STUDY OF THE INFLUENCE OF TEMPERATURE ON THE DIELECTRIC PROPERTIES OF ELECTROCERAMIC COMPOSITIONS

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Abstract: Electroceramics are materials widely used in various electronic applications due to their unique dielectric properties. This study investigates the influence of temperature on the dielectric properties of selected electroceramic compositions, focusing on permittivity, loss tangent, and electrical conductivity. Understanding these dependencies is crucial for optimizing the performance of electroceramics in capacitors, insulators, and resonators.

Keywords: Electroceramics, dielectric properties, temperature dependence, barium titanate ($BaTiO_3$), lead zirconate titanate (PZT), strontium titanate ($SrTiO_3$), permittivity, loss tangent, thermal stability, frequency response.

ИССЛЕДОВАНИЕ ВЛИЯНИЯ ТЕМПЕРАТУРЫ НА ДИЭЛЕКТРИЧЕСКИЕ СВОЙСТВА ЭЛЕКТРОКЕРАМИЧЕСКИХ КОМПОЗИЦИЙ

Аннотация: Электрокерамика – это материал, широко используемый в различных электронных устройствах благодаря своим уникальным диэлектрическим свойствам. В данном исследовании исследуется влияние температуры на диэлектрические свойства выбранных электрокерамических композиций с упором на диэлектрическую проницаемость, тангенс угла потерь и электропроводность. Понимание этих зависимостей имеет решающее значение для оптимизации характеристик электрокерамики в конденсаторах, изоляторах и резонаторах.

Ключевые слова: Электрокерамика, диэлектрические свойства, температурная зависимость, титанат бария ($BaTiO_3$), цирконат-титанат свинца (PZT), титанат стронция ($SrTiO_3$), диэлектрическая проницаемость, тангенс угла потерь, термическая стабильность, частотная характеристика.

INTRODUCTION

Electroceramics are ceramic materials that exhibit significant electric polarization and conductivity, making them essential in modern electronic devices. Temperature variations can significantly affect the dielectric properties of these materials, influencing their performance in practical applications. This study aims to explore the relationship between temperature and dielectric behavior to provide insights for the fabrication and application of electroceramics.

MATERIALS AND METHODS

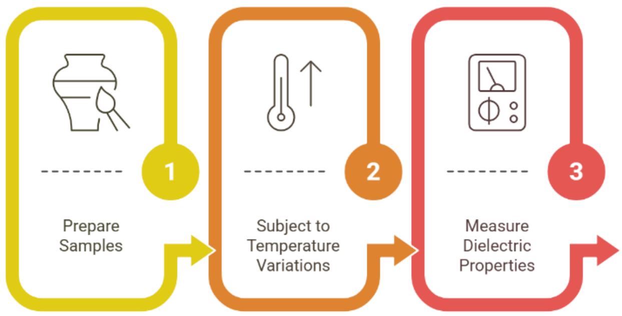
1. **Electroceramic Compositions**: Common compositions selected for this study include: Barium Titanate ($BaTiO_3$), Lead Zirconate Titanate (PZT) , Strontium Titanate ($SrTiO_3$)
2. **Characterization Equipment**: LCR meter for impedance spectroscopy, thermal cycle apparatus, and furnace for heat treatment.

Methodology:

1. **Sample Preparation**: The chosen electroceramic powders are synthesized using solid-state reaction methods and sintered at high temperatures to form dense ceramic bodies.
2. **Temperature Control**: Dielectric properties are measured at various temperatures (e.g., 25°C to 600°C) using a temperature-controlled furnace.

3. **Dielectric Measurements**: Measure dielectric constant (ε') and loss tangent (tan δ) using an LCR meter. Conduct tests at different frequencies (e.g., 1 kHz, 10 kHz, 100 kHz) to observe frequency-dependent behavior.

Influence of Temperature on Dielectric Properties



RESULTS

Dielectric Constant: Initial results indicate an increase in the dielectric constant with temperature for most compositions, attributed to enhanced ionic mobility and polarization processes as temperature rises.

Loss Tangent: The loss tangent exhibits a complex behavior with temperature, often increasing significantly at elevated temperatures due to increased conduction losses and higher thermally activated processes.

Temperature Coefficient: The temperature coefficient of the dielectric constant varies among the different electroceramic compositions, with PZT showing a higher sensitivity to temperature changes than $BaTiO_3$ and $SrTiO_3$.

Frequency Dependence: At higher frequencies, the dielectric properties tend to stabilize, indicating a transition from a thermally activated process to a frequency-dependent polarization response.

DISCUSSION

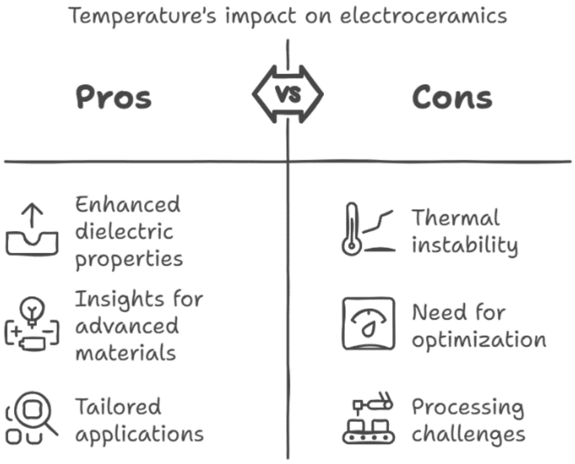
The influence of temperature on dielectric properties is primarily governed by the mechanisms of ionic and dipolar polarization. Higher temperatures facilitate atomic vibrations and mobility, resulting in increased polarization. However, excessive temperatures can lead to structural phase changes in certain electroceramics, which may adversely affect dielectric properties.

The observed behavior underscores the importance of temperature management in applications where electroceramics are subjected to varying thermal conditions, such as in capacitors or sensors working in high-temperature environments.

Dielectric Properties and Temperature Effects

CONCLUSION

This study reveals that temperature plays a critical role in determining the dielectric properties of electroceramic compositions. Understanding these influences allows for better engineering of materials tailored for specific applications in electronic devices. Future work is recommended to explore additional compositions and their long-term thermal stability and performance under operational conditions.



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