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INVESTIGATION AND RATIONALE ON INTERFACIAL ENGINEERING AND CVD TECHNIQUES FOR SOLID-STATE BATTERIES

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Abstract

High-energy-density solid-state batteries (SSBs) has a demand to be extensively utilized, requiring the need for scaling up fabrication techniques and integrating solid electrolytes that are roughly the same thickness as the separators used in ordinary lithium-ion batteries via interfacing techniques. Despite having advantageous qualities and a high degree of flexibility, Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD) are still seen as techniques that have space for improvement when it comes to the production of thin film batteries. In a related perspective, the purpose of this research is to examine the underlying rationale for the widely used thin-film and CVD procedures for SSB. In order to explore the intended purpose of the study, an integrated design of survey questionnaire was issued to members of the scientific community for their participation.

Keywords: *Solid-state Batteries, Vapor deposition, Thin-film, Electrode.*

1. Introduction

The limitations of conventional capacitors are expected to be solved by the potential next-generation technology for storing electricity known as the solid-state battery (Cangaz et al., 2020). Compared to standard battery life, those batteries conserve electricity in an improved and long-lasting manner (Liu et al., 2021). Due to its capacity to develop precise, and uniform coatings on electrode materials, thin film deposition techniques are considered to fabricate battery electrodes (Chen et al., 2020) In light of CVD's versatility and ability to deposit a variety of materials, including metals, and other compounds, it is possible to create electrode materials with specialized properties to satisfy certain performance needs. Although deposition techniques were identified with more potential for SSB, investigation on the reason for implementation and role of superior consideration has not been analysed in detail in later years.

The study aims to analyse the underlying insights for the prominent usage of CVD and thin-film techniques for SSB. The defined objective of the study has been investigated with the aid of administering survey questionnaires to the scientific community. The insights obtained has been considered for data interpretation and comprehended in the conclusion.

2. Literature Review

According to Han et al., (2021), the chemical change that occurs of the newly created tiny film is closely tied to how the layer reacts that came before it in the process of subatomic layer development. Li et al., (2022), highlighted that over time, deterioration may occur at the junction between the electrode and the electrolyte, which might decrease the longevity of the battery and capacity to store a charge. As different materials' thermal expansion coefficients vary, solid-state batteries frequently endure severe mechanical stress. The component breaking and deterioration caused by this stress could shorten the battery's cycle life and overall reliability.

On the context of CVD and PVD, Fitzgerald et al., (2022) comprehended that PVD can also take the form of vacuum evaporation. The research also established that the gas-phase processes in CVD also allow for fine control over the composition and stoichiometry of the deposited films, improving material characteristics and performance. By contrast Bahri et al., (2023) reported that, PVD is frequently chosen for applications where high-purity materials, high deposition rates, and relatively straightforward equipment setups are sought.

3. Methodology

The study adopted an integrated approach incorporating the quantitative and qualitative aspects in the study. Closed and open-ended survey questions were administered and by utilising the data from individuals from science community, the investigation was employed. 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 with expertise in vapor deposition techniques were considered for the study and the individuals with no prior knowledge about SSB and VD were excluded from the study. The following questions, along with demographic data requirements, were administered to the participants by means of a questionnaire which included the metrics of 5-point Likert scale, binary options and open response inquiries.

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

S. No	Questions from Questionnaire
1	What are the best strategies for interfacial engineering to achieve better adhesion and stability in solid-state batteries?
2	More than solid block why thin film method is preferred?
3	Why do you prefer vapor deposition techniques for thin film coatings?
4	Are physical deposition methods excelling than chemical methods?
5	On what scale pressure affect CVD?

4. Results and discussion

When participants were offered an open-end response, several responses were received due to 211 population and significant responses were discussed below excluding the repeated responses considered. Whereas most of the responses for question no.1, stated that, "Surface activation techniques, the introduction of interlayers, and optimizing the choice of electrode-electrolyte materials are some of the greatest tactics for interfacial engineering. This can be introduced in solid-state batteries to produce improved adhesion and stability". Concerning the question no.2, the respondents registered that, "In comparison to solid block electrodes, thin film electrodes have a surface area that is appreciably greater for every unit of volume that they occupy. This larger surface area makes it possible to have more active sites for the storage of ions, and it also improves the overall electrode- electrolyte interaction, which ultimately leads to improved battery performance".

Among the responses sorted out, responses for question no.3 were given as, "Atomistic film results in stronger interfacial bonding and better film quality. So, in thin film applications, their capacity to coat enhances the geometries which lead to uniform coverage and enhanced performance".

