A Review Paper on Comparison of Lithium and Sodium Ion Batteries for Electric Vehicle

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Abstract:
Petroleum reserves like gasoline and diesel are running out, and since their use increases air and noise pollution, it is necessary to look at alternatives. Instead of using petrol, a new technology has been developed to reduce pollution, and currently extensive research is being done on batteries. Since lithium-ion batteries have the highest energy density of any commercially available battery technology right now, they are mostly used in this situation. Lithium-ion batteries have a significant price to pay for the great energy density they provide. In the crust of the planet, lithium is a scarce element. So utilise sodium ion batteries to overcome that. The lithium-ion battery and sodium-ion battery operate in exactly the same ways. In this review study, lithium ion and sodium ion batteries are compared in terms of their energy density, life cycle, market demand, charging speed, price, safety, and operating principle.

Key word: lithium ion batteries, sodium ion batteries, working principle, environmental impact.

1. Introduction

In addition to being increasingly used in larger-scale applications like electric vehicles and energy storage systems, lithium-ion batteries have emerged as the preferred option for portable electronic gadgets. They are a flexible and effective power storage solution in the current world due to their high energy density, larger cycle life, recharge ability, and quick power delivery. Because Li-ion batteries have a high energy density compared to their size and weight, one of its main benefits is that they can store a lot of electrical power. Li-ion batteries are more cost-effective and environmentally friendly than primary batteries, which must be disposed of after use. For large-scale energy storage applications, sodium presents significant advantages in terms of cost and availability because it is more accessible and less expensive than lithium. Compared to lithium, sodium resources are more broadly accessible, which might help to enhance accessibility and reduce production costs. The development of sodium batteries is still in its early phases. In large-scale energy storage systems, where cost-effectiveness and scalability are essential considerations, this makes sodium batteries an appealing option. sodium batteries are a new technology that have the potential to be more advantageous than lithium-ion batteries in terms of cost, availability of resources, and safety. Dr Ashish Rudola PhD holder in sodium-ion batteries. He invented a new Fe-based cathode and developed a non-flammable liquid non-aqueous electrolyte. [6]

2. Literature Review

M Shipour etc. [1] developed a sodium-ion battery and he conducted an experiment using a NASICON-type anode and fluorophosphates cathode. This cell’s specific energy, which is 50 Wh/Kg, is higher than that of a comparable cell using an organic electrolyte. He had maintained that organic cells' electrode electrochemical processes held up in watery settings. According to the electrochemical impedance data, irreversible side reactions cause the creation of a protective layer on both the negative and positive electrodes at slow cycle rates.

Tanish Patel [2] mentioned comparison of lithium-ion batteries (LIBs) and sodium-ion batteries (SIBs), he said, indicates that lithium and sodium ion benefits and drawbacks. LIBs are better suited for high-energy and high-performance applications due to their increased power and energy densities. because of their potential for thermal runaway, cost more and present safety risks. SIBs, on the other hand, have a lower energy and power density but are more widely available, less expensive, and safer to use.

Jens F. Peters etc. [3] This offers a thorough analysis of the prospective pricing for sodium-ion battery cells of the 18650 type in comparison to equivalent lithium-ion cells. The cells are based on pre-commercial datasheets that are already in existence, allowing for a thorough breakdown of costs for components with unique layout needs for various cell chemistries.

Hossein Yadegari and Xueliang Sun [4] concluded subsequently Na-O2 batteries have sparked optimism for the creation of an affordable, high-energy storage technology. he conducted an experiment on reversible superoxide electrochemistry controlling the ORR or OER process at the air electrode, this system has a lower charging over potential and a higher energy efficiency than the Li-O2 battery system. Another major obstacle to Na-O2 battery development is the increased chemical reactivity of metallic Na. Through a solution-mediated ORR process, a mixture of SEs and liquid electrolytes can safeguard the metallic Na electrode, prevent dendrite growth, and maintain a high discharge capacity.

