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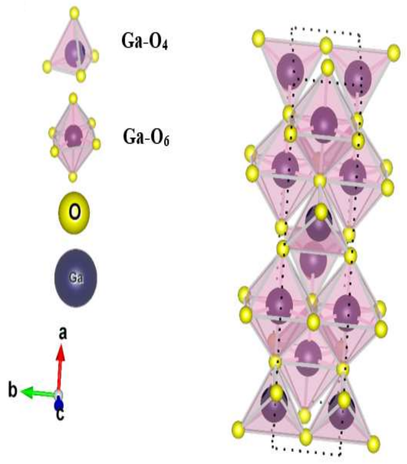
Strain and Defect – Engineered Modulation of Structural, Optical, and Magnetic Properties in Ho^{3+} Doped β-Ga_2O_3 Nanoparticles

Abhishek Sharma[1], Vir Singh Rangra[1]
[1]Himachal Pradesh University
Shimla India -171005

INTRODUCTION & AIM

- ✓ β-Ga_2O_3 is an ultra-wide bandgap semiconductor (~4.8 eV) known for its exceptional thermal and chemical stability.
- ✓ To date, the effects of holmium (Ho) doping in beta-gallium oxide (β−Ga_2O_3) have not yet been investigated.
- ✓ Doping with Ho^{3+}- ions, which possess a larger ionic radius and rich 4f electronic states, introduces controlled lattice strain and defect states, enabling the modulation of structural, optical, and magnetic properties.
- ✓ This defect-engineering strategy tailors material functionalities, making Ho^{3+}-doped β-Ga_2O_3 a promising multifunctional material.



METHOD

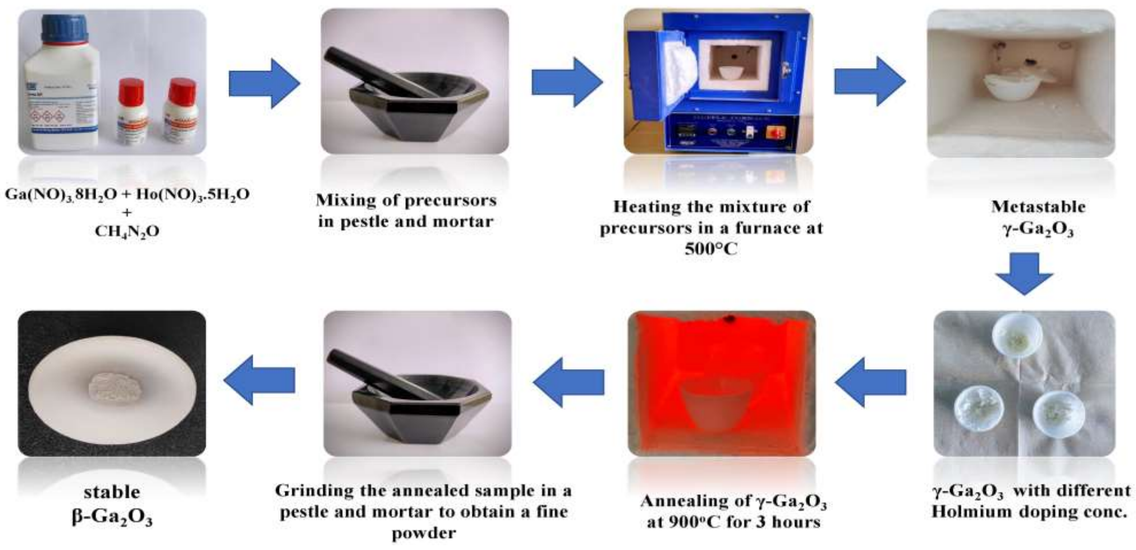


Table 1: Structural parameters of Holmium doped β−Ga_2O_3 samples

Samples	β − GOH-1	β − GOH − 2	β − GOH − 3
2θ (deg)	31.71	31.75	31.75
FWHM β (deg)	0.3824	0.3038	0.2955
W-H Size DW−H	9.65	11.49	11.73
DW−H Dislocation Density (δ × 10^{-3} (nm^{-2})	10.738	7.574	7.267
Strain (ϵ × 10^{-3})	-2.94	2.52	-2.41

CONCLUSION

- ✓ The crystallite size exhibits a non-uniform trend, initially decreasing at 1 % Ho doping and then partially recovering at higher concentrations.
- ✓ Williamson–Hall analysis reveals the presence of compressive lattice strain, which progressively relaxes with increasing Ho concentration.
- ✓ UV–Vis absorption analysis shows a systematic blue shift in the absorption edge, indicating an increase in the optical bandgap energy upon Ho incorporation.
- ✓ Photoluminescence spectra display pronounced quenching of emission intensity, suggesting the activation of non-radiative recombination channels with increasing Ho content.
- ✓ Magnetic measurements show that pure β-Ga_2O_3 exhibits diamagnetic behavior, whereas Ho-doped samples display progressively stronger paramagnetic responses with increasing Ho concentration, without showing any magnetic hysteresis.

