Journal of Analysis and Computation (JAC)
(An International Peer Reviewed Journal), www.ijaconline.com, ISSN 0973-2861
Volume XVII, Issue I, Jan-June 2023

A REVIEW STUDY OF LITHIUM – SULFER BATTRIES FOR THE FUTURE ENERGY ASPECTS

Dharmesh Singhal[1], Manoj Pathak[2], S. K. Dixit[3], U.K.Pareek[4]

[1234]Jaipur Engineering College and Research Centre, Jaipur

ABSTRACT

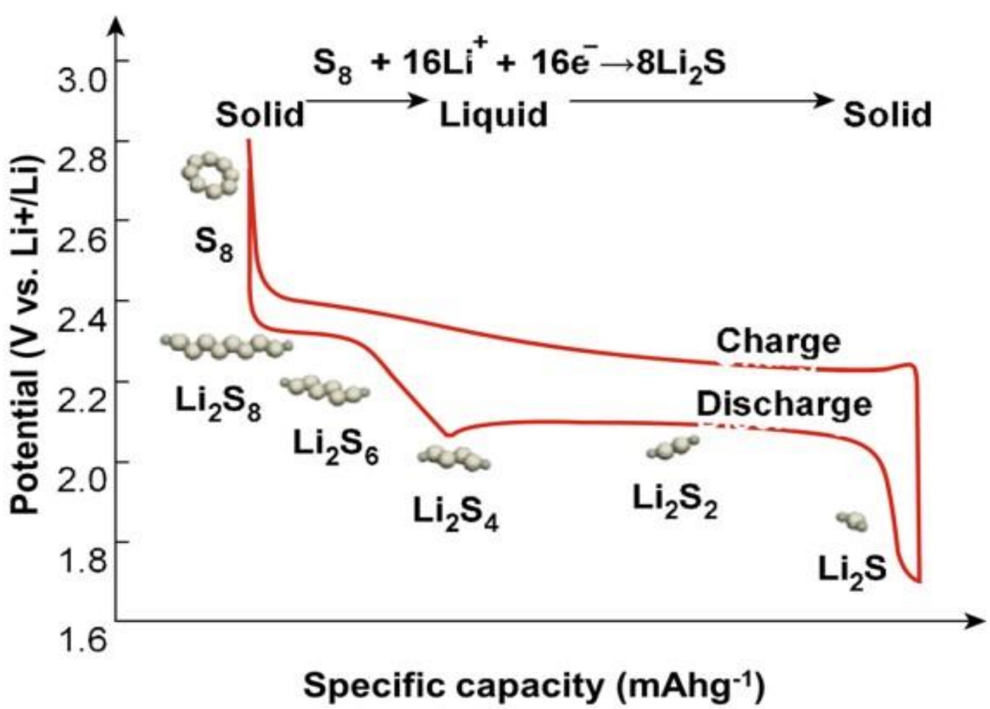
Lithium-sulfur (Li-S) batteries have garnered significant attention in recent years due to their high theoretical energy density, low cost, and abundance of sulfur resources. An increasing amount of research has been conducted on Li-S batteries over the past decade to develop fundamental understanding, modelling, and application-based control. However, there are still some challenges impeding Li-S battery from practical application, such as the shuttle effect of lithium-polysulfide (LiPSs), the growth of lithium dendritic, and the potential leakage risk of liquid electrolytes. This review focuses on the most crucial issues of solid-state Li-S battery, recent advancements in Li-S battery technology. capacity fading, low sulfur utilization, polysulfide shuttling, and safety concerns associated with Li-S batteries It will be also presented that by preparing cathode of Li-S battery with suitable materials and morphological structure, high-performance LSB can be obtained.

Keywords: - Lithium-sulfur battery, Lithium polysulfide, Cathode, Sulfur.

1. Introduction:-

The increasing demand for high-energy-density and cost-effective energy storage systems has driven extensive research in the field of advanced batteries. Various types of new energy storage technologies such as multi-ion batteries, sodium-ion batteries, metal-air batteries, ultra-capacitors, all-solid-state batteries, and redox-flow batteries are currently under development. The lithium-sulfur battery (LSB) is one of the most promising candidates to be the next-generation rechargeable battery, i.e., the post lithium-ion battery. No doubt that the lithium-ion batteries (LIBs) have achieved great success in the field of portability, high energy density, and long lifetime. However, even the most optimized LIBs cannot satisfy the requirement of the market of long-term range electric vehicles. For this reason, researchers have put their attention into other battery systems such as Li-S battery.

