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Full-cell Li-ion batteries successfully produced with Campoona graphite

Highlights

- Collaboration with The University of New South Wales (UNSW) has led to the assembly and successful implementation of commercially scalable full-cell configuration lithium-ion batteries using Archer's Campoona graphite.
- Campoona graphite found suitable for use in electric vehicle and consumer electronic markets with batteries created using three commonly used cathode variants: lithium-nickel-manganese-cobalt (NMC), lithium-iron phosphate (LFP), and lithium-cobalt oxide (LCO).
- Key battery performance parameters were met or exceeded, owing in-part to the exceptional structural and chemical properties of Archer's Campoona graphite, with further materials' optimisation expected to improve overall battery performance.
- The outcomes of the work provide a definitive use for Archer's Campoona graphite, and will now be used to target potential offtake partners in the lithium-ion battery supply chain and electric vehicle markets.
- The global lithium-ion battery market is forecast to grow over the next 10 years to US$130 billion[1], with major market segments of transportation and mobility servicing a rapidly growing electric vehicle market in China, Europe and the US[2].

Archer Exploration Limited (ASX:AXE, Archer) is pleased to announce the following results of the collaboration between Archer and The University of New South Wales (UNSW) related to the development and implementation of Archer's Campoona graphite for use in commercially relevant lithium-ion batteries.

Full-cell lithium ion batteries that are functional and commercially scalable, and that incorporated Archer's Campoona graphite, were successfully assembled and validated for performance. The batteries were prepared with Archer's Campoona graphite at the anode, and commercially equivalent cathode materials and chemistries used in consumer electronics and electric vehicles. The cathode materials used to construct the full-cells were lithium-nickel-manganese-cobalt (NMC), lithium-iron phosphate (LFP), and lithium-cobalt oxide (LCO), and the batteries were prepared as coin-cells *i.e.* in a small-sized compact battery construction resembling a coin (Fig. 1).

Fig. 1. Coin-cell battery assembly used for the full-cell configurations incorporating Archer Campoona graphite and the commercially relevant cathode chemistries.

Archer's 99% acid-leached graphite from Campoona was used with no further optimisation. The NMC and LCO cathode chemistries were prepared at UNSW, while the LFP cathode materials used were commercially sourced. All synthesis, fabrication, characterisation and testing was carried out at UNSW (Fig. 2). Key battery performance parameters, including specific capacity and cycle stability, were in-line with industry state-of-art values, owing in-part to the exceptional structural and chemical properties of Archer's Campoona graphite.

Commenting on the work, Archer CEO Dr Mohammad Choucair said: "The speed in which we are able to deliver such exceptional outcomes is testament to the strong technical leadership and culture of excellence at Archer. Collaboration with UNSW has greatly accelerated our advance in the battery space. We are now able to demonstrate complete, functioning, and commercially relevant batteries with Archer's graphite. We have reached a major milestone towards integrating our substantial graphite resource in the lithium ion battery supply chain."

"It is important that we formulated, built, and tested full-cell batteries using Campoona graphite using different cathode chemistries, as there is no one industry standard cathode for lithium ion batteries, with different manufacturers using different chemistries. The work definitively shows that Archer's graphite can be used in conjunction with different types of cathodes, making it suitable for multiple potential battery markets." Dr Choucair concluded.

Next Steps:

Focus will be on addressing the trade-off between cost and battery performance: Archer will continue to target partnerships with lithium ion battery manufacturers to scale and integrate Campoona graphite further downstream in the supply chain. Knowledge sharing with potential commercial partners will be facilitated in confidence through the availability of technical data detailing the outcomes of this work.

The collaboration with UNSW will continue with the aim of generating value-add to Archer's proposed Campoona development through the co-development of intellectual property associated with general challenges to reach ultra-high graphite purities, and establishing optimal morphologies for lithium-ion intercalation chemistry useful for commercially relevant cathode formulations.

