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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

Technology Overview

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

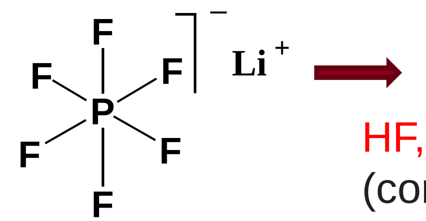
Due to inherent limitations, there is interest in replacing LiPF6 salt. LiBOB is viewed as a good option because:

•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.

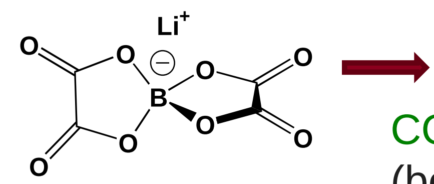
❖The core technology provided by this invention is the purification procedure, the quality-control standard and the resulting pure form of LiBOB obtained from this process.

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



HF, POF_3, etc
(corrosive, toxic)

SOA Electrolyte contains $LiPF_6$



CO_2, $B(OH)_3$
(benign)

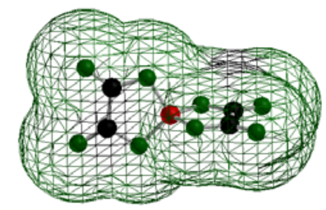
Thermally Stable Electrolyte contains LiBOB

Technology Overview

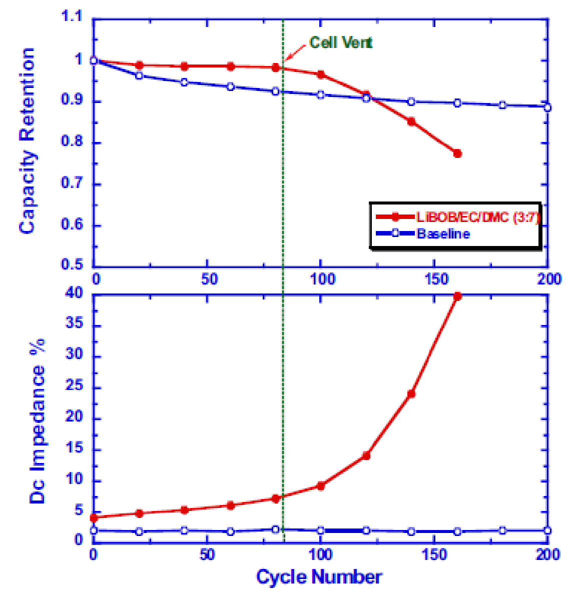
The innovation of preparing pure form of LiBOB and the QC

- 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 ^{o}C
- It also improves safety under abusive over-charge and high-temperature storage

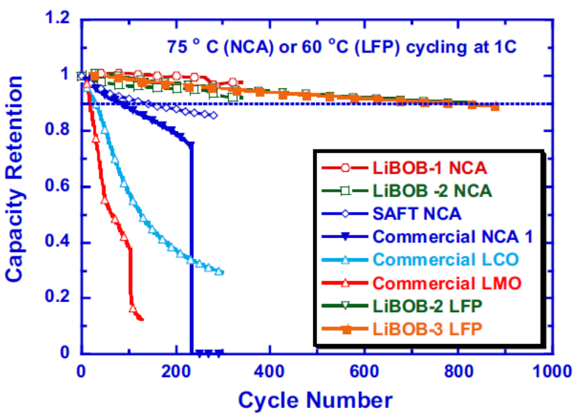
LiBOB

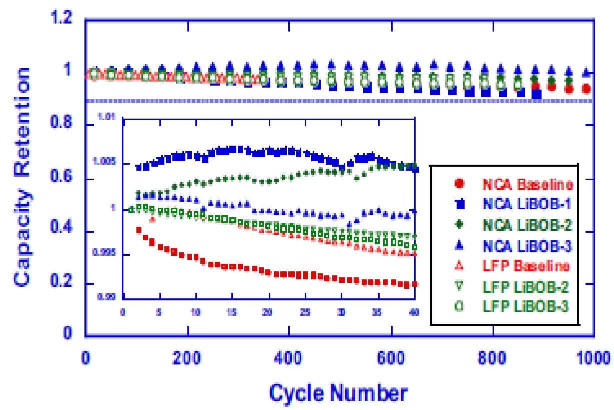


Impure LiBOB does not support HT operation



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





Technology Advantages

High temperature stability is critical for battery packs in electrified vehicles

- SOA electrolyte fail to do so
- Become dangerous over 60 ^{o}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 ^{o}C
- Significantly reduces cell impedance

Video - SOA Electrolyte ($LiPF_6$) w/o LiBOB

Video - Electrolyte with pure LiBOB

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 $LiPF_6$
- Higher stability for both over-charge and HT abuses

