WHITE PAPER

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Future of E-mobility is in the Hands of Chemicals & Materials Companies

E-mobility Opening New Doors of Opportunity

FutureBridge

As the market grows for Electric Vehicles (EVs) and new technologies, material solutions will play an important role to meet new requirements and overcome design challenges. There has been a shift from graphite-based anodes to silicon-based anodes to improve battery charge capacity, as silicon has a high density of energy per unit of material and can store 10 times the charge as compared to graphite and improve the performance of lithium-ion batteries. Next-generation batteries, such as sodium-ion and lithium-sulfur, are currently under development and are expected to replace the lithium-ion batteries in EVs; however, lithium-sulfur batteries become unstable over time and their electrodes deteriorate, thereby limiting their widespread adoption. With the advent of next-generation batteries, there would be a demand for more specific chemicals and materials that could function as binders to control the swelling and cracking of electrodes as well as act as a protective coating for them.

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Introduction

According to FutureBridge analysis, it is estimated that 5-8% of all vehicle production will be made up of pure electric, full hybrid, or plug-in hybrid vehicles by 2020.

With electric vehicles and new technologies on the brink of significant growth, automakers and the automotive industry need material solutions that can help meet new requirements and overcome design challenges.

Global MNC companies such as BASF offer a broad portfolio of electric mobility solutions ranging from the chemistry of the battery to lightweight components that limit energy usage, with a significant focus on research & development to help automakers address challenges, such as low cost of vehicles and high battery life.

Relevancy of “Chemicals and Materials” in the Electric Vehicles Market

The Electric Vehicles (EV) revolution is picking up pace, with countries such as the U.K. and France, mandating deadlines to phase out petrol and diesel engine cars. Until recently, electric vehicles have struggled to travel further than 200 miles on a single charge, and the recharge time makes long journeys an ordeal since EV batteries have traditionally been expensive and relatively inefficient.

A revolution in materials used in rechargeable EV batteries will increase their efficiency, making long distances achievable, and creating shorter charging times.

EXHIBIT 1: Snapshot of Battery Components and Raw Materials

Source: FutureBridge Analysis

Battery Raw Materials

Electric car batteries rely on a host of materials–*from lithium to nickel, cobalt, and graphite*–while some cars require/consume rare earth minerals.

Automakers and battery producers are focused on gaining supply agreements from mining companies for metals. Moreover, there is a high consumer uptake of electric vehicles and governments worldwide are launching policies to shift from combustion engines to electric vehicles.

In September 2017, the Chinese carmaker, Great Wall Motor, signed an agreement with the Australian lithium miner, Pilbara Minerals, to secure the supply of chemical-grade spodumene concentrate for a period of five years.

The global automotive sector is focused on securing access to large-scale, consistent, high-quality sources of battery materials in low-risk jurisdictions.

EXHIBIT 2: Snapshot of Raw Materials

LITHIUM

Lithium is currently extracted from hard rock in Australia and from brines in the deserts of South America. While lithium is more abundant, it also faces a supply shortfall over the next few years, as new projects struggle to meet supply. The demand for lithium is expected to be four times greater at 779,000 tons by 2025.

COBALT

Cobalt is a by-product of copper and nickel mining, and thus, its production depends on the demand for those metals. Furthermore, more than half of the world's cobalt stores are found in the politically unstable Democratic Republic of the Congo. Most lithium-ion batteries require cobalt and graphite to do their job of retaining and discharging electricity. While lithium and graphite are plentiful, it is cobalt that has sever supply constraints.

NICKEL

Nickel helps improve the power of the battery, and is one-sixth the cost of cobalt and around 20 times more abundant. The demand for battery-grade nickel is projected to grow from 75,000 tons in 2016 to 400,000 tons by 2025, depending on which chemistries take hold.

Johnson Matthey

- Johnson Matthey is set to build a demonstration plant in Lancashire to drive forward the production of its nickel-based battery material for electric vehicles. The "multi-million pound" plant, which will be up and running by the late 2019, forms a part of the company's **£200m investment plan** to develop a cobalt-free battery material that could cut the cost and increase the range of electric vehicle batteries.
- The plant will be housed at an existing Johnson Matthey site in Clithero, owing to the facility's existing expertise in nickel products.

Source: FutureBridge Analysis

Cathode & Anode Active Materials

The supply of several of the main materials used in EV batteries is limited. Combined with the increasing number of electric vehicles being developed, there is rapid innovation in batteries used to power them. Finding materials that can be cheaply produced as well as improving battery efficiency and durability and lowering weight are priorities for the automotive industry. For example, materials such as silicon and graphene are likely candidates to replace graphite as materials of choice for the anode. Using these materials will increase the range that can be achieved by vehicles on a single charge.

CATHODE

Lithium-ion batteries are broken down into two sub-types; Lithium Iron Phosphate (LFP) and metal oxides that include Nickel Manganese Cobalt (NMC), Nickel Cobalt Aluminum (NCA), Cobalt (LCO), Manganese (LMO), and Lithium Titanite (LTO). With the exception of LTO, the material composition of the cathode gives its name to the lithium-ion type, with the anode most commonly made of graphite.

