Final Year Project Showcase Batch-2022
Year 2026

	Department: Materials Engineering Programme: BE Materials Engineering
1	**Project Idea** Advanced dielectric ceramics are essential for high-frequency communication, capacitors, resonators, and other electronic devices, yet many conventional materials face limitations in thermal stability, dielectric loss, and processing cost. This project aims to synthesize bismuth-doped erbium magnesium zirconium oxide (EMZ) double perovskite ceramics using a conventional solid-state reaction method. Bismuth concentration is systematically varied from 0 to 50% to investigate its influence on crystal structure, dielectric properties, microwave performance, and polarization behavior. The project focuses on developing phase-pure, thermally stable, and low-loss dielectric ceramics for advanced electronic applications. The project goal is "Synthesis and Characterizations of Perovskite Ceramics for Different Electronic Applications".
2	**Process** Among various ceramic synthesis techniques, the conventional solid-state reaction method was selected because of its simplicity, scalability, low processing complexity, and suitability for large-scale production. High-purity erbium oxide, magnesium oxide, zirconium oxide, and bismuth oxide were used as starting materials. The powders were accurately weighed according to the required compositions, mixed and homogenized using an agate mortar, followed by calcination at 900°C for 5 hours. The calcined powders were then granulated using PVA binder, uniaxially pressed into pellets, and sintered at 1500°C for 3 hours to obtain dense ceramic samples with controlled composition and structure.
3	**Outcome** The project successfully produced bismuth-doped EMZ double perovskite ceramics with controlled compositions from 0 to 50% Bi^{3+} doping. XRD characterization confirmed the formation of a single-phase orthorhombic structure without detectable secondary phases. Bismuth doping influenced the dielectric response of the ceramics, with 25% Bi showing the highest permittivity, while 10–15% Bi provided a favorable balance between high permittivity and low dielectric loss. The ceramics also demonstrated stable dielectric behavior up to 400°C, supporting their potential for reliable electronic applications.
4	**Evidence (Theoretical Basis):** The synthesis and property development of Bi-doped EMZ ceramics are supported by double perovskite and solid-state reaction principles. The $A_2BB'O_6$ structure provides ordered B-site cation arrangements that contribute to lattice stability and allow property modification through doping. Bi^{3+} substitution introduces controlled lattice distortion and enhances polarizability, influencing dielectric behavior. XRD analysis confirms the phase and crystal structure, while dielectric measurements evaluate permittivity and loss over the investigated frequency range. P-E measurements provide information about polarization response. The observed structure-property relationships support the theoretical basis of Bi-doped double perovskite ceramics for dielectric applications.
5	**Competitive Advantage or Unique Selling Proposition:**
a	**Attainment of any SDG;** **SDG-9** is addressed through the development of advanced dielectric ceramics for next-generation electronic and communication technologies. The materials have potential applications in microwave resonators, capacitors, high-frequency communication devices, and other advanced electronic components. **SDG-12** is supported through the use of conventional solid-state processing and stable oxide precursors, providing a scalable and comparatively simple manufacturing route. **SDG-13** is also supported because low-loss dielectric materials can improve energy efficiency in electronic and communication systems by reducing dielectric energy dissipation.

b	**Any Environmental Aspect:** Environment-friendly ceramic processing, stable oxide materials, reduced chemical waste, and scalable solid-state synthesis. The process avoids toxic organic solvents and produces chemically stable ceramic products with potential for long service life and reduced electronic waste.	
c	**Cost Reduction of Existing Product:** The project uses readily available oxide precursors including erbium oxide, magnesium oxide, zirconium oxide, and bismuth oxide, avoiding expensive organometallic precursors and complex wet-chemical processing. Conventional solid-state synthesis requires standard equipment such as furnaces, hydraulic presses, and grinding facilities, reducing infrastructure and production costs. The single calcination and sintering stages also simplify processing and improve scalability, providing a potentially affordable alternative to more complex dielectric ceramic manufacturing routes.	
d	**Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process:** Controlled Bi^{3+} doping provides a direct method for optimizing dielectric properties according to application requirements. The optimized calcination at 900°C for 5 hours and sintering at 1500°C for 3 hours promote phase formation and densification. Uniaxial pressing of PVA-bound powders improves pellet consistency and reduces processing defects. XRD-guided composition optimization minimizes trial-and-error, while the conventional single-stage thermal treatments simplify production, reduce processing steps, and improve overall manufacturing efficiency.	
e	**Expanding of Market share:** The advanced ceramics market is expanding with increasing demand for high-frequency communication, automotive electronics, consumer electronics, and industrial sensing systems. However, processing cost, thermal instability, and dielectric losses can limit the use of conventional materials. The developed EMZ ceramics offer a low-cost and scalable solid-state synthesis route, thermal stability up to 300°C, and dielectric loss below 3% across the investigated frequency range. Further optimization of Bi^{3+} concentration can improve performance and enable these materials to compete in emerging high-temperature and high-frequency electronic applications.	
f	**Capture New Market:** Emerging markets include 5G and 6G communication systems, microwave resonators and filters, high-density capacitors, electric vehicle electronics, high-temperature electronic systems, IoT sensors, RFID devices, and renewable-energy power electronics requiring stable and low-loss dielectric materials.	
