Frontiers in Integrated Science and Technological Innovation

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PREFACE

The rapid convergence of scientific disciplines and technological domains has redefined the landscape of modern research and innovation. *Frontiers in Integrated Science and Technological Innovation* is conceived as a comprehensive volume that captures this multidisciplinary evolution, bringing together diverse yet interconnected studies spanning materials science, mechanical engineering, energy systems, healthcare, social sciences, and environmental sustainability.

This book opens with an exploration of advanced materials, highlighting recent developments in polyester composites with a focus on their mechanical and tribological behavior. Such studies underline the growing importance of engineered materials in enhancing durability and performance across industrial applications. Complementing this, investigations into perovskite nanoparticles and D-Phenylglycinium derivatives provide deep insights into structural, morphological, optical, and nonlinear optical properties, emphasizing their potential in next-generation optoelectronic devices.

The volume also bridges technology with societal dimensions. The analysis of multi-generational workforce dynamics in Chennai city offers a timely perspective on organizational behavior, workplace diversity, and the challenges faced by young professionals in a rapidly evolving economic environment. This inclusion reinforces the idea that technological progress must be understood alongside human and social factors.

Healthcare advancements form another critical pillar of this collection. The discussion on recent strategies for managing Chronic Obstructive Pulmonary Disease (COPD) reflects the integration of medical research with technological interventions, aiming to improve patient outcomes and quality of life. Such contributions demonstrate the vital role of interdisciplinary approaches in addressing complex health challenges.

Engineering innovation is further showcased through studies on surface engineering and coating technologies for tool steels, as well as automotive safety systems like rear collision warning mechanisms. The structural integrity analysis of electric vehicle battery enclosures under impact conditions underscores the urgency of developing safe and reliable solutions in the transition toward sustainable mobility.

Energy and environmental sustainability are central themes woven throughout the book. Reviews on vegetable oil-based fuels and biofuels highlight alternative energy pathways for reducing emissions in compression ignition engines. These discussions are complemented by a broader examination of sustainability and environmental chemistry, focusing on principles, processes, and remediation strategies essential for addressing global ecological concerns.

Collectively, the chapters in this volume reflect a unifying vision: that innovation thrives at the intersection of disciplines. By integrating theoretical insights, experimental research, and applied technologies, this book aims to serve as a valuable resource for researchers, academicians, and industry professionals seeking to navigate and contribute to the evolving frontiers of science and technology.

It is our hope that this compilation not only informs but also inspires further interdisciplinary collaboration and transformative innovation. We extend our sincere thanks to our publisher, Scientific Research Reports, Chennai, India, for their dedicated efforts in preparing this book and for ensuring the inclusion of enriched and high-quality technical content.

Wishes and Regards,

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CONTENTS

Chapter 2

Structural, Morphological and Surface Investigation of Perovsikte (LSNO) Nanoparticles

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Abstract

Perovsikte-type transition metal oxides have emerged as promising electrode materials for next-generation energy storage systems due to their remarkable electronic conductivity, structural stability, and tunable redox properties. In the present study, lanthanum strontium nickel oxide ($LaSrNiO_3$, LSNO) nanoparticles were synthesized and systematically characterized to investigate their structural, morphological, and surface properties relevant to electrochemical applications. The crystalline phase and structural purity of the synthesized LSNO nanoparticles were confirmed using X-ray diffraction (XRD), revealing a well-defined perovskite crystal structure with sharp diffraction peaks. Fourier transform infrared spectroscopy (FTIR) analysis verified the formation of metal–oxygen bonds and confirmed the presence of characteristic vibrational modes associated with the perovskite lattice. The surface area and pore distribution were examined through Brunauer–Emmett–Teller (BET) analysis, indicating a mesoporous structure that is favorable for electrolyte ion diffusion and enhanced electrochemical activity. Morphological examination using scanning electron microscopy (SEM) revealed agglomerated nanoscale particles with irregular yet porous surface

