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Growth of Cobalt Doped β-Ga_2O_3 Crystal for Saturable Absorber Application

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Presented by :-

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Gallium Oxide

- Ga_2O_3 is a group III transparent semiconducting oxide.
- It has wide bandgap of approximately 4.8 eV.
- Exhibits polymorphism.
- It has five polymorphs $\alpha, \beta, \gamma, \delta$ and ε.
- β-Ga_2O_3 is the only stable polymorph.
- It has monoclinic crystal structure.

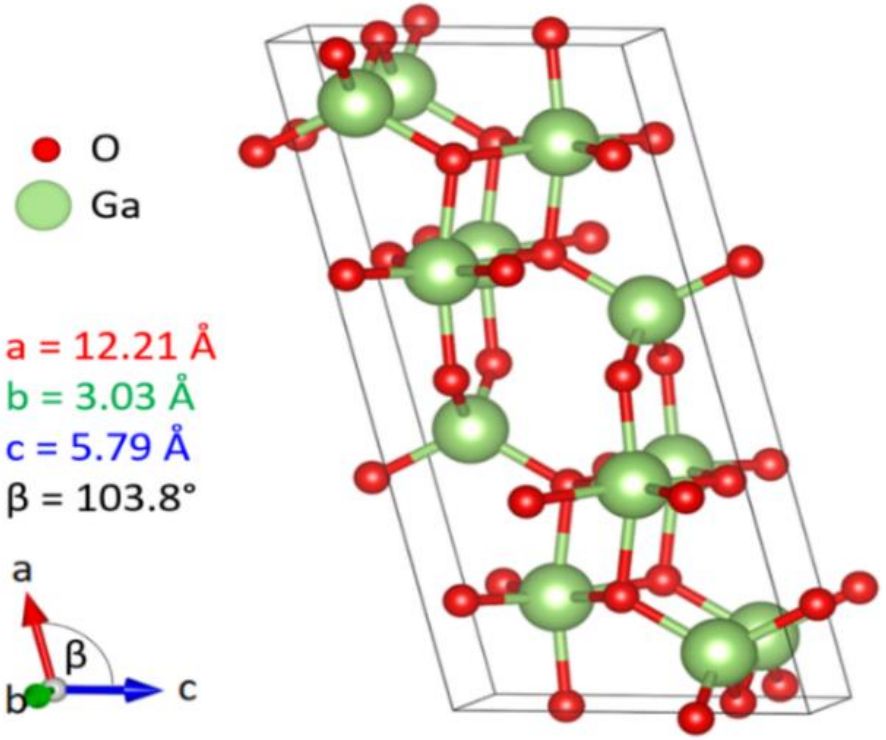


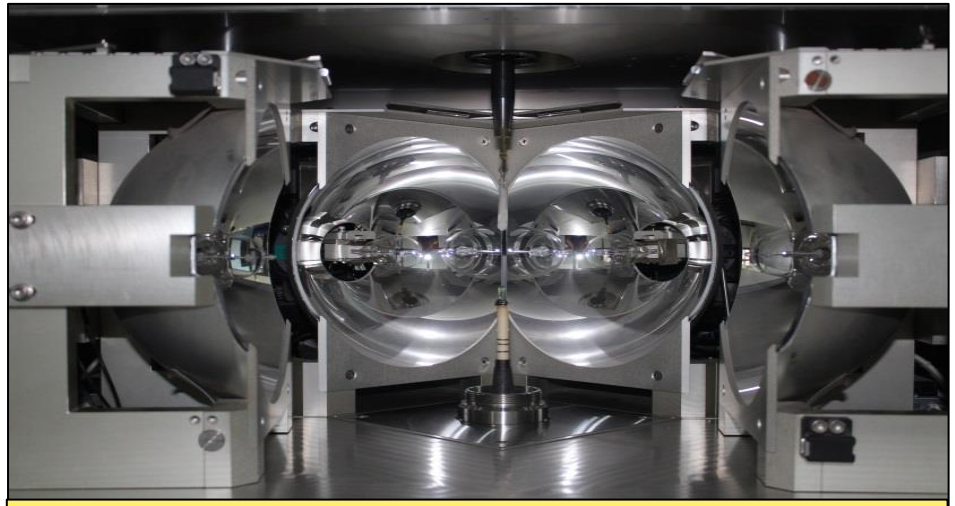
Figure: Crystal structure of β-Ga_2O_3

Source: https://www.fv-berlin.de/en/research/research-highlight/galliumoxid-der-neue-stern-am-halbleiterhimmel0