3. Comparison of Working Principle

An anode is made up of graphite and cathode is made of lithium metal oxide. The electrolytes made up of lithium salt. The separator is made up of polyethylene. Figure.1 shows during charging of cell the charger is connected in between the electrodes as see the lithium is present in form of lithium metal oxide and cathode when current I flows from charger through the cathode the lithium itself is relies as positive ion forms, lithium oxide and travel through electrolyte to anode at anode it combines with carbon electrode to form of lithium carbon. the electrons flowing opposite direction at cathode the lithium metal oxide produces

$$LiMo_2 = Li + Mo_2 + e^-$$

At anode combines with lithium ion to form

$$C_6 + Li + e^- = LiC_6 \text{ is called cell reaction.}$$

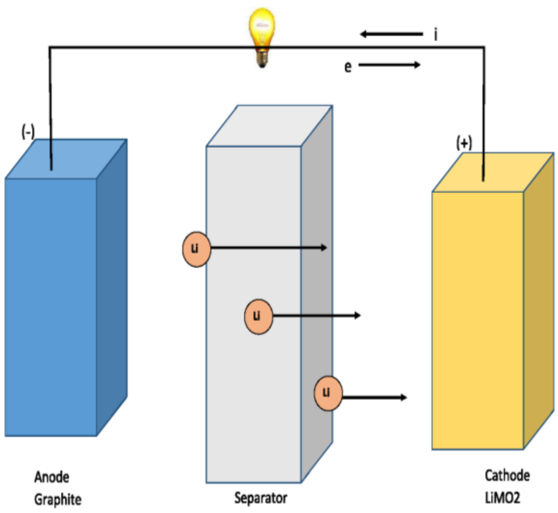

FIGURE 01. Structure of Charging and Discharging of Lithium Ion Batteries

During the cell as load is connected electrodes the lithium ion it presents at anode in the form of lithium carbon. The current flows through load from cathode and electron flowing opposite direction. the lithium ion released from the anode and travel towards the cathode. And cathode again combines to form lithium metal oxide

at cathode $MO_2 + Li + e^- = Li\ MO_2$

at anode $Li\ C_6 = C_6 + Li + e^-$

While the materials used for the electrodes and electrolyte differ from those used in lithium-ion batteries, sodium-ion batteries operate on a similar concept. Anode and cathode are the two electrodes that make up a sodium-ion battery. The anode of a sodium-ion battery is typically constructed from carbon-based substances like hard carbon or graphite. When charged, these materials have the ability to intercalate sodium ions, and when discharged, they can release them. Depending on the formulation, the cathode in sodium-ion batteries can vary, but typical components include transition metal oxides, phosphates, or polynomic compounds. During the charge and discharge cycles, the cathode material experiences a reversible reaction with sodium ions.

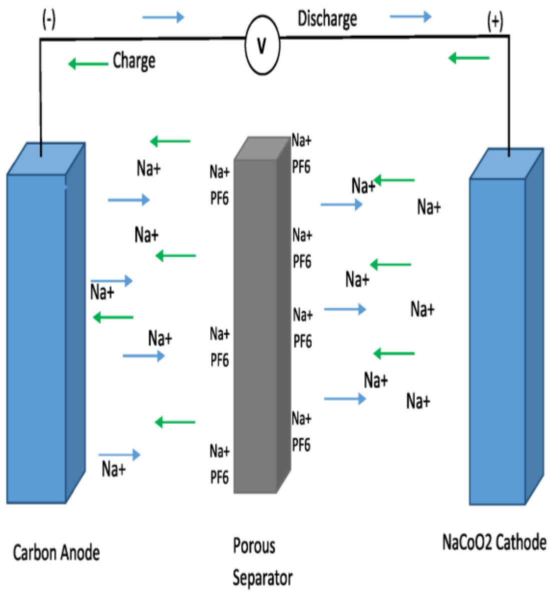

FIGURE 02. Structure Charging and Discharging of Sodium Ion Batteries

$$3Na2FeFe(CN)6+Fe2O3= 3FeFe(CN)6+2Fe+3Na2O$$

Charging discharging iron based sodium ion battery.