Sulfur is nontoxic and environmentally friendly, which is of great significance for large-scale application. Gifted with these inherent advantages, LiS battery is a competitive candidate for the next generation batteries. The research on Li-S battery can be traced back to the 1940s.5 Since then, many efforts have been put into this area to increase the discharge capacity and enhance the cycle stability of Li-S battery. Li-S batteries have higher specific energy (calculated to be approximately 6–7 times that of their LIB equivalent), superior safety, and is cost effective due to the relatively high availability of sulfur. Researchers have explored various strategies to enhance the cycling stability, sulfur utilization, and overall performance of Li-S batteries. Li-S battery applies metal lithium as anode and sulfur as cathode active material. sulfur is nontoxic and environmentally friendly, which is of great significance for largescale application. Gifted with these inherent advantages, LiS battery is a competitive candidate for the next generation batteries. The research on Li-S battery can be traced back to the 1940s.5 Since then, many efforts have been put into this area to increase the discharge capacity and enhance the cycle stability of Li-S battery.



A typical charge/discharge Profle for Li-S Battery

The typical two-plateau charge/discharge voltage profile of Li-S battery with organic liquid electrolyte is shown in which the higher plateau refers to the reaction S8 + 4e- → 2S42-, while the lower one refers to the reaction S4 2- + 4e- → 2S2- + S2 2-.

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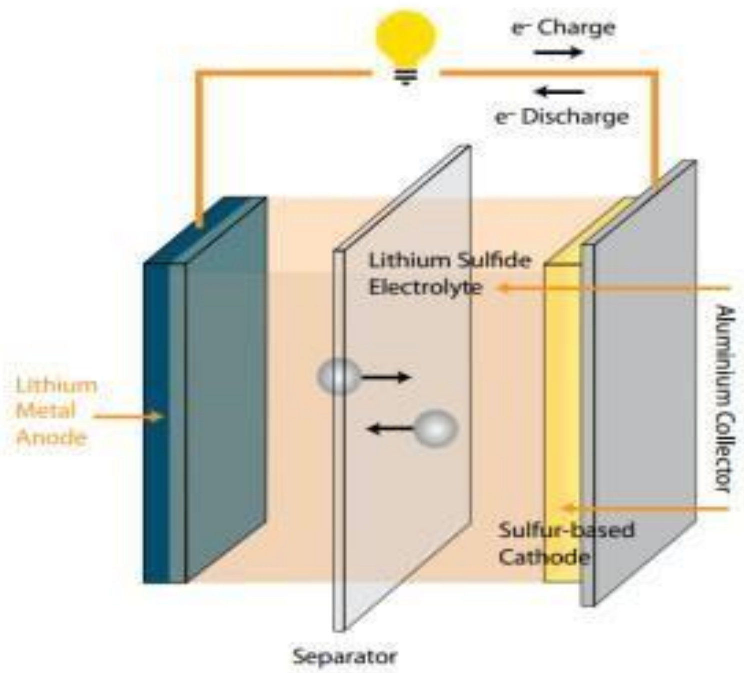
Methodology:-



The Working procedure of LI-S Batteries can be understood by step by step process as following:

Charge (Discharge Preparation):-

Before the charging process, the Li-S battery is in a discharged state, with the sulfur (S) cathode having absorbed lithium ions (Li+) during the previous discharge cycle.

The anode, typically composed of lithium metal or a lithium-ion host material, is prepared for the charging process.

Charging (Discharge):-

The charging process begins by applying an external voltage or current to the battery.

Lithium ions (Li+) are extracted from the anode and migrate through the electrolyte towards the cathode.

At the cathode, sulfur undergoes a series of electrochemical reactions with the incoming lithium ions. The sulfur is reduced, forming a variety of intermediate lithium polysulfide (Li2Sx, where x > 1) during the charging process.

As a result of the sulfur reduction, the electrons released from the anode flow through the external circuit, creating an electric current that can be utilized for various applications.

Discharging (Charge):-

When the Li-S battery is discharged, the flow of electrons is reversed.