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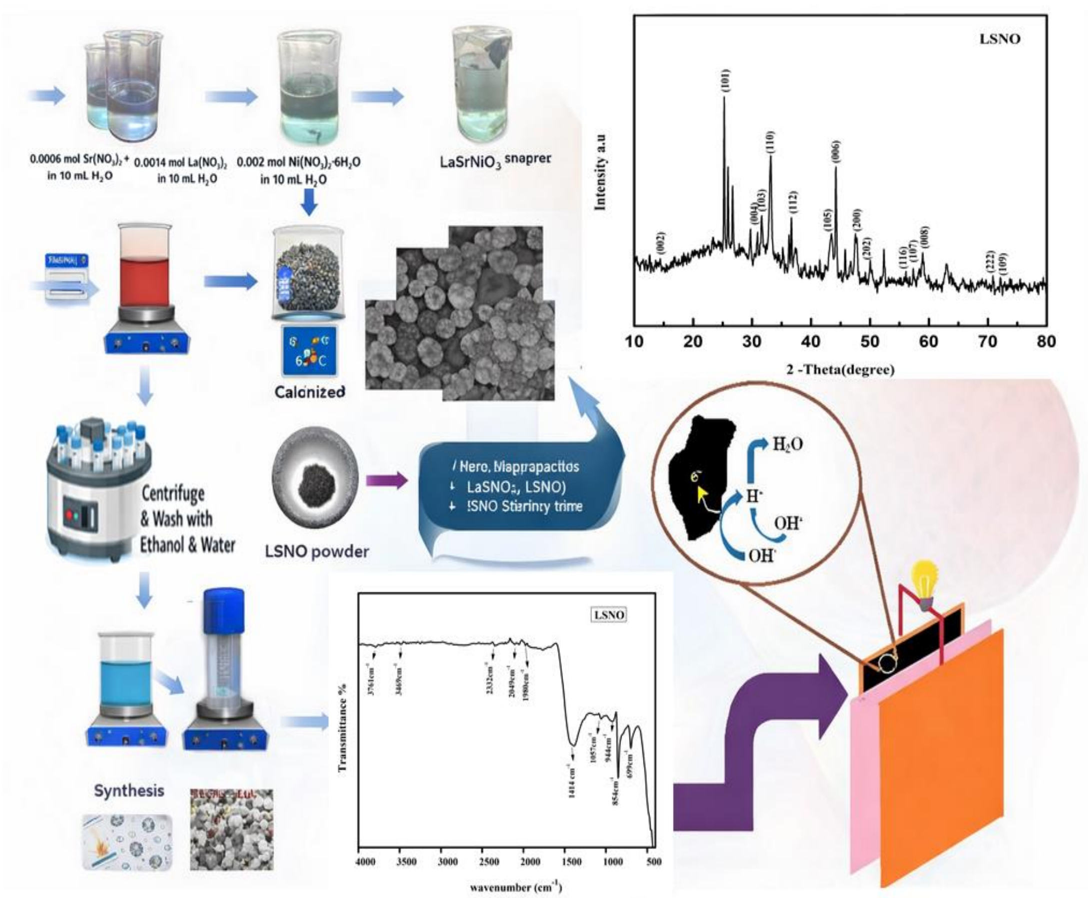
textures, which provide abundant active sites for charge storage processes. Elemental composition and chemical purity were validated by energy-dispersive X-ray spectroscopy (EDAX), confirming the presence of La, Sr, Ni, and O elements without significant impurities. The combined structural and surface analyses suggest that LSNO nanoparticles possess desirable physicochemical properties suitable for high-performance electrochemical energy storage devices such as super capacitors. These findings provide valuable insights into the design and optimization of Perovsikte-based electrode materials for advanced energy storage technologies.

Keywords: Perovsikte oxide, Nano material, Transition metal Oxide, LSNO nanoparticles, BET surface area, Energy storage devices.

