engineering proceedings

MDPI

Proceeding Paper

Development of LiI-Doped PEO/PMMA-Based Solid Polymer Electrolytes Reinforced with SnO_2 Nanofillers †

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† Presented at the 6th International Electronic Conference on Applied Sciences, 9–11 December 2025; Available online: https://sciforum.net/event/ASEC2025.

Abstract

The current research investigates the electrochemical performance of plasticized nanocomposite solid polymer electrolytes derived from a polyethylene oxide (PEO)–polymethyl methacrylate (PMMA) blended system with lithium iodide (LiI) as the dopant salt and tin dioxide (SnO_2) nanoparticles as the inorganic nanofillers. Thin nanofilms of the synthesized electrolytes were prepared and progressively examined by using X-ray diffraction (XRD), Fourier-transform infrared spectroscopy (FT-IR), Ultraviolet visible (UV–Vis) spectroscopy, and Scanning electron microscopy (SEM). XRD characterization confirmed the successful establishment of the polymer electrolyte matrix and reflected a significant decrease in crystallinity upon the incorporation of nanofillers, whereas crystallite size was estimated using the Debye–Scherrer equation. FT-IR spectra showed prominent molecular interactions and complexation of polymer, salt, and nanofiller components. UV–Vis spectroscopy provides information on the optical absorption behavior, whereas the SEM micrograph shows the morphological features and homogeneity of plasticized nanocomposite solid polymer electrolyte films. The addition of SnO_2 nanofillers was shown to improve both the structural and electrochemical properties of the electrolyte system, highlighting its potential usage in solid-state batteries and other high-end electrochemical devices. These enhancements make the developed nanocomposite solid polymer electrolytes viable candidates for high-performance, flexible lithium-ion battery applications, offering a promising route toward safer and more efficient energy storage systems. Comprehensive electrochemical performance evaluation will be addressed in future studies.

Keywords: tin oxide; solid-state batteries; polymer electrolytes

1. Introduction

As a cost-effective energy-storage device, lithium-ion batteries possess high energy density and have gained widespread attention due to their excellent performance and reliability. However, most commercially available lithium-ion batteries employ organic liquid electrolytes containing various lithium salts. In practical applications, these liquid electrolytes suffer from several drawbacks, including poor chemical stability, flammability, and the risk of leakage, which pose serious safety concerns. To overcome these limitations, solid electrolytes have been introduced, offering enhanced safety along with advantages such as high energy density, improved performance, long service life, and simplified battery design. Solid electrolytes are broadly classified into inorganic solid electrolytes and organic polymer solid electrolytes [1].

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Academic Editor: Nunzio Cennamo

Published: 13 March 2026

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Polyethylene oxide (PEO) is a widely studied polymer electrolyte due to its non-ionic, non-toxic, biodegradable nature and low cost. At temperatures below 100 °C, PEO dissolves easily in water, irrespective of its molecular weight or degree of polymerization. Structurally, PEO is a semi-crystalline polymer consisting of both amorphous and crystalline phases. Solution-cast PEO films exhibit high flexibility, whereas polymethyl methacrylate (PMMA) films possess excellent optical transparency but are brittle under mechanical stress. Compared to polar PEO, PMMA demonstrates superior thermal stability, weather resistance, chemical inertness, and relatively low dielectric permittivity, making it an important dielectric material for use as an insulating layer in organic thin-film transistors. In PEO–PMMA blends, the flexibility of the film arises from PEO acting as a plasticizer for PMMA, while PMMA enhances mechanical stability and reduces the crystalline phase of PEO. Tin oxide (SnO_2) is a well-known n-type semiconductor with a wide band gap and it has been extensively investigated for applications in gas sensors, dye-sensitized solar cells, optical and optoelectronic devices, and hybrid microelectronic systems [2]. The incorporation of SnO_2 into PEO–PMMA blends has attracted significant attention, as SnO_2-dispersed polymer matrices have demonstrated improved ionic conductivity in solid polymer electrolytes [3].

Furthermore, the synthesis of polyethylene oxide (PEO)–polymethyl methacrylate (PMMA) blends doped with LiI and SnO_2 nanoparticles has been explored for tunable electrical and optical applications. These nanocomposites are lightweight, cost-effective, easy to process, and exhibit good mechanical strength along with favorable optical and electrical properties. Such characteristics make them suitable for various optoelectronic applications, including sensors, solar cells, transistors, diodes, capacitors, and energy-storage devices. XRD studies revealed faster ion transport with diminished crystallinity, while FTIR showed functional group analysis. Optical studies of PEO-PMMA–LiI–SnO_2 nanocomposites reveal enhanced optical absorption in the ultraviolet region (200–280 nm). With increasing SnO_2 concentration, parameters such as absorbance and ionic conductivity increase, whereas transmittance and optical band gap decrease. The reduction in the band gap is particularly advantageous for optoelectronic device applications [4]. Surface topography was perceived by scanning electron microscopic studies.