ACKNOWLEDGEMENT

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FUTURE WORK / REFERENCES

For future study, we can investigate the upconversion in our holmium-doped sample by exciting it with a near-infrared laser and analyzing the subsequent higher-energy visible light emission.

❑ **Sharma, Abhishek, and Vir Singh Rangra. "Effect of gadolinium doping on the structural, morphological, vibrational, and optical properties of β−Ga_2O_3: a solid-state combustion approach." Ceramics International 51.13 (2025): 17583-17592.**

RESULTS & DISCUSSION

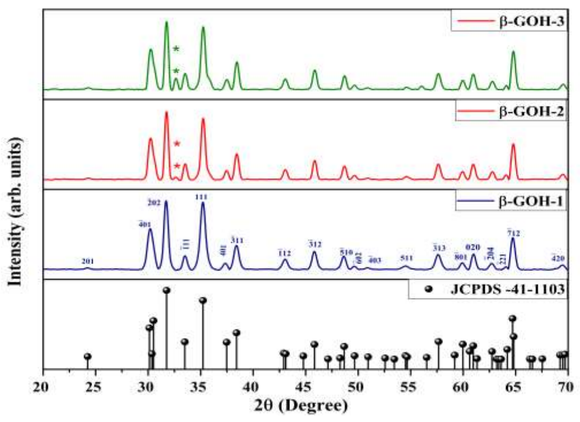

Fig.1 XRD spectra of Holmium doped samples at 1, 2 and 3 wt. %

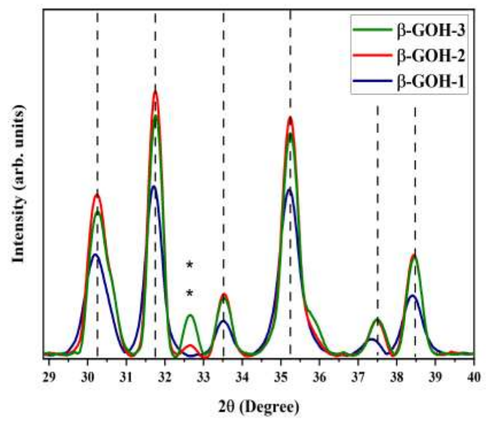

Fig2. Shifts in XRD peaks