Graphical Abstract



1. Introduction

The rapid growth of global energy demand and the increasing reliance on renewable energy sources have driven significant research interest toward the development of efficient and sustainable energy storage technologies. Among the various energy storage systems, electrochemical supercapacitors have gained considerable attention due to their high power density, fast charge–discharge capability, and long cycling stability compared with conventional batteries[1] However, the performance of supercapacitors largely depends on the properties of electrode materials, particularly their electrical conductivity, surface area, and redox activity. Therefore, the development of advanced electrode materials with improved electrochemical characteristics has become a critical research focus in recent years.

Transition metal oxides have emerged as promising candidates for energy storage applications owing to their multiple oxidation states, good electrochemical activity, and structural versatility. In particular, perovskite-type oxides with the general formula ABO_3 have attracted significant interest due to their flexible crystal structure and tunable physicochemical properties. In this structure, the A-site is typically occupied by rare-earth or alkaline-earth metals, while the B-site is occupied by transition metals. The interaction between these cations leads to unique electrical, magnetic, and catalytic properties, making perovskite oxides suitable for applications in catalysis, fuel cells, sensors, and electrochemical energy storage systems. Lanthanum-based perovskite oxides have been widely investigated because of their excellent electronic conductivity and structural stability. Among them, lanthanum strontium nickel oxide ($LaSrNiO_3$, LSNO) has gained increasing attention as an efficient electrode material due to

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its enhanced electrical conductivity and favorable redox characteristics arising from the mixed valence states of nickel ions [2]. The substitution of lanthanum with strontium at the A-site introduces oxygen vacancies and improves charge transport properties, which significantly enhances the electrochemical activity of the material. These characteristics make LSNO a promising candidate for high-performance supercapacitor electrodes. In addition to composition, the electrochemical performance of perovskite materials is strongly influenced by their morphology, particle size, and surface area. Nanostructured materials typically exhibit improved electrochemical performance due to their large surface-to-volume ratio and shorter ion diffusion pathways.

Therefore, controlling the synthesis process to obtain nanoscale perovskite particles with desirable surface characteristics is essential for optimizing their energy storage performance. Various synthesis techniques such as sol–gel, hydrothermal, combustion, and co-precipitation methods have been employed to prepare perovskite oxide nanoparticles [3]. Among these methods, the sol–gel approach offers several advantages, including better compositional control, homogeneous mixing of precursor ions, and the ability to produce highly crystalline nanostructures at relatively lower temperatures. Furthermore, the method allows precise tuning of particle size and morphology, which is critical for improving electrochemical performance. In order to evaluate the suitability of LSNO nanoparticles for energy storage applications, comprehensive characterization of their structural, morphological, and surface properties is required. X-ray diffraction (XRD) analysis provides essential information regarding the crystalline phase and structural integrity of the synthesized material. Fourier transform infrared spectroscopy (FTIR) helps identify functional groups and metal–oxygen bonding interactions within the lattice. Surface area and porosity measurements using Brunauer–Emmett–Teller (BET) analysis are crucial for understanding ion accessibility and electrolyte interaction during electrochemical processes. Additionally, scanning electron microscopy (SEM) enables the observation of particle morphology and aggregation behavior, while energy dispersive X-ray analysis (EDAX) confirms elemental composition and purity. In this work, LSNO nanoparticles were synthesized and systematically characterized using XRD, FTIR, BET, SEM, and EDAX techniques[4] The aim of this study is to investigate the structural and surface characteristics of LSNO nanoparticles and evaluate their potential as electrode materials for electrochemical energy storage applications. The obtained results provide valuable insights into the relationship between material structure and performance, contributing to the development of advanced perovskite-based energy storage systems.