8 Ah Li ion cell

Battery Pack in Prius

Technology Advantages

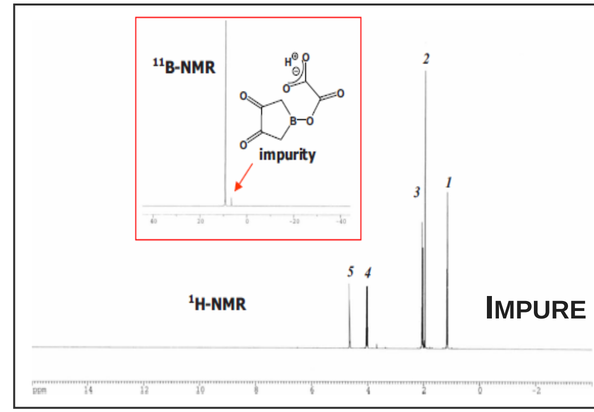
This invention holds a number of advantages over the current state-of-art:

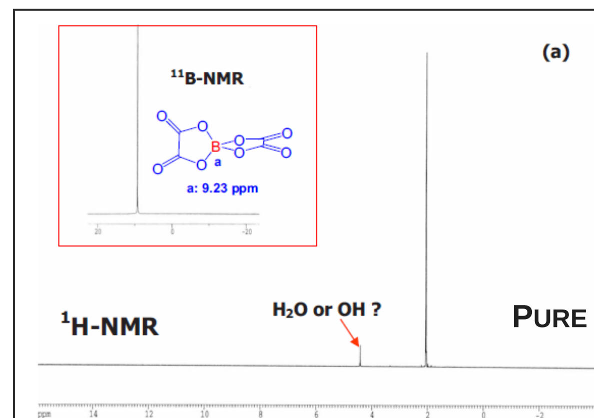
- Enables the high temperature application of Li ion battery
  - Demonstrates excellent stability at high temperature; up to 80ºC
- Is well suited for harsh environments of Hybrid Electric Vehicles (HEV
- Provides superior performance vs. existing commercial LiBOB; maintains 95% energy density after 1,000 cycles
  - at 75 ºC capacity retention ~90% at 1000^{th} cycle while most SOA failed before 400^{th} cycle
  - at 60 ºC capacity improved by 15% vs. SOA at 2000^{th} 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

Method of preparation of these novel additives

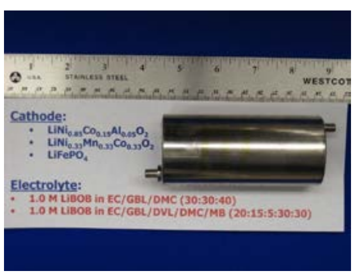
Soxhlet Extraction

Evaporation/Precipitation
Recrystallization





Structural characterization/QC



Coin Cells
Industry Cells (8 Ah)

Military Applications

– 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

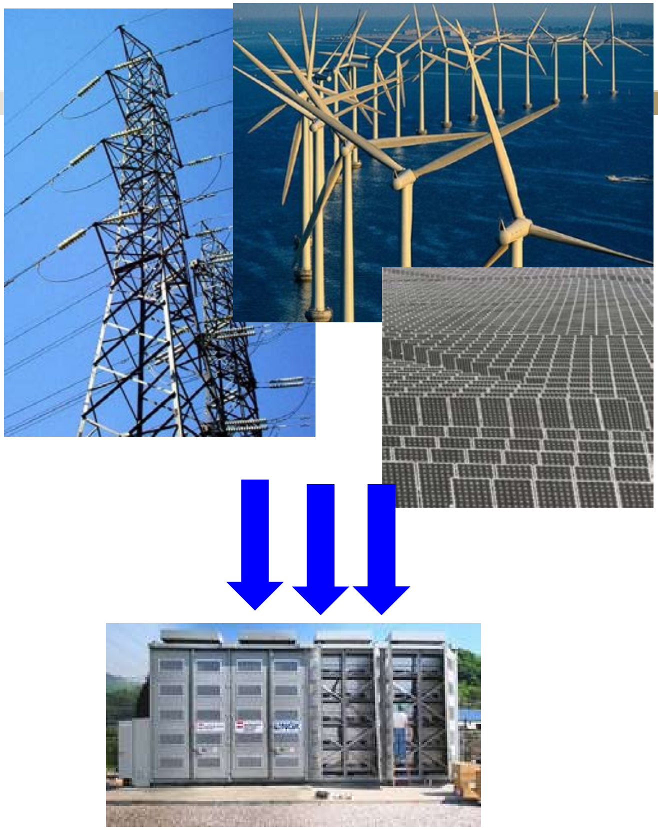
Commercial Applications

Two major markets
- Electric Vehicle, Hybrid Electric Vehicle
- Large scale stationary energy storage

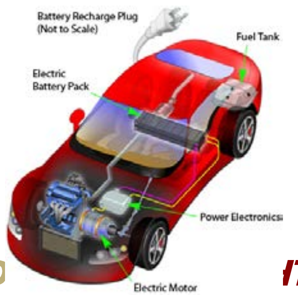
The invention provides high temperature stability of Li ion battery.

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.



Energy Storage for Grid Stabilization



Electrified Vehicular Power Systems

Technology Agreements

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.