

Talga Anode Achieves Outstanding Freezing Temperature Performance

- Commercial development tests of Talga’s Li-ion battery anode product, Talnode™-C, include outstanding low temperature performance results
- Talnode-C retains 100% capacity and 100% cycle efficiency at 0°C, outperforming current commercial products in tests at a leading independent battery institute in Japan
- Potential to solve cold temperature performance and safety issues for Li-ion batteries

Australian advanced materials technology company, Talga Resources Ltd (“Talga”)(ASX:TLG), is pleased to announce outstanding low temperature test results from its engineered graphite anode product for lithium-ion (“Li-ion”) batteries, Talnode™-C.

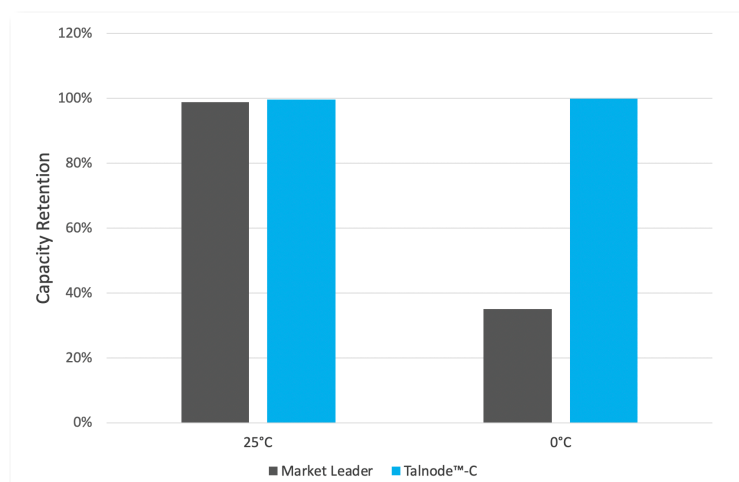
Development of Talnode-C is accelerating through rigorous commercial validation processes at multiple commercial partner facilities and independent battery institutes in Asia, USA and Europe. In new tests conducted at a leading Japanese battery institute, Li-ion batteries using Talnode-C were subjected to performance tests under a range of temperatures including freezing conditions. Highlights of the test results include:

- Retention of 100% capacity and 100% cycle efficiency at freezing temperature (0°C)
- Out-performance of market leading commercial anode products

In freezing conditions Li-ion batteries usually suffer lower capacity retention and cycling efficiency, causing shorter runtime of devices such as laptop computers and mobile phones, or shorter driving range of electric vehicles. Cold temperatures can also cause deposits of lithium metal to form in the battery, causing internal short circuits that can lead to fire in the cell, making low temperature performance a critical technical deliverable for Li-ion batteries¹.

Talga Managing Director, Mr Mark Thompson: *“These results show Talnode-C has the potential to solve problems that have long challenged Li-ion batteries in cold weather applications, where conventional graphite anodes struggle or fail to perform. This is a further demonstration that Talga’s anode products made from our high grade graphite deposit in Sweden, using wholly owned process and refining technology, have exciting potential in the fast growing Li-ion battery market.”*

Figure 1 Comparison of capacity retention between anode graphite market leader and Talnode™-C at 25°C after 30 charge-discharge cycles and at 0°C after 60 charge-discharge cycles.



Moving Forward

Market validation of the Talnode™ product range, and in particular the flagship Li-ion anode product Talnode-C, continues as Talga works to incorporate the development of its new class of high-performance graphitic carbon anode products into its long-term business strategy.

Advanced testing and validation, including the surface treatment and coating of Talnode-C, progresses across multiple commercial partner facilities and independent battery institutes in Asia, USA and Europe. It is expected that Talnode-C, a fully engineered and formulated active anode-ready product to be marketed directly towards Li-ion battery manufacturers, will form the foundation of a near-term commercialisation opportunity for the Company's larger scale development of the Vittangi graphite project in Sweden.