2. Synthesis of LSNO Nanomaterial

Lanthanum strontium nickel oxide (LSNO) nanoparticles with the general perovskite formula ABO_3 were synthesized by separately dissolving the A-site precursors (La and Sr salts) and the B-site precursor (Ni salt). As illustrated in Fig. 1, 0.002 mol of $Ni(NO_3)_2{\cdot}6H_2O$ was dissolved in 10 mL of distilled water and magnetically stirred for 15 minutes to obtain a clear solution. In a separate beaker, 0.0006 mol of $Sr(NO_3)_2$ and 0.0014 mol of $La(NO_3)_3{\cdot}6H_2O$ were dissolved in 10 mL of distilled water and stirred for 15 minutes to ensure complete dissolution. Subsequently, the two precursor solutions were combined and continuously stirred for an additional 30 minutes to obtain a homogeneous mixture of Ni^{2+}, La^{3+}, and Sr^{2+} ions. The resulting mixed solution was then slowly introduced into 10 mL of 1

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M NaOH solution under constant stirring conditions. Upon the addition of NaOH, the solution immediately changed to a light brown color, and after approximately two hours of continuous stirring, a blue precipitate was observed. The obtained precipitate was collected and repeatedly centrifuged using ethanol and distilled water in order to remove residual ions and possible impurities. After the purification process, the collected material was dried in a hot air oven at 60 °C overnight. The dried product was then finely ground using a mortar and pestle to obtain a uniform powder. Finally, the powder was calcined in air at 750 °C for 3 hours, resulting in the formation of highly crystalline LSNO nanoparticles.

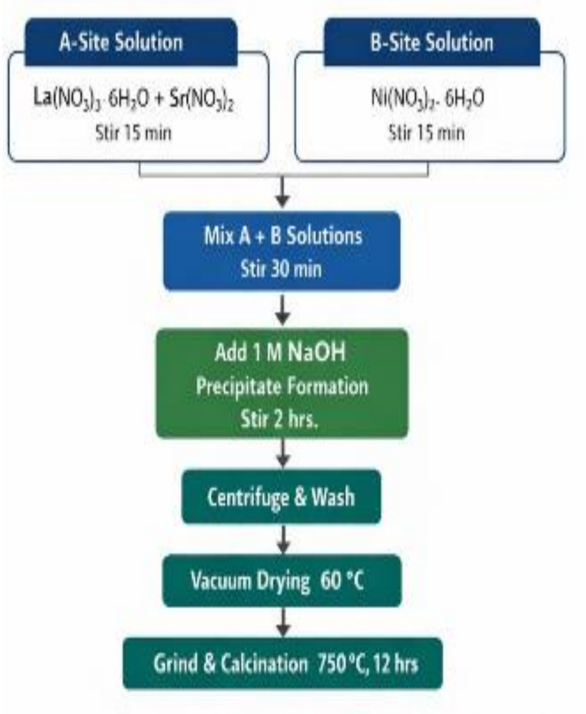

Figure 1: Synthesis of LSNO powder

3. Results and Discussion

3.1 X-ray Diffraction (XRD) Analysis

The crystal structure and phase purity of the synthesized LSNO nanoparticles were investigated using X-ray diffraction analysis. The

XRD pattern exhibits several well-defined diffraction peaks corresponding to the characteristic planes of the perovskite structure[5] Prominent peaks were observed at diffraction angles corresponding to planes such as (101), (110), (112), (105), (200), and (222), indicating the formation of a crystalline perovskite phase. The sharpness and intensity of the diffraction peaks suggest a high degree of crystallinity in the synthesized material. No significant impurity peaks were detected in the diffraction pattern, confirming the successful formation of phase-pure LSNO nanoparticles [6]. The crystalline structure of the material plays a crucial role in facilitating electron transport and improving electrochemical performance. The average crystallite size of the synthesized LSNO nanoparticles can be estimated using the Debye–Scherrer equation:

$$D=0.9\lambda/\beta\cos\theta \qquad (1)$$

Where D represents the crystallite size, λ is the wavelength of the X-ray radiation, β is the full width at half maximum (FWHM) of the diffraction peak and θ is the Bragg diffraction angle.

