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- **Energy Storage/Standby**  
Lead – The most efficient technology
- **Motive Power**  
Lead – The best overall solution
- **Hybrid Electric Vehicles (HEV)**  
Lead is getting lighter
- **Safety and Reliability**  
Lead – A longer track record in safety and reliability than other rechargeable battery technologies
- **Sustainability/Recycling**  
Lead – One of the highest recycling rates on the planet



## Hybrid Electric Vehicles (HEV)

### Lead is getting lighter

Future endeavors to maximize the lead battery's energy density show great promise as manufacturers develop new ways to make current collectors more efficient and take up less space. This leaves more room for active material, improving the battery's power-per-pound. Lowering the weight-to-power output is an important benefit for Plug-in Hybrid and Electric Drive vehicles, where weight is a critical issue in performance.

### Next Generation Lead Technology: Performance Enhanced Through Creativity

Dramatic improvements in the performance of lead batteries have come about not through the use of rare or expensive materials, but through the creative use of the raw materials that lead manufacturers have been using for decades.

The novel use of standard, readily available materials has enabled engineers to achieve the technological breakthroughs that are making a new generation of affordable, efficient and environmentally safe lead batteries available for use in hybridelectric vehicles, the electric powergrid, and other energy storage programs.

The addition of certain types of carbon to the traditional lead battery has led to the production of new lead designs. These are breaking performance standards and positioned to become the low-cost alternative to batteries produced with nickel metal hydride (NiMH) or lithium ion(Li-Ion) technology.



**Weight is not a limiting factor in most hybrid vehicle designs:**

Although lead has lower specific energy than nickel metal hydride (NiMH) or lithium ion batteries in HEVs are rather small (about 1kWh) so the weight penalty of adopting lead is modest – especially since lead does not need the supplementary battery and 12 V starter motor that supports NiMH in low temperature conditions, or the cell-by-cell battery management that lithium ion must have to ensure safety.

### Carbon + Supercapacitor = Performance Breakthrough

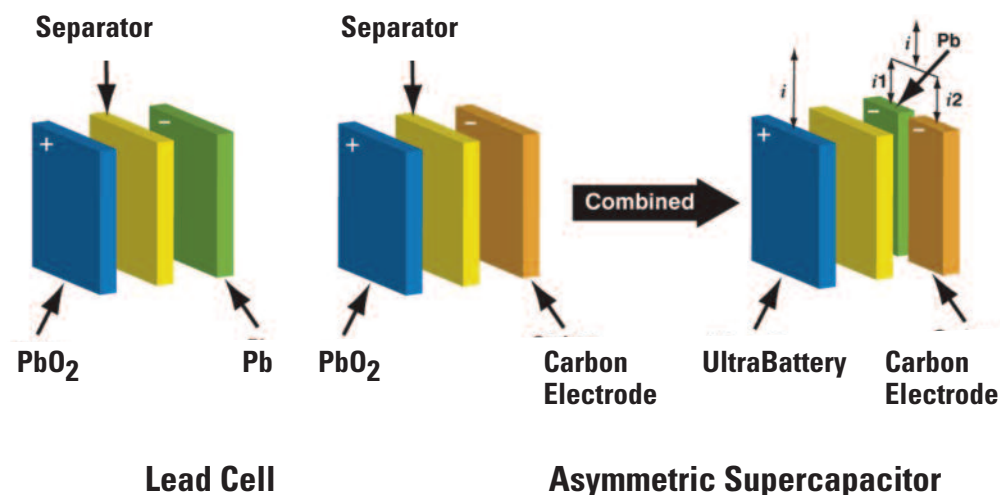
For years, scientists have known that the accumulation of lead sulfate can prevent lead batteries from achieving the sustained level of high-rate partial state of charge (HRPSoc) operation required for heavy duty performance in hybrid electric vehicles and other energy storage applications.

This problem would occur whenever a lead battery's 'state-of-charge' remained significantly below 100% for a sustained period. Conversely, whenever the battery's state-of-charge would rise much above 70 percent, it could not accept a recharge from either a regenerative braking system or a charge from the engine itself.

One solution has been to insert a super-capacitor into the battery to act as a 'buffer' to manage the high-rate charge/discharge process so that the unit can operate successfully within a state-of-charge window below 70 percent.

In one such design, called the UltraBattery, a supercapacitor carbon electrode is combined with the lead battery's negative plate to better regulate the flow (charge and discharge) of energy, thereby extending the power and life of the battery itself. The Advanced Lead-Acid Battery Consortium (ALABC) tested the UltraBattery in a Honda Insight HEV. The vehicle easily surpassed the 100,000-mile durability test without any conditioning or equalization treatment.