Low Temperature Technical Background

Li-ion batteries are widely used at room temperature because of their high specific energy and energy density, long cycle life, low self-discharge, and long shelf life². When charging a Li-ion battery, the lithium ions inside the battery are soaked up (as in a sponge) by the porous negative electrode (anode), made of graphite.

Under temperatures approaching freezing (0°C) however, the lithium ions aren't efficiently captured by the anode. Instead, many lithium ions are reduced to lithium metal and coat the surface of the anode, a process called *lithium plating*, resulting in less lithium available to carry the flow of electricity. Consequently, the battery's capacity and cycle efficiency drops and this translates to poorer performance³.

In cooler countries of the northern hemisphere, it has been measured that the driving range of electric vehicles can be reduced by 41% in real world sub-zero conditions⁴.

The most significant negative effect of low temperature on Li-ion batteries is the generation of lithium metal growths called dendrites, which can perforate the separator and cause a short circuit or fire in the lithium-ion cells. A highly visible example of this was in the 2013 grounding of Boeing 787 Dreamliner aircraft following a spate of electrical system failures, including fires. Investigation found that cold winter overnight temperatures fostered lithium plating within the battery cells and caused the short circuits⁵.

About Talga

Talga Resources Ltd is an advanced materials technology company enabling stronger, lighter and more functional graphene and graphite enhanced products for the multi-billion dollar global battery, coatings, construction and composites markets. Talga has significant advantages in graphene production owing to its vertically integrated high grade Swedish graphite deposits and in-house process to product technology. Company website: www.talgaresources.com

Figure 2 Electric vehicle range is negatively impacted by low temperature.



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1. *"Temperature effect and thermal impact in lithium-ion batteries: A review"* Progress in Natural Science: Materials International, Shuai Ma et al, Dec 2018.
2. *"The Limits of Low-Temperature Performance of Li-Ion Cells"* Huang et al. Journal of The Electrochemical Society, 147 (8) 2000.
3. *"Final Technical Report: Internal Short Circuits in Lithium-Ion Cells for PHEVs"* Sriramulu & Stringfellow, 2014.
4. *"Electric Vehicle Range Testing: AAA proprietary research into the effect of ambient temperature and HVAC use on driving range and MPGe"* American Automobile Association, Feb 2019.
5. *"Aircraft Serious Incident Investigation Report"* All Nippon Airways Ltd, JA804A. Sep 2014.



TECHNICAL GLOSSARY

Anode	The negative electrode in a battery during discharge. In Li-ion batteries, it consists of graphite and other carbons coated on copper.
Aqueous anode formulation	A chemical formulation that contains graphite mixed in a water based solution which is suitable to be coated on copper and dried to leave a pure graphite based layer to form the Li-ion battery anode.
Battery capacity	The total battery capacity, usually expressed in mAh/g available to perform work. The actual capacity of a particular battery is determined by a number of factors, including the material properties, cut-off voltage, discharge rate, temperature, method of charge and the age and life history of the battery.
Battery efficiency	Refer to coulombic efficiency.
Battery module	An assembly of cells in series and parallel encased in a mechanical structure.
Capacity	Capacity represents specific energy in ampere hours (Ah) or mAh/g. Ah is the discharge current a battery can deliver over time.
Capacity fade/ ageing	Permanent loss of capacity with frequent use or the passage of time due to unwanted irreversible chemical reactions in the cell.
Cathode	Electrode that, in effect, oxidises the anode or absorbs the electrons. During discharge, the positive electrode of a voltaic cell is the cathode. When charging, that reverses and the negative electrode of the cell is the cathode.
Charge	The conversion of electric energy, provided in the form of a current, into chemical energy within the cell or battery.
Cell	A closed electrochemical power source. The minimum unit of a battery comprised of 4 key components including cathode, anode, electrolyte and separator. Li-ion battery cells come in three different shapes (design architecture) being prismatic, cylindrical or pouch.
C-rate	C-rate is a measure of the rate at which a battery is charged relative to its maximum capacity. A 1C rate means that the charge current will charge the entire battery in 1 hour (60 minutes), 0.2C means complete charging is made during 5 hours (60minutes/0.2 = 5 hours) and 5C means that complete charging was made in 12 minutes (60 minutes/5 = 12 minutes).
Coin cell	An electrochemical device, composed of positive and negative plates and electrolyte, which is capable of storing electrical energy. It is the basic “building block” of a battery in lab scale tests using circular half or full coin shaped cells.
Coulombic efficiency	The ratio (expressed as a percentage) between the energy removed from a battery during discharge compared with the energy used during charging to restore the original capacity.
Cycle	The discharge of a charged battery with subsequent recharge. The number of cycles a rechargeable battery can withstand before performance degrades is the accepted method of measurement for rating rechargeables’ expected life.
Cylindrical cell	Components of a battery assembled inside a cylindrical metal container.
Discharge	The conversion of the chemical energy stored within a cell to electrical energy, and the subsequent withdrawal of this electrical energy into a load.