A sodium-ion battery's electrolyte acts as a conductor, allowing sodium ions to travel between the anode and cathode. It typically comprises of a solid-state sodium conductor or a sodium salt dissolved in an organic solvent. The selection of an electrolyte is influenced by properties including stability, ionic conductivity, and safety.

Figure.2 shows a sodium-ion battery is connected to an external power source while it is being charged. The anode is where sodium ions from the electrolyte are intercalated or absorbed into the carbon-based substance. The battery stores energy as a result of the intercalation process. The cathode receives electrons concurrently and interacts chemically with the sodium ions from the anode. Energy is stored in the cathode material during this reaction.

The energy that has been stored released when the battery is discharged. Current is drawn by the external load or gadget linked to the battery. Desorbed or released sodium ions leave the anode and go through the electrolyte to the cathode. The sodium ions are taken up by the cathode material during this reversible reaction, which also releases electrons that pass via the external circuit to power the device.

4. Comparison of Lithium and Sodium Battery used in Evs

Table 1. Factors of lithium ion vs sodium ion batteries

Sr. no.	Factors	Lithium ion batteries	Sodium iron batteries
1	Energy density	Higher	Low
2	Life cycle	Longer	Short
3	Charing speed	Faster	Slow
4	Cost	Expensive	Chipper
5	Safety	Thermal runway Couse not safe	Combatively safe
6	Maturity and market availability	More Maturity	Less maturity
7	Natural resources	Scarce	Abundant
8	Weight	Lightweight	Bulky
9	Temperature	Unstable of wide range	Stable
10	Low temperature performance	low	good
11	Battery	Flammable	Non-flammable

When comparing lithium-ion (Li-ion) batteries and sodium-ion (Na-ion) batteries for use in electric vehicles (EVs), several factors effect on them.

Table 1. shows Comparison to Na-ion batteries and Li-ion batteries typically have a higher energy density. Li-ion batteries can supply and store more electrical energy per unit of weight or volume. Longer driving ranges and smaller battery packs are made possible. by higher energy density. Lithium-ion batteries today offer a higher energy density improvement, giving them the upper hand in this regard. Li-ion batteries often last longer between charges than Na-ion batteries.

The number of charge and discharge cycles a battery may go through before its capacity starts to noticeably decline is referred to as cycle life. Na-ion batteries have a limited cycle life of a few hundred to thousands. The cycle life of Na-ion batteries is now lower. Longer cycle life is preferred. in the market of EVs batteries are frequently charge and discharge mode, so extending battery performance and lifespan.

Li-ion batteries typically charge more quickly so EVs growth will high. to Li-ion technology's make optimisation support of fast charging protocols. Na- ion batteries still in few growths in development. Fast charging is essential for EVs since it cuts down on charging time and improves the convenience of long-distance travel. Na-ion batteries may have an edge in terms of cost because sodium is more widely available and less expensive than lithium. Comparatively, because of their extensive use, lithium-ion batteries have benefited from economies of scale, making them more marketable.

Na-ion batteries may have a cost advantage, although this might also depend on the individual market circumstances, the resources that are available, and improvements in production techniques. While there are safety concerns with both Li-ion and Na-ion batteries, there are some differences as well. Thermal runaway, which can cause fire or explosion if improperly controlled, has occasionally resulted in safety incidents involving lithium-ion batteries. The thermal stability of Na-ion batteries is often better, and they are thought to provide less of a fire risk. Any battery technology used in EVs must, however, be operated safely and with the aid of battery management systems. [6]

Compared to Na-ion batteries, Li-ion batteries are more developed and often used. but this level of technological maturity for sodium-ion batteries has been achieved in just eight years – with a few more years of similarly rapid development, the signs are indicating that the energy densities of commercial sodium-ion batteries would be comparable to those of NMC-based lithium-ion batteries. In the near future, it is realistic to expect that sodium-ion batteries would break through into the long-range eV market.

