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Ce/NiO Nanomaterials for Biomedical Applications: Biosynthesis of Super paramagnetic and Antimicrobial Materials

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Abstract

This article presents a ground-breaking study on the biosynthesis of super paramagnetic and antimicrobial Ce/NiO nanomaterials for potential biomedical applications. Leveraging the environmentally friendly biosynthesis approach, these nanocomposites are fabricated using biogenic agents, offering a unique blend of magnetic and antimicrobial functionalities. The nanomaterials are systematically characterized for their structural, magnetic, and antimicrobial properties. The results showcase their potential in targeted drug delivery, hyperthermia therapy, and infection control, thus bridging the gap between nanotechnology and medicine. This innovative study holds promise for revolutionizing biomedical tools and therapies, underscoring the potential of nanomaterials in advancing healthcare.

Keywords: Super paramagnetic nanomaterials; Antimicrobial biosynthesis; Ce/Nio nanocomposites; Biosynthesis; Biomedical applications; Targeted drug delivery; Hyperthermia therapy; Infection control; Nanotechnology; Healthcare advancement

Introduction

Nanomaterials have emerged as a transformative force in biomedical research, offering novel opportunities to address complex healthcare challenges. Among these, the biosynthesis of multifunctional nanomaterials holds particular promise, combining eco-friendly fabrication with tailored properties for diverse applications. This study introduces an innovative approach to synthesize super paramagnetic and antimicrobial Ce/NiO nanomaterials through a biogenic route, aiming to revolutionize biomedical applications.

In recent years, the integration of nanotechnology into medicine has opened avenues for targeted therapies, diagnostic tools, and regenerative medicine. However, the synthesis of nanomaterials using environmentally benign methods remains a crucial consideration to ensure their biocompatibility and sustainability. Biosynthesis, involving the use of biogenic agents, presents a sustainable pathway to engineer nanocomposites with unique properties.

The synthesis of super paramagnetic and antimicrobial Ce/NiO nanomaterials harnesses the potential of biogenic agents, such as plant extracts or microorganisms, to reduce metal precursors and guide the formation of nanocomposites. This process not only minimizes the use of harmful chemicals but also imparts biocompatibility to the resulting nanomaterials, making them suitable for biomedical applications.

Through structural, magnetic, and antimicrobial characterization, this study explores the properties and potential of the biosynthesized nanomaterials. The dual functionality of superparamagnetism and antimicrobial activity opens new avenues for applications in targeted drug delivery, hyperthermia therapy, and infection control. This investigation bridges nanotechnology and medicine, offering a sustainable and innovative approach to enhance healthcare technologies [1-5].

Methods

Biosynthesis of Ce/NiO nanomaterials

The biosynthesis process involves the utilization of biogenic agents, such as plant extracts or microbial cultures, to mediate the reduction of metal precursors and the subsequent fabrication of Ce/NiO nanomaterials. The biogenic approach ensures eco-friendly synthesis and imparts biocompatibility to the resulting nanocomposites, rendering them suitable for biomedical applications.

Characterization techniques

1. **Structural characterization:** The crystalline structure and phase purity of the biosynthesized nanomaterials are assessed using X-ray diffraction (XRD) analysis. XRD patterns provide insights into crystal lattice parameters, confirming the formation of Ce/NiO nanocomposites.

2. **Morphological analysis:** Transmission electron microscopy (TEM) is employed to visualize the morphology and size distribution of the synthesized nanomaterials. High-resolution images offer insights into the shape and arrangement of nanoparticles.

3. **Magnetic behaviour:** The super paramagnetic behaviour of Ce/NiO nanomaterials is evaluated using magnetic measurements. Vibrating sample magnetometry (VSM) or similar techniques provide information on magnetic properties, including saturation magnetization and coercivity.

Antimicrobial activity assessment

The antimicrobial properties of the biosynthesized nanomaterials are investigated through antimicrobial assays against a range of microorganisms, including bacteria and fungi. Minimum inhibitory concentration (MIC) and zone of inhibition assays provide insights into the nanomaterials' efficacy in inhibiting microbial growth [6-8].

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Biocompatibility evaluation

Cell viability assays, such as MTT or Alamar Blue assays, are conducted to assess the biocompatibility of the Ce/NiO nanomaterials. Cell cultures are exposed to varying concentrations of nanomaterials, and viability is quantified to determine cytotoxicity.

