RAPID ADVANCEMENTS TO ANTEO'S BATTERY COMPOSITES

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HIGHLIGHTS

- **Test work using Anteo fabricated silicon composites confirm reproducible production of 14wt.% silicon anodes which meet near-term industry target levels**
- **Silicon composite anodes achieved a reversible cycling capacity of 550mAh/g which equates to a 57% improvement over state-of-the-art graphite anodes (~350mAh/g)**
- **Cycle testing demonstrated capacity retention of >80% after 170 cycles**
- **These latest technology developments to be applied to proprietary silicon materials supplied by Anteo's industry collaborators with further updates on progress and results being anticipated over the coming months**

Anteo Diagnostics Limited (ASX: ADO) ("Anteo or the Company) is pleased to report very encouraging test results from the Battery Division which is developing products to enable high silicon content anodes for use in lithium-ion batteries. The company's proprietary fabricated silicon composites are integrated into conventional graphite electrodes in order to significantly increase the anode's capacity. These 'Anteo enhanced' anodes can now be reproducibly fabricated and incorporated into lithium ion batteries to increase the energy density and extend battery life between charges.

Following the release of initial results in August 2018, Anteo is very pleased to report a significant improvement from the latest electrochemical test work undertaken in the Company's Queensland laboratories.

In broad terms, the Anteo-fabricated proprietary silicon composites which form part of the negative electrode in a lithium ion battery, delivered a 57% improvement in reversible cycling capacity over state-of-the-art graphite anodes. This means that owing to the increase in the anode's capacity, more anodes can be incorporated into the same volume of a battery leading to an increase of the battery's energy density by weight and volume. As well, capacity retention of the anode was greater than 80% after 170 cycles, with capacity levels at this cycle number still showing a substantial improvement over a state-of-the-art graphite benchmark. This means that even at cycle 170, the silicon anode is able to store substantially more charge.

A more in-depth technical review of these results is included in this report (see Technical review below).

Comment

Anteo's Chief Executive Officer Christopher Parker commented: "Results from this latest round of test work are very encouraging. They reinforce the progress and the appeal of Anteo's technology in enhancing the performance of lithium ion batteries to meet the energy and lifetime requirements of tomorrow's applications. Anteo's silicon composites clearly have a big role to play here and we look forward to further improving on these latest results with our collaborators.

Anteo's team is clearly making great progress in advancing our technology using a variety of silicon substrates. We are confident of being able to continue this positive momentum with further impactful results expected over the coming months"

Project background

Rapidly advancing applications such as electric vehicles, consumer electronics and energy storage systems rely on lithium ion batteries with progressively higher energy density to satisfy the need for longer runtimes, smaller and lighter products, and lower cost. These are strong industry drivers to increase the energy density of lithium ion batteries, and the main focus on improving the negative electrode, the anode, is to integrate as much silicon into existing graphite anodes as is possible.

Silicon offers a 10-fold increase in capacity by weight and a more than 3-fold increase in capacity by volume relative to the industry standard of graphite. The boost in capacity can further translate into a decreased cost per energy stored ($/Wh), where a higher silicon content in anodes equates to a higher storage capacity.

To date it has proven challenging to achieve stable electrodes and long battery life with sufficiently high levels of silicon to make a substantial impact on either battery energy densities or cost. Top battery manufacturers have therefore limited the addition of silicon to their anodes to a maximum level of about 6%.

The main objectives in obtaining stable cycling performance with silicon anodes are:

- to control the effects of silicon's volume expansion which broadly relates to preventing the loss of contact by silicon with the conductive network thereby
- improving interface control between silicon and the battery electrolyte and
- to consequently minimise the degradation of the anode structure.

Technical review

The key results of our most recent work are summarised below and include:

- **Outcome 1:** High tap density silicon composites were fabricated and successfully integrated into conventional graphite anodes.
- **Outcome 2:** Two silicon composite electrodes were reproducibly fabricated, owing to improvements in process development, with a silicon content of 6% and 14% and a strong focus on meeting near term industry demand for higher silicon content anodes.
- **Outcome 3:** The silicon composite anode containing 14% silicon achieved a 1st delithiation capacity of >600 mAh/g with an ongoing reversible capacity of 550 mAh/g.
- **Outcome 4:** An anode capacity of 550 mAh/g means a 57% improvement over state-of-the-art graphite anodes (~350 mAh/g).
- **Outcome 5:** Discharge/charge cycle testing at a commercially useful rate of 0.5C (2 hours) demonstrated good capacity retention of >80% after 170 cycles (tests ongoing).