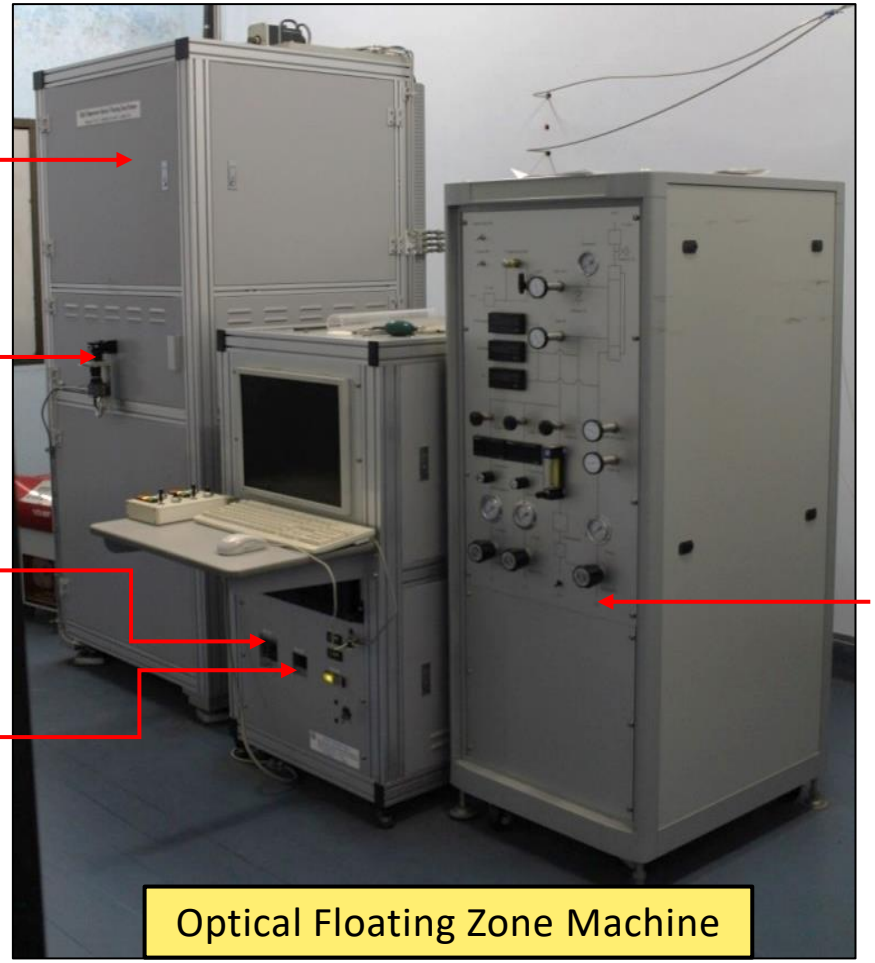
Optical Floating Zone method

- Eliminates the use of crucible.
- Ease to growth and high efficiency
- Metal oxides with high melting point.

It is based on the principle of heating of a material using light.