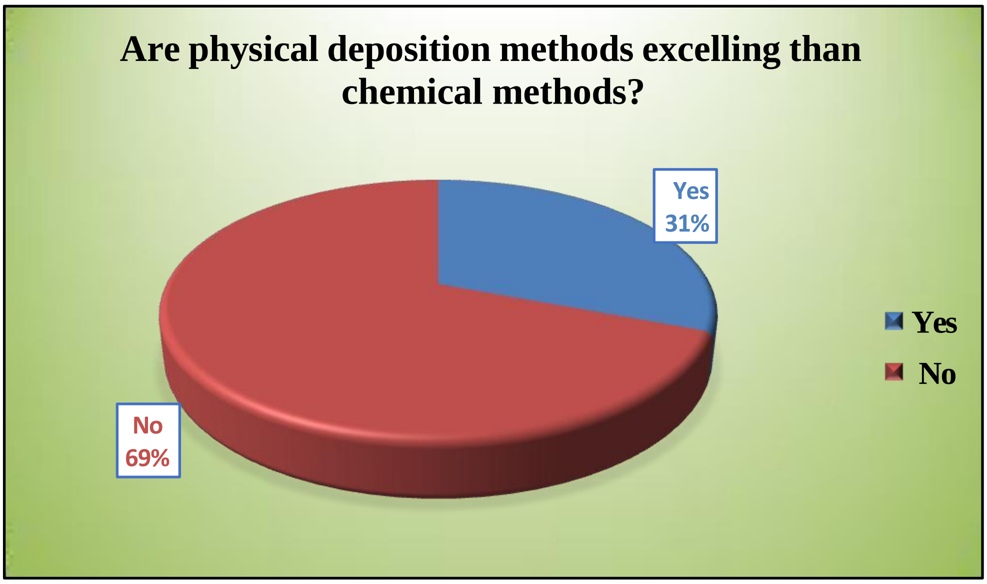

Figure 1: Data showing comparison of physical and chemical deposition method preferences for SSB

Figure 1 shows that the major respondents agree that CD are better when compared to PD methods. The reasons such as interfacial adhesion, controlled deposition is excellent in CD methods. The data shown in figure 2 represents that 87% of respondents strongly agreed that pressure has significant influence in CVD technique by indicating high scale of response in the survey questionnaire.

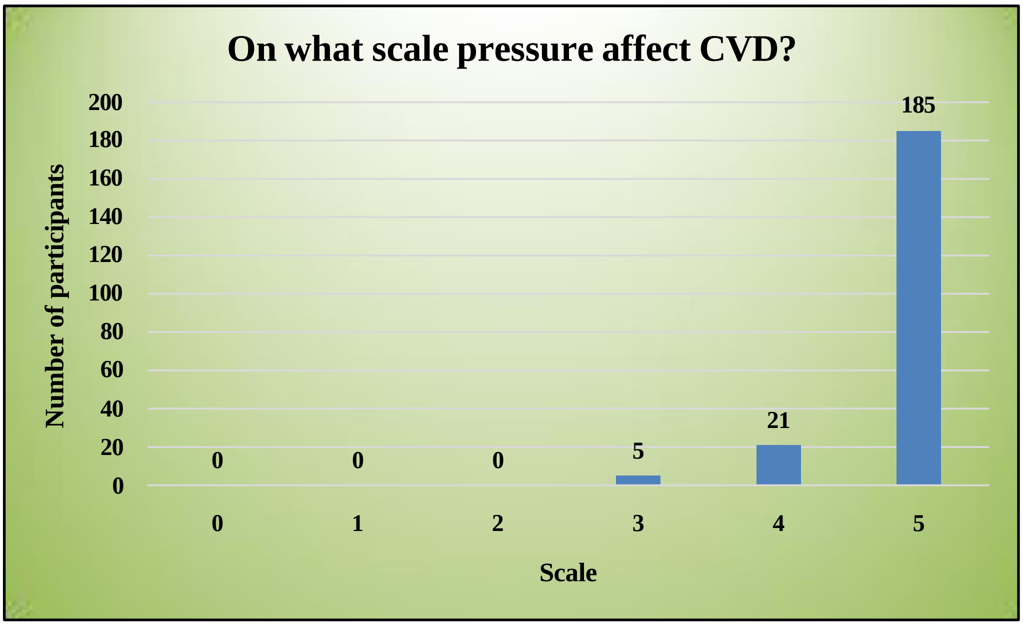

Figure 2: Data showing the effect of pressure in CVD

The adhesion and stability of the material are improved by using deposition techniques to produce thin films in a homogeneous and controlled manner. In order to eliminate undesirable side reactions and enhance cycling stability, solid-state batteries must have stable interfaces between the solid electrolyte and the electrode materials. The insights obtained in our study rendered that adopting a solid-state electrolyte material with a structure appropriate for the application and chemically compatible with both the electrode and the separator can lead to improved interfacial stability.