2. Experimental Details

2.1. Chemicals and Materials

Commercially available polyethylene oxide ($M_w \approx 5 \times 10^5$ g mol^{-1}) and polymethyl methacrylate (PMMA; $M_n \approx 9.96 \times 10^5$ g mol^{-1}) were employed in this study, both sourced from Sigma-Aldrich. Lithium iodide (LiI), employed as the ionic salt for charge carrier generation, was also obtained from Sigma-Aldrich. Tin oxide (SnO_2) nanoparticles with an average particle size of <100 nm were used as the inorganic nanofiller to enhance structural, dielectric and ionic transport properties. Analytical-grade acetone was used as the solvent throughout the experiment.

2.2. Preparation of PEO–PMMA–LiI–SnO_2 Nanocomposite Polymer Electrolyte Films

Nanocomposite solid polymer electrolyte films based on PEO–PMMA–LiI–SnO_2 were synthesized using the solution casting technique, which ensures uniform dispersion of salt and filler within the polymer matrix. Initially, 0.2 g of PEO and 0.1 g of PMMA were dried separately in a vacuum drying oven at 373 K for 15 min to remove any absorbed moisture. Lithium iodide (LiI) was also pre-dried under the same conditions to prevent hygroscopic effects that could influence ionic conductivity. The dried PEO and PMMA were dissolved in 30 mL of acetone and magnetically stirred for 1 h at room temperature to obtain a clear and homogeneous polymer blend solution. After achieving complete dissolution, 0.03 g of

https://doi.org/10.3390/engproc2026124078

LiI salt was added slowly to the polymer solution under continuous stirring and allowed to mix for 1 h, ensuring uniform dissociation of lithium ions within the polymer host matrix.

Subsequently, SnO_2 nanoparticles were incorporated into the polymer–salt complex in two different weight percentages, namely 3 wt% and 5 wt%. The mixture was further stirred for 2 h to achieve homogeneous dispersion of SnO_2 nanoparticles and to minimize agglomeration. The resulting viscous solution was then cast onto glass Petri dishes and maintained under ambient conditions for 24 h to achieve gradual solvent removal of free-standing films. The dried films were carefully peeled off and stored in desiccators to avoid moisture absorption before further characterization. Thus, flexible and mechanically stable PEO–PMMA–LiI–SnO_2 nanocomposite polymer electrolyte films with 3 wt% and 5 wt% SnO_2 were successfully prepared for structural and optical studies [5].

3. Results and Discussion

3.1. X-Ray Diffraction Analysis of PEO–PMMA–LiI–SnO_2 Polymer Electrolytes

The PMMA/PEO-based polymer electrolyte's XRD pattern shown in Figure 1 reveals broad diffraction peaks at $2\theta \approx 19.1^\circ$ and 23.5°. These peaks are consistent with the PEO phase's semi-crystalline structure [6]. A significant amorphous phase from blending with PMMA is indicated by the broadness of the diffraction peak. When nanofillers are added, there is a discernible decrease in peak intensity and an increase in broadening, indicating a reduction in the polymer matrix's crystallinity [7]. Strong interactions between the polymer and the fillers cause the regular arrangement of polymer chains to be disrupted, which leads to an increase in conductivity of the specimen [8]. The filler appears to be uniformly distributed throughout the PMMA/PEO matrix based on the absence of distinct diffraction peaks associated with it [9]. Ion transport benefits from the enhanced amorphous nature shown by XRD because it encourages greater chain flexibility and segmental motion, both of which are necessary for enhanced ionic conductivity. The enhanced amorphous phase observed at higher filler concentration is favorable for ionic transport and electrochemical performance, which is associated with FTIR results too.