6	**Target Market:** The primary target markets include telecommunications for microwave resonators, filters, and high-frequency components; consumer electronics for capacitors and timing devices; and automotive electronics for electric and hybrid vehicle systems. Aerospace, industrial automation, renewable energy, smart-city infrastructure, and research institutions also represent potential markets where thermally stable and low-loss dielectric ceramics are required.	
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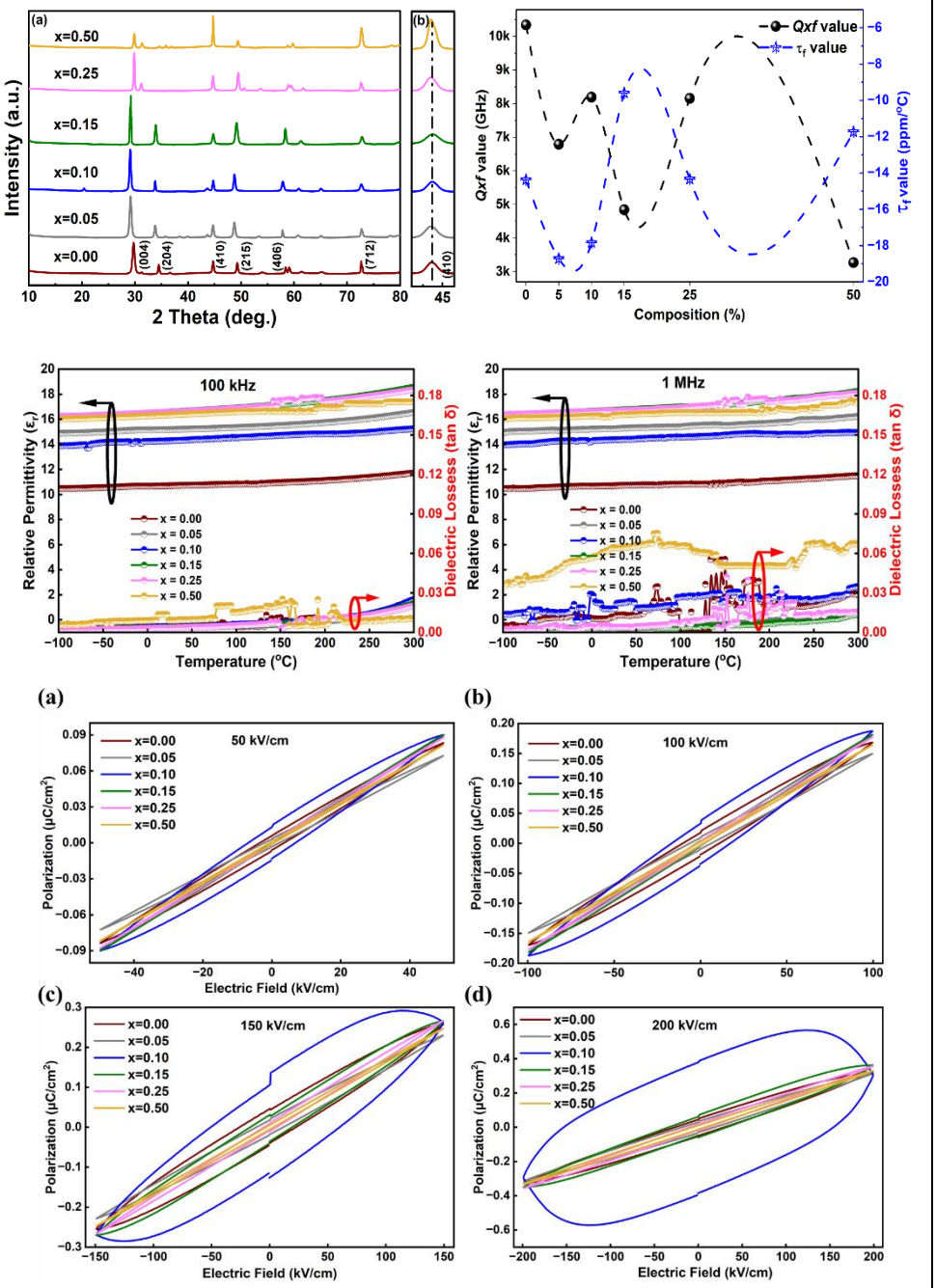
10	**Pictures (If any)**