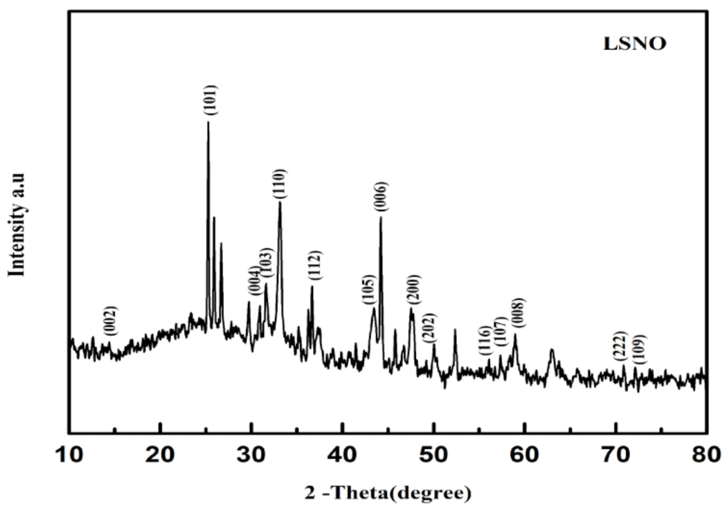

Figure 2: XRD patterns of LSNO sample

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The nanoscales crystallite size obtained from the analysis indicates that the synthesized LSNO material possesses a large active surface area suitable for electrochemical reactions.

3.2 FTIR Analysis

Fourier transform infrared spectroscopy was employed to identify the chemical bonding and functional groups present in the LSNO nanoparticles. The FTIR spectrum shows several absorption bands corresponding to different vibrational modes of the material. The broad absorption band observed around 3400–3700 cm^{-1} is attributed to the stretching vibration of hydroxyl (–OH) groups, which may arise from adsorbed moisture on the surface of the nanoparticles. Peaks located around 2300–2000 cm^{-1} correspond to the presence of atmospheric CO_2 adsorption. A strong absorption band appearing near 600–700 cm^{-1} is assigned to the metal–oxygen stretching vibration associated with the Ni–O bond in the perovskite lattice.

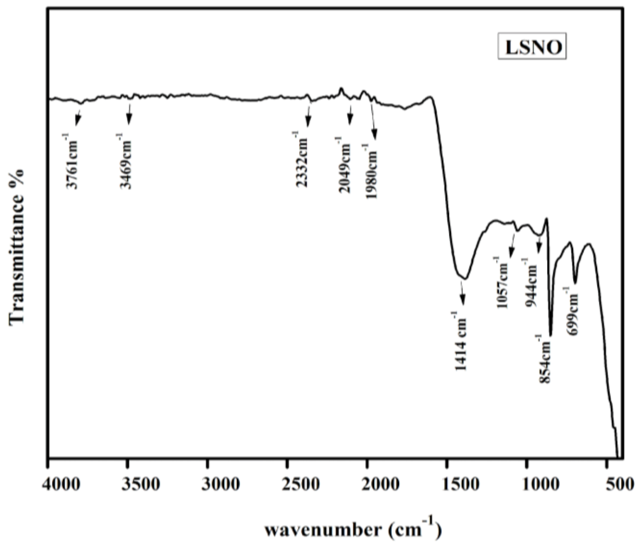

Figure 3: FT-IR spectra of LSNO

This band confirms the formation of the LSNO perovskite framework. Additional peaks observed around 850–1000 cm^{-1} are attributed to lattice vibrations and metal–oxygen bending modes within the oxide structure. These FTIR results confirm the successful formation of the metal–oxygen network characteristic of perovskite oxide materials.

