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ASX Announcement

25 May 2020

AnteoTech Advances Battery Technology Program

Highlights

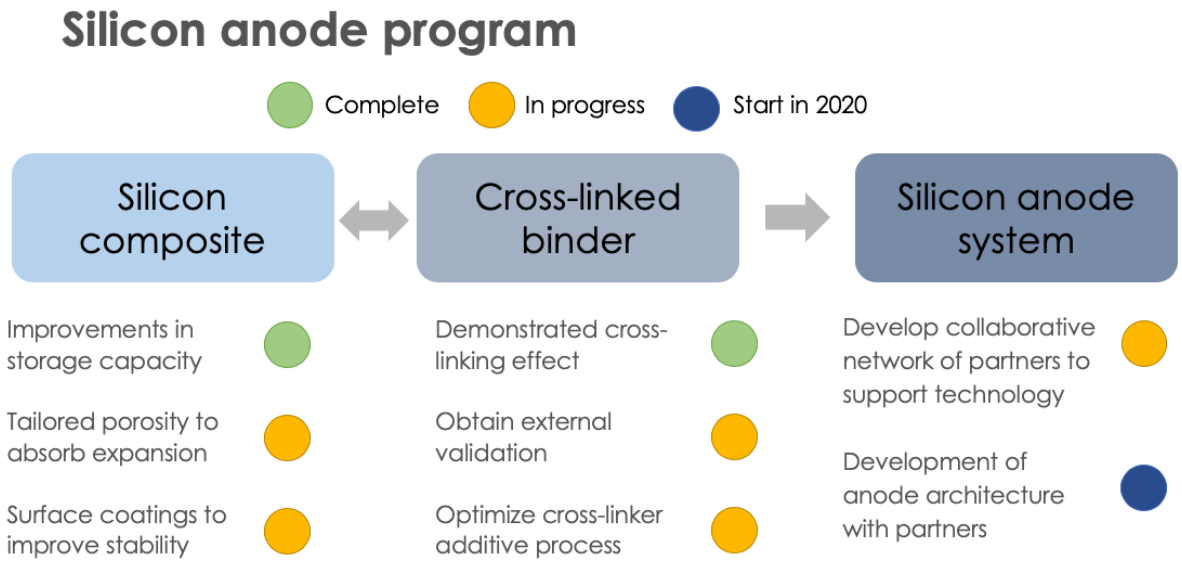
- **Collaborator 1 confirms specific capacity attributes of generation 1 silicon composite**
- **Initial storage capacity focus of silicon composite development complete and successful; now focusing on enhancing cycle stability and increasing silicon levels to broaden market opportunity**
- **Strong market interest in the Cross-linker additive development aimed at capturing what is currently an unfulfilled market opportunity**
- **Cross-linker additive electrochemical testing results very encouraging**
- **Short term realisation of value focusing on Cross-linker additive**
- **Collaboration network is expanding and providing new opportunities**
- **Development of energy enhancement platform on track to capture market uptake**

AnteoTech Ltd (ASX: ADO) ("Anteo" or "the Company") is pleased to announce that its battery program is advancing its commercialisation objectives and provides this update on progress for the period since the previous update in December 2019.

Development Update

Silicon Composite

AnteoTech Energy's development efforts currently encompass three separate programs of work aimed at penetrating the silicon anode market efficiently. The summary below provides details of those programs and the current stage progression.



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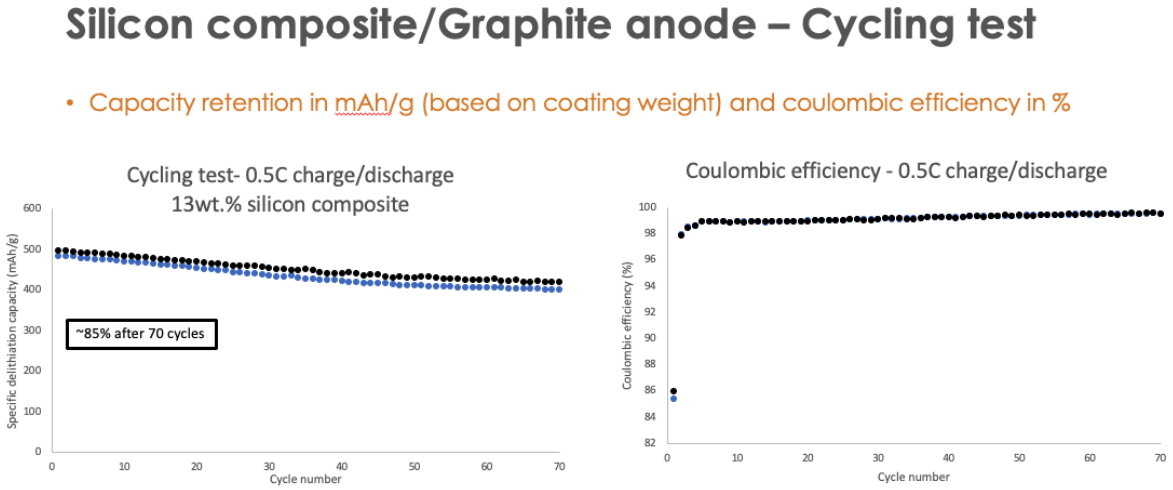
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Specific Capacity & Performance Update

