Sodium-ion Energy Storage Batteries

Swapnil Arun Namekar[1], Sudhanshu Pathak[2]
[1]Assistant Professor, Department of Electrical Engineering, Bharati Vidhyapeeth Deemed To Be University, College of Engineering, Pune, India
[2]Student, Department Of Electrical Engineering, Bharati Vidhyapeeth Deemed To Be University, College of Engineering, Pune, India

Abstract- **Sodium-based energy storage systems are attracting tremendous attention along with the growing demand for electric vehicles and grid-scale energy storage. Sharing similar intercalation chemistry to their lithium counterpart, sodium-ion based systems show promising potential for large-scale application due to the benefit of the low cost and natural abundance of sodium sources. The high abundance of sodium and its low cost compared to lithium renewed the high interest on sodium ion batteries as cheaper solution for electrochemical energy storage. Indeed, sodium ion batteries have recently proposed as possible candidates for stationary and mobile energy storage devices. Here In this review, we briefly summarize the recent progress in the material design for sodium-ion batteries, including both inorganic and organic materials.**

INTRODUCTION

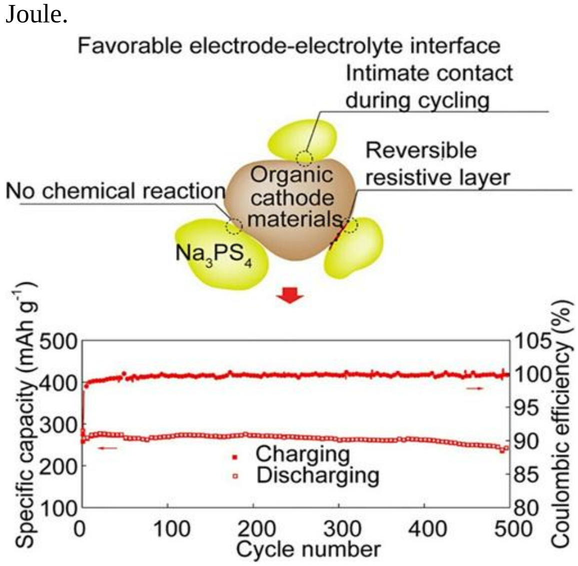
A type of rechargeable battery analogous to the lithium-ion battery but using sodium ions (Na+) as the charge carriers. Its working principle and cell construction are identical with that of the commercially widespread lithium-ion battery with the only difference being that the lithium compounds are swapped with sodium compounds: in essence, it consists of a cathode based on a sodium containing material, an anode (not necessarily a sodium-based material) and a liquid electrolyte containing dissociated sodium salts in polar parotic or aprotic solvents. During charging, Na+ are extracted from the cathode and inserted into the anode while the electrons travel through the external circuit; during discharging, the reverse process occurs where the Na+ are extracted from the anode and re-inserted in the cathode with the electrons travelling through the external circuit doing useful work. Ideally, the anode and cathode materials should be able to withstand repeated cycles of sodium storage without degradation

SODIUM BATTERIES ARE ONE STEP CLOSER TO SAVING YOU FROM A MOBILE PHONE FIRE

Today, lithium-ion batteries are king, powering everything from our cellphones to our cars. But in rare, dramatic instances, their reliance on flammable liquid electrolytes has caused them to catch fire. Researchers are exploring lithium solid state batteries to address this problem. But that doesn't address the cost. A recent analysis by Bloomberg New Energy Finance predicts that demand for lithium will explode, increasing 1500-fold by 2030. That could send lithium prices skyrocketing because the metal is mined in only a handful of countries.

Sodium, a fellow alkali metal, has similar chemical behavior and is far more abundant, so many research groups have crafted solid sodium batteries over the past decade. But the batteries, which use nonflammable solids to ferry sodium ions from one electrode to another, tend to break down quickly. In one common setup, during discharge, sodium atoms give up an electron at one electrode (the anode), creating an electric current that's used to do work. The now positively charged sodium ions then move through an ion-ferrying sulfur-based electrolyte to the second electrode (known as a cathode), which is made of a ceramic oxide compound. When the ions arrive, the cathode swells in size. Then, when the battery is recharged, an applied electric voltage drives sodium ions out of the cathode, causing it to shrink. The ions go back to the anode, where they reunite with electrons. But the repeated swelling and shrinking can crack the brittle ceramic and cause it to detach from the solid electrolyte, killing the battery To tackle this problem, researchers led by Yan Yao, a materials scientist at the University of Houston in Texas, created a cathode from a flexible organic compound containing sodium, carbon, and oxygen, they reported last year in Angewandte Chemie International Edition. The material's flexibility allowed it to swell and shrink through 400 charging cycles without breaking apart and losing touch with the sulfur-based electrolyte. And the cathode stored 495 watt-hours per kilogram (Wh/kg), just slightly less than most conventional lithium-ion cathodes. But the researchers still had a problem. The sulfur-based electrolyte is somewhat fragile. And the sodium cells' operating voltage tore apart the electrolyte.

Yao's team has now solved this issue by redesigning the cathode. As before, the researchers used a flexible organic compound. But each molecule of their new one, abbreviated PTO (for pyrene-4,5,9,10-tetraone), holds twice as many sodium ions as the previous version, enabling the battery to hold 587 Wh/kg, roughly on par with standard lithium-ion cathodes. Meanwhile, the cathode's flexibility allows the battery to manage 500 charge and discharge cycles while retaining 89% of its storage potential, nearing the performance of conventional lithium-ion cells. As a bonus, the cell operates at a lower voltage, which keeps the electrolyte intact, the team reports today in Joule.



If further durability improvements follow, the nonflammable battery could find many low-voltage uses, such as powering the next generation of wearable devices. But for voltage-hungry applications, such as electric cars, researchers will need to boost another parameter: the difference in electric potential (measured in voltage) between the two electrodes.

Lead-acid batteries themselves are quite safe in operation, but the use of corrosive acid-based electrolytes hampers their safety. Lithium-ion batteries are quite stable if cycled with care but are susceptible to catching fire and exploding if overcharged thus necessitating strict controls on battery management systems. Another safety issue with lithium-ion batteries is that transportation cannot occur at fully discharged state – such batteries are required to be transported at least at 30% state of charge. In general, metal-ion batteries tend to be at their most unsafe state at the fully charged state, hence, the requirement for lithium-ion batteries to be transported at a partially charged state is not only cumbersome and more unsafe but also imposes additional costs. Such requirement for lithium-ion battery transport is on account of the dissolution concerns of Cu current collector if the lithium-ion battery's voltage drops too low

ADVANTAGES AND COMPARISON BETWEEN OTHER BATTERY

Lead-acid battery	Lithium-ion battery	Sodium-ion battery	
Cost	Low	High	Low
Energy Density	Low	High	Moderate/High
Safety	Moderate	Low	High
Materials	Toxic	Scarce	Earth-abundant
Cycling Stability	Moderate (high self-discharge)	High (negligible self-discharge)	High (negligible self-discharge)
Efficiency	Low (< 75%)	High (> 90%)	High (> 90%)
Temperature Range	-40 °C to 60 °C	-25 °C to 40 °C	-40 °C to 60 °C
Remarks	Mature technology; fast charging not possible	Transportation restrictions at discharged state	Less mature technology; easy transportation

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