3.3 BET Surface Area Analysis

The surface area and porosity of the LSNO nanoparticles were analyzed using nitrogen adsorption–desorption measurements based on the BET method. The obtained isotherm exhibits a typical adsorption–desorption behavior indicating the presence of mesoporous structures within the material. The gradual increase in nitrogen adsorption with increasing relative pressure suggests the presence of interconnected pores and a relatively high surface area [7].

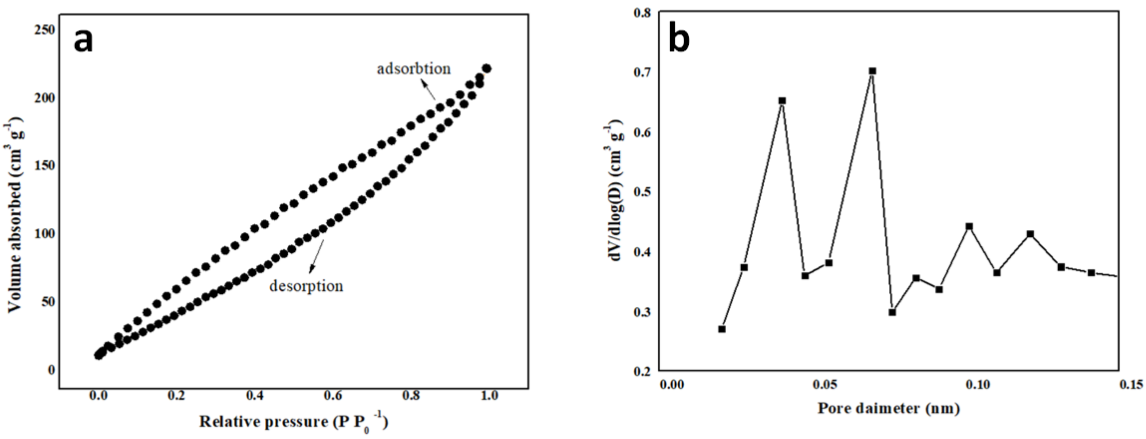

Figure 4: (a) N2 adsorption-desorption isotherms and (b) Pore Size distribution of the LSNO sample

The mesoporous nature of the material facilitates efficient ion diffusion and electrolyte penetration, which are essential for improved electrochemical performance in supercapacitor applications. The pore size distribution curve indicates the presence of pores in the

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nanometer range, further confirming the mesoporous structure of the LSNO nanoparticles.

3.4 SEM Analysis

The surface morphology of the synthesized LSNO nanoparticles was examined using scanning electron microscopy. The SEM images reveal that the particles possess a clustered and agglomerated morphology with irregular shapes. The individual particles appear to be in the nanoscale range and form interconnected networks. Such agglomerated nanostructures provide a porous architecture that can enhance electrolyte accessibility and increase the number of electrochemically active sites. The rough surface texture observed in the SEM images further contributes to improved charge storage behavior by facilitating rapid ion transport [8].

