ORIGINAL RESEARCH PAPER

OPEN ACCESS

SYNTHESIS AND DIELECTRIC STUDIES OF TRYPTOPHAN-DOPED EUF₃ NANOPARTICLES

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Abstract:

The Holmium-doped EuF₃ nanoparticles were synthesized at room temperature using an aqueous solution method, with tryptophan acting as an organic ligand. X-ray diffraction analysis confirmed the formation of a hexagonal phase. The calculated lattice parameters were a = b = 6.966 Å and c = 7.322 Å, corresponding to a unit cell volume of 307.69 Å³. These values show close agreement with standard JCPDS data (No. 32-0373). The average crystallite size, estimated using the Debye–Scherrer equation, was found to be 73.54 nm. Structural analysis revealed that the nanoparticles belong to the hexagonal phase with space group P3c1 (165). Scanning electron microscopy images indicated a flake-like morphology with particle sizes ranging from 54 to 62 nm, along with small globular features. Dielectric properties, including dielectric constant (ε′), dielectric loss (ε″), and loss tangent (tan δ), were investigated over a frequency range of 100 Hz to 5 MHz at room temperature. Both dielectric constant and dielectric loss exhibited an exponential decrease with increasing frequency. The low dielectric loss observed at higher frequencies suggests potential applicability of these nanoparticles in electronic devices.

Keywords: *Tryptophan, Dielectric Constant, Dielectric Loss, Loss Tangent*

Introduction

Nanotechnology has led to significant advancements across diverse scientific and technological domains. The enhanced surface-to-volume ratio of nanostructured materials, compared to their bulk counterparts, has enabled their application in numerous fields. Lanthanide-based nanomaterials are particularly important for light-emitting devices due to their sharp emission characteristics (1,2). Rare-earth nanoparticles are extensively used

as catalysts, in permanent magnets, and in optical applications (1). Owing to their narrow emission bands, lanthanides serve as essential components in light-emitting devices (2), lasers for optical signal enhancement (3), and optical fibers (2,3). Europium-based compounds are well known for their use as red phosphors in cathode ray tube displays. In microelectronic circuits (4), dielectric materials play a crucial role, and their properties are strongly influenced by particle size and morphology. Dielectric materials are widely used in capacitors, electronic memory devices, and optical filters (5). Nanomaterials exhibiting high dielectric permittivity and low dielectric loss over a broad frequency range are of considerable interest. Frequency-dependent dielectric behavior provides valuable insight into charge transport and polarization mechanisms (6). In the present study, the frequency-dependent dielectric properties—namely dielectric constant, dielectric loss, and loss tangent—of Ho-doped EuF_3 nanoparticles synthesized in the presence of tryptophan are reported.

Materials and Methods

Experimental design

EuF_3 nanoparticles were synthesized using a chloride-based route, and microwave irradiation was employed to minimize particle agglomeration. Distilled water was used as the solvent, and the starting materials included $EuCl_3 \cdot 6H_2O$ (0.064 mol, 1.65 g), $HoCl_3 \cdot 6H_2O$ (0.064 mol, 0.8680 g), tryptophan ($C_{11}H_{12}N_2O_2$; 0.064 mol, 0.130 g), and NH_4F (0.576 mol, 3.200 g). All reagents were water soluble. Ammonium fluoride was used in threefold excess relative to the other precursors, resulting in a molar ratio of 1:3.

For the synthesis, 7 mL of europium chloride solution was taken in a 100 mL beaker, followed by the addition of 1.5 mL each of holmium chloride and tryptophan solutions. Subsequently, 10 mL of ammonium fluoride solution was rapidly injected into the mixture under continuous stirring. A white precipitate formed within a few seconds. The resulting suspension was subjected to microwave irradiation for 30 minutes to facilitate drying. The obtained nanocrystals were repeatedly washed with distilled water and dried in a microwave oven (800 W, 24 L capacity). A bottom-up synthesis approach was adopted, and the nanoparticles were found to be stable during subsequent characterization.

Results

Dielectric studies
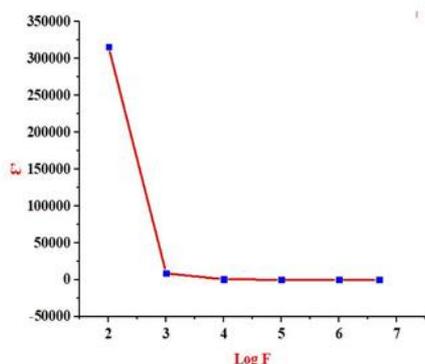
Figure 1: Variation of Dielectric constant with log frequency of EuF₃: Ho@ Tryptophan
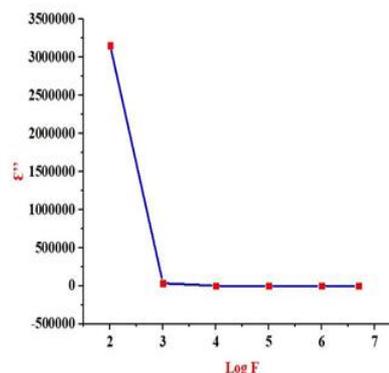
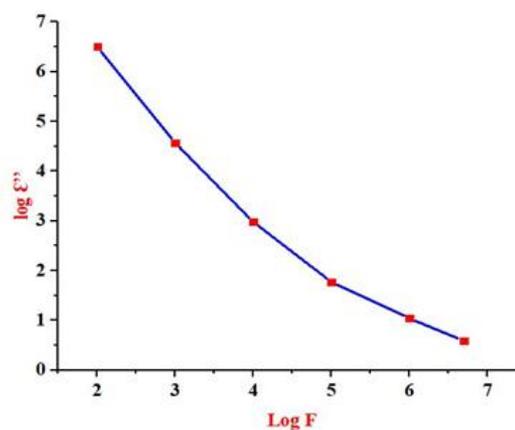**Figure 2: Variation of Dielectricloss verses log of frequency of EuF₃: Ho@ Tryptophan**