Generation 1 Silicon Composite – Demonstrating Improvement in Storage Capacity.

Our Generation 1 Silicon Composite was developed with the specific aim of demonstrating an ability to improve storage capacity. We intentionally targeted specific collaborators in Northern Asia who were looking for solutions to improve storage capacity. To measure the performance of our composite in an anode electrode consisting of conventional battery materials, a silicon composite was blended with state-of-the art graphite to form an anode coating. We targeted a silicon composite content of 13% in the anode where the silicon composite was comprised of a high percentage of silicon (~50%).

The specific capacity attributes of our Generation 1 composite were tested in our hands and provided about 500 mAh/g, retaining 85% capacity after 70 cycles. This is a very good result, and in comparison to a non-silicon anode designs, represents a 40% lift in storage capacity of the anode.



We recently met with Collaborator 1 who provided a written report of evidence and verbal feedback on their initial testing of our Generation 1 silicon composite. Their results mirrored ours (see above). This provided validation of the processability of our composites in their hands and the specific capacity qualities of our silicon composite, providing an important foundation for our program going forward.

It is important to note that use of silicon in the anode requires a solution that caters for the repeated expansion and contraction of the silicon particles as they are charged and discharged. The solution requires a design that enables the silicon to increase up to three times in volume without damaging the silicon itself, without damaging the anode structure, without disturbing the connection with other anode components or continuously exposing new active material surfaces to electrolyte.

In the last Quarterly Activities Report we noted that Collaborator 1 had informed us that they would like to move their assessment of our composite to full cell, 500 cycle, testing and that we had agreed. They also informed us that a useful result for them would be a capacity retention threshold of 80% or above after 500 cycles. Silicon based anodes have cycling and expansion characteristics that can be controlled via optimisation of a number of different parameters. Prevention of cycling instability due to expansion is a development focus in our

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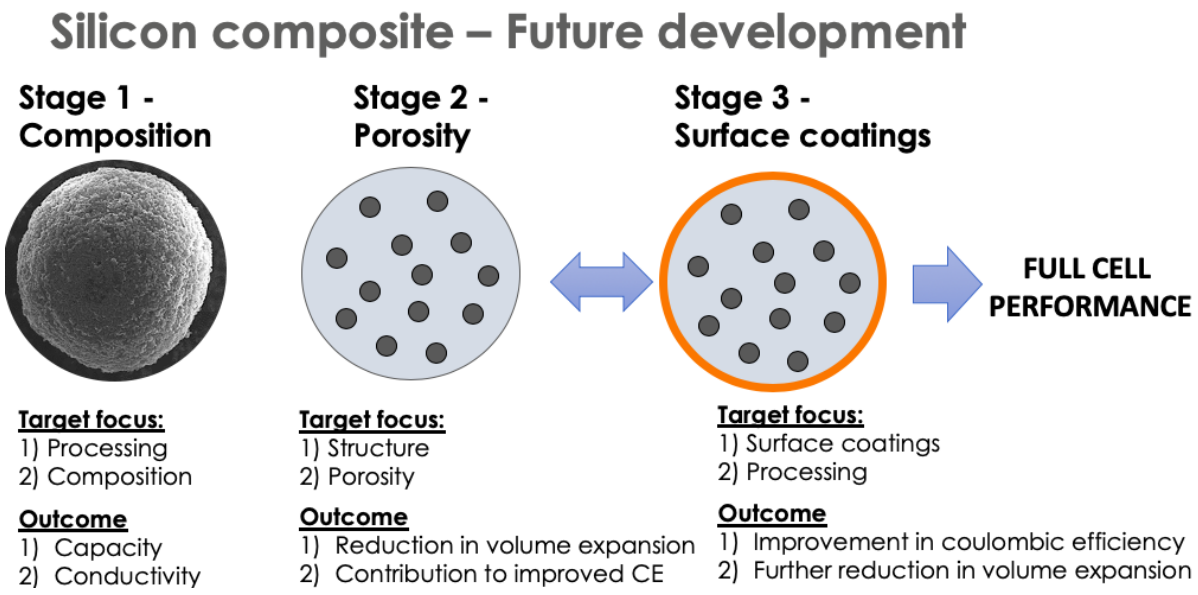
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Generation 2 silicon composite. Due to this fact, we asked that Collaborator 1 consider testing our Generation 2 silicon composite when it is available, and they have agreed.