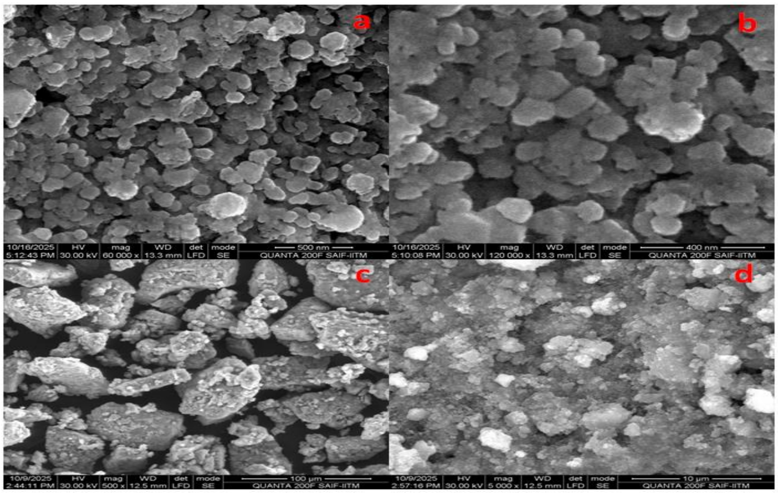

Figure 5: SEM image of LSNO, (a-d) for as prepared

3.5 EDAX Analysis

Energy dispersive X-ray spectroscopy was performed to determine the elemental composition of the synthesized LSNO nanoparticles. The EDAX spectrum clearly shows the presence of lanthanum (La), strontium (Sr), nickel (Ni), and oxygen (O) elements, confirming the successful formation of the intended perovskite compound. The quantitative elemental analysis reveals weight percentages of approximately La (24.99%), Ni (25.98%), Sr (30.96%), and O (18.06%), which are consistent with the stoichiometric composition of LSNO. The absence of additional impurity peaks indicates the high purity of the synthesized material.

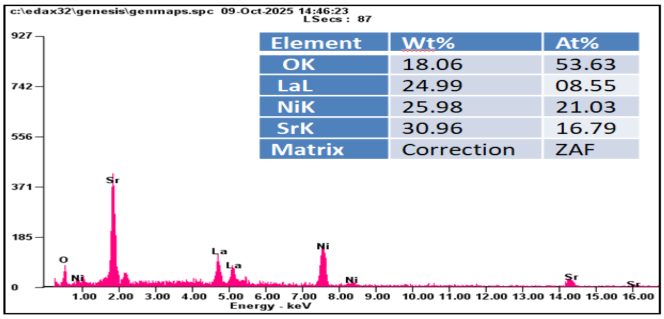

Figure 6: EDAX for LSNO sample.

4. Conclusion

In summary, lanthanum strontium nickel oxide (LSNO) nanoparticles were successfully synthesized and systematically characterized to evaluate their structural and surface properties for energy storage applications. XRD analysis confirmed the formation of a highly crystalline perovskite phase without detectable impurities. FTIR spectroscopy verified the presence of characteristic metal–oxygen bonds associated with the LSNO lattice structure. BET analysis revealed a mesoporous architecture with a relatively high surface area, which is beneficial for electrolyte diffusion and electrochemical activity. SEM observations demonstrated nanoscale particles with agglomerated and porous morphology, providing abundant active sites for charge storage processes. EDAX analysis confirmed the elemental composition and purity of the synthesized material.Overall, the structural integrity, porous morphology, and favorable surface

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characteristics of LSNO nanoparticles indicate their strong potential as electrode materials for high-performance supercapacitor and energy storage devices. Future work will focus on evaluating the electrochemical performance of LSNO-based electrodes and exploring composite structures to further enhance their energy storage capability.

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Chapter 3

Synthesis, Growth, Structural, Optical Assessments and Second Order NLO Studies of D-Phenylglycinium Derivatives for Optoelectronic Applications

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Abstract

The domain of nonlinear optics is witnessing considerable expansion, incorporating knowledge from multiple scientific areas, such as physics, chemistry, optics, crystal growth, optoelectronics, and engineering. The study of nonlinear optics garners significant attention in organic-inorganic blend compounds, owing to their diverse properties that find applications in various fields. In-depth investigations have concentrated on the non-linear optical characteristics of organic and semi-organic crystals, which hold promising applications in device fabrication. A single crystal of D-phenylglycine derivatives, including Bis(D-phenylglycinium) sulfate monohydrate (BDPGS) and D-phenylglycine hydrochloride (DPGCL), were synthesized and grown through the slow evaporation method utilizing water as a solvent. The single crystal XRD analysis demonstrated that BDPGS crystallizes in the monoclinic space group $P2_1$, while DPGCL crystallizes in the orthorhombic space group $P2_12_12$. The optical properties of the compounds were characterized through UV-Visible absorption and reflectance spectra, revealing cut-off wavelengths of 230 nm and 228 nm for BDPGS and DPGCL,

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