Lithium ions (Li+) are released from the cathode and migrate back to the anode through the electrolyte.

At the cathode, the lithium polysulfides (Li2Sx) react to form sulfur and release additional lithium ions.

The released lithium ions are then captured by the anode, returning to their initial state.

Current Advancement:-

Electrode Materials: Sulfur-carbon composite cathodes, which enhance the utilization of sulfur and improve cycling stability. Nanostructured sulfur and sulfur-based materials have shown promise in mitigating the dissolution of polysulfide intermediates and improving overall performance.

Cell Design and Architecture: 3D-structured electrodes, hierarchical porous structures, and sulfur encapsulation techniques have been explored to enhance sulfur utilization, increase energy density, and improve cycling stability.

Electrolytes: Solid-state electrolytes, polymer-based electrolytes, and the use of functional additives have shown potential in reducing polysulfide shuttling and enhancing the stability of the Li-S battery system.

Industrial Partnerships: Several collaborations between academic institutions, research organizations, and industry partners have emerged to accelerate the development and commercialization of Li-S battery technology.

Challenges:-

Sulfur Utilization: Full utilization of sulfur is challenging. During discharge, sulfur undergoes complex electrochemical reactions, leading to the formation of soluble lithium polysulfides. These polysulfides can migrate within the battery, resulting in loss of active material and reduced cycle life.

Polysulfide Shuttle Effect: The movement of polysulfide intermediates (e.g., Li2 Sx, where x > 1) between the cathode and anode, commonly known as the polysulfide shuttle effect, is a significant challenge for Li-S batteries. The polysulfides can dissolve in the electrolyte, diffuse through the cell, and react at undesired locations, leading to capacity loss and self-discharge.

Cycling Stability: Li-S batteries often suffer from poor cycling stability, particularly at high discharge rates and extended cycling. Repeated sulfur reduction and lithiation processes can cause structural degradation of the cathode.

Electrolyte Compatibility: The electrolyte in Li-S batteries must effectively transport lithium ions between the electrodes while being chemically stable and preventing unwanted side reactions. Finding suitable electrolyte systems that suppress polysulfide shuttling and provide high ionic conductivity.

Future Directions:-

The future direction of Li-S batteries involves multidisciplinary research, collaboration between academia and industry, and advancements in materials science, electrochemistry, and manufacturing processes. Li-S batteries can provide longer driving ranges, reducing the need for frequent charging in electric vehicles ,can help store renewable energy generated from sources such as solar and wind power, can enhance the capabilities of portable electronic devices, can provide reliable and efficient energy storage solutions for remote areas or regions, their higher energy density and potentially longer battery life can enhance the functionality and usability of wearable devices.

Concluding Remarks:-

Solid-state Li-S battery with high theoretical energy density and low cost is a research hotspot of new energy storage equipment. Li-S batteries have the potential to revolutionize various industries and applications. This review focus on the basic knowledge ,working procedure, challenges and advancement techniques related to Li-S batteries. However, it is important to note that further research, technological advancements, and large-scale manufacturing capabilities are required to overcome the remaining obstacles and make Li-S batteries commercially viable. Continued research, technological advancements, and collaborative efforts will pave the way for the widespread adoption of Li-S batteries, contributing to a more sustainable and energy-efficient future.

References:-

[1] Ryohei Mori, “Cathode materials for lithium-sulfur battery”

[2] Hui Pan , Zhu Cheng , Ping He , Haoshen Zhou , “A Review of Solid-State Lithium-Sulfur Battery: Ion Transport and Polysulfide Chemistry”

[3] Chaoshan Wua, Jiatao Loub, Jun Zhangb, Zhaoyang Chena, Akshay Kakar, "Current Status and Future Directions of All-Solid-State Batteries with Lithium Metal Anodes, Sulfide Electrolytes, and Layered Ternary Oxide Cathodes"

[4] Wild M, O'Neill L, Zhang, Purkayastha R, Minton G, Marinescu M, Offer GJ (2015) Lithium sulfur batteries, a mechanistic review. Energy Environ Sci 8:3477–3494. https:// pubs. rsc. org/ en/ conte nt/artic lelan ding/ 2015/ ee/ c5ee0 1388g

[5] Pan H, Cheng Z, He P, Zhou H (2020) A review of solid-state lithium–sulfur battery: ion transport and polysulfide chemistry. Energy Fuel 34(10):11942–11961. https:// doi. org/ 10. 1021/ acs.energ yfuels. 0c026 47.

