Meeting Electrical Vehicles Battery Demands

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Abstract

Facing imminent oil shortages and adverse environmental impact of internal combustion engines, major automobile manufacturers are actively developing, marketing several types of electric vehicles (EV); hybrid electric vehicle, plug-in hybrid electric vehicle, and battery electric vehicle (HEV, PHEV, BEV). The vehicles differ by their respective drive trains, a combination of internal combustion engine (ICE) and electric motor (EM) powered with large battery packs, ~10 KWh ~ 80 KWh. Since 1990s, Valence Technology (VT) has been developing battery electrode cathode materials and large format battery cell technologies to meet the varied demands on safety, temperature stability, long cycle life, wide range of charge/discharge ~1C~30C drive train power demands.

ICE vehicles and EV

Gasoline and diesel ICE have dominated ground transportations for slightly more than a hundred years since ~1900. Even though it is a complicated machinery but over years of intense development it has evolved into a low cost, reliable machine and identified with our life style of comfort, convenient and good performance. For example, the public has grown accustom to the operation parameters of a typical mid-range ICE automobiles shown below;

Range per tank	200	600	miles
Gasoline or diesel tank volume	10	20	gallon
Fill up time	5	15	minutes
Gasoline cost	1.5	5.0	$/gal
Vehicle cost	10,000	40,000	$
Acceleration, 0 to 60 mph	12	6	sec
Vehicle weight	2,000	4,000	lb
Operating temperature range	-30	50	deg C

Attempting to replace the ubiquitous ICE automobiles, the EV has to match the above operation parameters as closely as possible to gain public acceptance, thus impose heavy demands on the battery system. The table below shows the battery pack performance requirement needed to meet closely the above parameters.

	Battery capacity	discharge C-rate	battery pack weight
HEV	~10 KWh	~10~30	150 lb
PHEV	~20 KWh	~10~20	250 lb
EV	~40 KWh	<~10	550 lb

To be competitive, the batteries also have to meet the following concerns;

1. Environmental impact	no negative impact, easily recycled
2. Safety	no fire, explosion hazard
3. Cost	long term target ~$0.25/Wh
4. Service life; calendar life, cycle life	~10 years
6. Operating temperature range	-30 to 50 deg C

Valence EV battery development

Large format large capacity EV battery technologies consist of four key areas, (a) cathode electrode materials, (b) large format cells, (c) battery pack, and (d) battery management system electronics. Valence has been developing the four key area technologies and making unique, significant advances in all areas.

Cathode material development :–

To mitigate the fire hazard posed by the earlier lithium ion cells such as lithium cobalt oxide cathode materials at high temperature, VT has pioneered a whole new class of lithium phosphate cathode materials, the lithium iron magnesium phosphate, lithium vanadium phosphate and lithium vanadium fluorophosphate (LFMP, LVP, LVPF) with strong IP position that have successfully address the thermal runaway safety issue and prove to be extremely stable under all extreme provocations such as electric shorting and mechanical puncturing thus could safely be used for large EV battery packs. Using the more matured LFMP, Valence has commercially marketed large battery pack of ~24V200Ah since 2005 with perfect safety record.

Both chemical and physical properties of LFMP have shown to be extremely stable in field operations, manifest through its exceptionally long cycle life and safety record. The cycle life of most of the LFMP cells are ~1000~2000 cycles at 80% initial capacity. The table below summarize some key parameters of LFMP.

Specific capacity density	127 mAh/gm
Tap density	0.9~1.0 gm/ml
Nominal voltage	3.2 V
Nominal cycle life (C18650)	~1500 cycles

To address the slightly lower specific capacity density of LFMP, VT has developed proprietary LVP cathode powder, which with specific capacity density of ~148 mAh/gm rival that of LCO.

Valence cell development :–

VT was one of the pioneers in developing and commercialization of large format prismatic cells as early as 1990s, and in recent years, has successful commercialized portable power packs using prismatic 5 Ah cells. VT's new energy cell design, the prismatic single 10Ah cell, demonstrated large capacity with good power rate up to ~10C. Shown in FIG 1 was the surface temperatures of a 10 Ah prismatic cell as a function of C-rate without external cooling; initial ambient temperature was 22C. Maximum temperature raised at 5C continuous discharge was ~58 deg C, and at 6C 1 min on/off pulses was ~38 deg C. These class of energy batteries when fully commercialized could thus meet both PHEV and BEV applications with only simple air cooling system thus greatly simplify power train system design.

In terms of charge/discharge power performance, LFMP material is extremely adept to material processing technologies that enable it to attain discharge rate up to ~30C. However, since no single battery cell electrode design could cover the entire wide C-rate range, VT has developed three classes of batteries, general purpose, energy and power batteries, with respective C-rate range of ~3C, ~10C and ~20C, to address different power demands of BEV, PHEV and HEV.

