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Comparative investigation on the structural, optical, magnetic and photocatalytic properties of Dy doped bismuth ferrite nanoparticles prepared by hydrothermal and sol-gel methods

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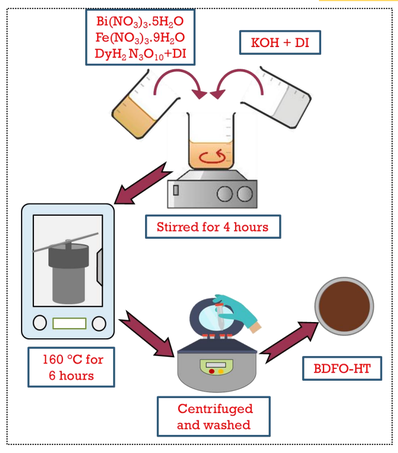
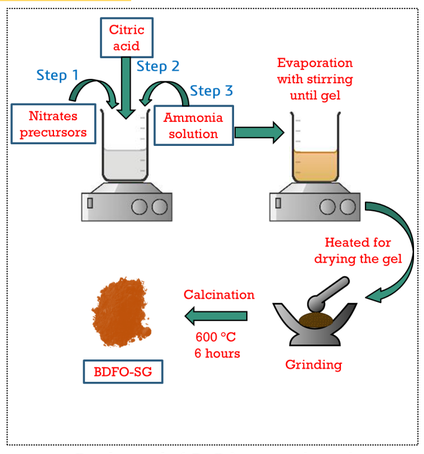
Objective

- The structural, morphological, optical and magnetic properties of bismuth ferrite nanoparticles comprehensively depend on the synthesis routes.
- Here, 10% Dy doped bismuth ferrite was synthesized adopting hydrothermal and sol-gel techniques denoted as BDFO-HT and BDFO-SG, respectively.
- The comparative analysis of the structural, morphological, optical, magnetic and photocatalytic properties were conducted extensively.
- Based on such investigation, an appropriate method can be adopted to fabricate rare-earth doped bismuth ferrite nanoparticles of desired properties for different technological applications.

