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U.S. Army Research, Development and Engineering Command

Pure Form of LiBOB Salt and the Purification Process Producing Such Form



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Inventor: Dr. Kang Xu ARL 09-33

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February 16, 2011

Technology Overview



The invention describes the synthesis and purification of a new lithium salt, bis(oxalato) borate (LiBOB).

Due to inherent limitations, there is interest in replacing LiPF6 salt. LiBOB is viewed as a good option because:

No P-F bond, does not attack organic components
Does not decompose thermally into HF (as LiPF6 does); CO2 as benign products

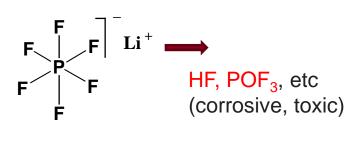
However, "purified" LiBOB is required to maximize performance benefits. This is currently difficult and expensive to achieve.

The core technology provided by this invention is the purification procedure, the quality-control standard and the resulting pure form of LiBOB obtained from this process.

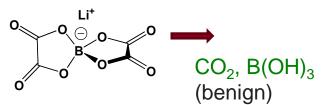
This pure form of LiBOB is a distinct compound as compared with other available commercial products.

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SOA Electrolyte contains LiPF₆



Thermally Stable Electrolyte contains LiBOB

Technology Overview

The innovation of preparing pure form of LiBOB and the QC

- Impure LiBOB from commercial source cannot support high temperature operation
- The pure form of LiBOB can support Li ion batteries operating at elevated temperatures up to 80 °C
- It also improves safety under abusive over-charge and high-temperature storage

Impure LiBOB does not support HT operation

1.1 Cell Vent Capacity Retention 0.8 0.7 LIBOB/EC/DMC (0.6 Baselin 0.5 50 100 150 35 % 30 Dc Impedance 25 20 15 100 Cycle Number

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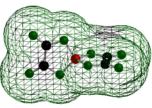
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1.2 75 ° C (NCA) or 60 °C (LFP) cycling at 1C Capacity Retention **Capacity Retention** 0.8 0.8 0B-1 NCA 0.6 0.6 OB -2 NCA 0.4 0.4 ICA LIBOB-0.2 LEP LIBOR-2 0.2 BOB-2 LFP LEP LIBOB--iBOB-3 LFF 0 200 400 200 400 600 800 1000 Cycle Number Cycle Number

Pure Form of LiBOB supports HT operation of Industry Li Ion Cells for > 1000 cycles Libob





High temperature stability is critical for battery packs in electrified vehicles

• SOA electrolyte fail to do so

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• Become dangerous over 60 °C due to HF production

The pure form LiBOB can widen service temperature range of Li ion batteries

•Dramatically improves capacity retention at both room and high temperature up to 80 °C

•Significantly reduces cell impedance

The invention of the process provides easy production of high purity of LiBOB and its effective Quality Control

Safety advantage over SOA electrolytes •LiBOB allows large format Li ion cells with higher safety than SOA electrolyte salt LiPF₆

•Higher stability for both over-charge and HT abuses

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8 Ah Li ion cell





Battery Pack in Prius

Video - SOA Electrolyte (LiPF6) w/o LiBOB

Video - Electrolyte with pure LiBOB

Technology Advantages

This invention holds a number of advantages over the current state-of-art:

- Enables the high temperature application of Li ion battery
 - Demonstrates excellent stability at high temperature; up to 80°C
- Is well suited for harsh environments of Hybrid Electric Vehicles (HEV
- Provides superior performance vs. existing commercial LiBOB; maintains 95% energy density after 1,000 cycles
 - at 75 °C capacity retention ~90% at 1000th cycle while most SOA failed before 400th cycle
 - at 60 °C capacity improved by 15% vs. SOA at 2000th cycle
- •Establishes purification process and standard; nearly 100% pure
- Improves safety of Li ion battery under both over-charge and HT abuses
- Open system accommodates a variety of cathode chemistries

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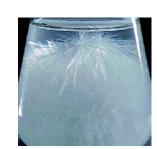
Technology Proof of Concept

Method of preparation of these novel additives

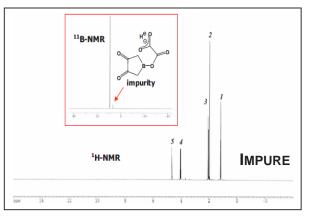


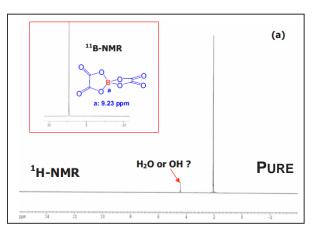
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Evaporation/Precipitation Recrystallization





Structural characterization/QC

Soxhlet Extraction



Coin Cells Industry Cells (8 Ah)



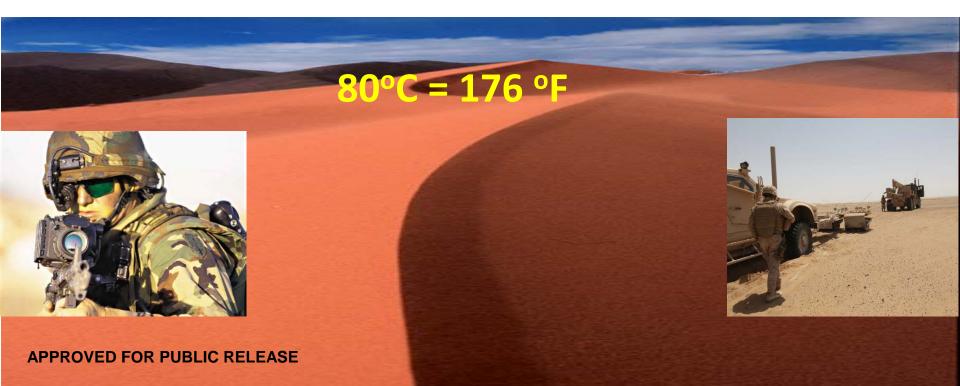
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- Military hybrid electric vehicle applications to reduce fuel consumption and reduce the need for dangerous logistical refueling operations
- Soldier Power in hot climate
 - Battery life significantly improved



Commercial Applications

Two major markets

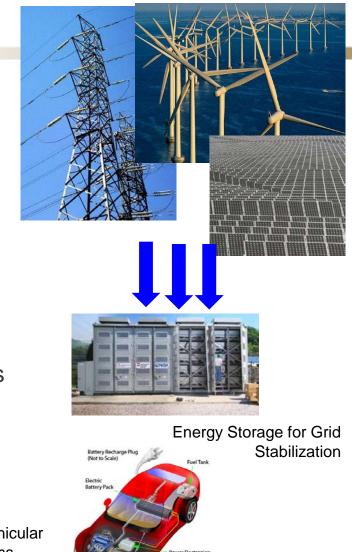
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- Electric Vehicle, Hybrid Electric Vehicle
- Large scale stationary energy storage

The invention provides high temperature stability of Li ion battery.

In particular, the invention benefits Li ion battery high temperature applications/environments such as those found in hybrid electric vehicles (HEV).

The purification method developed is also useful for producing other salts that have the BOB anion, such as NaBOB, Mg(BOB)₂ or other metal salts as additives, ionic liquid for double layer capacitors and batteries, etc.



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Electrified Vehicular Power Systems

TECHNOLOGY

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A patent license and CRADA is sought.

The current technology is TRL 6 and will benefit from a collaboration between the inventor team and the commercialization partner in order to speed the development to the market. This would most readily be done through a license agreement/CRADA.

A provisional patent application has been filed.