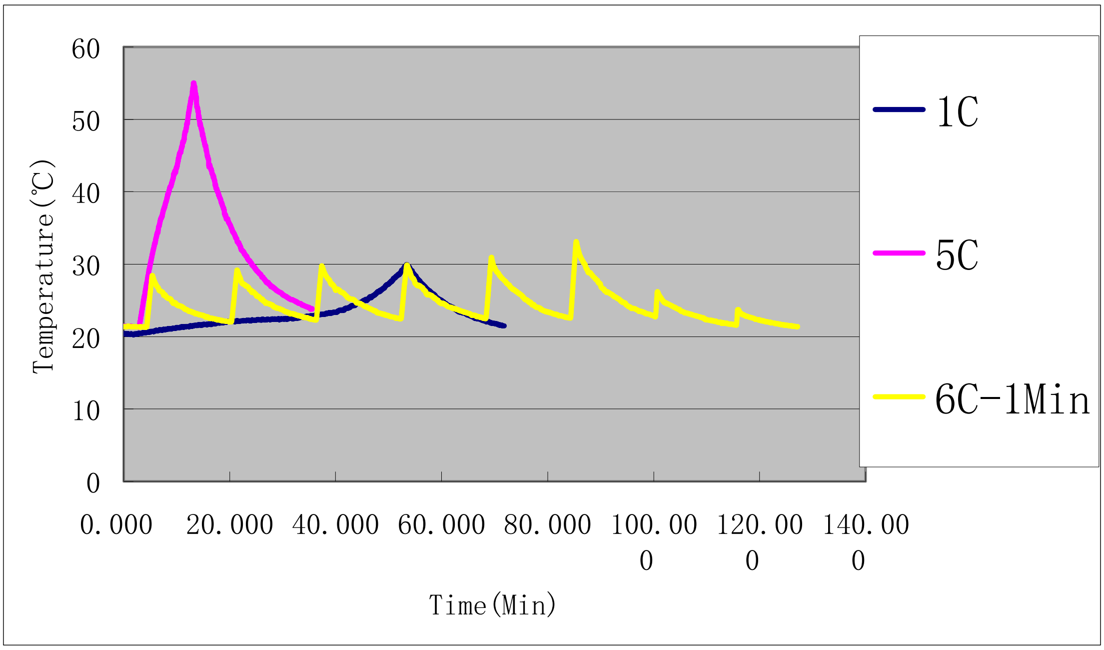

FIG 1. Cell surface temperatures at 1C, 5C continuous discharge, and at 6C 1 min pulse discharge. At 5C continuous discharge, the surface temperature is still below 60 deg C.

The large format prismatic cells also show exceptional safety in electric shorting test. The large flat surfaces help conduct the heat generated to surrounding rapidly thus lower the overall temperature. Fig 2 shows the surface temperatures at four different surface locations of a 10 Ah cells during and after electric short; the highest temperature reached was ~220 deg C; a temperature well below the ignition temperature of the electrolyte. No flame or explosion was observed.

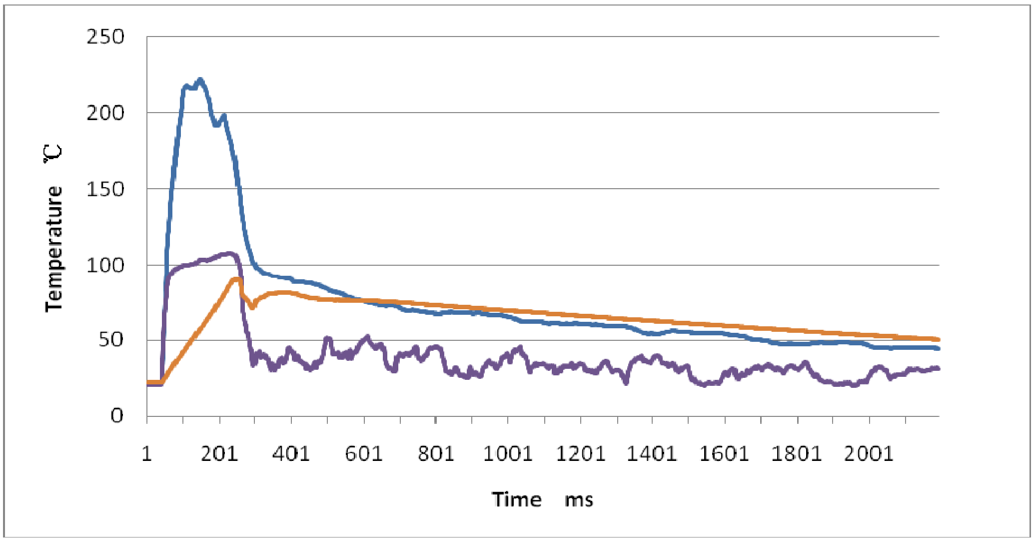

FIG 2. Surface temperatures at three different locations of a 8 Ah cell in electric shorting test.