Synthesis

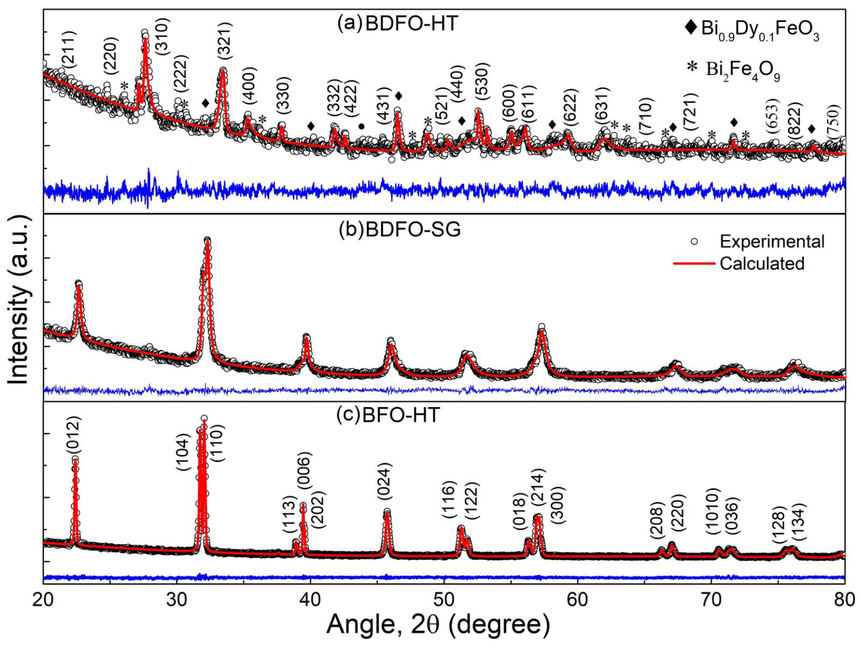


Hydrothermal (HT) technique

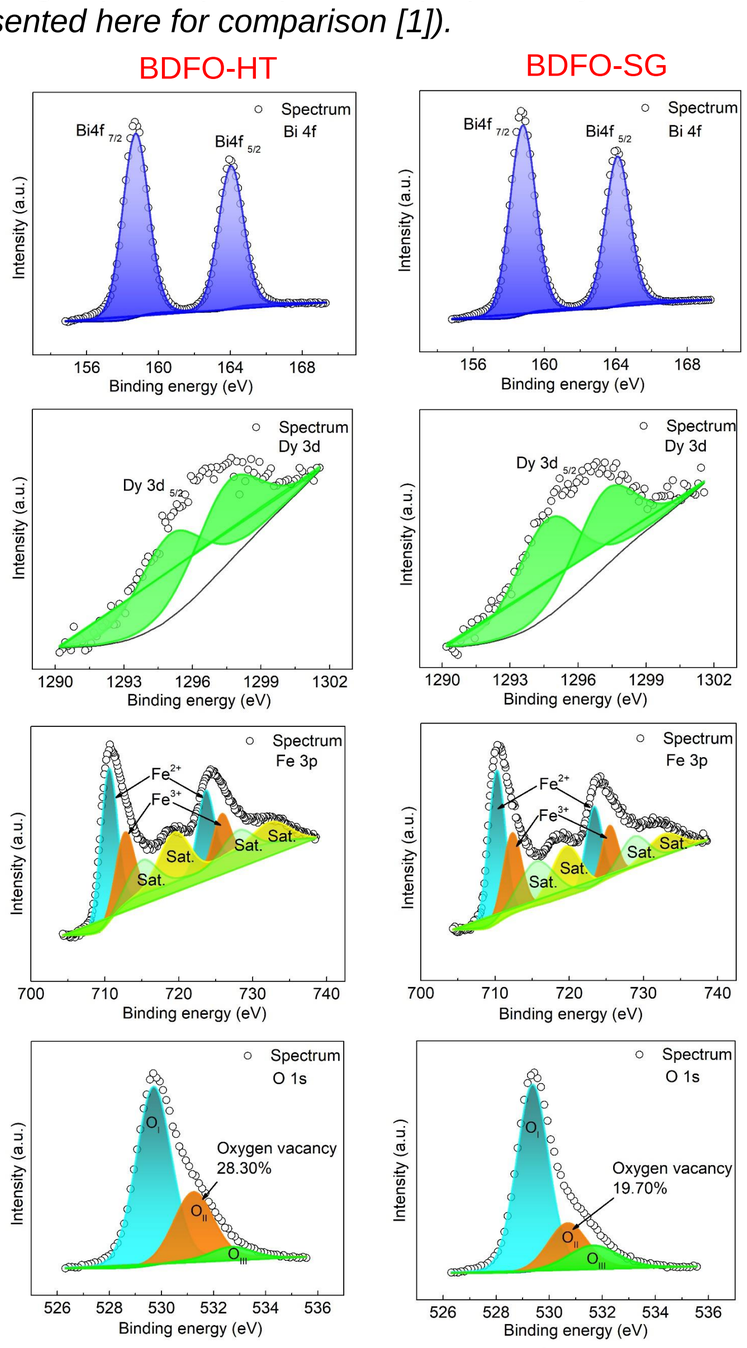


Sol-gel (SG) method

XRD and XPS analyses

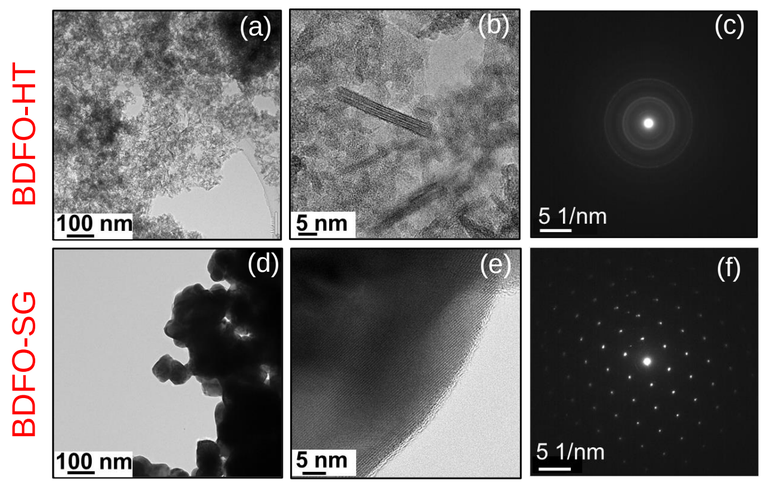


- *XRD patterns of BDFO-HT revealed the presence of mixed sillenite ($Bi_{25}FeO_{40}$, $Bi_2Fe_4O_9$) and perovskite ($BiFeO_3$) phases.*
- *The BDFO-SG had rhombohedral perovskite structure with space group R3c (undoped BFO prepared by HT method is presented here for comparison [1]).*



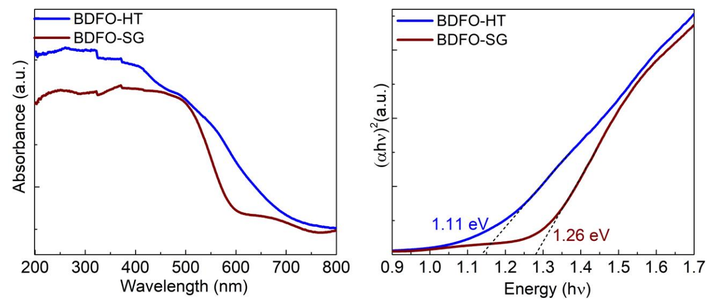
- *During SG synthesis the formation of Fe^{2+} was restrained, leading to the reduction of the oxygen vacancy in BDFO-SG.*