Full cell, 500 cycle, testing of the Generation 1 silicon composite was due to be completed at the end of June but there has been some delay due to COVID-19 and to date we have not received updated time frames. Our Generation 2 composite is in production and in-house testing and will be provided to Collaborator 1 later in 2020.

Generation 2 Silicon Composite – Tailored Porosity to Absorb Expansion / Surface Coatings to Improve Stability

Our current development focus is to design a composite that incorporates tailored porosity in order that the expansion is absorbed. As well, we are working to develop a program with a new European collaborator (Collaborator 4) to coat our silicon composite particle to protect it and improve performance. Our work on porosity is progressing well. We have generated and are testing several Generation 2 composites with encouraging early results. Our work with Collaborator 4 has completed planning and definition stages and testing will begin in August 2020.



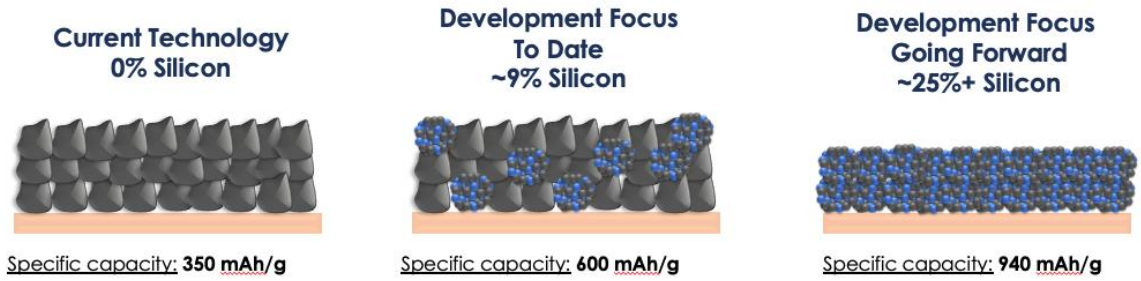
Our Generation 1 silicon composite testing regimes blended graphite with low quantities of silicon/silicon composite to test and replicate the processes of Collaborators 1 and 3. The approach makes it challenging to achieve substantial improvements over current volumetric capacity targets and the solution is specifically designed to cater for the needs of graphite producers who represent an important Li-ion battery market segment.

In 2020 we will conduct the first phase investigation of a program to focus on silicon composite dominant anodes. The combination of development work in the area of porosity and coating will allow us to produce a working anode at significantly higher levels of silicon within the anode and this will enable us to provide a further attractive value proposition to the Li-ion battery OEM market.

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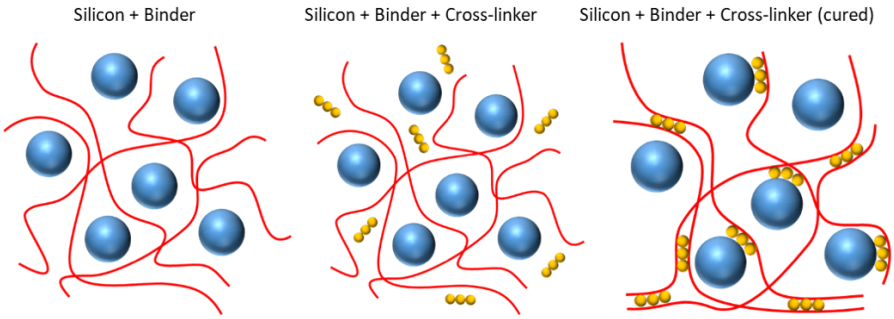
Analysis and modelling of our initial development effort for silicon dominant anodes has been undertaken and we believe an initial target of 25% silicon content composite, which will produce anode coatings of around 900mAh/g when charged, is appropriate. We will look to use the development effort to optimise the anode design to control expansion and improve cycling stability. Upon achieving optimal results we will move to raise the silicon content in order to achieve specific capacity attributes beyond the 1,000 mAh/g mark which is the articulated threshold target of the major OEMs.