Assembled feed rod and seed rod inside the OFZ machine

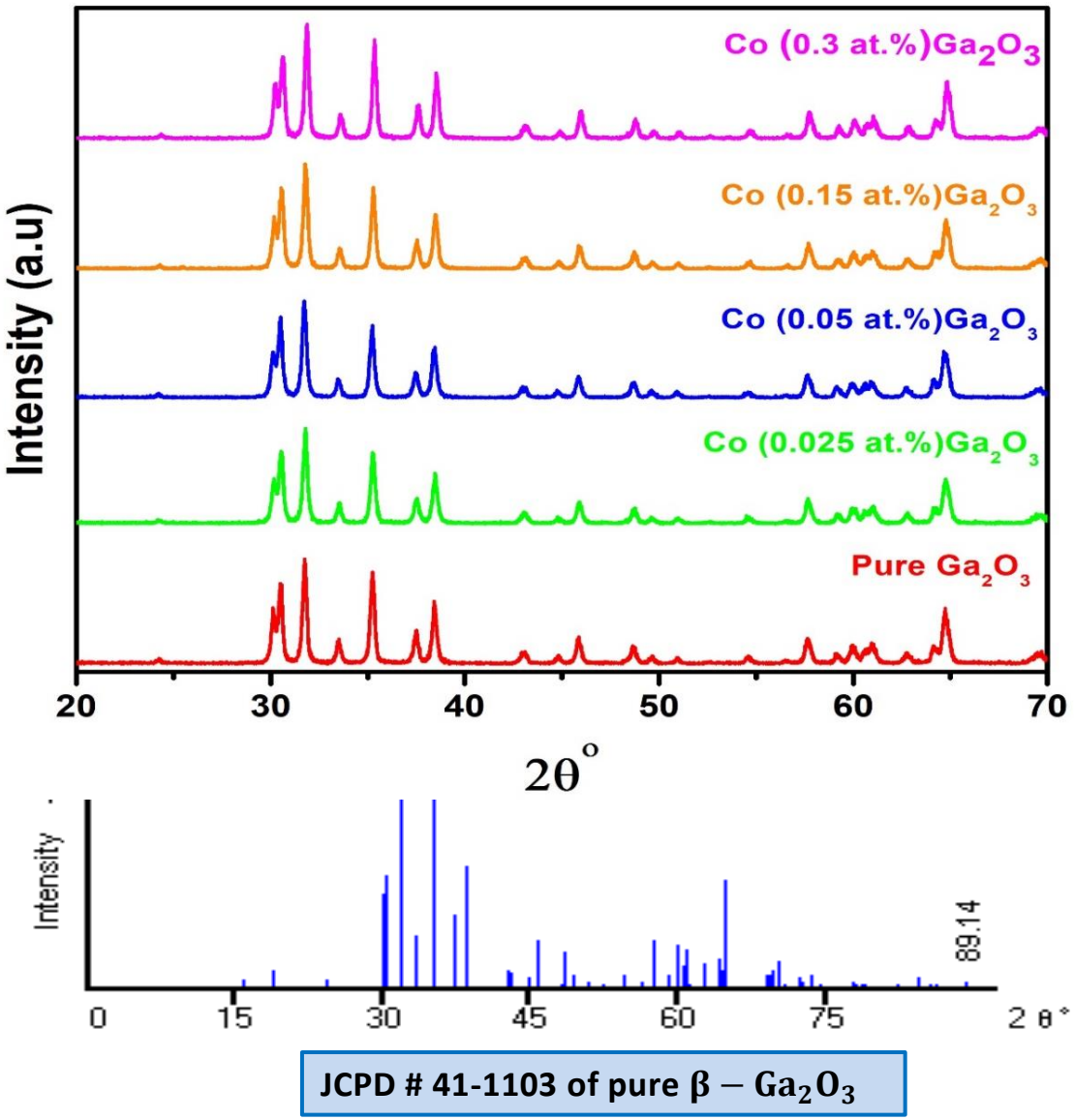


Optical Floating Zone Machine

Laser & Functional Material Division (LFMD) at RRCAT, Indore, (M.P.)

Feed rod and seed rod

Powder XRD of synthesized charge



JCPD # 41-1103 of pure $\beta - Ga_2O_3$

The absence of any additional peak confirms that there is no formation of any secondary phase.