Fig. 2. Coin-cell batteries assembled with full-cell configurations incorporating Archer Campoona graphite anodes and the commercially relevant cathode chemistries NMC, LFP, and LCO. The clips holding the coin-cells measure the charge and discharge properties of the battery to validate performance.

Background:

Market Summary

The global lithium-ion battery market is forecast to increase to US$130 billion by 2028[1] with growth concentrated in the Asia Pacific region. Lithium-ion battery devices service a number of growing market segments where high-power density and long life-times are required at ambient and near-ambient conditions, including the growing market segment of electric vehicles (EVs).

Recent forecasts from the Bloomberg New Energy Finance Report[2] shows sales of EVs increasing from a record 1.1 million worldwide in 2017, to 11 million in 2025 and then to 30 million in 2030, as they become cheaper to make than internal combustion engine cars. China is expected to lead the global transition to EVs, with sales there expected to account for almost

50% of the global EV market in 2025 and 39% in 2030, and to be the single largest market for EV's by 2030[3]; Europe is next at 14%, followed by the US at 11%.

The potential for EVs to gain significant market share in to 2020 is dependent on reducing the relatively high cost of batteries compared to oil and gas, to well below US$100/kWh.[3] The trade-off between cost and battery performance (dollars per kilowatt hour, $/kWh) can be addressed fundamentally via a two-pronged approach; decreasing costs by using cheaper materials, efficient processing, and efficiencies of scale; and improving battery performance through effective materials and formulations.

Lithium-ion Battery Technology

Lithium-ion batteries consist of a group of batteries which operate chemically through lithium-based active materials of the cathode and graphite in the anode.[4] As a result, there are numerous types of lithium-ion battery of different formulations that can function for a number of applications. Various battery chemistries offer distinct pros and cons for commercially-important parameters, such as cost, performance, and safety.[3]

Lithium-ion batteries are commonly referred to by the constituents in the cathode, as the chemistry of the cathode is often performance limiting. The prominent technologies for automotive applications include lithium-nickel-manganese-cobalt (NMC), lithium-nickel-cobalt-aluminium (NCA), and lithium-iron phosphate (LFP) chemistries.[5] In consumer electronics, lithium-cobalt oxide (LCO) is predominantly used.[3]

Improvements in the anode are centred on using graphite with high structural quality and purity, and an appropriate particle size and optimal morphology for effective lithium-ion intercalation chemistry. Materials processing results in graphite morphologies that contribute to performance trade-offs[6], with typical examples including spherodisation, ad-mixing constituents like silicon, and the use of synthetic derivatives.

The University of New South Wales (UNSW)

Archer is engaged in a Collaboration Agreement and Research Service Agreement with UNSW to focus on carbon-based energy storage technology. Archer enjoys a unique relationship with UNSW and facilities within UNSW including those in the Mark Wainwright Analytical Centre. This Centre, unique in its diversity in Australia, comprises AUD$100 million of state-of-the-art characterisation equipment, managed by over 80 instrument scientists ready to engage and drive research projects within Archer. The Centre has a broad range of capabilities that fulfil Archer's aims to participate in the integration of advanced materials in battery technologies that provide future opportunities and new markets to underpin the development of Archer's substantial graphite resources.

Previous Work

Previous work performed by The Commonwealth Scientific and Industrial Research Organisation (CSIRO) (ASX Announcement 7 May 2015) was independently verified by UNSW. Battery electrodes were prepared from Campoona graphite in coin cells in a *half-cell* configuration for simple testing *i.e.* only the performance of the anode (graphite) is measured and considered in a control environment (only lithium metal at the cathode). The *half-cell* testing by UNSW, used together with the early work performed by the CSIRO, quantified and qualified the parameters required for the construction and operation of the full-cells. Full-cells are EV and consumer electronic markets' relevant configurations.

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For more information about Archer's activities, please visit our website:

https://archerx.com.au/

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[6] Miller, A.; Li, A. Q. Benchmark Mineral Intelligence, **June 2018**. Graphite Price Assessment. Benchmark Mineral Intelligence.