Next Generation Battery Technology

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We have seen from our article in the last issue of AAEN that as vehicle manufacturers steadily move to improve drive systems and resultant fuel economies that the traditional Lead Acid battery may not be able to keep up with the technology enhancements now envisaged.

Vehicle Type	Battery Capacity
Conventional Internal Combustion Engine (Diesel/petrol)	0.3 kWh
Micro hybrid 1 (ISS)	0.5 kWh
Micro hybrid 2 (ISS + Kinetic Recovery)	0.7 kWh
Micro hybrid 3 (ISS + Kinetic Recovery + Passive Boost)	1.0 kWh
Traditional Hybrid (Diesel/Petrol + battery/electric motor)	1.5 kWh
Plug-in hybrid (Traditional Hybrid with plug-in charging)	5-8 kWh
Electric vehicle (Plug-in charge electric motor only)	15-30 kWh

For new eco-solutions to function the vehicle battery has to support more loads and must therefore increase in capacity. The greater requirements placed on the battery has resulted in the development of completely new battery technologies.

Production of vehicles featuring new technologies designed to reduce CO2 emissions and improve fuel economy will have increased to approximately 70-80% of all vehicles produced in Europe by end 2015 (In excess of 30 million vehicles).

High volume production vehicles from 2008/09 onwards feature technologically advanced and modified forms of the conventional flooded Lead acid battery, such as AGM (Absorbent Glass Mat) and EFB (Enhanced Flooded Battery). Carbon negative plates are also being explored in an effort to improve battery Ah capacities.

Perhaps the future battery will be a Lithium-ion based construction with its significantly improved features over the regular Lead Acid battery.

	Lead acid	Lithium-ion
Cathode	PbO_2	$LiFePO_4$, $LiMn_2O_4$
Anode	Pb	C
Salt/Electrolyte	H_2SO_4	$LiPF_6$
Solvent	H_2O	Carbonate
Voltage	2.0	3.3, 3.7

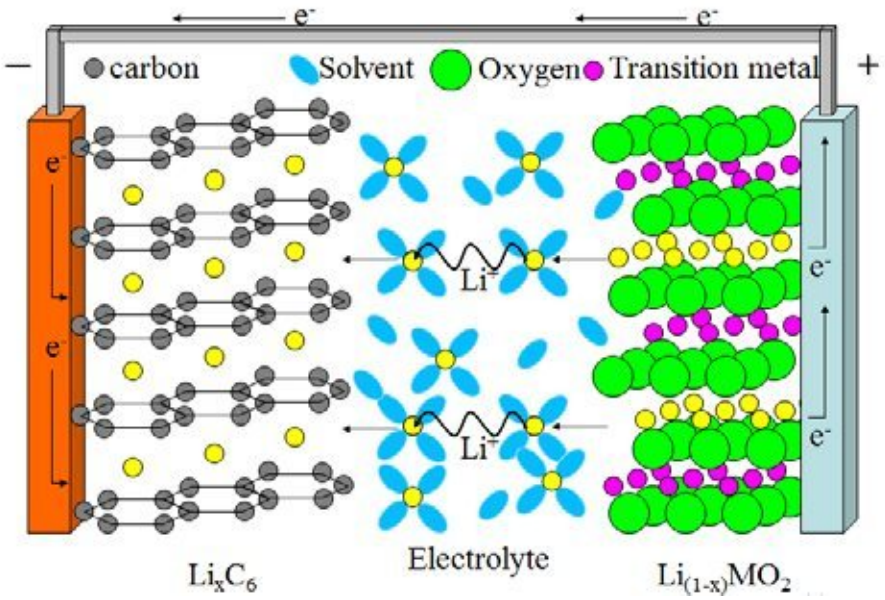
Differences between Lead Acid and Lithium-ion Batteries;

- Lead Acid is a physical / chemical deposition and dissolution reaction – electrolyte concentration is reduced
- Lithium-ion is a transfer of ions only – insertion and extraction reaction. No electrolyte concentration change.

Chemistry Differences;

The table shows the output voltage differences in battery performance when comparing Lead Acid with Lithium. A Lithium 12 volt battery typically has just 4 cells, is less weight (by around 2/3) and is generally smaller in dimensions.

The illustration shows how the Lithium ions (represented by yellow dots) transfer from the anode to the cathode and back again. Unlike a Lead Acid battery there is no physical transfer



of metals and no electrolyte concentration change. Recharge of a Lithium battery is relatively simple chemically – essentially moving the Li ions back to the charged anode (positive) grid location.