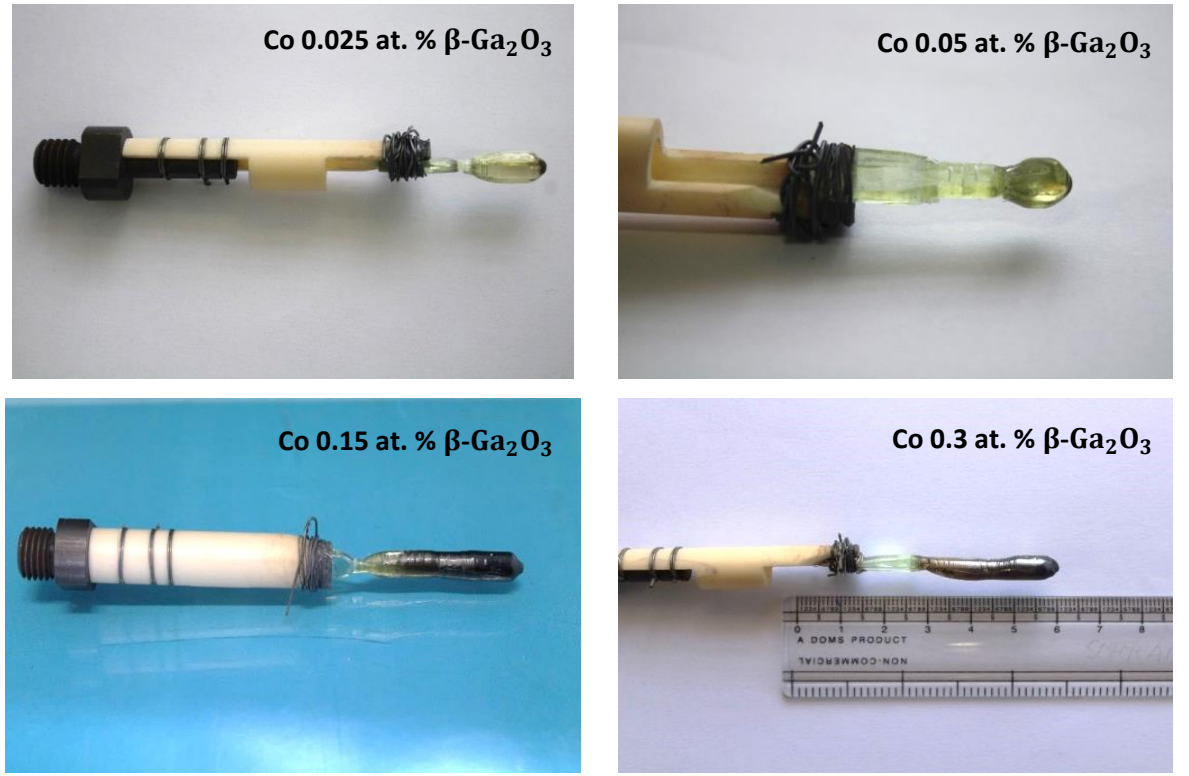


Figure: As grown β-Ga_2O_3 crystals of different doping concentration

Absorption spectra of Co: β-Ga_2O_3 crystals

- The observed absorption band has a special interest for the potential use as a saturable absorber to obtain self Q-switching for the infrared lasers operating in the range of 1 to 1.6 µm.

- Bandgap of Co doped β - Ga_2O_3 were determined precisely from absorption coefficient data using the Tauc relation:

$$\alpha^{2n} = \alpha_0(h\vartheta - E_g)$$

Crystal	Indirect Bandgap	Direct Bandgap
Co (0.025 at. %) Ga_2O_3	3.58 eV	3.69 eV
Co (0.05 at. %) Ga_2O_3	3.56 eV	3.62 eV
Co (0.15 at. %) Ga_2O_3	3.40 eV	3.61 eV
Co (0.3 at. %) Ga_2O_3	3.48 eV	3.59 eV

