

IIT-M designs room temperature sodium sulphur battery

The battery was able to achieve higher charge storage capacity and nearly zero self-discharge when not in use

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While conventional sodium sulphur batteries require very high temperature (300 degree C) for operation, researchers at the Indian Institute of technology (IIT) Madras have designed a new sodium sulphur battery that can be operated at room temperature. By operating the battery at room temperature, the team was able to achieve higher charge storage capacity (technically called the specific capacity) and nearly zero self-discharge when the battery is not being used.

Storage and retention

While high temperature sodium sulphur batteries have charge storage capacity of about 558 mAh per gram, the battery designed by the IIT Madras team was able to achieve as much as 1,034 mAh per gram at a current density of 50 mA per gram.

The battery also showed 83% retention of capacity even at the end of 500 cycles of charging and discharging.



Preventing leakage: The shielding layer helps significantly reduce self-discharge of the battery, say (from left) Ajay Piriya, Ramaprabhu Sundara and Kamaraj Muthusamy

To assess the capacity retention, the researchers used higher current density of 500 mA per gram. "The charge storage capacity was 650 mAh per gram to start with and after 100 cycles it reduced to 570 mAh per gram, at the end of 500 cycles, the charge storage capacity was 499 mAh per gram," says Ajay Piriya from IIT Madras and first author of a paper published in the journal *Advanced Materials*

Interfaces.

The first step that the team led by Ramaprabhu Sundara from the Department of Physics at IIT Madras took to operate the battery at room temperature was by changing the electrolyte used.

Novel electrolyte

Conventionally, sodium sulphur batteries use a solid electrolyte (sodium beta alumina), which by default re-

duces the diffusion of sodium ions from the anode to the cathode at room temperature. It is to increase the diffusion of sodium ions that the temperature is raised to about 300 degree C.

So in place of a solid electrolyte the researchers used a glass fibre separator soaked in ether-based electrolyte that allows the battery to be operated at room temperature.

"Changing the electrolyte alone is not sufficient to improve battery performance as there are other problems with sodium sulphur batteries," says Prof. Sundara. Sodium is supposed to react with sulphur and produce stable sodium sulphide through intermediate steps. Each of the intermediate step produces different sodium polysulphides. "The intermediate sodium polysulphides are unstable and get dissolved into the electrolyte. The dissolved polysulphides cause twin problems that reduce the capacity and durability of the battery," he explains.

The first problem is that with increasing amount of polysulphides getting dissolved into the electrolyte, there is a net loss in the cathode sulphur. In addition, the dissolved polysulphides move towards the anode and form a coating over it. This reduces the performance of the battery.

Shielding layer

To address the twin problem, the team added a shielding layer very close to the cathode. The shielding layer is made of white graphite mixed in a polymer matrix.

"The polymer allows the sodium ions to pass through while the white graphite added to the polymer matrix prevents the migration of polysulphides to the anode," says Kamaraj Muthusamy from the Department of Metallurgical and Materials Engineering at IIT Madras and a co-author of the paper. The boron and nitrogen present in the layered structure of the white graphite act as binding sites for the polysu-

phides. The polysulphides that are chemically bound by the polymer composite react with sodium and produce sodium sulphide.

"Nearly all of the sulphur gets converted into sodium sulphide when we used the shielding layer between the cathode and the separator," Ms. Piriya says. "Since the migration of the polysulphides to the sodium anode is prevented by the shielding layer, self-discharge of the battery is significantly reduced."

The battery was tested for self-discharge by measuring the open circuit potential of a fully charged battery for 16 continuous days. They found the potential remaining constant at 2.35 volt when the shielding layer was used; the voltage dropped without the shielding layer.

While conductive carbons are added to the sulphur to make it electrically conductive in conventional sulphur batteries, the researchers used partially exfoliated multiwalled carbon nanotubes.