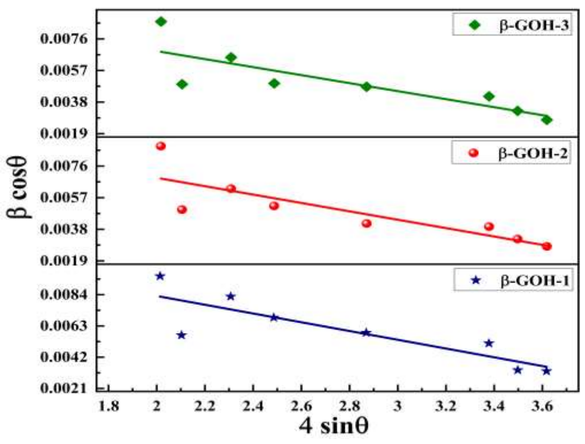

Fig.3 Williamson-Hall (W-H) plot

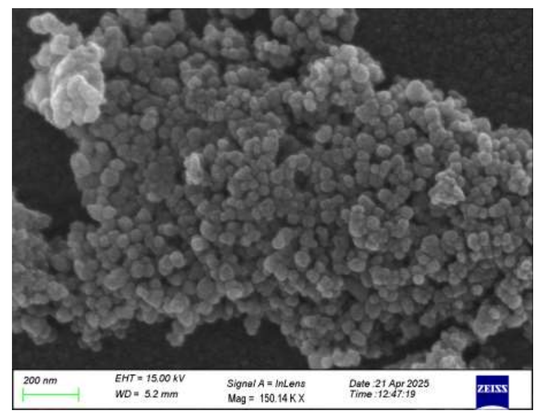

Fig4. FESEM micrograph of Holmium doped samples at 1% wt.% concentration

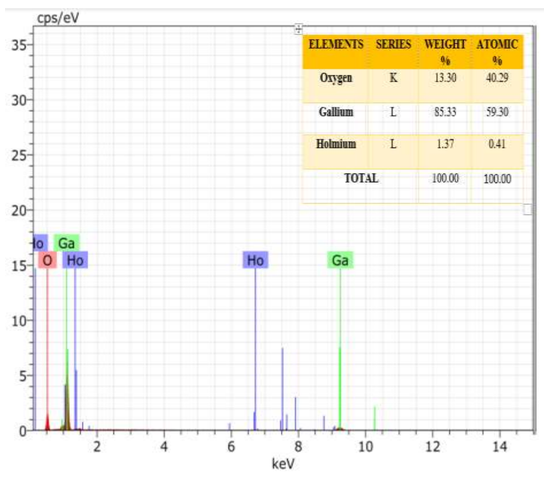

Fig.5 Holmium doped samples at 1% wt.% concentration

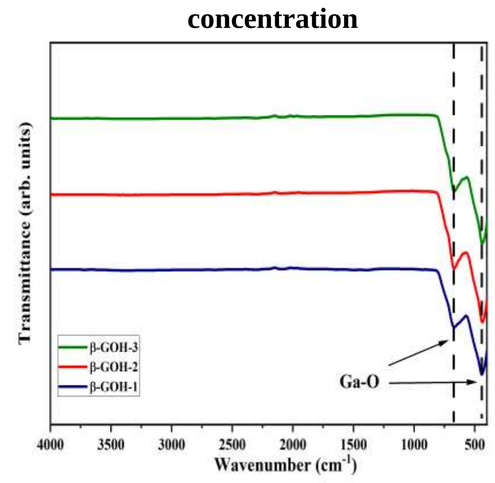

Fig. 6 FTIR Spectra

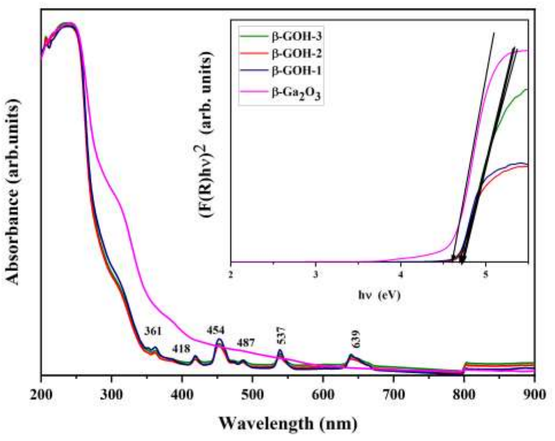

Fig8. Absorbance Spectra of pure and Holmium doped samples

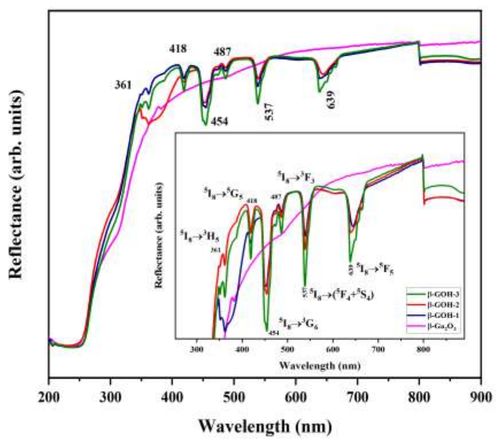

Fig9. Reflectance Spectra

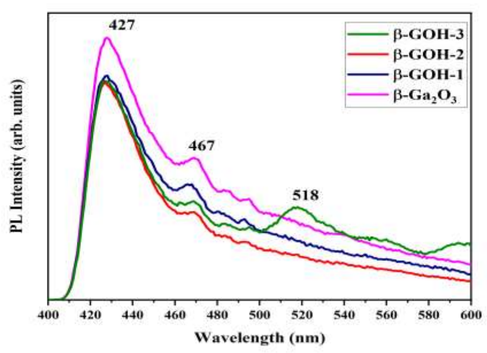

Fig9. PL Spectra of pure and Holmium doped samples

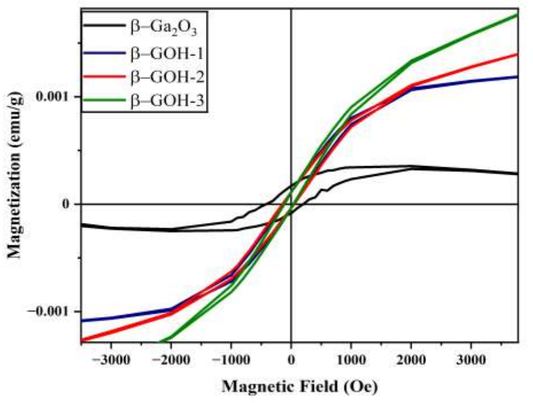

Fig10. Magnetic Hysteresis(M-H) loop of pure and Holmium doped samples