Plastic Supercapacitors: A Potential Solution to the Energy Crisis

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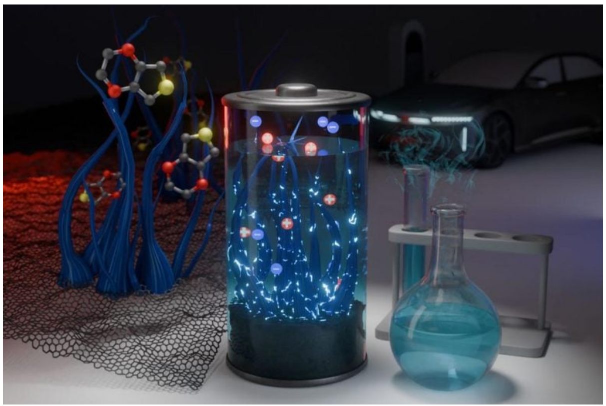

Courtesy of SynEvol
Credit: Maher El-Kady

Plastics have influenced our contemporary society and changed how we exist. For many years, they were mainly utilized in electronics due to their outstanding insulating characteristics. Nonetheless, during the 1970s, researchers stumbled upon the fact that certain plastics are capable of conducting electricity. This innovation transformed the field and opened up opportunities for new uses in electronics and energy storage.

A highly prevalent electrically conductive plastic in use today is poly(3,4-ethylenedioxythiophene), often referred to as PEDOT. This substance creates a pliable, clear layer frequently used on surfaces like photographic films and electronic parts to inhibit static accumulation. PEDOT is utilized in touchscreens, organic solar panels, and electrochromic devices, such as smart windows that alter transparency at the touch of a button.

Although PEDOT has various applications, its utilization in energy storage has been restricted. Commercial versions of PEDOT generally exhibit low electrical conductivity and a constrained surface area, which limits their capacity to store substantial energy amounts.

UCLA chemists are tackling these issues with a novel technique to regulate the morphology of PEDOT for the precise growth of nanofibers. These nanofibers display remarkable conductivity and increased surface area, which are vital for improving the energy storage efficiency of PEDOT. This method, detailed in a publication in Advanced Functional Materials, showcases the capability of PEDOT nanofibers for use in supercapacitors.

In contrast to batteries, that store energy via slow chemical processes, supercapacitors accumulate electrical charge on their surface to store and release energy. This enables them to charge and discharge very rapidly, making them perfect for uses that need quick surges of power, like regenerative braking systems in hybrid and electric cars and camera flashes. Improved supercapacitors are, consequently, a pathway to diminished reliance on fossil fuels.

The difficulty with supercapacitors lies in developing materials that have sufficient surface area to store substantial energy. Conventional PEDOT materials lack in this aspect, restricting their effectiveness.

The chemists at UCLA created the new substance via a distinctive vapor-phase growth method to generate vertical PEDOT nanofibers. These nanofibers, akin to thick grass rising upwards, significantly enhance the material’s surface area, enabling it to accumulate more energy. By placing a drop of liquid with graphene oxide nanoflakes and ferric chloride onto a graphite sheet, the researchers then subjected the sample to vapor of the precursor molecules which ultimately created the PEDOT polymer. Rather than forming a very thin, flat layer, the polymer extended into a dense, fur-like structure, substantially enhancing the surface area in comparison to traditional PEDOT materials.

“The distinctive vertical growth of the material enables us to produce PEDOT electrodes that can store significantly more energy than conventional PEDOT,” stated Maher El-Kady, corresponding author and materials scientist at UCLA. "Electric charge accumulates on the material's surface, and conventional PEDOT films lack sufficient surface area to store a significant amount of charge." We augmented the surface area of PEDOT and consequently enhanced its capacity sufficiently to create a supercapacitor.

The writers employed these PEDOT formations to create supercapacitors featuring remarkable charge storage ability and exceptional cycling endurance, achieving close to 100,000 cycles. The breakthrough may open up possibilities for more efficient energy storage solutions, directly tackling global issues in renewable energy and sustainability.

“A polymer is fundamentally an extended sequence of molecules constructed from shorter segments known as monomers,” stated El-Kady. “Imagine it as a necklace assembled from separate beads linked together.” We warm the liquid state of the monomers within a chamber. As the vapors ascend, they undergo a chemical reaction upon contacting the surface of the graphene nanoflakes. This process leads to the linking of monomers to create vertical nanofibers. These nanofibers possess a significantly larger surface area, allowing them to store considerably more energy.

The new PEDOT material has demonstrated remarkable outcomes, surpassing expectations in multiple key aspects. Its conductivity is 100 times greater than that of commercial PEDOT products, rendering it significantly more efficient for charge storage. What is even more impressive is that the electrochemically active surface area of these PEDOT nanofibers is four times higher than that of conventional PEDOT. This expanded surface area is vital as it enables a greater amount of energy to be contained within the same material volume, greatly enhancing supercapacitor performance.

Due to the innovative method that develops a dense layer of nanofibers on the graphene sheet, this material now possesses one of the highest charge storage capacities for PEDOT recorded so far—over 4600 milliFarads per square centimeter, almost an order of magnitude greater than traditional PEDOT. Additionally, the material is remarkably robust, enduring over 70,000 charging cycles, significantly outlasting conventional materials. These developments pave the way for supercapacitors that are not only quicker and more effective but also more durable, which are crucial attributes for the renewable energy sector.

“The outstanding performance and longevity of our electrodes indicate significant promise for graphene PEDOT’s application in supercapacitors that can assist our society in fulfilling our energy requirements,” stated Richard Kaner, the corresponding author and a distinguished professor of chemistry and materials science and engineering at UCLA, whose research team has led the way in conducting polymer research for more than 37 years. As a PhD candidate, Kaner played a role in the discovery of electrically conductive plastic alongside his mentors Alan MacDiarmid and Alan Heeger, who subsequently won a Nobel Prize for their research.

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