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QUANTIFYING THE POTENTIAL AND LIMITATIONS OF SOLID-STATE BATTERIES: A COMPREHENSIVE SURVEY

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Abstract

Researchers are offering considerable thought to the concept that electrochemical energy production, conversion, and storage could be a more environmentally responsible and sustainable alternative to meet the ever-increasing need for energy in the modern age. The limitations of conventional capacitors are expected to be solved by the potential next-generation technology for storing electricity with the solid-state battery. It is crucial to study the benefits and key challenges of the solid-state batteries along with their recommended fabrication method as a requirement for usage and significant advancement. In consideration to this context, the study focuses to analyse the usefulness and challenges of solid-state batteries and significance of deposition techniques for fabrication. To investigate this objective, the study has adopted quantitative study with survey questionnaire technique. With the insights obtained, it has been comprehended in the conclusion that solid-state batteries are very effective for long-term consideration and has potential advancement nature, which also requires intensive research in concern to increasing usage requirement.

Keywords: *Solid-state batteries, Electrode fabrication, Thin-film, Lithium batteries*

1. Introduction

Solid-state batteries(SSB) are an exciting new development in the field of energy storage technology. In comparison to conventional batteries that contain liquid electrolyte, these batteries provide a number of significant benefits (Boaretto et al., 2021). The potential impacts of solid-state batteries could be seen across a wide range of business sectors and application areas due to the breadth of their applicability(Li et al., 2022). The desire for safer, more energy-dense, longer-lasting, and faster-charging battery technologies is the primary impetus behind the research motivation on solid-state batteries(Jin et al., 2023). To completely realize the potential of SSBs and make them effective in a variety of applications, it is necessary to address on the issues relating to materials, commendable fabrication technique and general performance.

Despite the fact that many research explored the advantages and disadvantages of SSB, neither of these studies included real-time investigation of individual opinions and suggestions on SSB from the scientific community.The study aims to analyse the usefulness and challenges of SSB and the significance of deposition techniques for SSB. The defined objective of the study has been investigated with the aid of administering survey questionnaires to the scientific community. Further, the data was interpreted and the insights were comprehended in the conclusion.

2. Literature Review

Boaretto et al., (2021)reported that, SSBs call for carefully controlled physical contact between the various parts and materials, in contrast to conventional LIBs, which wet the cathode and anode with liquid electrolyte to ensure the transfer of Li-ions. According to Lin et al., (2022)**,** The solid electrolyte film is the cause of the TFLBs' high level of safety as well as their superior electrochemical performance. It is challenging to maintain stable control over the composition as well as the structure of the solid electrolyte.

On the other hand, Lee et al., (2022)highlighted from the research that Solid-state electrolytes (SEs) with a high ability to conduct ions have been invented in the last decade, such as $Li_{10}GeP_2S_{12}$ and Li_6PS_5Cl. However, the practical applications are limited, particularly in electric vehicles, because of the low-rate capability that is caused by a number of issues which including Li+ kinetics, poor interfacial contact and the formation of Li dendrites. However, according to the study byJanek & Zeier, (2023), there are still problems with long-term performance, specific power, and financial feasibility with recent global efforts to establish solid-state batteries as a potentially safe and reliable high-energy and high-rate electrochemical storage technology.

3. Methodology

A quantitative study utilising the data from individuals from science community was employed to conduct the investigation. Users with a population count of 211 were considered as the study participants with the knowledge and experience of vapor deposition techniques for SSB. Additionally, participants were classified based on their knowledgeon SSB, vapor techniques and the category of expertise. In order to better comprehend the knowledge, usefulness and challenges on SSB, the responses and investigation in scientific community perspective are crucial. The following questions, along with demographic data requirements, were administered to the participants by means of a questionnaire which includes the metrics of 5-point Likert scale and open brief response inquiries.

Table 1:*Details of questions administered in the Questionnaire*

S. No	Questions from Questionnaire
1	Since how long you have been in scientific research?
2	On what scale you represent your knowledge in deposition techniques
3	Are deposition techniques more prevalently used for battery applications?
4	On what scale vapor deposition techniques are helpful for Solid state Battery electrode fabrication?