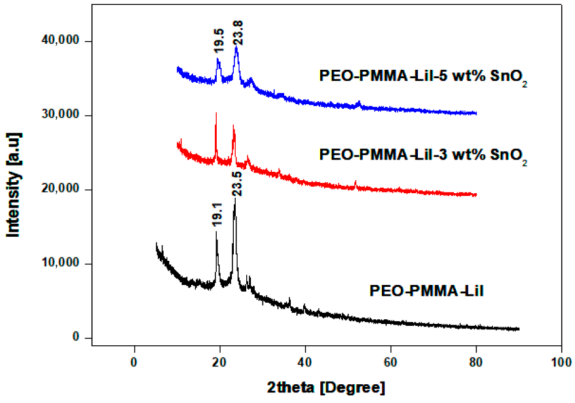

Figure 1. XRD profiles of PEO-PMMA-LiI, PEO-PMMA-LiI-3 wt%SnO_2 and PEO-PMMA-5 wt% SnO_2 blended plasticized nanocomposite solid polymer electrolytes recorded at room temperature in the 2θ range of 10–80° using Cu Kα radiation (λ = 1.5406 Å).

Figure 2 depicts the deconvoluted X-ray diffraction graph obtained for the PEO–PMMA–LiI system and its 5 wt% SnO_2-filled plasticized nanocomposite solid polymer electrolyte. The crystalline peaks at $2\theta \approx 19.1^\circ$ and 23.5°, together with a broad amorphous halo confirm the semi-crystalline nature of PEO. Peak expansion after the inclusion of 5 wt% SnO_2 highlights improved amorphous character due to increasing disorder in

the structure. The average crystallite dimension (D) was evaluated based on the Debye–Scherrer relationship,

$$L = \frac{n\lambda}{\beta cos\theta} \quad (1)$$

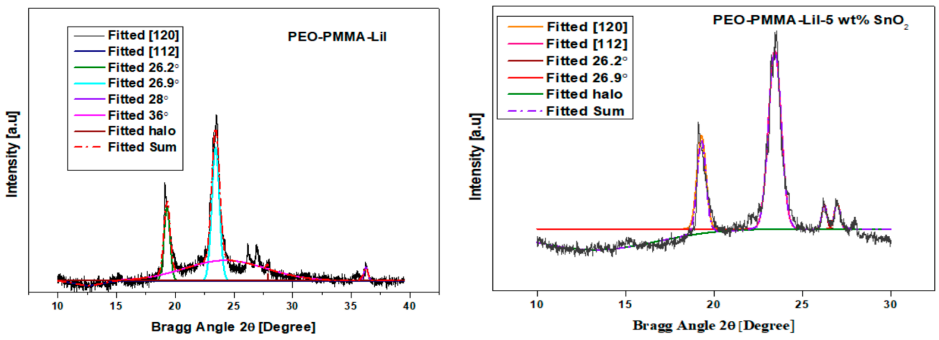

Figure 2. Illustration of the deconvoluted X-ray diffraction obtained for the PEO–PMMA–LiI system and its 5 wt% SnO_2-filled plasticized nanocomposite solid polymer electrolyte obtained using Gaussian peak fitting.

For the Debye–Scherrer calculation, the shape factor n was assumed to be approximately 0.89, while λ, β, and θ correspond to the X-ray wavelength, peak full width at half maximum, and Bragg reflection angle, respectively [10]. By the above equation, crystallite size assessed discloses a lessening of particle size from 50 nm for the PEO–PMMA–LiI system to 26 nm for the SnO_2-incorporated composite, highlighting the interface of SnO_2 nanoparticles with the polymer matrix.

3.2. Functional Group Analysis by Infrared Spectroscopy

The FTIR spectra of PEO–PMMA–LiI and best conducting PEO–PMMA–LiI–5 wt% SnO_2 polymer electrolytes provide clear evidence of polymer–salt–filler interactions, as evidenced from Figure 3. The FTIR spectrum of the PEO–PMMA–LiI polymer electrolyte exhibits a characteristic band at approximately 1099 cm^{-1}, which is associated with C–O–C stretching vibrations of PEO, confirming the presence of ether oxygen groups responsible for lithium-ion coordination. Upon incorporation of 5 wt% SnO_2, this band shifts to ~1040 cm^{-1}, indicating enhanced coordination between Li^+ ions and ether oxygen atoms, along with interfacial interactions between polymer chains and SnO_2 nanofillers [11,12].