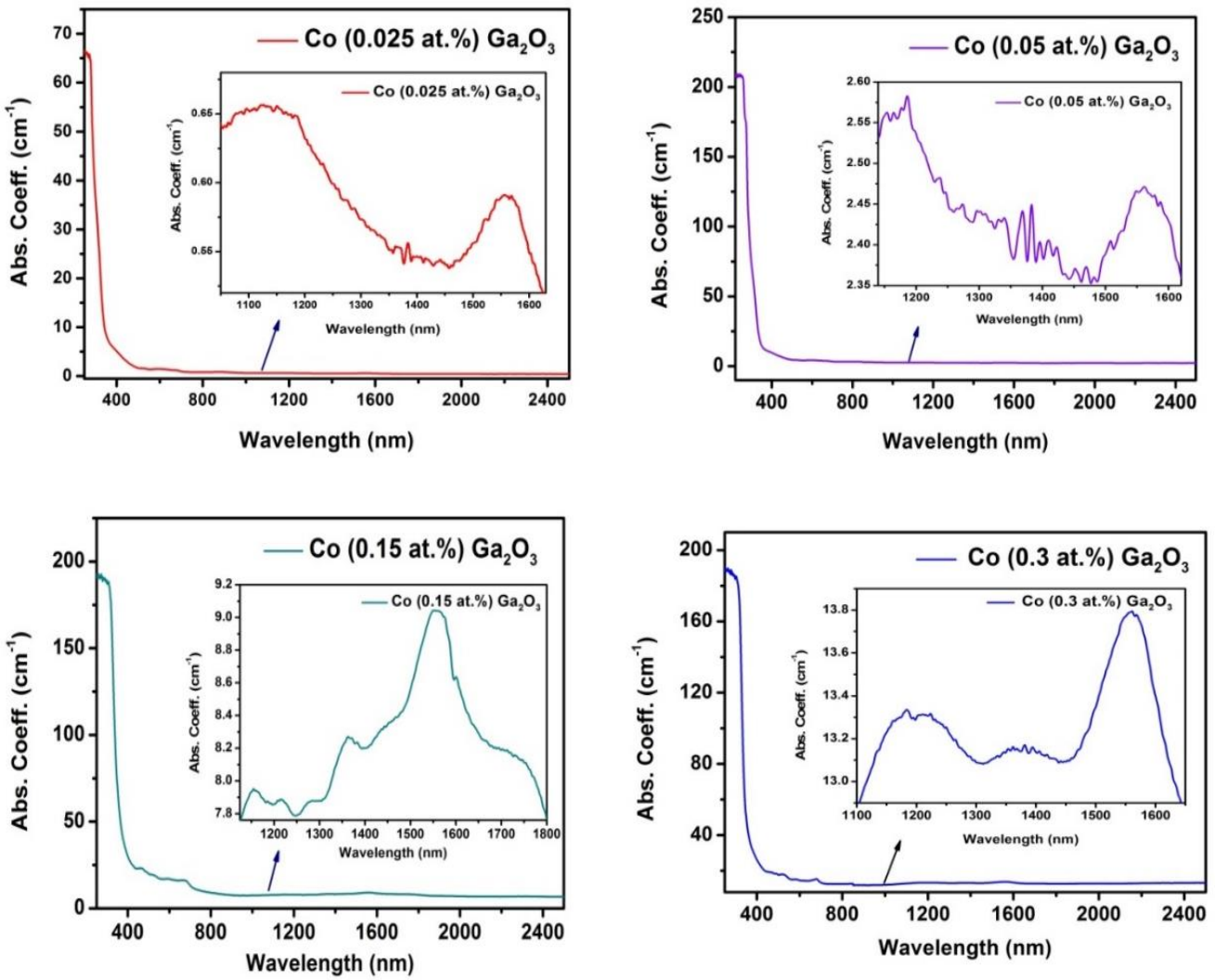


Figure: Absorption spectra of Co: β-Ga_2O_3 crystals

Urbach Energy

- Urbach energy tells about the structural defect present in the crystal lattice.
- It is calculated by plotting the graph between logarithm of absorption coefficient (ln α) and incident photon energy.
- It is inverse of the linearly fitted slope of the plotted graph.