The thin film's homogeneity and rate of deposition are both influenced by the pressure inside the reaction chamber, which also affects the concentration of precursor molecules in the gas phase. In order to develop coatings on electrode surfaces that are homogenous and free of structural imperfections, the pressure must be properly controlled. A pressure that is too high could cause an uneven film to form or undesirable side effects, whereas a pressure that is too low could lead to poor adhesion and partial surface covering.

5. Conclusion

The above discussed research adopted integrated research to investigated on the deposition techniques for SSB and the interfacial technique significances. The data for the study was obtained from the administered survey questionnaire among the scientific community. The insights interpreted from the descriptive responses and data obtained led to evidently comprehend that, in order to improve the contact and interaction between these materials while lowering interfacial resistance, interfacial techniques are used. Different approaches are being researched intensely in light of innovative requirements.

Additionally, it was evident from the responses of the experts that thin film CVD coatings can improve important electrode parameters like electrical conductivity, ionic conductivity, and surface area. These advancements may result in battery electrodes with improved rate capabilities, greater capacity, and longer cycle lives. Further, the study carries over to investigate on CVD and interfacial techniques for SSB fabrication with respect to diverse materials.

References

1. Bahri, M., Gebre, S. H., Elaguech, M. A., Dajan, F. T., Sendeku, M. G., Tlili, C., & Wang, D. (2023). Recent advances in chemical vapour deposition techniques for graphene-based nanoarchitectures: From synthesis to contemporary applications. *Coordination Chemistry Reviews*, *475*, 214910. https://doi.org/10.1016/J.CCR.2022.214910
2. Cangaz, S., Hippauf, F., Reuter, F. S., Doerfler, S., Abendroth, T., Althues, H., & Kaskel, S. (2020). Enabling High-Energy Solid-State Batteries with Stable Anode Interphase by the Use of Columnar Silicon Anodes. *Advanced Energy Materials*, *10*(34), 2001320. https://doi.org/10.1002/AENM.202001320
3. Chen, Y., Wang, Z., Li, X., Yao, X., Wang, C., Li, Y., Xue, W., Yu, D., Kim, S. Y., Yang, F., Kushima, A., Zhang, G., Huang, H., Wu, N., Mai, Y. W., Goodenough, J. B., & Li, J. (2020). Li metal deposition and stripping in a solid-state battery via Coble creep. *Nature, 578*(7794). https://doi.org/10.1038/s41586-020-1972-y
4. Fitzgerald, K., Numan-Al-Mobin, A., Kustas, F., & Smirnova, A. (2022). Mechanisms of Lithium-Ion Transport in Solid-State Electrolyte and Cathode Materials Prepared By PVD. *ECS Meeting Abstracts*, *MA2022-02*(4), 529. https://doi.org/10.1149/MA2022-024529MTGABS
5. Han, L., Hsieh, C. Te, Chandra Mallick, B., Li, J., & Ashraf Gandomi, Y. (2021). Recent progress and future prospects of atomic layer deposition to prepare/modify solid-state electrolytes and interfaces between electrodes for next-generation lithium batteries. *Nanoscale Advances*, *3*(10), 2728–2740. https://doi.org/10.1039/D0NA01072C
6. Li, J., Ji, Y., Song, H., Chen, S., Ding, S., Zhang, B., Yang, L., Song, Y., & Pan, F. (2022). Insights Into the Interfacial Degradation of High-Voltage All-Solid-State Lithium Batteries. *Nano-Micro Letters*, *14*(1), 1–13. https://doi.org/10.1007/S40820-022-00936-Z/SCHEMES/1
7. Liu, G., Shi, J., Zhu, M., Weng, W., Shen, L., Yang, J., & Yao, X. (2021). Ultra-thin free-standing sulfide solid electrolyte film for cell-level high energy density all-solid-state lithium batteries. *Energy Storage Materials*, *38*, 249–254. https://doi.org/10.1016/J.ENSM.2021.03.017