

Energy-efficient magnetite-chitosan/GO nanocomposites: structural, dielectric, and conductivity analysis for sustainable energy solutions

Sanjeeta Rani^a, Priti Goyal^a, Laishram Saya^b, Sunita Hooda^c and Manisha Verma^a

^aDepartment of Physics, Acharya Narendra Dev College, University of Delhi, New Delhi, India; ^bDepartment of Chemistry, Sri Venkateswara College, University of Delhi, New Delhi, India; ^cPolymer Research Laboratory, Department of Chemistry, Acharya Narendra Dev College, University of Delhi, New Delhi, India

ABSTRACT

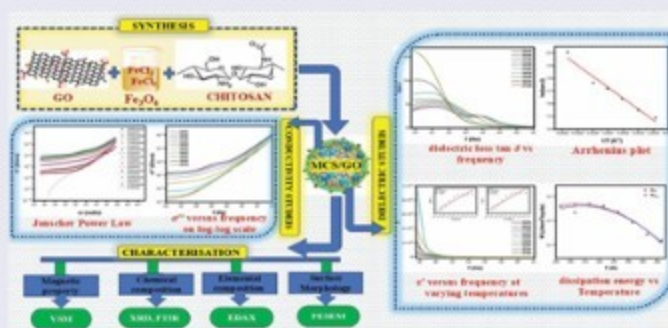
This study presents the development of a multifunctional biopolymer-based magnetite–chitosan/graphene oxide (MCS/GO) nanocomposite with enhanced structural, magnetic, and dielectric properties. XRD, FTIR, and FESEM scans confirmed the presence of Fe_3O_4 nanoparticles with a spinel structure embedded in the chitosan-GO matrix. The composite exhibited superparamagnetic behaviour with a saturation magnetisation of ~ 33.65 emu/g. Impedance spectroscopy revealed temperature and frequency dependent dielectric relaxation attributed to interfacial polarisation, dipolar motion, and space charge effects. Arrhenius plots revealed thermally activated dielectric relaxation and conduction mechanisms, each with distinct activation energies. Conductivity analyses confirmed a hopping-based mechanism transitioning from small polaron hopping to correlated barrier hopping with temperature. A consistent exponential decline in dissipation energy with temperature confirms dielectric relaxation as a primary mode of energy loss. Furthermore, conduction-related energy dissipation is nearly five orders of magnitude lower than dielectric losses, underscoring the superior insulating properties of MCS/GO.

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KEYWORDS

Magnetic chitosan; graphene oxide; superparamagnetism; activation energy; dissipation energy; dielectric relaxation; Jonscher's law; interfacial polarization



Highlights

- Superparamagnetic MCS/GO nanocomposite synthesized and structurally confirmed.
- Low-frequency relaxation peaks show strong interfacial interactions.
- High-frequency dielectric stability with temperature-independent $\tan \delta$.
- Integrated structural, magnetic, and dielectric results via SPH, CBH, UDR, Jonscher's law.
- Strong dielectric performance and low energy loss suit advanced electronics.