E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23 January 2025
PTDI, UiTM Cawangan Johor Kampus Pasir Gudang

e ISBN 978-967-0033-34-1

ORGANIZED BY:

Electrical Engineering Studies, College of Engineering
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang
https://tiec-uitmpg.wixsite.com/tiec

E-PROCEEDINGS
of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

23rd JANUARY 2025
PTDI, UiTM Cawangan Johor, Kampus Pasir Gudang

Organized by

Electrical Engineering Studies, College of Engineering,

Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.

https://tiec-uitmpg.wixsite.com/tiec

Editors

Aznilinda Zainuddin

Maisarah Noorezam

e ISBN: 978-967-0033-34-1

Published in Malaysia by
Universiti Teknologi MARA (UiTM) Cawangan Johor
Kampus Pasir Gudang, 81750 Masai

CONTENTS

PREFACE

It is with great pleasure that we present the e-proceedings of International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), which compiles the extended abstracts submitted to the International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), held on 23 January 2025 at **PTDI, Universiti Teknologi MARA (UiTM) Cawangan Johor, Kampus Pasir Gudang.** This publication serves as a valuable resource, showcasing the intellectual contributions on the invention and innovation among students, academics, researchers, and professionals.

The International Tinker Innovation & Entrepreneurship Challenge (i-TIEC 2025), organized under the theme "Fostering a Culture of Innovation and Entrepreneurial Excellence," is designed to inspire participants at various academic levels, from secondary students to higher education students and professionals. The competition emphasizes both innovation and entrepreneurship, encouraging the development of product prototypes that address real-world problems and have clear commercialization potential. By focusing on technological and social innovations, i-TIEC 2025 highlights the importance of turning creative ideas into viable, market-ready solutions that can benefit users and society. The extended abstracts in this e-proceedings book showcase the diverse perspectives and depth of research presented during the event, reflecting the strong entrepreneurial element at its core.

We extend our sincere gratitude to the contributors for their dedication in sharing their innovation and the organizing committee for their hard work in ensuring the success of the event and this publication. We also appreciate the support of our collaborators; Mass Rapid Transit Corporation Sdn. Bhd. (MRT Corp), Universitas Labuhanbatu, Indonesia (ULB), Universitas Riau Kepulauan, Indonesia (UNRIKA) and IEEE Young Professionals Malaysia, whose contributions have been instrumental in making this event and publication possible.

We hope that this e-proceedings book will serve as a valuable reference for researchers, educators, and practitioners, inspiring further studies and collaborations in both innovation and entrepreneurship. May the knowledge shared here continue to spark new ideas and market-ready solutions, advancing our collective expertise and fostering the growth of entrepreneurial ventures.

B-ST135: ENHANCEMENT OF SODIUM BISMUTH TITANATE (NBT) DIELECTRIC PROPERTIES THROUGH ALUMINUM (AL3+) SUBSTITUTION FOR ENERGY STORAGE

Nur Shakila Othman[1,2], Zalita Zainuddin[2], and Atiqah Mohd Afdzaluddin[2]
[1]Universiti Kuala Lumpur, Royal College of Medicine Perak, No 3 Jalan Greentown, 30450 Ipoh, Malaysia
[2]Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

Corresponding author: Nur Shakila Othman, p117840@siswa.ukm.edu.my

ABSTRACT

This research explores the enhancement of sodium bismuth titanate (NBT) ceramics through Al3+substitution at the A-site to overcome limitations in energy storage capabilities. While NBT exhibits promising dielectric and ferroelectric properties, issues such as limited temperature stability, low energy storage capacity, and dielectric losses require innovative solutions. By employing systematic Al3+incorporation (x=0.00x = 0.00 to x=0.08), this study achieves significant optimization of microstructural, optical, and dielectric properties. The lead solid-state reaction method used for synthesis ensures precise control over stoichiometry and processing conditions. X-ray diffraction (XRD) confirms successful Al3+incorporation into the A-site, while scanning electron microscopy (SEM) reveals improved grain size and distribution. The modified ceramics exhibit grain sizes ranging from 1±0.31 \pm 0.3 μm to 6±1.016 \pm 1.01 μm and relative densities of 84-90%, enhancing structural integrity. Optical characterization shows tunable band gaps (2.99–3.17 eV), improving optical performance in the visible region. Dielectric measurements reveal a higher dielectric constant, improved capacitance, reduced losses, and enhanced temperature stability compared to pure NBT. Al3+substitution also improves electrode-material interactions, resulting in superior energy storage capabilities. This innovative, lead-free approach addresses environmental sustainability while positioning aluminum-modified NBT ceramics as ideal candidates for next-generation electronic applications.