Cross-Linked Binder

In previous announcements we detailed encouraging early testing results demonstrating binding attributes derived when AnteoCoat is combined with composite constituents including conventional binders. We have now executed a comprehensive development program with an initial objective of providing a Cross-linking additive to existing binders that are used in the market and in particular those that are used for silicon based active materials.

The Cross-linker additive is being specifically developed for use with water-based binders for two specific reasons:

1) to ensure that silicon containing anodes can be manufactured at a competitive price point; and
2) because water-based binders already possess the carboxyl/carboxylate and hydroxyl functionalities required to create a tightly Cross-linked network structure once paired with AnteoTech's additives.



A) In conventional electrodes active material and binder are bound by weak supramolecular interactions forming a loose network (left image). B) The addition of AnteoTech's Cross-linker additive at the end of the slurry fabrication process allows for homogeneous mixing of the slurry components and coating onto current collector foils (middle image). C) The formation of the cross-linked network occurs during a curing step creating a tightly linked network structure using multi-point interactions between cross-linker additive, binder and particles (right image).

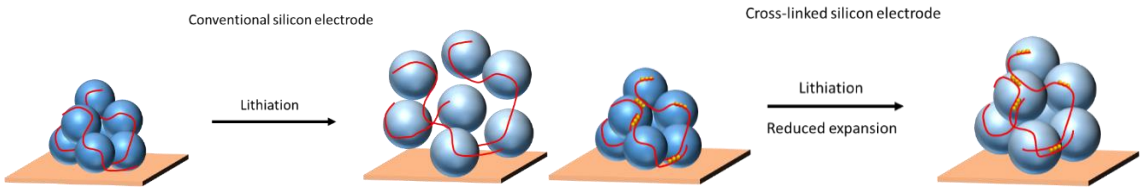
We have demonstrated strong Cross-linking effects with a range of standard, off-the shelf, water-based binders including NaCMC, NaAlginate and LiPAA. The next phases in product development will focus on optimising cross-linking behaviour for various electrode

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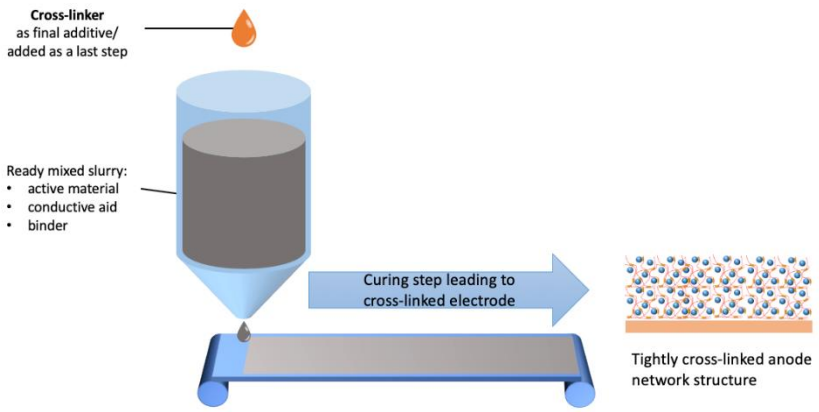
compositions and silicon levels. This is expected to highlight benefits of improved coating adhesion/cohesion and increased stress-resistance under repeated volume expansion and contraction, the major challenge for silicon-based electrodes. Current development work is targeting the release of a first generation of cross-linker samples, in the form of a water-based solution, for external evaluation by partners by the end of June 2020.



In conventional silicon-based electrodes the silicon undergoes repeated volume expansion and contraction during charge-discharge cycles leading to breakage of the electrode network and detachment from the current collector. A Cross-linked electrode network displays increased cohesion and adhesion strength alleviating the stresses of cycling.

Process orientated development

The Cross-linker additive is designed to be a drop-in additive that can be incorporated into conventional electrode manufacturing processes with no changes to the process. Added as a last step in the slurry mixing process, the target development foresees the slurry to remain freely processable for the required period of processing time. The additive will then cross-link the binder and electrode components during a curing step of the coated electrode sheets. This approach allows the transfer of the positive attributes of cross-linked electrode networks, namely increased network strength, to conventional electrode manufacturing without specialised binders requiring complex synthesis.