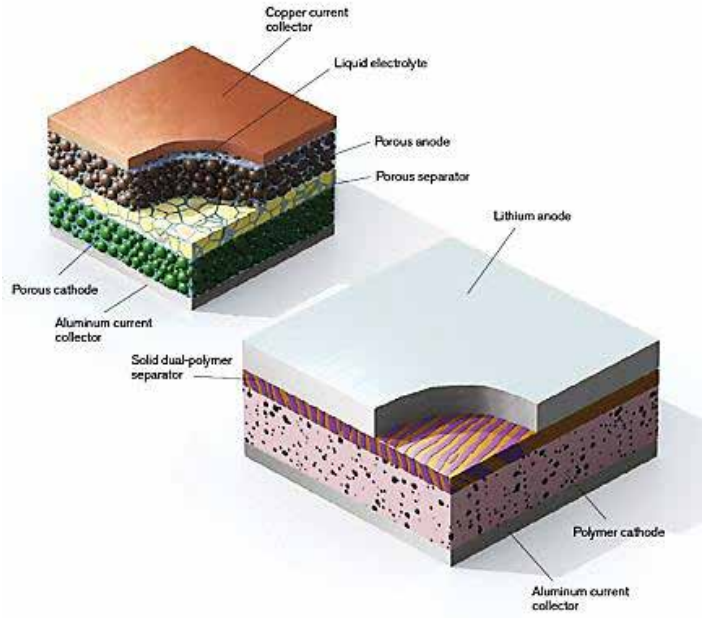
Due to the need for managing the Lithium battery pack in regard to safety in operation there is a need for a Battery Management System (BMS) to be incorporated. There are two fundamental BMS designs used;

- Active- where miniature electronics are incorporated into each cell and connected by slaves to a master control system – all built into the top of the battery.
- Passive- where the cells are managed chemically – not suitable for general automotive applications, but seen in camera batteries, mobile phones etc.

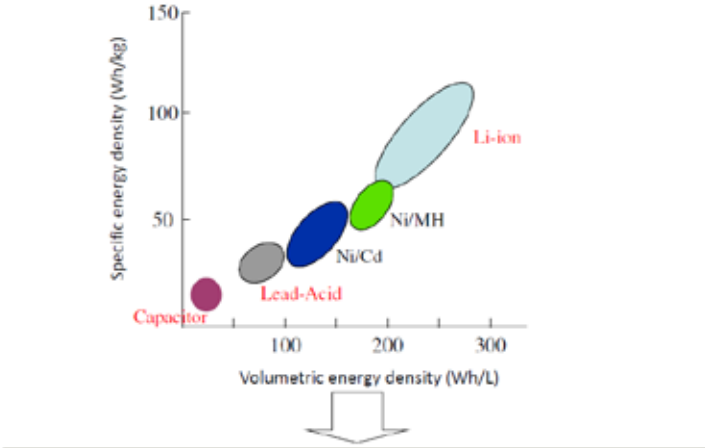
Here is an image of the new Johnson Controls Type 31 automotive Lithium-Iron Phosphate (LiFePO4) battery clearly showing the internal BMS.

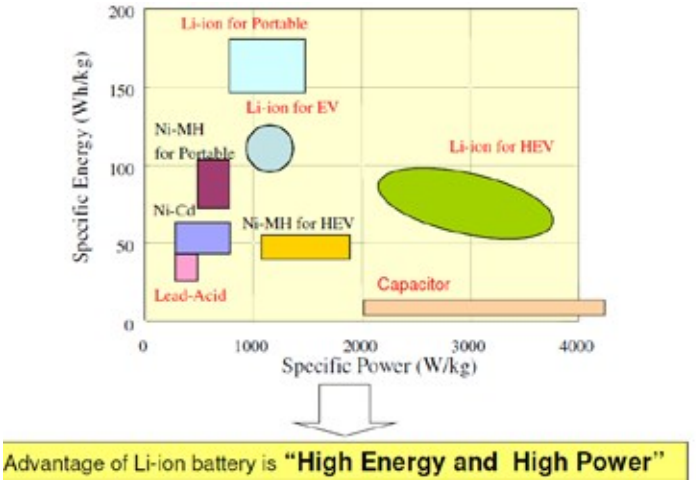
Most automotive Tier-1 Lithium battery manufacturers give a visible LED display in the top cover of the battery that indicates the SOC and SOH of the battery at a glance.

Lithium Polymer cells are not suited to the high current demands of an automotive application and they are constructed on a much smaller dimensional scale than the prismatic type cells used in the new generation of Lithium automotive batteries. Some Battery Electric Vehicles (BEV or EV) incorporate multiples of the Li-Polymer cells however in well controlled situations as an EV is a traction battery application not a cranking requirement.



The illustration shows the typical construction of a Li-Po cell.





The relationship between volumetric and specific energy is demonstrated in the charts. It can be readily seen that the LIFePO4 battery far out performs the regular Lead Acid type.

The relationship between specific energy and specific power is another great advantage of the Lithium constructed battery over Lead Acid.

The EV industry has supported the Lithium-ion chemistry substantially now with 98% of all EV manufacturers moving across to Lithium based battery chemistries.

Some vehicle manufacturers (such as VAG) are now starting to incorporate a Lithium battery at 48 volts into their vehicles, thus allowing exceptional power delivery capabilities.