Few layer graphene (FLG)	Stack of graphene having a total thickness of 5 layers or less.
Graphene	A 1-10 atom thick layer of crystalline carbon, with superlative properties of strength, conductivity and transparency.
Graphene nanoplatelets (GNP)	Stack of graphene having a total thickness of 10-100 layers and properties of strength, conductivity and barrier properties that far exceed that of graphite.
Graphite	An allotrope of carbon in which carbon has sp ² hybridisation. Can be found as a natural mineral or can be synthesised using great pressure and temperature. Natural graphite consists of many stacked layers of graphene, approximately 3 million layers of graphene per millimetre of graphite.
Lithium	A soft, silvery-white metallic element, the lightest of all metals
Lithium-ion (Li-ion)	Elemental lithium devoid of an electron having an oxidation state of +1.
Lithium-ion battery	Rechargeable battery where Li-ion shuttles between graphitic anode and cobalt, manganese, nickel and/or other metals in combinations as cathode.
mAh/g	Milliampere hours per gram – a unit for battery capacity/materials.
Milling	The process of breaking material into small fine parts by grinding following crushing, or machining/cutting material using rotating equipment.
NMC	A Li-ion cathode consisting of Nickel Manganese Cobalt Oxide.
Packaging efficiency	The efficiency with which the battery components (cells, electronic circuits, contacts etc.) can be packed in a given volume.
Percolation	The process of a liquid moving slowly through a porous substance.
Pouch cell	Battery cell packaged into a flat-shaped flexible, heat-sealable foil pouch.
Prismatic cell	A slim rectangular sealed battery cell in a metal or inflexible case. The positive and negative plates are stacked usually in a rectangular shape rather than rolled in a spiral as done in a cylindrical cell.
Rate capability	The rate capability specifies the speed a battery is charged or discharged.
Reversible capacity	The reversible capacity is the capacity that is available to the load after the electrode is formed.
Roll to roll fabrication	Continuous fabrication of battery cells using rolled sheets of battery components and coating them with the active materials as they roll onto a spool for subsequent cutting and packaging into cells.
Shaping/ Spheronising	The milling of graphite flakes into sub-15 micron sized spherical shaped particles to reduce size and surface area to suit formulations for Li-ion battery anodes.
Solid Electrolyte Interface	A solid electrolyte interface (SEI) is a layer formed on the graphite anode that can act as a barrier, obstructing interaction and resulting in increased internal resistance and capacity loss.
Specific energy	Specific energy, or gravimetric energy density, defines battery capacity in weight (Wh/kg); energy density, or volumetric energy density, reflects volume in litres (Wh/l). Products requiring long runtimes at moderate load are optimised for high specific energy; the ability to deliver high current loads can be ignored.