Mechanical nail puncture on the large format cells show also no fire or explosion even though the nails were not removed from the cell after penetration. In fact the surface temperatures measured raise slowly and in our test reached a mild 45 deg C, FIG 3.

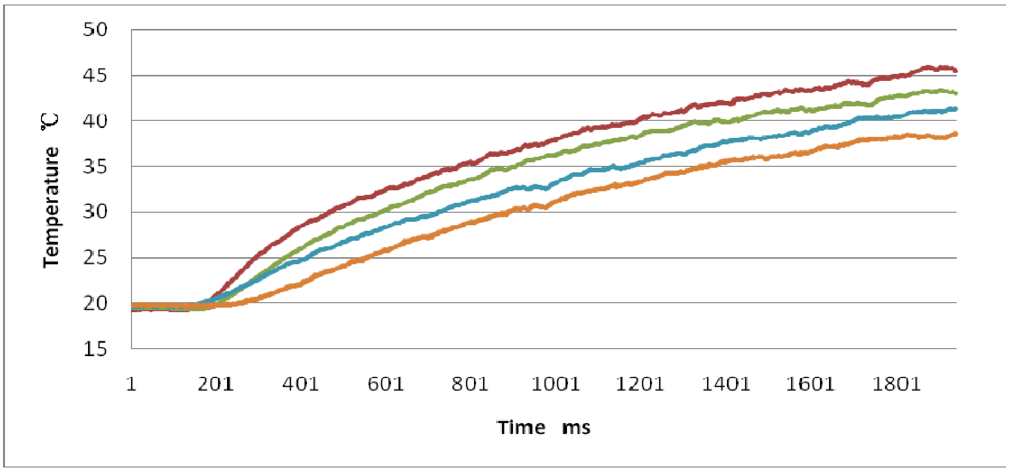

FIG 3. Surface temperatures at four different locations of a 8 Ah cell after nail punctures.

Valence battery pack and BMS development :–

VT has successful developed and commercialized U-charge lines of large battery pack; stand alone packs with voltage vary from 12 V to 19 V and capacity 40 Ah to 165 Ah. Its BMS not only protect the packs also provide effective “balancing” of the components cells during charging of battery. The batteries can be link in series and parallel to form a large battery bank. As an example, the batteries was connected to form a 700V battery to power a HEV bus. The system has been operating for more than two years without drama. Base on the long life cycle LFMP cells, the battery pack also show exceptionally good and stable cycle life. Fig 4 below shows the long term cycle data ~2400 cycle at 80% remaining capacity of a nominal 12V100Ah general purpose battery pack at room temperature.

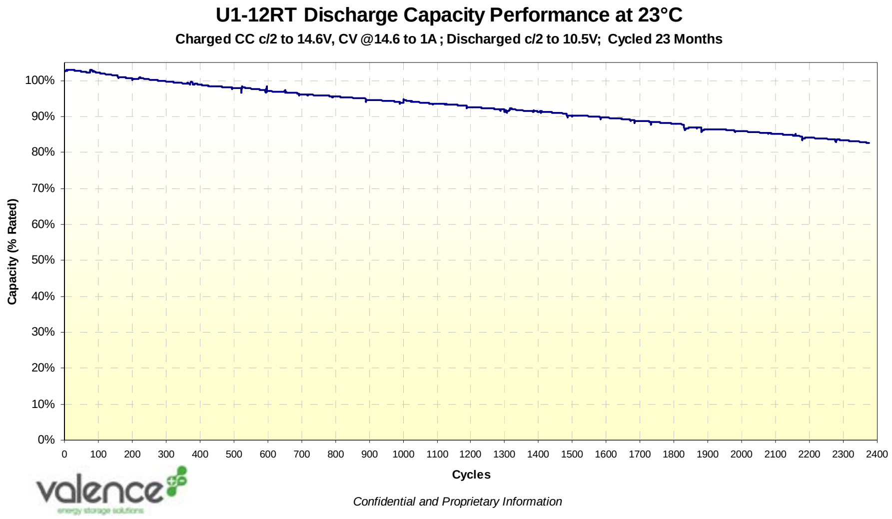

FIG 4. Long term cycling of a 12V40Ah battery pack showing more than 2400 cycles; cycling with BMS.

Summary

VT has pioneered and commercialized a new class of phosphate chemistry cathode materials such as LFMP, LVP with exceptional safety performance that could provide the critical impetus to jump start the EV industries. VT further is developing and marketing large format large capacity prismatic cells using LFMP and LVP. Together with commercial experience of large battery packs and battery management system electronics VT is well position to meet the demanding EV battery industries on safety, life cycle and power rating.