Crystal	Urbach energy(E_u)
Co (0.025 at. %) Ga_2O_3	0.29213 eV
Co (0.05 at. %) Ga_2O_3	0.26151 eV
Co (0.15 at. %) Ga_2O_3	0.33975 eV
Co (0.3 at. %) Ga_2O_3	0.2357 eV

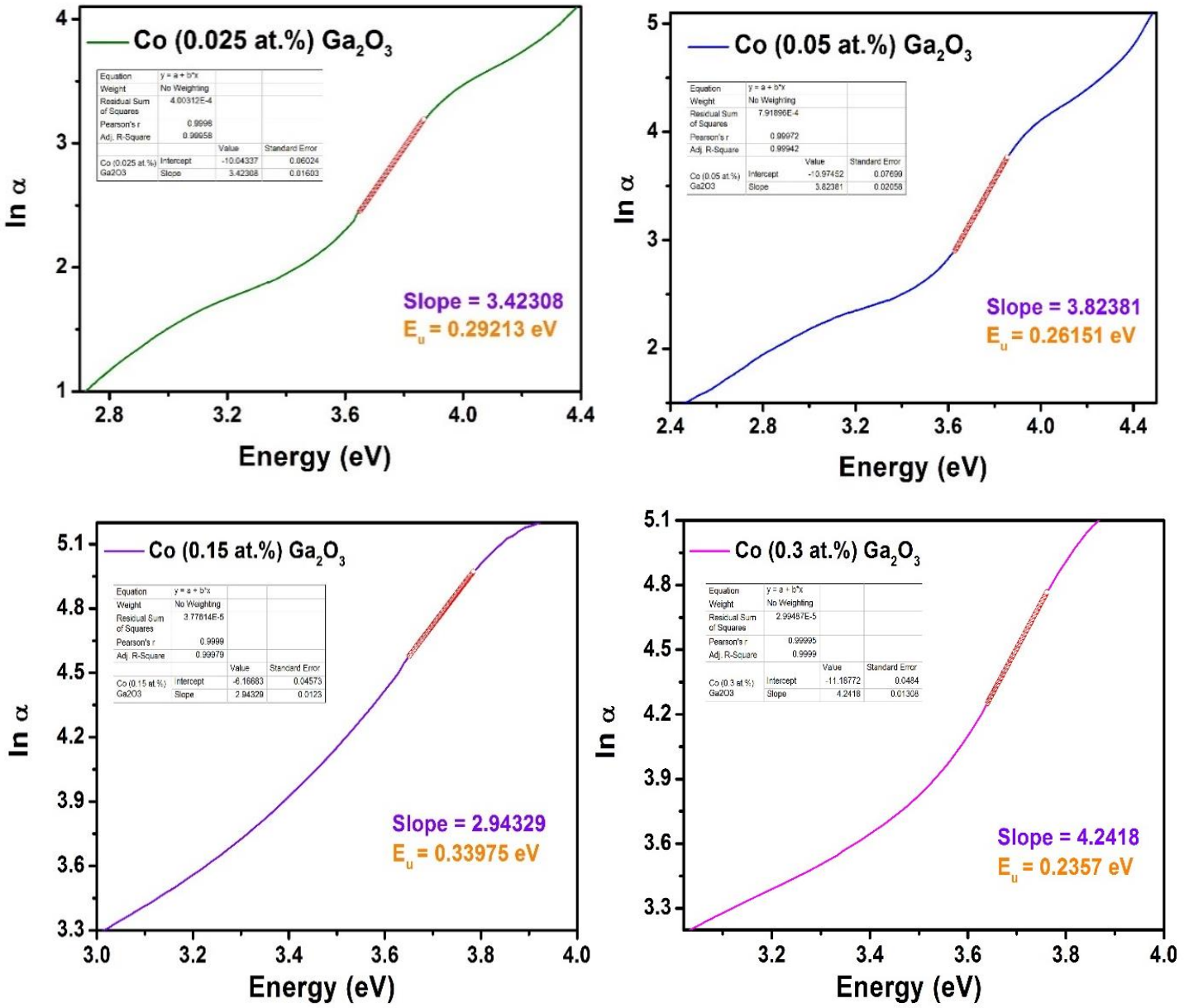


Figure: Urbach energy curve of Co: β-Ga_2O_3 crystals

Fourier Transform Infrared (FTIR) Spectroscopy

- FTIR Spectrometer records a broadband near infrared (NIR) to far infrared (FIR) spectra of the materials.
- FTIR spectroscopy detects absorption bands associated with lattice vibrations in the crystal.
- It allows identification of structural and molecular variations, and functional groups present in the sample.

