Graphene Supercapacitors: A Storage Option for A Sustainable Future

ENERGY INNOVATION REPORT

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New Storage Options for a Sustainable Energy Future

Since the global oil crisis of the 1970s, batteries have undergone rapid innovation, becoming a more efficient, less expensive, and longer-lived technology solution for energy storage. The development of rechargeable and powerful lithium-ion batteries revolutionized the current Information Age, enabling technologies like portable electronics and long-range electric vehicles to storage for renewable energy sources.[1] In 2019, the Nobel Committee for Chemistry noted, "Lithium-ion batteries have revolutionized our lives since they first entered the market in 1991. They have laid the foundation of a wireless, fossil fuel-free society, and are of the greatest benefit to humankind."[2]

In the past decade, the rapid growth in production and affordability of battery and other storage technologies has caught the attention and excitement of governments, companies, and investors. As electric vehicle sales grow and demand more energy storage solutions for renewable energy increases , the battery market is expected to surge to nearly $426 billion globally in the next decade.[3] In the past four years, the U.S. Department of Energy invested over $1.6 billion in energy storage research and development, setting the ambitious goal to "develop and domestically manufacture energy storage technologies that can meet all U.S. market demands by 2030."[4]

Scientists are exploring an exciting new energy storage technology, graphene supercapacitors, as an alternative to traditional options. While battery technologies have undergone rapid advancement, the state-of-the-art lithium-ion battery still takes time to recharge, degrades over continued use, and relies upon non-renewable mineral resources.[5] Graphene supercapacitors could provide a promising solution to these pitfalls. Engineers seek to build upon existing supercapacitor technology to create a lightweight energy storage option that charges and releases energy nearly instantaneously, never degrades, and is biodegradable or even biocompatible. Applications are endless, from electric cars that could recharge in less time than it takes to fill a tank of gasoline and laptops that charge in seconds, to large scale storage of intermittent renewable energy sources.[6] Scientists and engineers are still researching methods to mass produce graphene as ultra-thin sheets, measuring one atom thick, for widespread use in supercapacitors.[7]

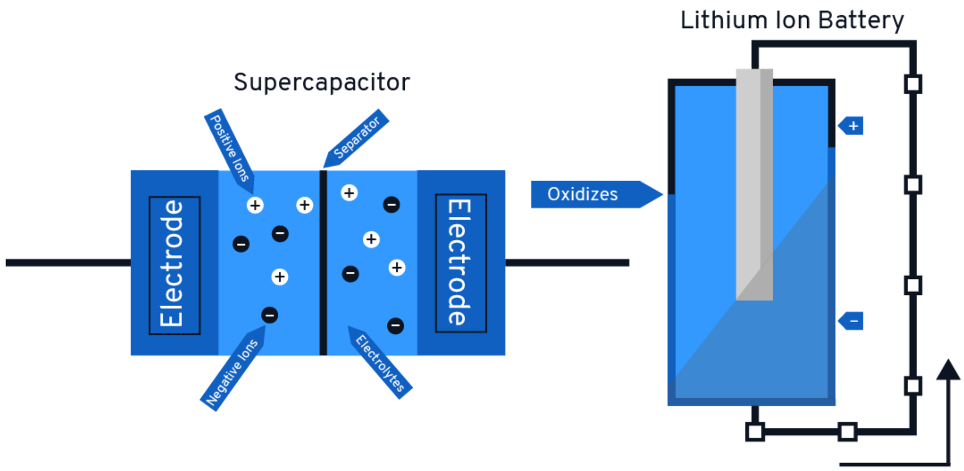
Supercapacitors as an Alternative to Batteries

Batteries and supercapacitors use different methods to produce energy, leading to different efficiencies. Batteries leverage a chemical reaction to produce power, enabling efficient storage of large amounts of energy. Alternatively, supercapacitors use electrochemical processes to capture static electricity and rapidly provide or uptake energy.[8]

Batteries use a chemical reaction, called oxidation, to transfer energy. Electrons are transferred from a positively charged electrode (cathode) to a negatively charged electrode (anode). When a device is connected between these two electrodes, energy can be siphoned from this voltage differential. Since it is a chemical reaction, it takes time to reverse the reaction and recharge the battery. After repeated use and recharge, the battery will naturally lose some of its voltage capacity and power.[9]

Alternatively, capacitors use an electrochemical, rather than a chemical, reaction to transfer electrons. The method stores charge in an electric field, like static accumulating on a balloon and transfers energy directly between two plates that hold opposing charges.[10] . Capacitors have been used in computers for decades, for memory protection. Supercapacitors extend the energy storage of this technology by adding additional layers, separated by an insulating material (dielectric).[11] The design does not require a chemical reaction and thus the plates do not readily degrade over time.

