The emergence of Technology - report

(Aluminium-graphite car batteries)

This report is about the newly emerging low-cost aluminium-graphite batteries. I chose this topic specifically because of my interest in electric vehicles and their components.

To start with, if we look specifically into EVs, we see that it has been one of the most emerging technologies of the past decade and it is also one of the most cost-effective environmental solutions as termed. It acts as a great alternative to the standard diesel or petrol cars that exist. there are also many countries like India, which have a sustainable solution of using compressed natural gas but as we know everything has a loophole in it, no matter what. And that is true with electric vehicles as well.

For example, (1) High initial cost- Since 40% of the cost of an electric vehicle, is for the battery, electric vehicles have a high initial cost which at the very beginning makes buyers lose interest. (2) high maintenance cost - we also know that if one of the components (battery) is that expensive in a car it makes maintenance of it a nightmare if it goes bad. Moreover, these batteries only last for up to 15 years only if maintained properly with checks and tests which makes it difficult for people. (3) concept of the car as a whole - we have also heard on the internet people saying that you pay for the software, not the car if you buy an electric vehicle. This topic has an indirect relation that the cars can be sold for their actual usability.

After thorough research on electric batteries, we can think of one of the most feasible solutions aluminium-graphite batteries. These batteries show a reversible capacity of $\approx$100 mAh g^{-1} and capacity retention of 88% after 200 charge-discharge cycles. A packaged aluminium–graphite battery is estimated to deliver an energy density of $\approx$150 Wh kg^{-1} at a power density of $\approx$1200 W kg^{-1}, which is $\approx$50% higher than most commercial lithium-ion batteries.

Lithium-ion batteries based on cation intercalation have been powering the increasingly mobile society for decades. In a conventional lithium-ion battery, the intercalation of lithium ions in both cathode and anode (i.e., graphite, silicon), while the utilization of the anions in the electrolyte has drawn much less attention. The phenomenon of anion intercalating into graphite by chemical or electrochemical means was discovered and proposed as a possible positive electrode for batteries by Rüdorff and Hofmann in 1938. However, the anion intercalation was achieved by using high concentration acid solution as the electrolyte, this brought serious safety issues that hindered its application. In the 1990s, soon after the commercial application of lithium-ion batteries, it was reported dual graphite intercalating molten electrolyte batteries that realized the application of anion intercalated graphite as a positive electrode in batteries by using room temperature ionic liquids as electrolytes. In the decades that followed, continued progress was made in graphite-based dual-carbon batteries with anion intercalation, including the incorporation of various anions into graphite. Electrolytes caused by the high positive potential of anion-intercalated graphite ($\approx$5 V vs Li/Li^+) and exfoliation of graphite layers upon repeated ion/solvent molecule intercalation/deintercalation, reported dual-carbon batteries showed unsatisfied charge-discharge reversibility.

A central challenge in the development of highly reversible dual-graphite batteries was to find a suitable electrolyte that allows simultaneous Li+ intercalation at the negative graphite electrode and anion intercalation at the positive graphite electrode. Traditional carbonate electrolytes consisted of ethylene carbonate, acyclic carbonates, and lithium salts. Ethylene carbonate in the electrolyte is a vital component for forming the solid electrolyte interface and protecting the graphite anode. Unfortunately, when used in dual-graphite batteries, the EC molecules in the electrolyte can bind tightly with PF6− anions and prevent these anions from intercalating into the interlayer space of the graphite positive electrode. Recently, several studies reported that the development of new electrolyte formulations significantly improved the reversibility of dual-carbon batteries. A reversible dual-graphite battery with simultaneous accommodation of Li+ and PF6- in the graphite structure is enabled by a high-voltage electrolyte based on fluorinated solvents and additives. The cell showed a reversible capacity of 60 mAh g-1 and capacity retention of 62 after 50 cycles at a C/7 rate. Dual graphite batteries have also been reported based on mixtures of lithium bis(trifluoromethanesulfonyl)imide with ionic liquids and SEI-forming additives. This electrolyte formula allowed stable TFSI- intercalation to the graphite positive electrode and highly reversible Li+ intercalation to the graphite negative electrode. The all-graphite cell exhibited a capacity of 97 mAh g-1 at a current rate of 10 mA g-1 and 50 mAh g-1 at 500 mA g-1 at an upper potential of 5.0 V and illuminated. A potential application of dual-ion batteries as an environmentally friendly energy storage technology.

Aluminum Graphite Battery's reliable performance is attributed to its specially designed composition. First, aluminium must be used instead of graphite anodes, unlike other reported dual-ion batteries. This construction eliminates the need for additional metal pantographs, resulting in significant weight savings. Another advantage is that the use of EC, which is commonly used in electrolytes to protect graphite anodes, can be easily eliminated. This allows the use of 100% EMV solvent in the electrolyte, not only solving the binding problem between EC and PF6− reported by Wand and Gao, but also much higher concentrations of LiPF6 are possible. EC solvent. It has also been shown that higher salt concentrations can lower the potential required for anion intercalation into the graphite cathode.

Battery performance is also found to be highly dependent on the metal used in the anode. Test on Metals | Photo Test on Metals EMC Runs 4 m LiPF6 | Graphite Battery with Different Metal Counter Electrodes (Cu, Fe, Li, Al). Surprisingly, the aluminium | 4 m LiPF6 in EMC | graphite battery has a much higher initial discharge capacity and better efficiency than the other batteries.

Although the Al | 4 m LiPF6 in EMC | Graphite battery exhibits impressive initial discharge capacity, the cycle stability of this battery is poor, which is due to the pulverization caused by the volume expansion of the aluminium during the alloying process. To improve the cycling stability, we performed a test adding his SEI-forming additive to the electrolyte to protect the aluminium counter electrode from powdering. After screening various electrolyte additives, we found that a small amount of vinylene carbonate (VC) was remarkably effective in improving the cycle life of aluminium-graphite batteries.

aluminium-graphite batteries consisted only of environmentally friendly and low-cost materials (such as aluminium and graphite) as electrode materials, and conventional lithium salts and carbonate solvents as electrolytes. Compared to conventional secondary battery technology (lithium-ion batteries), there is a clear advantage in terms of manufacturing costs. Furthermore, as the Al counter electrode in the aluminium-graphite batteries acts as both the anode and the current collector, the dead load and dead volume of this battery could be significantly reduced, which results in a battery with both high specific energy density and high-volume energy density.

In summary, there have been developments for a novel aluminium-graphite battery composed of only environmentally friendly low-cost materials (I.e., aluminium as the counter electrode, graphite as a positive electrode), and a specially designed carbonate electrolyte. As aluminium acted as both the negative current collector and the negative active material, these batteries show significantly reduced dead load and dead volume. It delivers a reversible capacity of 104 mAh g^{-1} (based on the mass of graphite) at a 2 C current rate, and a capacity retention of 88% after 200 cycles.

According to the composition of conventional packaged battery, a packaged aluminium-graphite cell is estimated to deliver an energy density of ≈220 Wh kg^{-1} at a power density of ≈130 W kg^{-1}, and ≈150 Wh kg^{-1} at ≈1200 W kg^{-1}, which are significantly higher than most commercial lithium-ion batteries, indicating its potential to be a low-cost power source with both high energy density and high-power density.