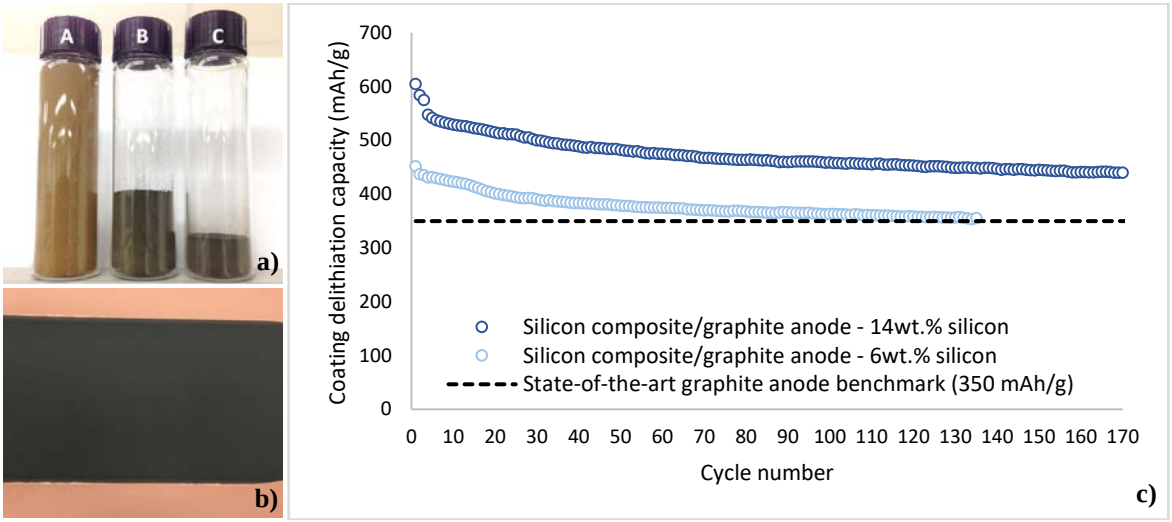

Figure 1: a) Tap density comparison of untreated nano-silicon (Vial A), a first composite (Vial B) and a second composite (Vial C) where all vials contain the same mass of silicon particles **b)** Anteo fabricated anode electrode coating on copper foil used for electrochemical cycle testing in coin cells **c)** Electrochemical cycling test of a 6% and 14% silicon composite/graphite anode and comparison against a hypothetical, ideal state-of-the-art graphite anode

Ongoing development work has produced silicon composites that demonstrate vastly improved tap densities (up to 10-fold) compared to bulk nano-silicon material (Image 1a). With a continued focus on developing products to enable high silicon content anodes for near term and future electric vehicle, consumer electronics and energy storage applications, this is an important achievement. A higher tap density means that energy can be stored more effectively in a given volume and that the silicon active material can be integrated into electrodes more efficiently during electrode fabrication.

A first high tap density silicon composite was combined with conventional graphite and integrated into an electrode coating at silicon contents of 6% and 14% in Anteo's battery lab (Figure 1b). The silicon composite/graphite electrodes were then assembled into coin half-cells and tested for their cycling stability. Coulombic efficiencies of 99.8-99.9% were achieved over the course of the cycling test. The anode containing 6% of silicon achieved a starting capacity of 452mAh/g and was cycled for 130 cycles up to the point where its capacity approached the hypothetical and idealised capacity of a state-of-the-art graphite benchmark anode of ~350mAh/g. The anode containing 14% of silicon achieved a high formation capacity of 605mAh/g with an ongoing reversible capacity of 550mAh/g during the extended cycling test at a commercially useful rate of 0.5C which corresponds to a 2h charge and discharge cycle (testing ongoing). The anode demonstrated good capacity retention and even at cycle 170, continues to provide a substantial improvement in capacity over the hypothetical and idealised graphite benchmark.

These encouraging results were unlocked by rapid advances to composite processing, electrode fabrication and battery testing made by Anteo's development team. Most importantly, the results obtained demonstrate that Anteo fabricated silicon containing anodes can be cycled for an extended period of time while retaining high levels of capacity.

The newly created data further supports Anteo's current direction and commitment in developing industry-first products that improve silicon's integration into conventional graphite anodes while reducing the detrimental effects of silicon on the electrode's overall structure and performance. In general terms, a reversible anode capacity of 550 mAh/g integrated into a conventional battery of constant volume corresponds to a noticeable increase in the range of electrical vehicles and longer runtimes for mobile electronics.

Next steps

Anteo will now leverage this newly generated information on processing techniques and apply learnings to the evaluation and full characterisation of the proprietary silicon materials supplied to Anteo by its collaborators who are manufacturing state-of-the-art battery components and electrodes. At the same time, internal development efforts will continue to advance the technology in combination with various silicon substrates to further improve on cycling stability of such materials in commercial lithium battery anodes. A further update on progress and testing is anticipated in the coming months.

ABOUT ANTEO GROUP – Anteo Diagnostics Limited (ADO:ASX)

Anteo Group is a surface chemical 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. Anteo's customers operate in the life sciences, diagnostics, energy and medical devices markets.

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