Keywords: Sodium Bismuth Titanate, Aluminum substitution, Energy storage, Dielectric properties, Microstructural engineering

1. Product Description

The innovation presents an advanced ceramic material system based on NBT, strategically modified with Al3+substitution at the A-site of the crystal structure. This modification, with Al3+incorporation ranging from x=0.00x = 0.00 to x=0.10, addresses critical limitations in energy storage applications by enhancing dielectric properties and thermal stability. Employing an environmentally friendly solid-state reaction method with precise control over stoichiometry and processing conditions, the synthesis ensures optimized material characteristics. Key structural features include controlled grain morphology with sizes ranging from 1 to 6 μm and an optimized density reaching up to 90% of the theoretical value.

Optical properties demonstrate tunable band gap engineering within the range of 2.99 to 3.17 eV, leading to an enhanced optical response in the visible region. Furthermore, dielectric properties exhibit superior performance with enhanced temperature stability, making this material highly suitable for advanced energy storage applications. These improvements are attributed to optimized grain boundaries, reduced oxygen vacancies, and enhanced dipole moment alignment, resulting in superior energy storage capabilities.

2. Experimental Flow Charts, Morphology, XRD Diffractogram and Table of Capacitance and dielectric material

The flow chart outlines three main stages: ceramic sample preparation, characterization procedures, and subsequent analysis in **Figure 1**. The structural evolution investigation demonstrates maintenance of the primary perovskite structure across all compositions (x = 0.00 to 0.08), with characteristic reflections at (110), (200), and (211) planes. XRD analysis shows crystallite size reduction (shift to higher angle) with increasing Al content, indicating successful lattice incorporation without secondary phase formation as shown in **Figure 2**. A non-monotonic trend in grain size evolution is observed, with maximum grain size (6.000 μm) at *x* = 0.02, followed by systematic decrease with further Al addition. The highest mean grain size is 6.000 ± 0.228 μm at x = 0.02, with the smallest standard deviation of 0.141 μm observed for x = 0.00, 0.04, and 0.06. The 95% confidence intervals show statistical significance, revealing a systematic trend in grain size evolution.

The grain size analysis at *x* = 0.02 reveals optimal conditions for grain growth at this composition. A strong linear relationship exists between grain size and theoretical density ($R^2 > 0.95$), with density ranging from 5.500 g/cm^3 to 5.367 g/cm^3. The optimal balance of properties occurs at *x* = 0.04, combining moderate grain size (4 μm) and density (5.433 g/cm^3) as shown in **Table 1.** The band gap statistics demonstrate a linear decrease with increasing Al content, showing precise control over optical properties and a strong correlation coefficient with grain size ($R^2 > 0.95$). The electrical characteristics of NBAT ($Na_{0.5}Bi_{0.5-x}Al_xTiO_3$) ceramics demonstrate complex relationships between composition and properties. The grain resistance (Rg) shows a significant increase from 28K Ω at x = 0 to 4.6 MΩ at x = 0.08, followed by a sharp decrease at x = 0.1, indicating a critical threshold in the Al3+ substitution effect. This behavior correlates with microstructural evolution and grain boundary properties. The conductivity exhibits an inverse trend, decreasing from 9.09×10^{-4} S/m (x = 0) to 7.95×10^{-7} S/m (x = 0.08). This suggests that Al3+ doping initially strengthens grain boundary resistance up to x = 0.08, beyond which the electrical properties deteriorate as shown in **Table 2.**

Notably, the permittivity remains relatively stable ($4\text{-}7\times10^3$) for most compositions but shows a marked increase to 1.58×10^4 at x = 0.08, likely due to enhanced polarization mechanisms and modified grain boundary characteristics. These trends indicate optimal electrical properties around x = 0.08 for capacitive

Table 1: Grain size measurement and band gap

Al3+ Content (x)	*Mean Grain Size (µm)*	*Density (gcm-3)*	*Band Gap (eV)*
0	1± 0.3	5.148	3.0366
0.02	6± 1.01	5.08	3.1608
0.04	4± 0.8	5.37	3.174
0.06	3± 0.5	5.28	3.1832
0.08	2 ± 1.3	5.26	3.1942