Figure 1: Supercapacitor Structures

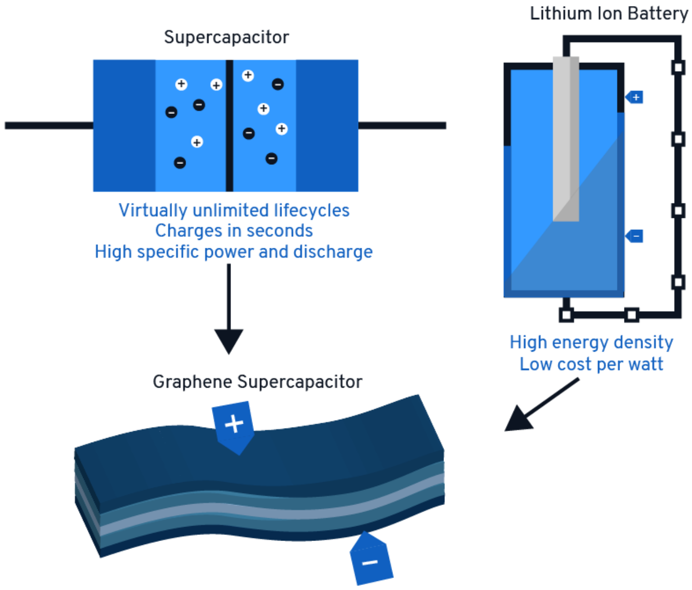


Supercapacitors have been used since the early 1970s alongside batteries.[12] They are commonly used in hybrid cars to capture or release rapid bursts of energy, during braking and starting, thus increasing the efficiency of electric motors.[13] While their power density is higher relative to a battery,releasing energy more rapidly,, lithium-ion batteries are more energy dense and thus more efficient for storing large amounts of energy.[14] To store the same amount of energy in a supercapacitor, the total surface area of the plates within would need to be significantly larger than that of a battery's electrodes. Existing supercapacitors are not an economically feasible option to replace batteries, given the large size and mass of material necessary to store a comparable amount of energy.

The Promise and Current State of Graphene

Graphene provides an exciting option forward to overcome the low energy density of modern supercapacitors. The substance is a honeycomb lattice of carbon atoms arranged into "two dimensional" sheets. These sheets boast a strength that is 200x stronger than steel, while being relatively lighter, flexible, and biodegradable.[15] Scientists and engineers believe that arranging these single atom-layers in a supercapacitor could greatly increase the surface area available within a capacitor, achieving an overall energy density that could outcompete existing battery technologies.[16]

Figure 2: Graphene Supercapacitors



The challenge, however, is efficiently manufacturing layers of graphene. In recent years, scientists have made progress as researchers have patented approaches to synthesize graphene with oxygen and hydrocarbon gas.[17] However creating and stacking single layers of graphene into a supercapacitor has proved challenging to manufacture.[18] In the meantime, engineers and companies are turning to hybrid graphene materials. Researchers in Europe are developing a hybrid supercapacitor that uses both graphene and titanium; it not only attains the power density of a supercapacitor but also the energy density of nickel metal hydride are rapidly developing and bringing the hybrid graphene materials to market.[19]

Conclusion

The graphene supercapacitor remains an ambitious, though ever closer, technology for energy storage. If achieved, the technology promises new capabilities for consumers and industries, increasing the range of electric vehicles, rapidly charging personal electronics, and capturing and storing greater amounts of energy from intermittent renewable sources. As the industry aspires for an efficient and effective way to manufacture pure graphene supercapacitors, private companies are not waiting around. New hybrid-graphene supercapacitors are already coming to market and are being incorporated into hybrid energy storage systems alongside lithium-ion batteries.[20]

Endnotes

Further information, references, and hyperlinks

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