Patent Portfolio Review

Lithium Exploration Group

February 1, 2017

Prepared by Eric R Dix

Founding Principal

INNOVATION ASSOCIATES

7749 Delmar Blvd Suite 1 ● Saint Louis MO 63130 ● 314.440.0955
www.innoassoc.com

Executive Summary

This report is intended to be a concise presentation of the nature and claims of the patent portfolio provided for analysis. Although necessarily technical in nature, the discussion seeks to minimize the quantity of detailed technical content as much as possible, albeit some level of technical content is mandatory in order to position the patents in their respective applications and market segments.

Having said this, in the process of compiling this report a comprehensive technical analysis of all the patents has been performed and a deeper discussion into any particular patent or particular aspect of any patent is available as desired. Finally, the scope of this analysis does not include any assessment of the commercial value of any one or the entirety of the patent portfolio but rather seeks to characterize the nature of the patent claims and approximately where they may align in application/market segments.

We begin by a top level view of the patents themselves. The first point to be made is that, although this patent portfolio is a "family" in the sense that all patents are based on the chemistry of the Boron atom, the specific market segments and technical applications are much broader than a singular chemical element focus.

Table 1 provides a summary of the patents under consideration. They are listed in chronological order and include columns designating the position/market segment they may be associated with by the nature of their claims as well as accompanied by a single letter designation for simplicity of reference in the text discussion.

Table 1 – Patent Portfolio List

Letter I.D.	Date Issued	Electrolyte Material	Electrolyte Process	Fuel Cell	Overcharge Protection	Patent No.
A	12/25/07	✓				7,311,993
B	03/25/08	✓				7,348,103
C	09/2/08			✓		7,419,623
D	12/16/08	✓				7,465,517
E	09/22/09			✓		7,591,964
F	12/03/09					Application
G	05/18/10		✓			7,718,154
H	08/31/10				✓	*7,785,740
I	07/19/11		✓			7,981,388
J	06/24/14			✓	✓	8,758,945

*United States Government also has rights to patent

This general alignment to the technology/business segment is helpful to develop a model that may be used in future efforts to assign potential value as well as to allow the logical grouping the individual patents together in their respective market emphasis for discussion. A summary discussion of each grouping follows.

Overcharge Protection Patents

The safety of batteries and lithium ion cells in particular garner considerable interest and with good reason, one only need note the recent issues with the Samsung Note 7. Two patents in the portfolio address one particular aspect of cell safety, specifically that of overcharge which is when the cell is charged to a voltage greater than the design voltage of a fully charged cell. This overcharge condition can lead to burns, fire and explosions and is generally addressed in two different approaches, one is via designed chemical reactions within the cell and the other is with the use of external electronic protective circuitry. The two patents (Patents H and J) here are of the chemical design within the cell category and specifically embody both liquid and gel electrolyte configurations. Patent J goes on to further state that the inventions disclosed are applicable to fuel cells, capacitors and "other energy conversion devices" which albeit without example data, intends to extend the coverage substantially. *Users and practitioners of these claims would be the actual manufacturers of lithium ion cells, and if the extended claims are valid, fuel cells and capacitors.*

Although both H and J are of the chemical design variety they have very different chemical approaches and claims. Patent H discloses a "shuttling" mechanism via the Boron salt to essentially return overcharge electrons in a closed loop cycle and limiting the voltage rise. Patent J discloses a chemical reaction of a polymeric material that becomes gelled or solid at a voltage just over the cell maximum voltage in a way that prohibits the flow of electrons thereby shutting the cell down. Patent J further claims the use of both the shuttling of electrons approach from the patent H Boron salt combined with the polymer material that will begin solidifying, i.e. both chemical approaches simultaneously in combination.

Given the technical nature of patents H and J, combined with the market desirability of safety protection in general, an expanded discussion of the nature of these claims and market limitations follow this Executive Summary section.

Electrolyte Material Patents

The three patents A, B and D may be grouped into what has been designated the "Electrolyte Material" segment. Generally the advantages claimed in this group of patents centers around the ability to utilize the salts at a lower concentration with lower viscosity (providing greater mobility) while maintaining equivalent or slightly better performance than conventional electrolyte salt solutions.