5. Impact of Excavation

Cobalt, nickel, and manganese are the main components of lithium ion batteries. This entire stuff is poisonous chemically. In comparison, lithium is causing problems with disposal, as well as landfills and fires. Lithium mining may have a harmful effect on the environment. reduces resources and causes water pollution. The environmental impact of mining is lessened by the fact that sodium is more plentiful and may be collected from saltwater.

6. Future of Sodium Ion Batteries

Technology based on sodium has been identified as a pertinent technology for the future. According to scientists, sodium-ion batteries will be less expensive than lithium-ion batteries. They are anticipated to be safer as well. It is predicted that sodium-ion technology will be as safe as lead-acid technology. [6] Na-ion cells are still being developed for pilot plant-scale manufacturing in contrast to the widespread use of Li-ion cells in energy storage sectors, portable electronics, electric vehicles (EVs), and large-scale energy storage. However, as new technology is introduced and costs are reduced. Na-ion batteries are anticipated to replace certain LFP shares in passenger EVs and energy storage. The cost savings are more compared to LFP cells, the manufacturing of Na-ion cells will approximately half reduction in material costs. compared to Li-ion batteries, Na- ion batteries represent a small market.

7. CONCLUSION

As mentioned above, there are various parameters that distinguish between lithium (LIB) and sodium (Na-ion) batteries. primarily the price and accessibility of lithium and sodium. Due to its longer life, higher density, rapid speed, and higher maturity, lithium ion (LIB) batteries are currently the most useful. Lithium is more effective than sodium ion (Na - ion) batteries. Electric vehicles (EVs) cannot employ sodium ion batteries directly due to a lack of study in this area and rapid discharging, bulky in weight. As a replacement for lithium ion batteries, sodium ion batteries are currently the subject of research.

References

1. M.Shirpour, X. Zhan and M. Doeff , Sodium-Ion Batteries: "Beyond Lithium-Ion" Conference: 2015 TechConnect World Innovation Conference (DC) , April 2015. **https://www.researchgate.net/publication/281464212**
2. Tanish Patel, A Comparative Study of Lithium-ion and Sodium-ion Batteries: Characteristics, Performance, and Challenges, Friedrich Alexander-Universität Erlangen-Nürnberg (FAU) 14 march 2023. https://nbnresolving.org/urn:nbn:de:bvb:29-opus4-218919
3. Jens F. Peters, Alexandra Peña Cruz, and Marcel Weil, Exploring the Economic Potential of Sodium-Ion Batteries,16 January 2019 http://www.mdpi.com/journal/batteries
4. Hossein Yadegari, and Xueliang Sun1, Sodium–Oxygen Batteries: Recent Developments and Remaining Challenges, Trends in Chemistry, March 2020, Vol. 2, https://doi.org/10.1016/j.trechm.2019.12.003
5. Simon Engelke, Current and future sodium-ion battery research Vol. 1, No. 1, March 2013 https://www.researchgate.net/publication/236330645
6. Dr.Ashish Rudola,The Future of Clean Transportation: Sodium-ion Batteries, www.bridgeindia.org.uk
7. YifeiLia, YanliangLianga,FranciscoC.RoblesHernandezb, Hyun DeogYooa, QinyouAna, YanYaoa, Enhancingsodium-ionbatteryperformancewith interlayer-expandedMoS2–PEO nanocomposites Nano Energy (2015) 15, 453–46, 121May2015 www.sciencedirect.com,
8. Windhu Griyasti Suci, Kiwi Aliwarga,Hendri, Widiyandari,Agus Purwanto, Sodium-ion battery from sea salt: a review, Materials for Renewable and Sustainable Energy (2022) 11:71–89 https://doi.org/10.1007/s40243-022-00208-1
9. Philipp Adelhelm, From Lithium-Ion to Sodium-Ion Batteries: Similarities and Surprises,