5	On what scale do solid lithium batteries fit into the near future?

4. Results and Discussion

The statistics of the obtained data were interpreted in a graphical format for insightful analysis. Figure 1 shows that, 132 participants in the study has more than 10 years of scientific research experience, whereas 25 individuals have more than 35 years of experience which evidenced the strong scientific research experiences. Figure 2 shows that major proportion of participants (161 individuals) had high knowledge in deposition techniques where no participants were considered without knowledge of deposition techniques. The responses shown in figure 3 depicts that deposition techniques were highly considered for battery electrode fabrication and 95% of the participants registered positive response for the question. Whereas 5% researchers, responded that in some cases different techniques can be employed for performance and efficiency purposes.

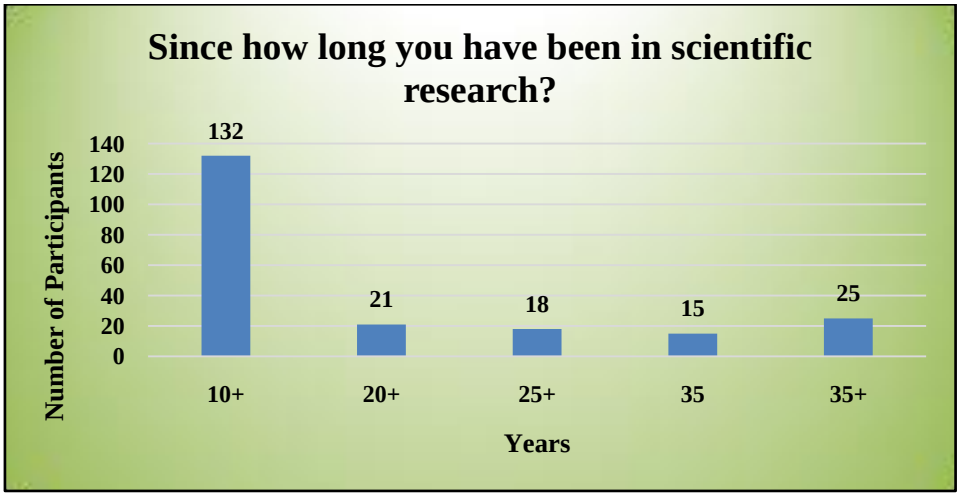

Figure 1: Data showing the years of scientific research experience of the participants

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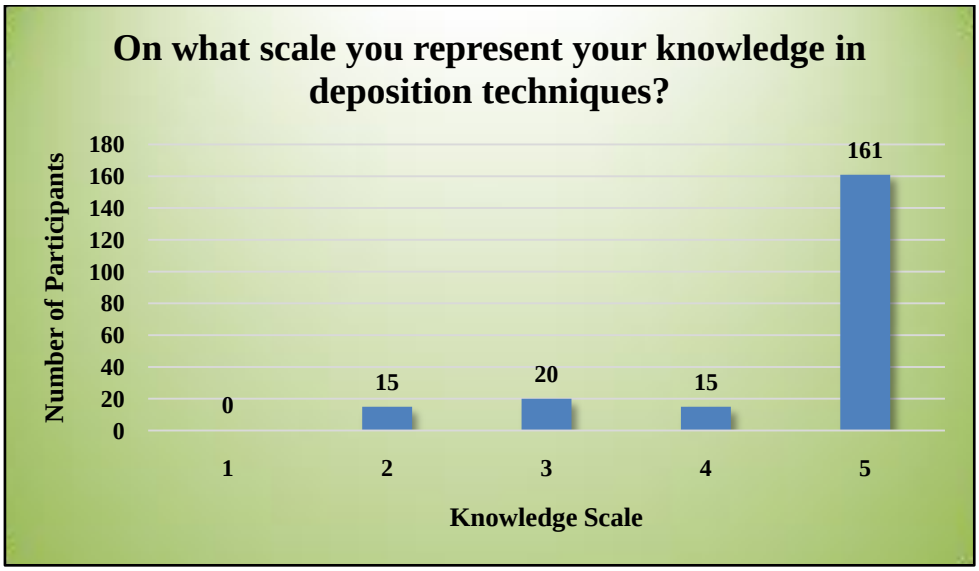

Figure 2: Data showing the knowledge scale of participants about deposition techniques.