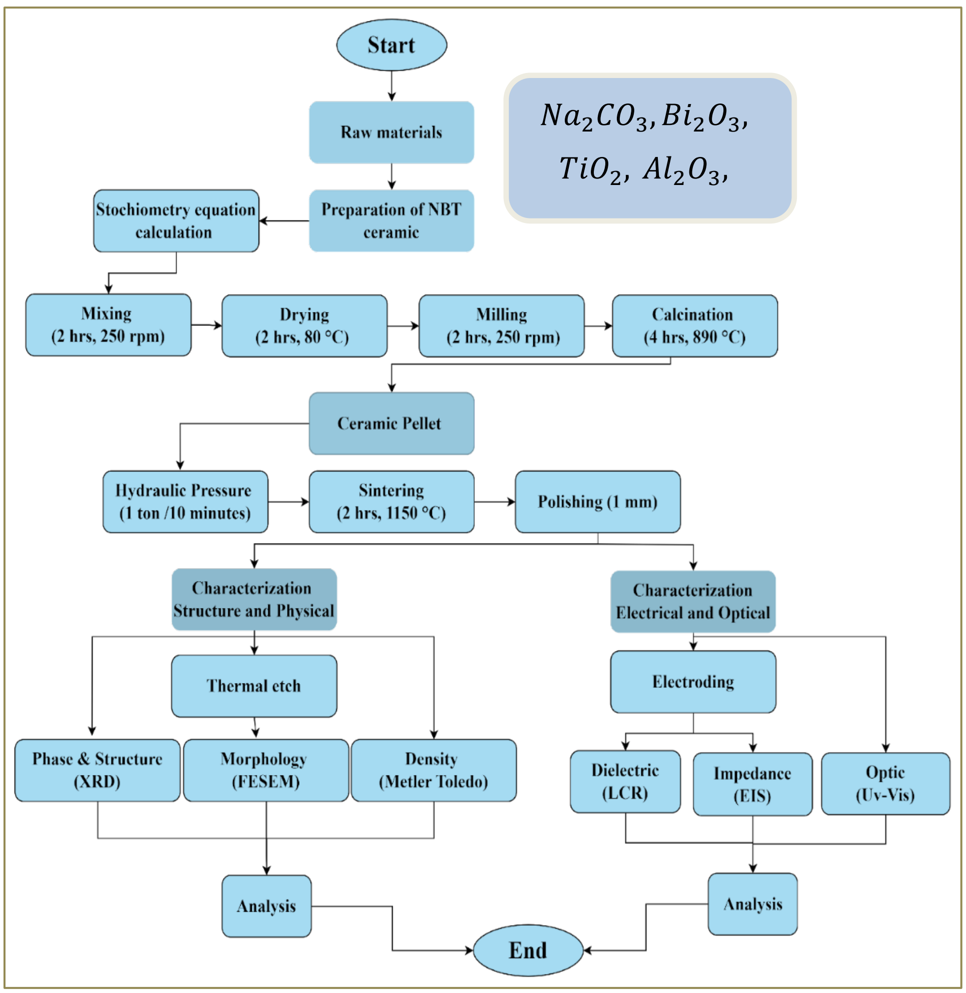


Figure 1. Research flow chart ceramic fabrication and characterization

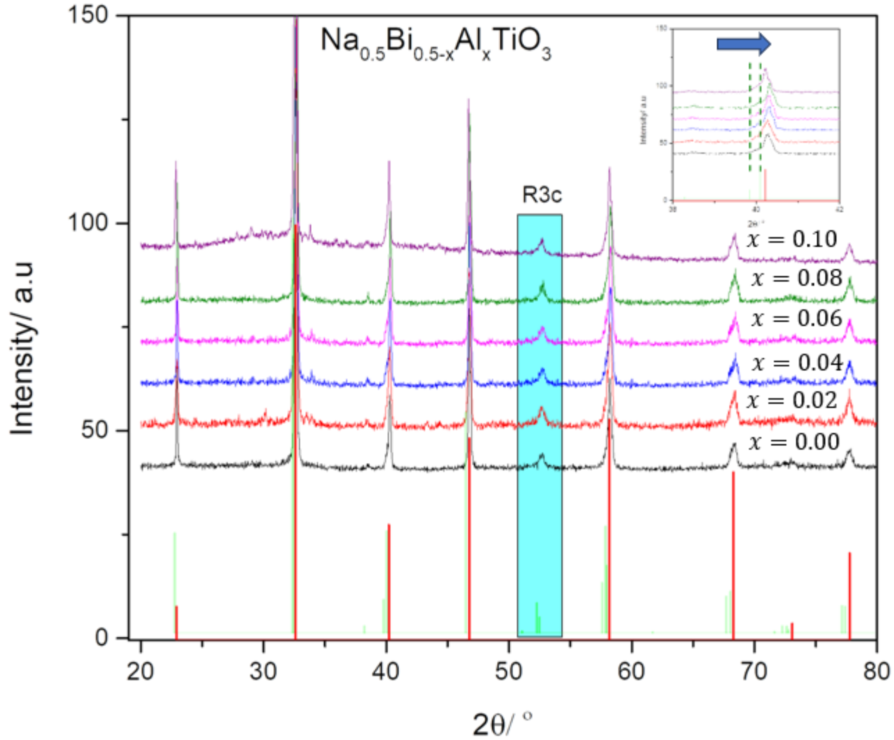


Figure 2. patterns of $Na_{0.5}Bi_{0.5-x}Al_xTiO_3$ ceramics (b) A magnified view of XRD patterns in selected region 2θ

Table 2: Comparison of electrical parameters Rgb (ohm), Cg (F), Rgb (ohm), Cgb (F) resulting from the fitting of the experimental data using equivalent circuit of $Na_{0.5}Bi_{0.5-x}Al_xTiO_3$

	Rg (Ω)	*Cg (F)*	*Rgb (Ω)*	*Cgb (F)*	*Conductivity (S/m)*	*Total Capacitance (F)*	*Permittivity*
0	2.8E+03	7.23E-10	1.10E+04	8.88E-10	9.09E-04	1.61E-09	6.45E+03
0.02	2.0E+06	3.32E-10	8.00E+06	7.96E-10	3.55E-06	1.13E-09	4.52E+03
0.04	2.0E+06	9.95E-10	2.00E+07	7.09E-10	1.61E-06	1.70E-09	6.82E+03
0.06	4.0E+06	1.45E-09	1.10E+07	3.55E-10	2.36E-06	1.81E-09	7.23E+03
0.08	4.6E+06	7.58E-10	4.00E+07	3.18E-09	7.95E-07	3.94E-09	1.58E+04

3. Novelty and uniqueness

The innovation's uniqueness lies in its strategic approach to A-site modification using aluminum, which simultaneously addresses multiple limitations of traditional NBT materials. The substitution technique results in a novel microstructural configuration that enhances dipole moment alignment while reducing oxygen vacancies. This approach differs from conventional doping methods by focusing on crystal structure optimization rather than simple compositional modifications. The resulting material demonstrates unprecedented stability across broader temperature ranges and improved energy storage capabilities without compromising environmental sustainability. This research represents the first systematic study of Al3+ modification in the NBT system as in **Figure 3**, achieving simultaneous