Morphological properties



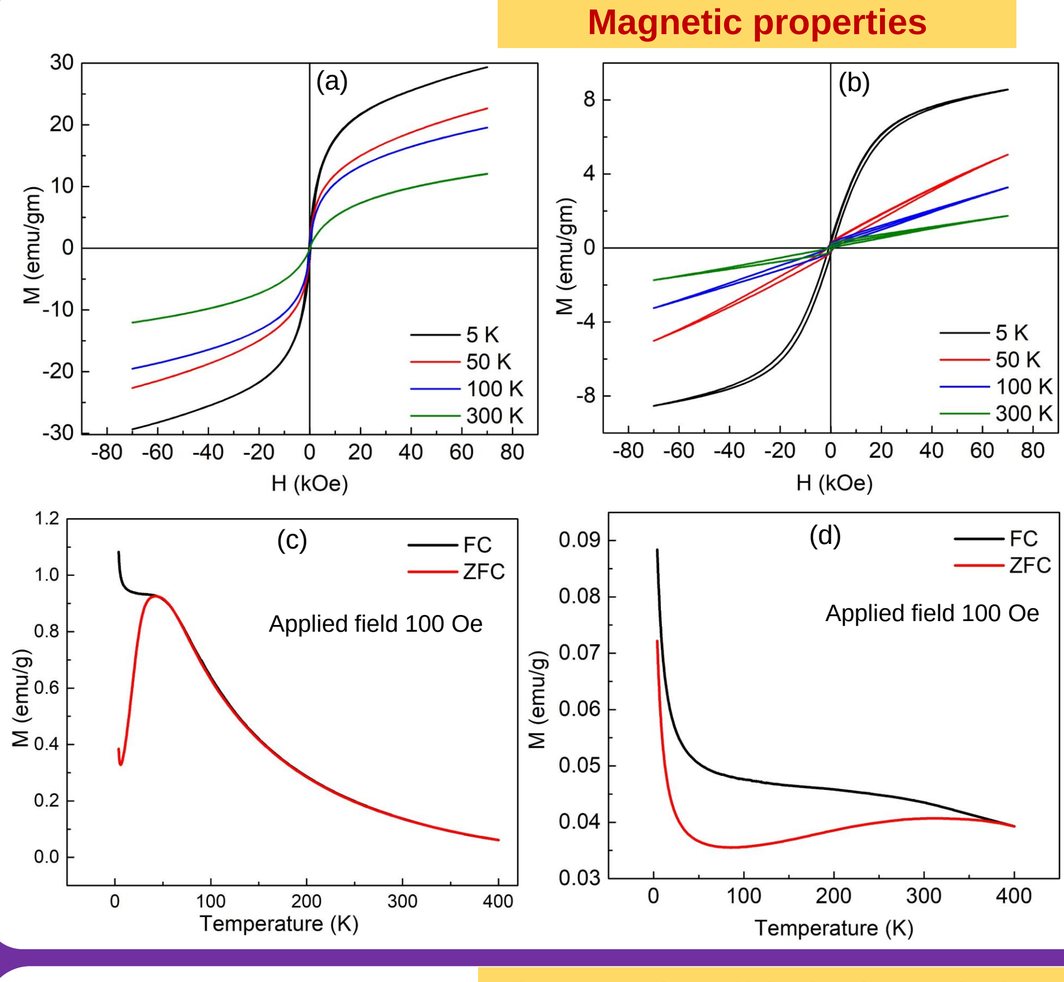
- *BDFO-HT demonstrated both nanopowder and nanorod like morphology (Fig. a, b).*
- *The size of BDFO-SG nanoparticles was around 70-80 nm (Fig. d).*

Optical properties



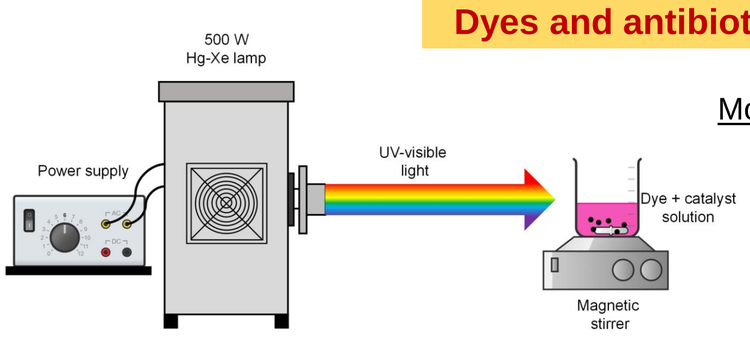
- *Compared to BDFO-SG, BDFO-HT samples demonstrated strong and broad UV-vis. absorption.*
- *The optical band gap of BDFO-SG sample was ~1.26 eV, while a reduction in band gap was observed for BDFO-HT.*

Magnetic properties



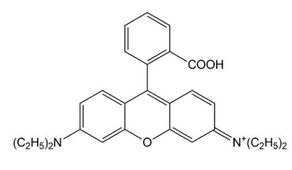
- *M-H curves of BDFO-HT (Fig. a) showed superparamagnetic nature, whereas BDFO-SG (Fig. b) demonstrated weak ferromagnetic nature in the antiferromagnetic domain.*
- *M-T curve of BDFO-HT (Fig. c) exhibited magnetic transition in the low temperature region. However, BDFO-SG demonstrated weak ferromagnetic nature in the antiferromagnetic background (Fig. d).*
- *Two BDFO samples prepared by two different routes showed completely different magnetic behavior.*