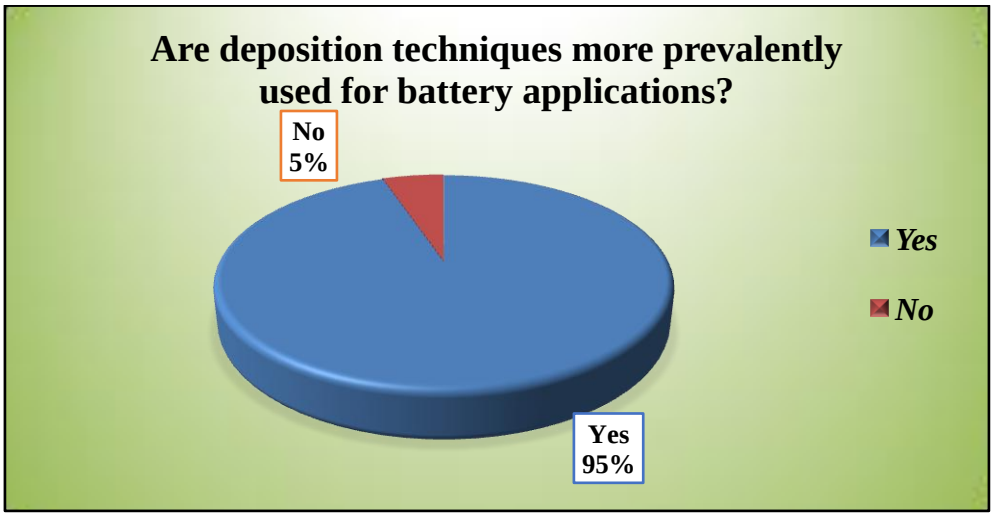

Figure 3 Data showing the binary response concerning the prevalent implementation of deposition techniques for battery applications

Figure 4 shows that 190 participants responded positively that vapor deposition (VD) techniques were certainly helpful to greater extent for SSB electrode designing. Only 9.4% of respondents showed interest indicating average helpfulness of the technique. According to the data depicted in figure 5, 48% of respondents foresee great role of Si and Li batteries in near future, whereas, 23% of researchers, responded that other materials can be also considered with optimization.

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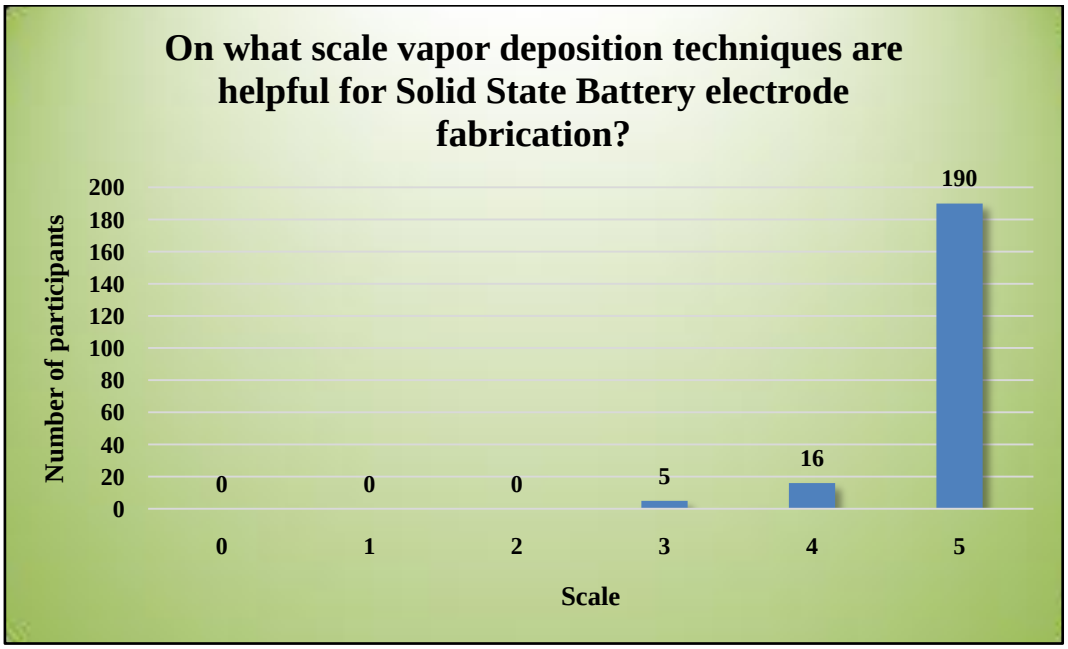