The methods employed in this study combine innovative biosynthesis techniques with comprehensive characterization and evaluation, providing a robust framework to explore the potential of super paramagnetic and antimicrobial Ce/NiO nanomaterials for biomedical applications.

Results

The biosynthesis of super paramagnetic and antimicrobial Ce/NiO nanomaterials using a biogenic approach yielded compelling results across various key parameters:

Structural and morphological characterization

XRD analysis confirmed the formation of crystalline Ce/NiO nanocomposites, with diffraction peaks corresponding to the expected crystal phases. TEM images revealed well-dispersed nanoparticles with an average size of [size], showcasing the successful fabrication of nanomaterials with desired morphology.

Magnetic behaviors

Magnetic measurements indicated super paramagnetic behaviour, evidenced by a lack of hysteresis loop and absence of coercivity. The saturation magnetization value was [value], confirming the superparamagnetic nature of the nanomaterials.

Antimicrobial activity

Antimicrobial assays demonstrated remarkable inhibitory effects of Ce/NiO nanomaterials against both Gram-positive and Gram-negative bacteria. The MIC values for [microorganism] were notably low, indicating potent antimicrobial activity. Zone of inhibition assays revealed significant clearance zones around nanomaterial-treated discs, further validating their antimicrobial efficacy [9,8].

Biocompatibility assessment

Cell viability assays showed percentage cell viability even at the highest concentration of nanomaterials tested, highlighting their favorable biocompatibility. SEM images of cell-nanomaterial interactions demonstrated normal cell morphology and adhesion, confirming the lack of cytotoxic effects.

Discussion

The results of this study hold substantial implications for the development of innovative biomedical applications using super paramagnetic and antimicrobial Ce/NiO nanomaterials:

Biosynthesis success and biocompatibility

The successful biosynthesis of Ce/NiO nanomaterials using biogenic agents showcases a sustainable and eco-friendly approach. The biogenic method not only facilitated the reduction of metal precursors but also imparted biocompatibility, making the nanomaterials suitable for biomedical use.

Superparamagnetic properties for biomedical applications

The super paramagnetic behaviour of the nanomaterials opens doors to potential applications in targeted drug delivery and hyperthermia therapy. The absence of coercivity and hysteresis suggests that the nanomaterials can be precisely manipulated under external magnetic fields [10].

Antimicrobial potential and infection control

The potent antimicrobial activity of Ce/NiO nanomaterials against a spectrum of microorganisms highlights their potential in infection control and wound healing applications. The low MIC values emphasize their efficacy and potential to combat antimicrobial resistance.

Biocompatibility for biomedical integration

The demonstrated biocompatibility of the nanomaterials suggests their safe interaction with living cells. This aspect is crucial for their integration into biomedical devices, drug delivery systems, or therapeutic interventions.

Future prospects and challenges

While the results are promising, challenges such as scalability, long-term stability, and potential in vivo toxicity need to be addressed. Further studies are warranted to explore the in vivo behaviour and therapeutic potential of these nanomaterials [11-13].

Conclusion

The synthesis and characterization of super paramagnetic and antimicrobial Ce/NiO nanomaterials through a biogenic approach have yielded promising results with profound implications for biomedical applications. This study's findings underscore the potential of biosynthesis in harnessing nanotechnology for sustainable healthcare solutions. The successful fabrication of nanocomposites with dual functionalities—superparamagnetism and antimicrobial activity—positions these materials as versatile candidates for innovative biomedical tools.

The biosynthesis process, utilizing biogenic agents, not only offers an eco-friendly alternative to conventional synthesis methods but also imparts biocompatibility to the resulting nanomaterials. This unique combination makes the Ce/NiO nanocomposites attractive for integration into various biomedical applications, spanning targeted drug delivery, hyperthermia therapy, and infection control.

The super paramagnetic behaviors of the nanomaterials holds immense promise for precise manipulation in external magnetic fields, enabling the development of localized drug delivery systems and hyperthermia therapies. The potent antimicrobial activity demonstrated against a range of microorganisms presents opportunities for infection control strategies, wound healing, and combating antimicrobial resistance.

The biocompatibility of the nanomaterials, validated through cell viability assays and microscopy, positions them for seamless integration into biological systems without adverse effects. This attribute is crucial for their translation into clinical settings, where compatibility with living tissues is paramount.

Acknowledgement

None

Conflict of Interest

None

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