optimization of structural, optical, and dielectric properties. The work introduces a novel approach to band gap engineering in NBT ceramics while providing an environmentally friendly alternative to lead-based materials. Through this innovative approach, we have successfully developed a material that not only enhances performance characteristics but also aligns with sustainable development goals in advanced ceramic technologies.

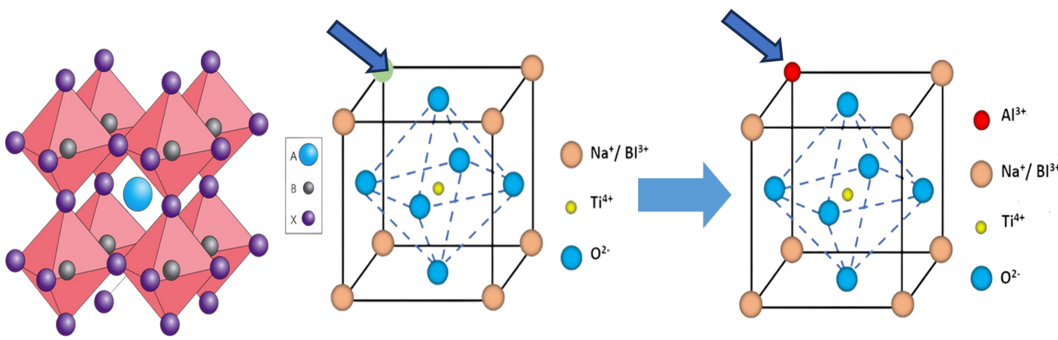


Figure 3. Substituting specific elements into perovskite structure

4. Benefit to mankind

This innovation addresses crucial energy storage challenges in modern electronics and renewable energy systems. The enhanced NBT material offers improved energy storage solutions for various applications, from consumer electronics to industrial power systems. Its improved thermal stability and reduced environmental impact align with global sustainability goals. The material's enhanced properties enable the development of more efficient and reliable energy storage devices, contributing to the broader adoption of renewable energy technologies. The development of this sustainable and lead-free electronic material represents a significant advancement in enhancing energy efficiency in electronic devices. Through its lead-free composition, the material significantly reduces environmental impact while demonstrating improved performance in electronic applications. This breakthrough not only addresses current technological needs but also paves the way for more sustainable and efficient electronic solutions in the future, making it a valuable contribution to both environmental conservation and technological advancement that can be visualised in **Figure 4**.