- Cobalt was the first material used for cathodes in lithium-ion batteries and has been used in vast amounts in recent years. Cobalt's tight compound molecular structure makes it ideal for maintaining a rapid flow of electrons through the battery.
- High purity nickel is needed to produce EV battery cathodes due to its extra durability. It is used in the cathode in nickel sulfate form. Nickel sulfate can be made from either class 1 (high-grade) or class 2 nickel. Although less expensive as raw material, class 2 nickel needs dissolving and purifying prior to its use in the cathode, which, in turn, becomes a costly process. Therefore, class 1 nickel serves to be the material of choice.
- Battery manufacturers are keen to use nickel as it is much cheaper than cobalt. It is often blended with small amounts of cobalt to produce more cost-effective cathodes. Therefore, the demand for class 1 nickel is expected to grow by 30% each year between 2018 and 2025, potentially reaching 570 kilotons, which is around ten times the current demand. These predictions mean that some recycling firms are showing an interest in nickel recycling from old batteries to help meet the demand. *Source: Matmatch (2018)*

ANODE

- *Current:* Graphite is the most commonly used material for EV battery anodes. 25kg of high purity graphite is needed for an average-sized battery, and up to 54kg for large batteries such as those used in the Tesla Model S.
- *Future:* Silicon has a number of advantages over graphite as an anode material, including the low cost of material procurement and manufacturing. Additionally, it can absorb and contain a much higher number of lithium-ions upon charging than graphite. This increases the efficiency of the battery, and thus, EVs can reach long

distances on a single charge. Silicon anodes are still in development; however, it is likely that they will be in commercial use by 2020.

Binders, Separators, and Electrolytes

The need to improve battery charge capacity efforts has led to the shift from graphite-based anodes to silicon-based anodes. Silicon has a high density of energy per unit of material. It can store 10 times the charge as compared to graphite and improve the performance of lithium-ion batteries. Several battery manufacturers are mixing silicon with graphite; however, in recent years, they are likely to replace graphite entirely. Though the shift has not been easy, automobile manufacturers and academicians have been struggling to make the switch to silicon, as silicon particles in the anode change size during discharge and charge, thereby lowering battery capacities over time.

One solution is to use different binders as they hold active ingredients in batteries together and put them in contact with foils, thereby making it possible for batteries to deliver electricity.

Several experts have deduced that binders stabilize silicon particles, which is essential in the development of efficient batteries that satisfy customer demands in a variety of ways–not just by being long-lasting but also by having thermostability and greater capacity.

SUNRISE

- The project, named SUNRISE (after Synthomer, UCL & Nexeon's Rapid Improvement in the Storage of Energy), will develop better battery materials based on silicon as a replacement for carbon in the cell anode, and optimize cell designs for automotive application. Nexeon will lead the silicon material development and scale-up stages of the SUNRISE project, while the leading polymer company, Synthomer, will lead the development of a next-generation polymer binder optimized to work with silicon, and ensure anode/binder cohesion during a lifetime of charges.

Source: eeNews Europe (2018) and FutureBridge Analysis

Cooling Fluids/Thermal Management

Regardless of the way vehicles are powered–whether through an internal-combustion engine or a battery pack powering an electric motor–most powertrains have a common enemy, i.e. heat.

Presently, there are 3 common battery thermal management methods used:

- Convection to air either passively or forced
- Cooling by flooding the battery with a dielectric oil, which is then pumped out to a heat exchanger system
- Cooling by the circulation of water-based coolant through cooling passages within the battery structure

3M

- 3M engineers are testing batteries in Novec, a non-flammable, non-conductive liquid used to cool supercomputers; the company aims to sell Novec to automakers to cool batteries. Maintaining a constant, low temperature helps electric vehicles drive long distances, thereby keeping batteries cool. One of the key issues faced by automakers includes lack of range that has been a major obstacle to the mass adoption of electric cars.

Source: FutureBridge Analysis

Polymers

Polymers have aided vehicle improvement for generations. Notably, polymers reduce vehicle weight when they replace heavier materials, such as metal and glass, thereby saving energy. An old rule of thumb in the automotive industry states that for every 10% of vehicle weight reduction, fuel economy improves by approximately 5%. Key developers of polymers in the market are shifting to electric cars and autonomous vehicles, which, in turn, emphasize on the use of plastics for electrical and electronic components.

There are a significant number of polymer components used in electrified vehicles, such as insulation for bus bars that connect battery cells with high-voltage components as well as battery enclosures made with thermoplastic composites. One of the key challenges for polymer makers will be supplying materials that can handle high temperatures associated with high voltages used in electric vehicles.

Based on information gathered from secondary research, it is understood that there will be increased demand for high-end resins in the near future. Solvay manufactures resins that include polyphthalamides, polyphenylene sulfide, and polyether ether ketone, are useful in high-voltage, high-heat applications, such as traction motors and power modules. *Source: Chemical and Engineering News (2017)*

SABIC

- Automakers are using Lexan PC resin while making large and clear surfaces, as is the current design trend for vehicles with electric, connected, and autonomous technologies. Lexan resin can remove weight and provide energy savings and increased driving range. In one study, Sabic and its industry partners established that the use of the Lexan resin with its insulating properties, could significantly reduce the burden on a car's Heating and Air Conditioning (HVAC) system, thereby making it possible to drive up to 15 additional kilometers with a single battery charge.

Source: SABIC (2018)

The Road Ahead

Next-generation batteries such as sodium ion and lithium-sulfur are presently under development and are expected to replace lithium-ion batteries in electric vehicles, as they are cheaper, weigh less, and can store nearly double the energy for the same mass. However, lithium-sulfur batteries become unstable over time, and their electrodes deteriorate, thereby limiting their widespread adoption.

When a lithium-sulfur battery stores and releases energy, the chemical reaction produces mobile molecules of sulfur that become disconnected from the electrode, causing it to degrade and ultimately lowering the battery's capacity over time. Researchers have traditionally worked to develop protective coatings for electrodes and new polymer binders that act as the glue, holding battery components together. These binders are intended to control or mitigate the swelling and cracking of electrodes.

With the advent of next-generation batteries in the next 5-10 years, there would be a demand for more specific chemicals and materials that could function as binders to control swelling and cracking of electrodes as well as act as a protective coating for them. *Source: Green Car Congress (2018)*

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