Initial Testing Results

The program focuses on obtaining external validation of the Cross-linking effect of the cross-linker additive when used in conjunction with commonly used water-based binders found in anode production.

To isolate the effect of the Cross-linker additive we constructed micro silicon only anodes with PAA binder of several polymer sizes and Cross-linker additive. This experiment was specifically designed to compare the effect of the Cross-linker additive against the control by keeping processing conditions and anode configurations consistent to eliminate variables that can impact the outcome. All electrodes were designed to feature the same starting capacity.

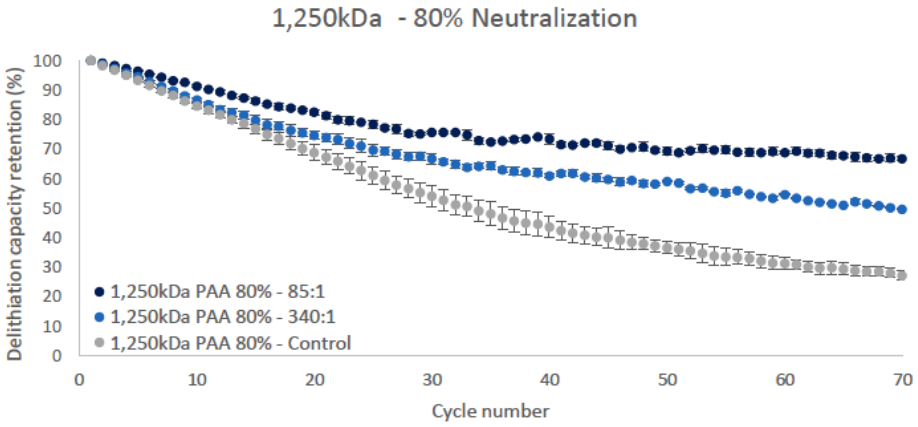
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Therefore the important result is the % difference between anode coatings, including the cross-linker additive and the control (no Cross-linker additive).

The first set of trials (1 slurry per anode configuration) shows a consistent trend that PAA plus Cross-linker performs better than anodes made from control slurries. The results for the 1,250 kDa molecular weight are shown below. Results for other polymer size ranges were found to follow similar trends.



Cycling curves in the figure above represent performance of electrodes that were tested in coin half cells. Each curve represents a three-cell average.

The results show a substantial uplift of electrochemical performance against the control (100-230% at 70 cycles). These results were the first set of testing results to be completed and we are currently repeating the tests to confirm the outcomes.

Note that reproduction of this performance using different anode designs is subject to the respective materials, coating composition and test methods employed. We expect that the results and values may change depending on the type of materials, coating composition and test method used. Our expanded collaboration program is very important in this regard as we expect to receive valuable feedback on performance from collaborators when different configurations of anode materials are used with our Cross-linker additive.

The results we are getting from our cross-linker additive program are very encouraging. We will continue to refine our cross-linker additive to deliver efficient performance uplift in silicon-based anodes over the coming months. Our first shipment for testing and evaluation will be sent to Collaborator 1 this week and we expect preliminary feedback from them soon after.

Other collaborative efforts on the Cross-linker additive are detailed in the Collaboration Update below.

Building an AnteoTech Combined Silicon Composite and Cross-Linked Binder Anode Solution

During 2020 we will begin preparing a development program to combine AnteoTech technology silicon composite and cross-linker additive anode design. We are encouraged by our development results to date on the individual anode components and believe that further development will provide a solution that provides a platform for significantly enhanced Li-ion battery performance.

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To optimise the solution, we will have the ability to adjust several attributes including:

- Control of expansion of the silicon anode via porosity attributes and coating technology currently in development to improve cycle stability;
- Use of the cross-linker additive to provide adhesion, cohesion and cross linking to raise the storage capacity of the anode and improve cycle stability; and
- Optimisation of silicon content within the composite in combination with cross-linker additive content maximise storage capacity and provide efficient cycle stability.

This program will require significant effort to design and execute and we will report on the characteristics of the program when preparation and planning work has been completed.

Collaboration Update

Importation difficulties associated with Collaborator 3 have now been resolved and shipments of AnteoTech samples have resumed as normal. We are waiting for an indication from Collaborator 3 regarding timing of Generation 1 silicon composite test results.

We reported earlier in the year the decision to expand the collaboration network for the battery program. This decision was taken in the knowledge that the European Union has decided to invest heavily in supporting Li-ion battery development, and the Northern Asian market was undertaking some consolidation due to competitive pressure from China.

