CAS Develops Advanced Biomass Materials for Energy Storage

Renewable biomass materials have important application prospect in the development of sustainable energy materials. In the vast blue ocean, there are abundant seaweed polysaccharides, chitin and other biomass materials. With these marine biomass materials, scientists have developed high performance energy materials which have important ecological, economic and social benefits.

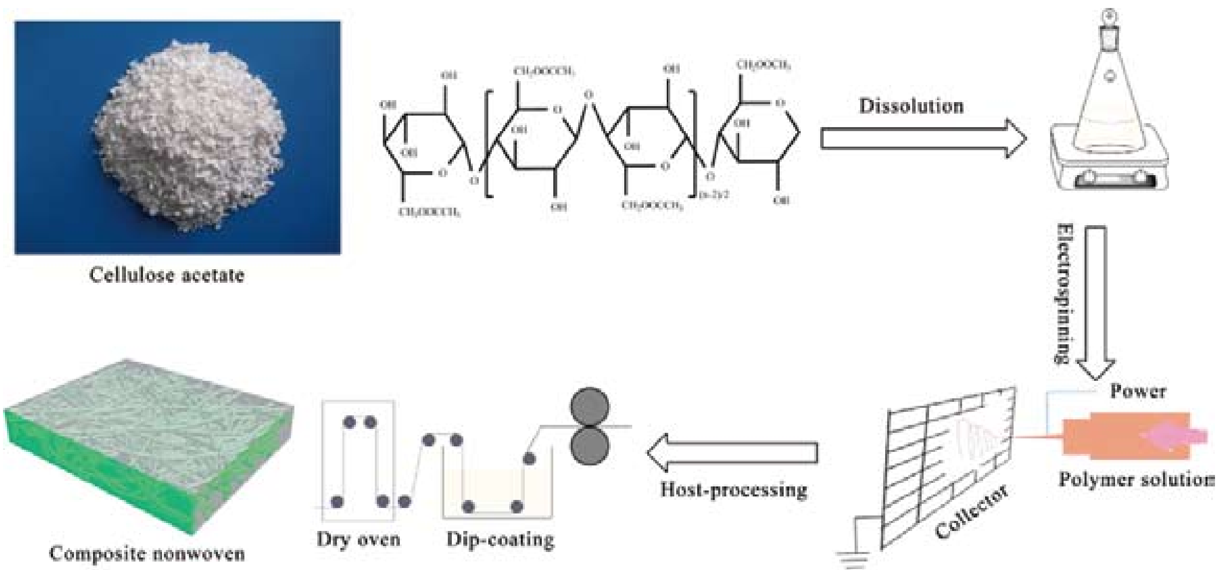
Under the leadership of Prof. CUI Guanglei, a group of researchers from the Qingdao Institute of Bioenergy and Bioprocess Technology (QIBEBT), Chinese Academy of Sciences have developed lithium ion battery (LIB) separators using cellulosic biomass materials and thermostable polymeric materials by nonwoven technology for electric vehicles & hybrid electric vehicles (*ACS Appl Mater. Inter.* 2013, 5, 128-134).

Their separator has a unique chemical and physical structure which is favorable to the access of electrolyte, the migration of lithium ions and the transport of electron. The separator also exhibited very exciting thermal stability at high temperatures. So far, key technical issues have been solved by optimizing material design and integrating molding process innovation.

Prof.CUI Guanglei at work.

To develop high performance LIB separators with low cost, superior thermal stability and enhanced flame retardancy, Prof. CUI's group has also worked out the polysulfonamide/sodium alginate/silica composite separator (*J. Electrochem. Soc.*, 2013, 160 (6), A769-A774).

Batteries using polysulfonamide-based composite separator showed excellent charge-discharge behavior and satisfactory cycle stability even at a temperature as high as

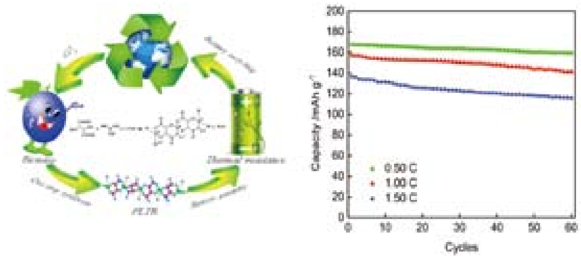


Schematic illustration for the renewable cellulose-based composite separator preparation. (Image courtesy Prof. CUI)

120°C. These advanced characteristics would remarkably boost the application of sodium alginate composite separator for high-power LIBs.

Polyvinylidene fluoride, which is a non-aqueous soluble binder, has been widely applied in the preparation of electrodes for LIB. But during the preparation of the slurry, large amounts of methyl pyrrolidine are used as the solvent, resulting in high production cost, potential environmental pollution, high brittleness, poor flexibility and low tensile strength. The electrodes using such kind of binder often suffer from electrode active power-material-falling phenomenon and material-cracks during the charge-discharge process. However, marine biomass materials such as sodium alginate, chitin and carrageenan possess advantages like low cost, high abundance and excellent adhesion properties. Via functional modification of marine biomass materials, Prof. CUI and his colleagues developed a novel aqueous soluble binder with high elastic modulus, which is economic and environmental friendly and able to withstand the expansion and contraction of the electrode active material particles during cycling. It is particularly suitable for high potential positive electrode materials and silicon-based electrode materials which have high energy density.

Traditional electrolytes (LiPF6) have high production cost, poor thermal stability and are extremely sensitive to water. With raw materials abundant in nature and a simple reaction process, the group has successfully designed and synthesized novel biomass-derived lithium borate salts (*Electrochim. Acta*, 2013, 92, 132-138) to obtain polymer electrolyte demonstrating highly thermal stability, improved electrochemical stability and high ionic conductivity. These fascinating characteristics would endow the polymer electrolyte a promising separator for powering LIBs for military use or space exploration.



PLTB@PVDF-HFP separator and its electrochemical performance for LIBs. (Image courtesy Prof. CUI)

Based on technological breakthroughs in high performance separator, electrolyte salt and binder, the scientists have also developed supercapacitors with high energy density and high power density by employing an advanced technology of pre-doping lithium ions. In such devices, nanostructured metal nitrides are used as high performance electrode materials. The interface between electrode and electrolyte is stabilized by virtue of the biomass cellulose membrane and the additives in the electrolyte. The energy density of the supercapacitors is as high as 30Wh/kg, which is comparable to that of lead acid batteries (*J. Mater. Chem*., 2012, 22, 24918; *J. Mater. Chem*. A, 2013, 1, 5949; *ACS Nano*, 2013, DOI: 10.1021/nn401402a). The team is now optimizing device configuration to develop high performance lithium ion capacitors.

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Schematic illustration of the preparation of $Ni_xCo_{2x}(OH)_{6x}$/TiN NTA and its electrochemical performance for supercapacitor. (Image courtesy Prof. CUI)