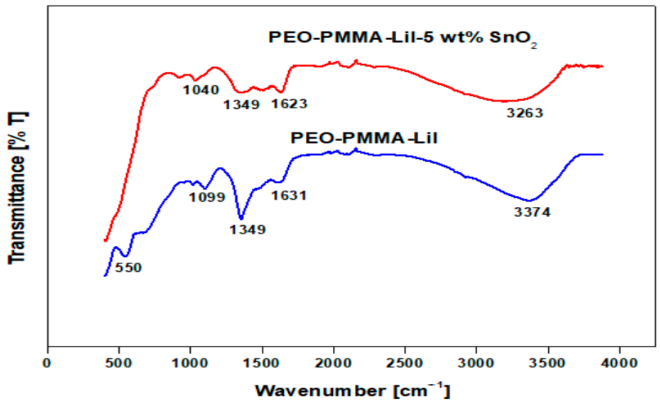

Figure 3. FT-IR spectra illustrating the PEO–PMMA–LiI system with 5 wt% SnO_2-incorporated plasticized nanocomposite solid polymer electrolytes at room temperature in the range of 400–4000 cm^{-1}.

The band appearing near ~1349 cm^{-1} corresponds to CH_2 bending vibrations, and the band gets broadened for the optimized PEO–PMMA–LiI–5 wt% SnO_2 electrolyte.

Generally, the characteristic PMMA carbonyl (C=O) stretching vibration is observed at ~1730 cm^{-1}, while the addition of LiI shifts this band to ~1631 cm^{-1}, which can be attributed to the coordination interaction between Li^+ ions and the carbonyl oxygen of PMMA. This interaction weakens the C=O bond and results in a significant shift in the carbonyl stretching vibration toward lower wavenumbers. A slight shift in the carbonyl band to ~1623 cm^{-1} after SnO_2 addition confirms the formation of polymer–salt–filler complexes and the involvement of carbonyl groups in coordination interactions [13]. In addition, the wide absorption band at 3374 cm^{-1} shifts to 3263 cm^{-1}, which can be attributed to O–H stretching vibrations arising from hydrogen bonding and intermolecular interfaces in the polymer matrix. The broadening and downward shift in this band upon SnO_2 incorporation indicate increased structural disorder and enhanced amorphous content [14]. Overall, the FTIR results confirm reduced polymer crystallinity and improved polymer segmental motion due to SnO_2 incorporation, which are favorable for efficient lithium-ion transport in solid polymer electrolytes and support their application in solid-state energy storage systems [15].

3.3. Optical Absorption Study of SnO_2 Nanoparticles

The UV–Visible spectrum of the PEO–PMMA–LiI–5 wt% SnO_2 nanocomposite polymer electrolyte, shown in Figure 4, displays a clear absorption peak at approximately 455 nm, arising from the electronic transition between the valence and conduction bands, which is a characteristic feature of semiconducting metal oxide nanomaterials [16,17]. The gradual decrease in absorbance beyond 600 nm suggests reduced photon interaction in the near-infrared region, consistent with reported optical behavior of SnO_2 nanoparticles [18–20].

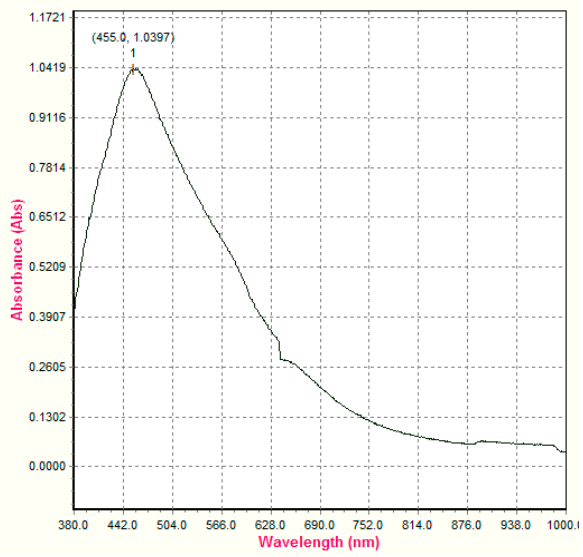

Figure 4. Optical absorption behavior of the PEO–PMMA–LiI polymer electrolyte system with 5 wt% SnO_2 filled plasticized nanocomposite solid polymer electrolyte recorded at room temperature in the wavelength range of 380–1000 nm.