Figure 4. Significance benefit to mankind through innovation

5. Innovation and Entrepreneurial Impact

The development of this enhanced NBT material creates new opportunities in the energy storage sector. It promotes innovation through its novel approach to material engineering and opens pathways for commercialization in various industries. The research has fostered collaboration between academic institutions and industry partners, creating a knowledge transfer ecosystem. The technology aligns with Malaysia's Advanced Materials Technology Roadmap (MySTiE) and Sustainable Development Goals (SDG 7&9) (**Figure 5**), positioning it for significant industrial impact. The market potential is particularly promising due to the growing demand for lead-free electronics, multiple application possibilities, and its scalable manufacturing process. The economic benefits are substantial, characterized by reduced manufacturing complexity, high market value potential, and patent-worthy material composition. This comprehensive development not only addresses current market needs but also establishes a foundation for future technological advancements in the sustainable energy storage sector, making it an attractive proposition for both industrial implementation and commercial development.

Figure 5. The related policy, government target and piezoelectric market

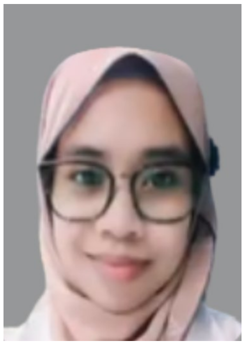
6. Potential commercialization

The modified NBT material shows strong commercialization potential in multiple sectors, particularly in high-performance capacitors for the electronics industry, energy storage systems for renewable energy applications, advanced ceramic components for automotive and aerospace industries, and smart grid infrastructure components. The scalable production process and competitive performance metrics make it an attractive option for industrial implementation, with potential market applications in both domestic and international markets. In electronic component manufacturing, the material excels in applications such as capacitors, sensors, memory devices, and energy storage systems. Its industrial applications extend to smart grid infrastructure, automotive electronics, and aerospace components, demonstrating its versatility and broad market potential. Furthermore, the material's applications in consumer electronics encompass mobile devices, computing systems, and smart home applications, positioning it as a versatile solution across the entire electronics ecosystem. This comprehensive market coverage, combined with its advanced technical capabilities, establishes the modified NBT material as a promising candidate for widespread commercial adoption across multiple industry sectors.

7. Acknowledgment

This research was supported by Universiti Kebangsaan Malaysia and Universiti Kuala Lumpur. Special thanks to the Ministry of Higher Education Malaysia for research funding and laboratory facilities support. We would like to express our sincere gratitude to Dr. Chong Man Kit, and Miss Haziqah Fadhlina Md Hussain for their valuable support and dedication during the laboratory experiments and photography sessions.

8. Authors' Biography



Nur Shakila Othman is a PhD student at Universiti Kebangsaan Malaysia (UKM) in Department of Applied Physics, currently working on advanced ceramic materials. Specializing in Ultrasound and Fundamental Physics at University Kuala Lumpur Royal of Medicine Perak College. With 3 years of experience in materials science, she has committed to contribute significantly to the field of ferroelectric materials and their applications in energy storage through her research.

Dr. Zalita Zainuddin is a Senior Lecturer in the Department of Applied Physics, Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM). She has expertise in applied physics and has been involved in various research related to advanced materials and technologies. With extensive experience, Dr. Zalita has contributed to the development of science and technology through nationally and internationally recognized publications and research.

Dr. Atiqah Mohd Afdzaluddin is a Senior Lecturer and Researcher at the Institute of Microengineering and Nanoelectronics (IMEN), Universiti Kebangsaan Malaysia (UKM). She specializes in MEMS packaging, electronic packaging, advanced materials, hybrid composites, and nanomaterials. With over 15 years of experience, Dr. Atiqah has pioneered innovative methods in electronic and MEMS packaging, contributing significantly to advancements in nanoelectronics technology. She has published numerous high-impact works and has been recognized for her contributions in this field.