STRUCTURAL BATTERIES

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INTRODUCTION

Structural battery composites cannot store as much energy as lithium ion batteries, but have several characteristics that make them highly attractive for use in vehicles and other applications. When the battery becomes part of the load bearing structure, the mass of the battery essentially 'disappears'.

Figure 1. Three cells structural battery using composites. The cell consists of a carbon fiber electrode and a lithium iron phosphate electrode separated by a fiberglass fabric, all impregnated with a structural battery electrolyte for combined mechanical and electrical function. Three structural batteries have been connected in series and laminated as part of a larger composite laminate. Each structural battery cell has a nominal voltage of 2.8 V. The laminate has a total voltage of 8.4 V and a stiffness in the plane of just over 28 GPa.

RESEARCH AND DEVELOPMENT

Researchers from Chalmers University of Technology have produced a structural battery that performs ten times better than all previous versions. It contains carbon fiber that serves simultaneously as an electrode, conductor, and load-bearing material. Their latest research breakthrough paves the way for essentially 'massless' energy storage in vehicles and other technology.

The batteries in today's electric cars constitute a large part of the vehicles' weight, without fulfilling any load-bearing function. A structural battery, on the other hand, is one that works as both a power source and as part of the structure – for example, in a car body. This is termed 'massless' energy storage, because in essence the battery's weight vanishes when it becomes part of the load-bearing structure. Calculations show that this type of multifunctional battery could greatly reduce the weight of an electric vehicle.

The structural battery uses carbon fiber as a negative electrode, and a lithium iron phosphate-coated aluminum foil as the positive electrode. The carbon fiber acts as a host for the lithium and thus stores the energy. Since the carbon fiber also conducts electrons, the need for copper and silver conductors is also avoided, reducing the weight even further. Both the carbon fiber and the aluminum foil contribute to the mechanical properties of the structural battery. The two electrode materials are kept separated by a fiberglass fabric in a structural electrolyte matrix. The task of the electrolyte is to transport the lithium ions between the two electrodes of the battery, but also to transfer mechanical loads between carbon fibers and other parts.

DISCUSSION

The project is run in collaboration between Chalmers University of Technology and KTH Royal Institute of Technology, Sweden's two largest technical universities. The battery electrolyte has been developed at KTH. The project involves researchers from five different disciplines: material mechanics, materials engineering, lightweight structures, applied electrochemistry and fiber and polymer technology. Funding has come from the European Commission's research program Clean Sky II, as well as the USA Airforce.

The development of structural batteries at Chalmers University of Technology has proceeded through many years of research, including previous discoveries involving certain types of carbon fiber. In addition to being stiff and strong, they also have a good ability to store electrical energy chemically. This work was named by Physics World as one of 2018's ten biggest scientific breakthroughs.

HISTORY

The first attempt to make a structural battery was made as early as 2007, but it has so far proven difficult to manufacture batteries with both good electrical and mechanical properties.
But now the development has taken a real step forward, with researchers from Chalmers, in collaboration with KTH Royal Institute of Technology in Stockholm, presenting a structural battery with properties that far exceed anything yet seen, in terms of electrical energy storage, stiffness and strength. Its multifunctional performance is ten times higher than previous structural battery prototypes.

A battery has an energy density of 24 Wh/kg, meaning approximately 20 percent capacity compared to comparable lithium-ion batteries currently available. But since the weight of the vehicles can be greatly reduced, less energy will be required to drive an electric car, and lower energy density also results in increased safety. And with a stiffness of 25 GPa, the structural battery can compete with many other commonly used construction materials.

Previous attempts to make structural batteries have resulted in cells with either good mechanical properties, or good electrical properties. But here, using carbon fiber, we have succeeded in designing a structural battery with both competitive energy storage capacity and rigidity," explains Leif Asp, Professor at Chalmers and leader of the project.

FUTURE POTENTIAL

The new battery has a negative electrode made of carbon fiber, and a positive electrode made of a lithium iron phosphate-coated aluminum foil. They are separated by a fiberglass fabric, in an electrolyte matrix. Despite their success in creating a structural battery ten times better than all previous ones, the researchers did not choose the materials to try and break records, rather, they wanted to investigate and understand the effects of material architecture and separator thickness.

A project, financed by the Swedish National Space Agency, is underway, where the performance of the structural battery will be increased yet further. The aluminum foil will be replaced with carbon fiber as a load-bearing material in the positive electrode, providing both increased stiffness and energy density. The fiberglass separator will be replaced with an ultra-thin variant, which will give a much greater effect – as well as faster charging cycles.

Such a battery could reach an energy density of 75 Wh/kg and a stiffness of 75 GPa. This would make the battery about as strong as aluminum, but with a comparatively much lower weight. It could be quite possible within a few years to manufacture smartphones, laptops or electric bicycles that weigh half asuch as today and are much more compact.

In the longer term, it is conceivable that electric cars, electric planes and satellites will be designed with and powered by structural batteries.

REFERENCE

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