3.4. Scanning Electron Microstructural Analysis

Figure 5a,b present the SEM micrographs of the PEO–PMMA–LiI and PEO-PMMA-LiI-5 wt% SnO_2 blended nanocomposite solid polymer electrolyte system. The surface morphology exhibits a granular and relatively homogeneous texture, indicating effective blending of the polymer host with the lithium salt and uniform incorporation of SnO_2 nanoparticles within the polymer matrix [21,22]. The presence of finely distributed spherical and irregularly shaped features confirms the successful embedding of SnO_2 nanofillers

into the PEO–PMMA network without phase separation [23]. The rough and uneven surface morphology arises from the disruption of the semicrystalline regions of PEO due to nanofiller incorporation, leading to an enhancement of the amorphous phase. Such morphology is widely reported to be beneficial for ion transport, as increased amorphous content facilitates polymer segmental motion and improves lithium-ion conductivity in solid polymer electrolytes. Overall, the SEM analysis confirms that the incorporation of 5 wt% SnO_2 effectively modifies the polymer matrix by enhancing filler dispersion, suppressing crystallinity, and promoting favorable microstructural features, thereby improving the electrochemical performance of the nanocomposite polymer electrolyte system [21,24].

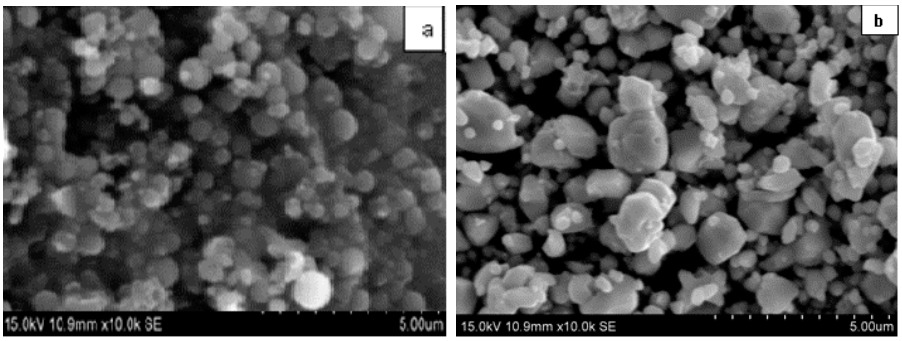

Figure 5. SEM photomicrographs appertaining to (**a**) PEO-PMMA-LiI and (**b**) PEO-PMMA-LiI-5 wt% SnO_2 blended nanocomposite solid polymer electrolytes at the voltage of 15 kV.

4. Conclusions

SnO_2-doped PEO-PMMA–LiI nanocomposite solid polymer electrolytes were successfully prepared and characterized. SnO_2 incorporation decreased the crystallinity of the polymer matrix, promoting amorphous domains that support ion transport, as substantiated by XRD results. FT-IR confirmed polymer–salt–filler interactions, while UV–Vis spectroscopy highlighted the optical properties of the nanocomposite electrolyte and SEM analyses verified the nanoscale nature and uniform morphology of the polymer electrolyte films. The combined effects of polymer blending, LiI doping, and SnO_2 reinforcement significantly enhanced the structural and functional properties, demonstrating the suitability of these nanocomposites for solid-state lithium-ion battery applications; however, detailed electrochemical investigations, such as ionic conductivity, transference number and cell performance studies are required and will be approached in future work.

Author Contributions: Conceptualization and methodology: A.S.; Validation: A.S. and M.T.T.; Visualization: A.S., M.T.T. and R.K.; Writing—original draft preparation: A.S., M.T.T. and R.K.; Review and editing: A.S. and M.T.T. All authors have read and agreed to the published version of the manuscript.

Funding: The authors would like to thank the Tamil Nadu State Council for Science and Technology (TNSCST) under the Student Project Scheme 2024–2025 (Grant No.PS-232).

Data Availability Statement: The data presented in this study are not publicly available due to privacy and ethical restrictions.

Conflicts of Interest: The authors declare no competing interests.

References

1. Zhang, D.; Li, L.; Wu, X.; Wang, J.; Li, Q.; Pan, K.; He, J. Research progress and application of PEO-based solid-state polymer composite electrolytes. *Front. Energy Res.* **2021**, *9*, 726738. [CrossRef]
2. Kim, J.H.; Lee, S.Y.; Park, J.S. Polymer blending strategies for enhancing ionic conductivity in solid polymer electrolytes. *Electrochim. Acta* **2020**, *353*, 136515.