The first two patents (A, B) claim invention of specific Boron salts to be used in the liquid electrolyte solution of a lithium ion cell. Patent D extends this general concept from just a liquid electrolyte solution to also include "gel" electrolyte configurations. Gel configurations are often referred to as Gel Polymer Electrolytes (GPE) or simply "Polymer Electrolytes" and are commonly found in a great number of popular consumer electronic devices, e.g. iPhone 7 etc. Although lower in conductivity these gel or polymer electrolytes are generally considered safer due to lack of free liquid organic solvents which are flammable. *Users and practitioners of these claims would be the actual manufacturers of lithium ion cells.*

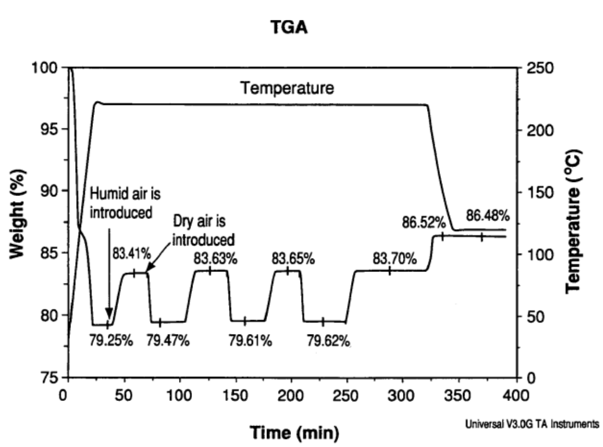
As these patents are of the 2007-2008 vintage it could be expected that, if valued commercially, these patents would be practiced in industry thereby validating whether the claimed advantages are recognized in the marketplace. If the patents are in commercial use Air Products would have this information through licensing revenue etc. and would be expected to supply that type of information to prospective purchasers of these patents. It would also be possible to seek answers to such questions independently as desired.

Electrolyte Process Patents

Patents G and I are grouped into the "Electrolyte Process" segment as they deal directly with the patenting of processes, i.e. not materials or products. Specifically patent G provides for a process to synthesize the precursor for the Boron salts that are included in this patent portfolio. Patent I provides for four process methods to produce a purer Boron electrolyte salt and electrolyte salt solution. Specifically four purification processes are offered, three describe processes wherein the liquid electrolyte solution may be variously purified by passing it through sieves/columns or ion exchange columns. The fourth purification method is to vacuum dry the solid salt at 180 C to remove impurities. *Users and practitioners of these claims would be electrolyte manufacturers and for patent G, specifically electrolyte manufacturers producing Boron based electrolytes.* The same statement as to whether these patents are commercially practiced or not as were made regarding the "Electrolyte Material" patents are applicable here.

Fuel Cell Patents

The fuel cell patents C and E in theory present a significant extension of the Boron electrolyte salt concepts to completely new market segments and multiple technologies over a range of fuel cell configurations. Both patents list preparation methods of the Boron materials and are accompanied by a series of analytical benchtop laboratory tests indicating that they have the physical characteristics which may allow them to be utilized in a variety of fuel cell applications. For example the figure below is the type of information presented, in this case a Thermal Gravimetric temperature scan of one of the prepared samples.



Given that the data presented are not actual functioning fuel cells but laboratory material preparations and subsequent analytical tests, one cannot make a substantive analysis of the advantages claimed in actual practice. We further note that these are 2008 and 2009 patents, which begs the question of commercial practice to date? However, given the expansive scope of the theoretical applications to these new market segments an exploration of the potential may be warranted. *Users and practitioners of these claims, if valid, are spread over a diverse group of fuel cell market segments and applications*.

Overcharge Protection Patents – Expanded Discussion

As previously stated, overcharge protection in lithium cells is generally handled by two different approaches, protection circuitry external to the cell and through offsetting chemical reactions internal to the cell and that patents H and J are methods which fall into the chemical reaction category. It has further been stated that the chemical approaches listed in the two patents are different in the nature of how they provide overcharge protection. An explanation of the basic ideas of each follows with comments regarding their respective market limitations.

When designing a chemical system to mitigate overcharge conditions one of the key considerations is to design the overcharge protection chemistry to be active at a voltage just above the design voltage of the cell, i.e. we don't want to shut down the cell at normal operating voltages nor do we want the safety event to get away at much higher voltages before the safety system mechanism becomes active.