[6] Mori R (2020) Recent developments for aluminum–air batteries. Electrochem Energy Rev 3:344–369. https:// doi. org/ 10. 1007/s41918- 020- 00065-4.

[7] Pradeep M, Ragul K and Varalakshmi K,(2021), "Voice and Gesture Based Home Automation System" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 08-18, doi 10.30696/IJEEA.IX.I.2021.08-18

[8] Jagan K, Parthiban E Manikandan B,(2021), "Engrossment of Streaming Data with Agglomeration of Data in Ant Colony" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 19-27, doi 10.30696/IJEEA.IX.I.2021.19-27

[9] M. Khadar, V. Ranjith, K Varalakshmi (2021), "Iot Integrated Forest Fire Detection and Prediction using NodeMCU" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 28—35, doi 10.30696/IJEEA.IX.I.2021.28-35

[10] Gayathri. M, Poorviga. A and Mr. Vasantha Raja S.S, (2021), "Prediction Of Breast Cancer Stages Using Machine Learning" Int. J. of Electronics Engineering and Applications, Vol. 7, No. 1, pp. 36-42, doi 10.30696/IJEEA.IX.I.2021.36-42

[11] Karthikeyen, N. Ramya, M. Sai Priya and C. Yuvalakshmi, (2021), "Novel Method Of Real Time Fire Detection And Video Alerting System Using Open-CV Techniques" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 43-50, doi 10.30696/IJEEA.IX.I.2021.43-50

[12] L.Prinslin, M.A.Srenivasan and R.Naveen (2021), "Secure Online Transaction With User Authentication" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 51-57, doi 10.30696/IJEEA.IX.I.2021.51-57

[13] S Lokewar, A Hemaranjanee and V. Narayanee (2021), "Edge Based Ecosystem For Internet Of Things (EBEFIOT)" Int. J. of Electronics Engineering and Applications, Vol. 9, No. 1, pp. 58-67, doi 10.30696/IJEEA.IX.I.2021.58-67

[14] Prof. K. Phani Srinivas and Dr. P. S. Aithal, (2000) . "Practical Oriented Analysis On The Signal Processing Using FFT Algorithm", Int. J. of Electronics Engineering and Applications, Vol. 8, Issue II, July-Dec. 2020. pp 01-10, doi 10.30696/IJEEA.VIII.II.2020.01-10

[15] Onintra Poobrasert, Sirilak Luxsameevanich, Sarinya Chompoobutr, Natcha Satsutthi, Sakda Phaykrew and Paweena Meekanon, (2000), "Heuristic-based Usability Evaluation on Mobile Application for Reading Disability ", Int. J. of Electronics Engineering and Applications, Vol. 8, Issue II, July- Dec. 2020, PP- 11-21, doi 10.30696/IJEEA.VIII.II.2020.11-21

[16] Rajeev Ranjan Kumar and S. P. Singh, (2020), "Variation Of Capacitive Reactance Of Coupled Microstrip Line Structure With Width Of The Similar Metal Strips" Int. J. of Electronics Engineering and Applications, Vol. 8, No. 2, pp. 22-28, DOI- 10.30696/IJEEA.VIII.II.2020.22.28

[17] Sunita Swain and Rajesh Kumar Tiwari, (2020), "Cloud Security Research- A Comprehensive Survey" Int. J. of Electronics Engineering and Applications, Vol. 8, No. 2, pp. 29-39, DOI- 10.30696/IJEEA.VIII.II.2020.29.39

[18] Ritesh Kumar Thakur, Rajesh Kumar Tiwari (2020), 'Security On IoT: A Review", Int. J. of Electronics Engineering and Applications, Vol. 8, No.2, July-Dec 2020, pp-40-48, DOI- 10.30696/IJEEA.VIII.II.2020.40.48.

[19] Rajesh Kumar Tiwari (2020). 'Human age estimation Using Machine Learning Techniques', International Journal of Electronics Engineering and Applications, Vol. 8, No. 1, pp.01-09, DOI- 10.30696/IJEEA.VIII.I.2020.01-09