3. Choudhary, S.; Sengwa, R.J.; Sankhla, S. Structural, dielectric, and ion transport behavior of PEO–PMMA-based nanocomposite polymer electrolytes. *J. Mater. Sci. Mater. Electron.* **2021**, *32*, 21534–21547.
4. Li, Y.; Zhou, D.; Liu, X.; Wang, Y. Role of inorganic nanofillers in regulating crystallinity and interfacial properties of polymer electrolytes. *Solid State Ion.* **2022**, *375*, 115827.
5. Hadi, A.; Hashim, A.; Al-Khafaji, Y. Structural, optical and electrical properties of PVA/PEO/SnO_2 nanocomposites for flexible energy devices. *Trans. Electr. Electron. Mater.* **2020**, *21*, 283–292. [CrossRef]
6. Amudha, S.; Rajalakshmi, K.; Tahira, A.Y.M.T. Novel Dispersion of CeO_2 Nanofiller in PEO/PMMA Blended Nanocomposite Solid Polymer Electrolytes. *Eng. Proc.* **2023**, *56*, 231.
7. Li, X.; Zhang, Y.; Chen, M.; Wang, J. Structural modification and crystallinity reduction in PEO-based nanocomposite polymer electrolytes. *J. Power Sources* **2020**, *450*, 227645.
8. Chen, M.; Liu, X.; Zhao, H.; Sun, Q. Effect of inorganic nanofillers on crystallinity and segmental dynamics of polymer electrolytes. *Mater. Chem. Phys.* **2021**, *263*, 124352.
9. Patel, R.; Singh, M.; Kumar, S. XRD analysis of nanofiller dispersion and amorphous phase enhancement in solid polymer electrolytes. *J. Energy Storage* **2023**, *55*, 105740.
10. Huang, Z.; Li, Y.; Wang, D.; Zhou, L. Nanoparticle concentration effects on structural ordering of polymer nanocomposites. *Electrochim. Acta* **2024**, *462*, 142892.
11. Al-Garadi, M.A.; Al-Shaikh, A.A.; Aziz, S.B. FTIR investigation of ion coordination and structural modification in polymer electrolyte systems. *Ionics* **2021**, *27*, 1241–1251.
12. Rahman, M.M.; Hossain, M.I.; Hashmi, S.A. Spectroscopic evidence of polymer–salt–filler interactions in PEO-based solid polymer electrolytes. *Mater. Today Commun.* **2023**, *36*, 106348.
13. Das, P.; Ghosh, A.; Banerjee, S. Role of carbonyl coordination and molecular interactions in blended polymer electrolytes. *Polym. Test.* **2020**, *89*, 106616.
14. Lee, J.H.; Kim, S.Y.; Park, J.S. Hydrogen bonding and amorphous phase enhancement in nanocomposite polymer electrolytes. *Solid State Ion.* **2022**, *378*, 115899.
15. Ahmed, S.; Gupta, R.; Singh, P. Influence of polymer segmental dynamics on ionic transport in solid polymer electrolytes. *J. Energy Storage* **2024**, *72*, 108410.
16. Das, S.; Choudhury, B.; Choudhury, A. Optical absorption and band gap tuning of SnO_2 nanoparticles synthesized by solution routes. *Opt. Mater.* **2020**, *108*, 110398.
17. Kaur, J.; Singh, D.; Kumar, R. Defect-induced optical properties of metal oxide nanoparticles. *Ceram. Int.* **2021**, *47*, 22110–22118.
18. Ramanathan, R.; Shankar, P.; Manikandan, A. Role of oxygen vacancies in optical and electronic properties of SnO_2 nanostructures. *Appl. Surf. Sci.* **2022**, *574*, 151656.
19. Mehta, A.; Patel, H.; Shah, M. Size-dependent optical properties of SnO_2 nanoparticles for electrochemical applications. *Mater. Lett.* **2023**, *331*, 133411.
20. Karthik, S.; Ramesh, R.; Kim, H.J. Optical behavior and defect engineering in nanostructured SnO_2. *J. Alloys Compd.* **2024**, *946*, 169389.
21. Chen, Y.; Liu, X.; Zhang, H.; Wang, J. Morphological and electrochemical characteristics of nanofiller-reinforced polymer electrolytes for lithium batteries. *J. Energy Storage* **2022**, *48*, 103982.
22. Wang, Y.; Li, Q.; Zhao, X.; Sun, Z. Effect of oxide nanofillers on crystallinity and morphology of PEO-based polymer electrolytes. *Mater. Chem. Phys.* **2023**, *297*, 127388.
23. Patel, R.; Singh, M.; Kumar, S. Structure–property correlation in nanocomposite solid polymer electrolytes. *Solid State Ion.* **2024**, *392*, 116176.
24. Gupta, A.; Rahman, M.M.; Hashmi, S.A. Influence of nanofiller dispersion on ion transport in polymer electrolyte systems. *Electrochim. Acta* **2021**, *389*, 138739.

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