Figure 4 Data showing the helpfulness scale of vapor deposition technique for battery electrode fabrication

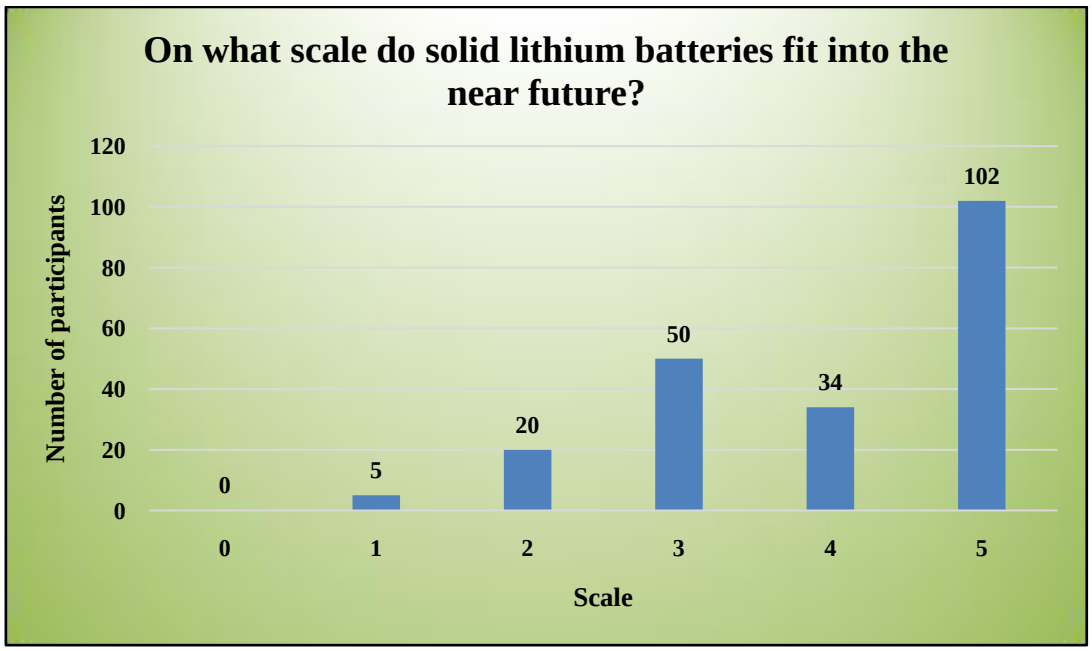

Figure 5 Response showing the significance of sodium lithium SSB in near future.

Deposition methods make it easier to include electrode designs with several layers into solid-state batteries. The use of deposition techniques also allows for the creation of conformal coatings on complex structures, which results in improved material contact between the solid-state electrolyte and electrode components. It is essential for there to be stable interfaces between the solid electrolyte and the electrode materials in solid-state batteries; this helps to prevent unwanted side reactions and improves cycling stability. In a context of descriptive analysis, according to Sun et al., (2023), complex electrode geometries, such as nanostructured or porous electrodes, are frequently used in batteries in order to enhance the electrode-electrolyte and boost the capacity of the battery.

From the data interpreted from the figure 5 it can be comprehended that, in comparison to conventional batteries, solid-state batteries may be able to store more energy in the same amount of volume. From the contextual analysis, it was evident that advanced lithium-ion batteries can withstand numerous cycles of charging and discharging without significantly losing capacity. This equates to a longer battery life and more energy storage capacity, which is essential for applications with higher power requirements and extended operational hours. For instance, the improved energy density of solid-state batteries may enable electric vehicles to travel farther between charges and require fewer recharges.

5. Conclusion

The above discussed study comprehended that, compared to liquid electrolyte batteries, SSBs may have a better energy density and hence, determined as the best potential for the energy storage application. The application of deposition techniques will continue to be an essential component in the process of scaling up electrode production as the technology behind solid-state batteries moves closer to commercialisation. Although lithium-ion batteries have demonstrated their effectiveness and dependability in energy storage applications, the pace of technological development, efforts to cut costs, environmental concerns, and competition from new battery technologies will all have an impact on the landscape in the future. Research is also required to concentrate on the deposition of multifunctional coatings in solid-state batteries, as this would allow the technology to go even further.

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