Dyes and antibiotic degradation

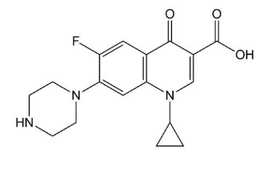


Schematically, a photocatalytic reactor setup for the pollutant degradation experiments [3]

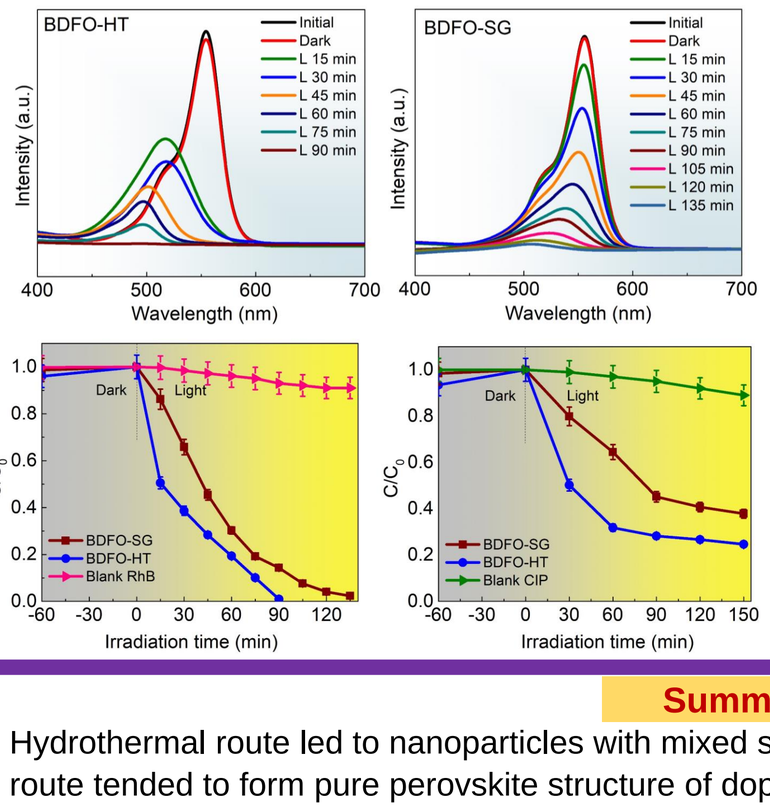
Molecular structure of pollutants under investigation:



RhB dye

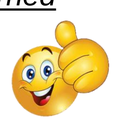


Antibiotic CIP



- *For BDFO-HT photocatalyst N-deethylation was the main pathway for the degradation of RhB within 90 min of solar irradiation.*
- *In contrast, for BDFO-SG the RhB degradation was completed within 135 min, mainly by the cleavage of the conjugated chromophore structure.*
- *BDFO-HT demonstrated superior degradation efficiency towards RhB and CIP degradation compared to BDFO-SG.*

Colored polluted water turned into clear water after degradation



Summary

- Hydrothermal route led to nanoparticles with mixed sillenite and perovskite structure but the sol-gel route tended to form pure perovskite structure of doped bismuth ferrite.
- Compared to the BDFO-HT samples, the BDFO-SG samples showed the presence of fewer oxygen vacant sites.
- A sharp magnetic transition was observed only in the BDFO materials prepared by hydrothermal technique.
- The BDFO-HT samples, due to its nanopowder like morphology and smaller band gap compared to BDFO-SG samples, showed better photocatalytic performance.
- The outcomes demonstrated a notable influence of the synthesis routes on the physical and magnetic properties of the synthesized nanoparticles.

References

1. Sharmin, Fahmida, et al., *Journal of Alloys and Compounds,* 901: 2022; 16364; 2. Sakar, Mohan, et al., *Nanoscale*, 11(48): 2019; 23503;
3. Sharmin, Fahmida, et al., *International Journal of Hydrogen Energy,* 46 (77): 2021; 38232-38246.