There are other novel lead designs which replace the negative lead electrode entirely with a pure carbon supercapacitor, or that use carbon as an electrode substrate. Among other benefits, these modifications can dramatically reduce the weight of the battery.



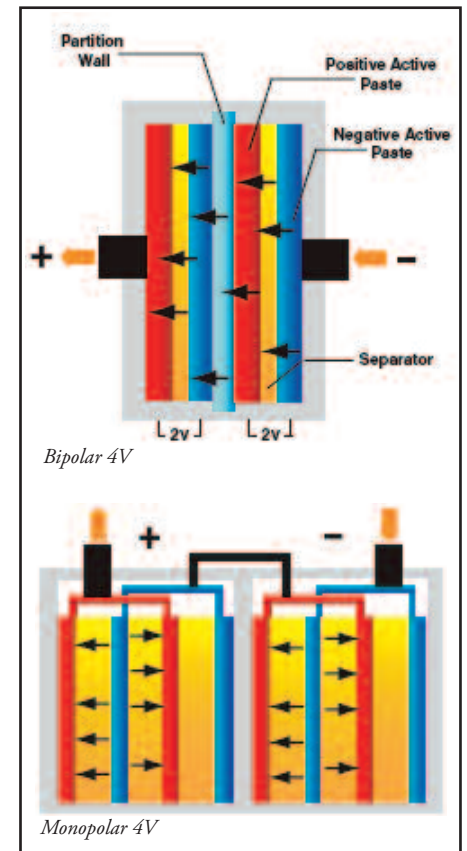
### The Commercialization of Bipolar Technology

As the lead industry continues its breakthrough work on incorporating carbon and supercapacitors in batteries to improve their performance, significant progress also is being made in another key area: the commercialization of bipolar technology. Bipolar technology can help produce batteries that will achieve the goals of more power and a smaller footprint, both very important in making hybrid electric vehicles more affordable for consumers.

The majority of batteries are made with conventional 'monopolar' technology, which uses two plates per cell. It then connects those cells in a series of metallic connectors outside of the cells or through a wall.

While bipolar and monopolar designs share the same lead chemistry, they differ in that bipolar battery cells are stacked so that the negative plate of one cell becomes the positive plate of the next. The cells are separated from each other by the bipolar plate, which allows each cell to operate in isolation from its neighbor.

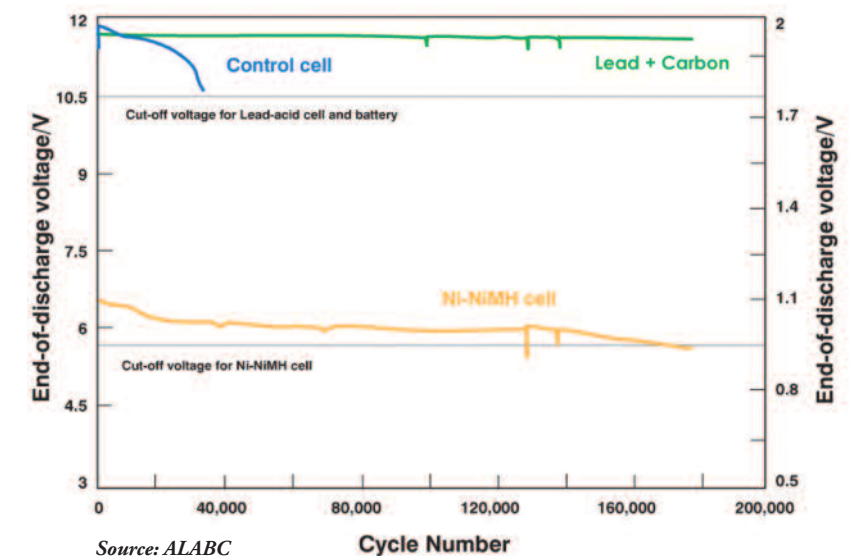
This construction reduces the power loss that is normally caused by the internal resistance of the cells. At each end of the stack, single plates act as the final anode and cathode. This construction leads to reduced weight since there are fewer plates and bus bars are not needed to join cells together. The net result is a battery design with higher power and less weight than conventional monopolar lead batteries.



Source: ALABC

### Lead + Carbon: Enabling Micro Hybrids for the Masses

New lead battery technology has sharply reduced the accumulation of lead sulfate deposits that previously inhibited the performance of lead batteries in HEV or other HRPSoc applications. This benefit has extended the life of traditional lead batteries three-fold, enabling large scale deployment of micro and medium hybrids with significant fuel economy and emissions savings at very low cost.



Source: ALABC