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Future electronics may be powered by a tiny 3D-printed battery

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Editorial

Mobile devices rely on energy storage, and there is a constant desire for smaller, yet more powerful batteries. Over the years, a lot of work has gone into researching new electrode materials, electrolytes, cell topologies, and fabrication methods in order to improve the electrochemical performance of batteries while lowering manufacturing costs. Simultaneously, 3D printing is transforming our society, and the technology is rapidly improving. It is quickly becoming the foundation for next-generation futuristic 3D printed energy systems, in which batteries and super-capacitors may be printed in nearly any shape. Manufacturers have had to design their products around the size and shape of commercially available batteries, which currently occupy the majority of space in modern electronic devices. The majority of them are cylindrical or rectangular in shape and are designed for coin and bag cells. As a result, when a producer designs a product, the battery must be a specific size and shape, thus wasting space and limiting design alternatives. This is increasingly posing a design challenge for future generations of flexible electronics. lithography-based 3D printing, template-assisted electrodeposition-based 3D printing, inkjet printing, direct ink writing, fused deposition modelling, and aerosol jet printing, among others, are all examples of 3D-printed batteries using various printing techniques. The authors also go into the operating principles, printing process, benefits, and drawbacks of each 3D printing technology, as well as the printing materials for the printed batteries' electrodes and electrolytes. 3D printing is an advanced production technology that uses digitally controlled deposition of phase change and reactive materials, as well as solvent-based inks, to produce complex 3D structures. This kind of fabrication usually starts with the creation of a 3D virtual model that is then cut into many 2D horizontal cross sections with the use of specific software. A cohesive 3D object can be produced by successively printing fresh 2D layers on top of prior levels. There are several types of 3D printing technologies that have been created and are currently in use:

- extrusion of material
- powder bed fusion
- photo-polymerization in a vat
- material jetting
- binder jetting
- sheet lamination
- directed energy deposition

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When it comes to batteries, 3D printing offers a number of important advantages over traditional battery fabrication methods:

- permitting the construction of complicated designs that are desired
- precise control of the electrodes' shape and thickness
- printing a solid-state electrolyte with a stable structure and a safer operation
- Possibility of low-cost, environmentally friendly alternatives, 3D printing may create innovative 3D-architected electrodes with bigger surface area and higher areal-loading density, resulting in shorter diffusion routes and lower resistance during the ion-transport process, improving battery energy density and power density. In terms of sustainability and environmental impact, 3D printing has the potential to drastically minimize material waste while also allowing for speedier manufacturing due to less complex fabrication techniques.

Overall, 3D printing opens up new possibilities for the quick manufacture of complicated 3D-structured batteries with great performance. However, not all 3D printing technologies and contemporary materials used in conventional batteries are suitable for manufacturing printed batteries due to compatibility issues with the preparation conditions, materials, and procedures. Currently, the most often utilized anode and cathode materials in 3D-printed batteries are lithium titanate (LTO) and lithium iron phosphate (LFP), which have low volumetric expansion, high rate capability, high stability, and security. Carbon nanomaterials are another potential material group for 3D-printed battery electrode materials. Ultrafast super-capacitors have been 3D printed using reduced graphene oxide and graphene, for example.

Because of their excellent mechanical strength, chemical stability, and enormous specific surface area, carbon nanotubes and carbon nanofibers are also popular materials for printing inks. The electrolyte is the most critical component of a battery, second only to the electrodes. It acts as a catalyst, facilitating the passage of ions from the cathode to the anode on charge and the reverse on discharge. The electrolyte determines the battery's electrochemical performance, cycle life, and safety. With the advancements in 3D printing technology, the electrolyte of batteries may now be directly printed, reducing fabrication methods, fabrication time, and manufacturing cost.

In conclusion, while great progress has been made in the fabrication of 3D-printed batteries, numerous difficulties remain before they can be widely used commercially. The fact that there are currently just a few printable materials, notably active materials, that can be employed as inks for 3D printing batteries is one of these problems. Furthermore, the majority of current research into 3D-printed batteries focuses on the electrode and electrolyte materials. Despite their importance in batteries, current collectors have received little attention for 3D printing fabrication. Furthermore, ink compatibility for each component to be built sequentially and successfully remains a major barrier for fully 3D-printed batteries.

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