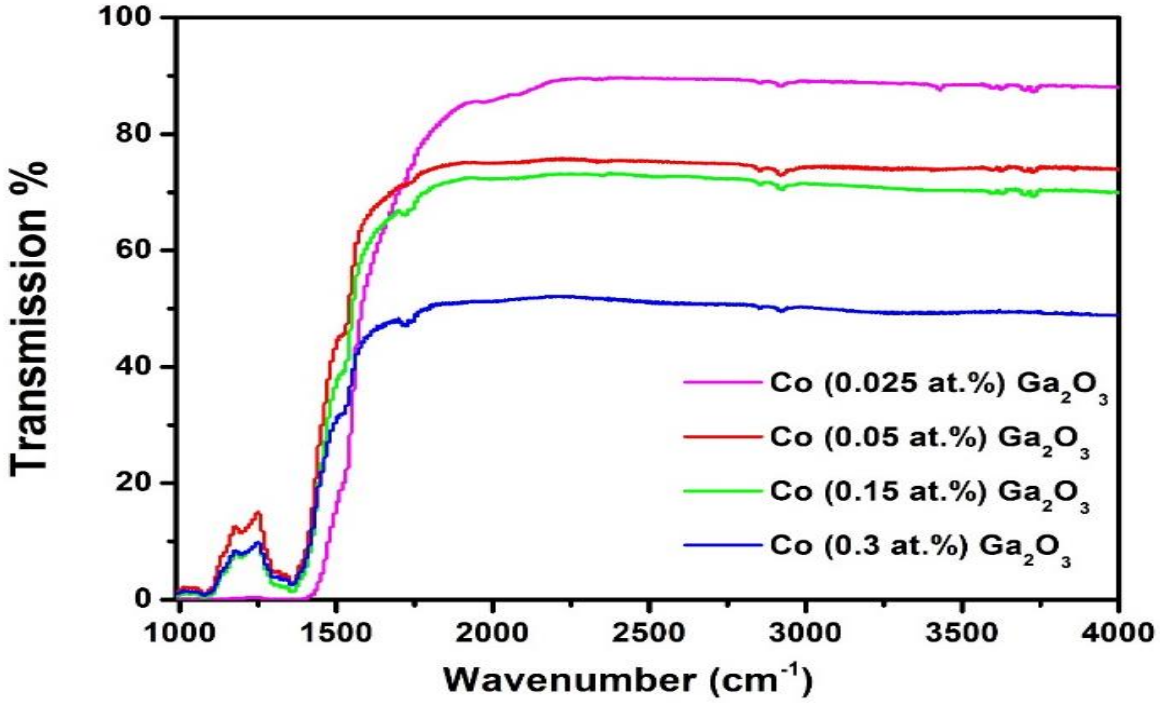


Figure: FTIR spectra of Co: β-Ga_2O_3 crystals

Conclusion

This work highlights the growth, structural and optical properties of Co doped β-Ga_2O_3 single crystal for its potential application as saturable absorber for passive Q-switching for the infra-red lasers operating in the range of 1 to 1.6 µm. Detailed investigation of effect of cobalt doping on gallium oxide with different doping concentration on various optical properties have been reported. A broad absorption band around 950-1700 nm due to Co doping was observed and can be used as saturable absorber for self Q-switching. Both undoped and Co-doped β-Ga_2O_3 crystal exhibit an indirect bandgap energy, however the bandgap energy of the Co-doped β-Ga_2O_3 crystal was found to be lower than that of undoped crystal grown under same conditions. It was also observed that with increasing Co concentration in the β-Ga_2O_3crystal the value of Urbach energy has increased, indicating the increase of defect state and disorder near the band edge.

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Thank-you

"The joy of success is incomplete without acknowledging the genuine efforts of people behind it"