The information disclosed in the referenced two patents do a good job of demonstrating that they are able to accomplish the goal of meeting this "voltage window" requirement. Specifically, a typical lithium ion cell may often be considered to be fully charged with the voltage reaches approximately 4.2 V and the data presented in patent H indicates that the safety chemistry of the Boron salt is active between 4.2 to 4.6 volts.

The Boron salts of patent H intended to provide overcharge protection may be referred to as "redox shuttle" agents which become oxidized at the cathode surface and diffuses to the anode to be reduced therein capturing in a closed loop cycle the energy that would otherwise lead potentially to a safety failure with excess current flowing one direction during overcharge conditions.

While useful, this redox shuttle safety mechanism has definite limitations in the current it can handle after which point the rate at which these shuttle agents may diffuse back and forth is exceeded and the safety concept is defeated by too high a current flow on overcharge. This limit typically is found at current for a cell at 1C or less (explanation of 1C in addendum at end).

This diffusion rate limitation leads to the second approach referenced in Patent J which is a material which polymerizes at voltages again slightly higher than the maximum cell design voltage. The material at this overvoltage first thickens and eventually fuses into a solid material shutting down the flow of current to avoid a safety failure. Patent J claims such a material and also claims the use of both this material and the redox shuttle Boron salt together in a synergistic "belt and suspenders" approach which offers a greater degree of safety than either of the chemical approaches used in isolation. Specifically there is a synergistic effect using the two together as the redox shuttle agent may be functioning simultaneously as the polymerization additive begins and helps to keep the voltage lower during the time necessary for polymerization throughout the cell to take place.

Having now described this combined overvoltage protection approach the fact remains that even when the two are used in combination, a current limit exists beyond which they are not completely effective and therefore electronic circuit protection is still necessary at these higher current rates to avoid what is referred to as "thermal runaway'. So, although the claims of Patent J are indeed beneficial, they do not eliminate the necessity of the inclusion of the external electronic circuit for properly addressing an overvoltage condition.

A strong argument may be made that all standard designs should employ both the two chemical safety features of Patent J in combination with electronic circuit protection and this type of argument is generally welcomed by cell manufacturers. The question to be answered is how does the solution from the Boron chemistry family stack up against other similar redox shuttle and polymerization overcharge solutions? *Users and practitioners of these claims would be the actual manufacturers of lithium ion cells, and if the extended claims are valid, fuel cells and capacitors.*

Closing Remarks

Improved safety will always garner great interest in this industry as will superior performance or reduced cost. This patent portfolio includes claims to each.

There are several avenues available as to how one might attempt to validate these claims and most are relatively straightforward.

- One approach, assuming the Boron electrolyte is available, is to approach one or more cell manufacturers, present the claims of improved overcharge safety, and request that they introduce it into a number of there test cells and perform a standard overcharge test.
- Another option, assuming the Boron electrolyte material is not available, is to contact electrolyte manufacturers and engage in a discussion of the merits of both the Electrolyte Material and Electrolyte Process patent claims and solicit their expert opinions.
- Similar approaches can be considered for the other market segments such as fuel cell markets, capacitor manufacturers, etc.

Separate from the task of validating the specific claims one may also consider the strategic nature of the portfolio itself and whether opportunities to leverage its commercial value in either a horizontal direction, a vertical direction or both. For example:

- Are there additional lithiated Boron oriented patents that are synergistic?
- Should an expansion into broader areas of overcharge protection be explored?
- What potential partners have similar interests/goals in related IP?
- And so on….

A bit of brainstorming would likely generate additional ideas as these a just a few.

Eric R. Dix

**Addendum - 1C Rate Explanation:*

The amount of current flowing in an overcharge situation is of course critical in identifying a prudent overcharge protection strategy and current level is usually expressed in "C" where C is the amount of energy in the cell in Ahr and 1C is the current that would drain a fully charged batter in one hour. For example a 500 mAhr capacity cell being charged or discharged at 500 ma would be discharging at 1C, i.e. theoretically fully drained in one hour at the same current as the cell energy is rated. A 1 Ahr cell charging/discharging at 1Amp would be C rate and completed in one hour and so on.