Two Northern Asian trips and one European trip (combined with Life Sciences initiatives) were conducted to begin the expansion. A planned US trip in April 2020 was cancelled and it is our intention to expand our collaboration network in the US when travel restrictions are lifted.

We have four new confirmed collaborations plus our original three collaborations – in total seven collaborations. All relationships are healthy and active and will continue to provide commercialisation and product improvement opportunities. Several other collaborations are in the process of being confirmed and we will announce those as they join our development program

Details of our current collaboration network are below:

Collaborator Number	Description	Silicon Composite Collaboration (Y/N)	Binder Additive Collaboration (Y/N)
1	As previously announced	Y	Y
2	As previously announced	Focus on strategic supply relationship	
3	As previously announced	Y	Y
4	A northern European surface coating company with specific IP for Li ion battery development used to coat the surfaces of anode separators and foils.	Focus on partnership -coating silicon composite	
5	A large central European silicon focused chemical company developing anode active materials. The company is targeting the Li ion battery market with its own materials and is looking to collaborate with and commercially partner smaller companies as an option play for their involvement in the industry	Y	Y
6	A large Northern Asian Chemical company that holds a significant share of the global anode binder market. The company is looking to enhance its prospects in the next evolution of anode active materials including silicon based technology.	N	Y
7	A large Western European based nano silicon producer. This collaboration has been developed in conjunction with Collaborator 3 and is focused on combining AnteoTech's silicon composite and technology with a range of high-quality nano silicon products.	Strategic supply and solution development in conjunction with Collaborator 3	

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Currently we are focused on development of the Generation 2 silicon composite and have agreed to collaborative testing of this product with Collaborators 1, 3 and 5. We have also completed the project planning for the use of coating technology on our silicon composite with Collaborator 4.

Separately we have been developing versions of the Cross-linker additive and have agreed testing of this product with Collaborators 1, 3, 5 & 6.

Commercialisation Update

The Li-ion battery initiative was undertaken to capture a market seeking enhanced Li-ion battery components and to provide greater energy density across a range of use cases.

We have researched the current market outlook and found a range of analysis that predicts the consumer electronics sector is the earlier adopter of new Li-ion battery component technologies. The EV (electric vehicle) sector is investing aggressively and will be a major user of new technologies in the future. The analysis also predicts that the technology window for return on investment is over 15 years and the volume increase in new Li-ion battery component technology will be seen from 2024.

The timing of our development work is important and at this point we are on track to commercialise within the prime take up period for new technology in the Li-ion battery component market.

Our commercialisation pathway has improved since December due to the expansion of the collaboration network, providing new opportunities and progression of product development, particularly the Cross-linker additive. Our commercialisation opportunities currently being pursued are:

- Sale of the Cross-linker additive as a product to be used in the anode component supply chain. This is a near term opportunity that will be triggered upon validation of anode enhancement in the hands of the collaborators we are sending samples to now;
- Sale of the silicon composite into the Li-ion battery active material market directly or via partnership. This is a medium-term opportunity dependent on further development work to provide cycle stability in full cell batteries >500 cycles; and
- Sale of the complete anode solution as a platform technology across multiple segments of the market. This is a long-term opportunity dependent on continued development work to optimise the Cross-linker additive, provide cycle stability of the anode and harmonise the relationship of the cross-linker additive and silicon composite.

Separately we continue dialogue with a number of parties including collaborators to secure further funding for the battery initiatives. This may take the form of:

- Project funding;
- Strategic investment by an individual organisation interested in securing access to our technology; and
- Consortium-based funding for investment return.

The near-term commercialisation opportunity centres on the Cross-linker additive as the development timelines are shorter than the silicon composite.

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We are encouraged by the results for the Cross-linker additive in electrochemical testing and if these results are duplicated in the hands of Collaborators 1, 3 and 5, there will be tangible opportunities to progress our commercial discussions based on their experienced uplift in performance.

Further increases in the collaboration network are planned and will be announced in future updates.

Results from collaboration assessment of the Silicon Composite and the Cross-linker additive will be announced as they are received.

This announcement has been approved by the Board.

ABOUT ANTEO GROUP – AnteoTech Ltd (ASX:ADO)

Anteo is a surface chemistry company with Intellectual Property ("IP") in its core technology product groups AnteoCoat™, AnteoBind™ and AnteoRelease™. The Company's purpose is to create shareholder value by identifying and solving important global industry problems by providing unique value-add solutions for its customers. Customers operate in the life sciences, diagnostics, energy and medical devices markets.

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