The variation of dielectric constant with frequency in the range of 1 kHz to 5 MHz is shown in Figure 1. At lower frequencies, the dielectric constant decreases rapidly, while at higher frequencies it becomes nearly constant and

frequency independent. The high dielectric constant observed in the low-frequency region is attributed to polarization effects, particularly space-charge polarization within the nanomaterial (7,8).
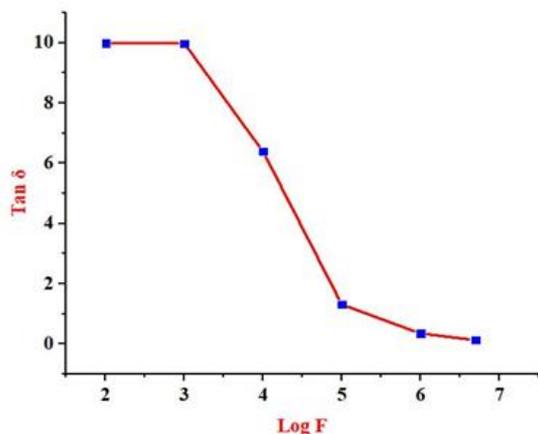
Figure 3: Variation Plot of log ε″ verses log frequency of EuF₃: Ho@ Tryptophan

Figure 4: Variation Plot of tan δ verses log frequency of EuF₃: Ho@ Tryptophan

Figure 2 illustrates the frequency dependence of dielectric loss from 1 kHz to 5 MHz. The dielectric loss exhibits higher values at lower frequencies and decreases significantly with increasing frequency. This behavior can be attributed to the reduced contribution of electrical conductivity in nanosized particles, which becomes negligible at higher frequencies.

The plot of log ε″ versus log frequency (Figure 3) shows an approximately linear relationship with slopes ranging from −0.79 to −1.92, indicating the dominance of dc conduction mechanisms in the synthesized nanoparticles (7,8). The variation of tan δ with log frequency (Figure 4) reveals a relaxation peak around 100 kHz, suggesting the involvement of the real part of the dielectric constant in the polarization process. Higher tan δ values at lower frequencies arise from dipolar polarization, whereas the decrease at higher frequencies is associated with space-charge polarization effects. At low frequencies, dielectric loss remains nearly constant, while at higher frequencies it gradually decreases as dipoles are unable to follow the rapidly varying applied field.

Conclusion

The Holmium-doped EuF₃ nanoparticles were successfully synthesized using tryptophan as a modifying ligand, and microwave irradiation was employed to reduce particle agglomeration. Structural analysis confirmed a hexagonal crystal structure with lattice parameters consistent with JCPDS No. 32-0373. The average crystallite size was determined to be 73.54 nm using the Debye–Scherrer method. Dielectric studies revealed a sharp decrease in dielectric constant at lower frequencies, followed by frequency-independent behavior at higher frequencies. Dielectric loss was found to decrease gradually with increasing frequency, which can be attributed to the reduced ability of dipoles to respond to high-frequency electric fields.

Acknowledgements

Conflict of interest

The authors declare no conflict of interest

References

1. Ronda, C. R., Justel, T., & Nikol, H. (1998). *Journal of Alloys and Compounds*, *275–277*, 669–676.
2. Kalyani, N. T., & Dhoble, S. J. (2016). *Renewable and Sustainable Energy Reviews*, *16*, 2696–2723.
3. Hasegawa, Y., Wada, Y., & Yanagida, S. (2004). *Photochemistry and Photobiology C: Photochemistry Reviews*, *5*, 183–202.
4. Mahajan, M. P., & Khandpekar, M. M. (2018). *International Journal of Scientific Research in Science and Technology*, *5*(4), 69–71.
5. Dhaouadi, H., Ghodbane, O., Hosni, F., & Touati, F. (2012). *International Scholarly Research Network*, 1–8.
6. Dass, S., Lalla, N. P., & Okram, G. S. (2014). *Indian Journal of Pure and Applied Physics*, *52*, 386–390.
7. Parab, P. S., Pawanoji, A. A., Pawar, A. S., & Mahajan, M. P. (2024). *Iranian Journal of Chemical Engineering*, *43*(4), 1414–1425.
8. Mahajan, M. P., Khandpekar, M. M., & Pawanoji, A. A. (2024). *Journal of Physics: Conference Series*, *2886*, 012008, 1–6.