the most recent trends in the EV industry.

The SiNANOde technology platform provides the simplest way to increase the energy and the power density by attaching nano-silicon directly onto the very same graphite powders supplied by large-scale suppliers already qualified by the EV cell makers.

This increases the value of EV batteries to OEMs, while decreasing costs and technical, financial & strategic risks.