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Electrospun Indium-doped Nanofibers Based on Gallium Oxide: Fabrication and Characterization

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INTRODUCTION & AIM

Despite the potential of fibrous semiconductors, data on materials like β-Ga_2O_3 nanofibers are limited. Their advantageous properties—wide bandgap, stability, and high surface area—make them promising for sensors and optoelectronics, but control over morphology and its effects is poorly understood.
This study aimed to fabricate undoped and In-doped Ga_2O_3 nanofibers by electrospinning to study their key characteristics.

METHOD

Electrospinning parameters were optimized to ensure stable jet formation, with systematic variation of gallium precursor concentration and solution composition. High-molecular-weight PVP (K-90, 1.5 MDa) was used as the polymer matrix; $Ga(NO_3)_3 \cdot 8H_2O$ and $In(NO_3)_3 \cdot 4.5H_2O$ served as precursors. Polymer content was 5–10 wt%, gallium 0.5–6 wt%, and indium 5, 10 wt% relative to gallium. Solutions were prepared in a 1:1 water–ethanol mixture and stirred at room temperature until homogeneous.
Electrospinning was performed at 25 ± 1 °C and 30 ± 1% RH for 40 min, followed by brief drying and 48 h conditioning. Fibers were annealed at 900 °C for 240 min (heating rate: 5 °C/min) to ensure complete polymer removal and β-Ga_2O_3 phase formation.
Morphology was analyzed using SEM. Elemental composition was assessed by EDS. Optical properties were analyzed by diffuse reflectance spectroscopy using the Tauc–plot method to estimate bandgap energy.

RESULTS & DISCUSSION

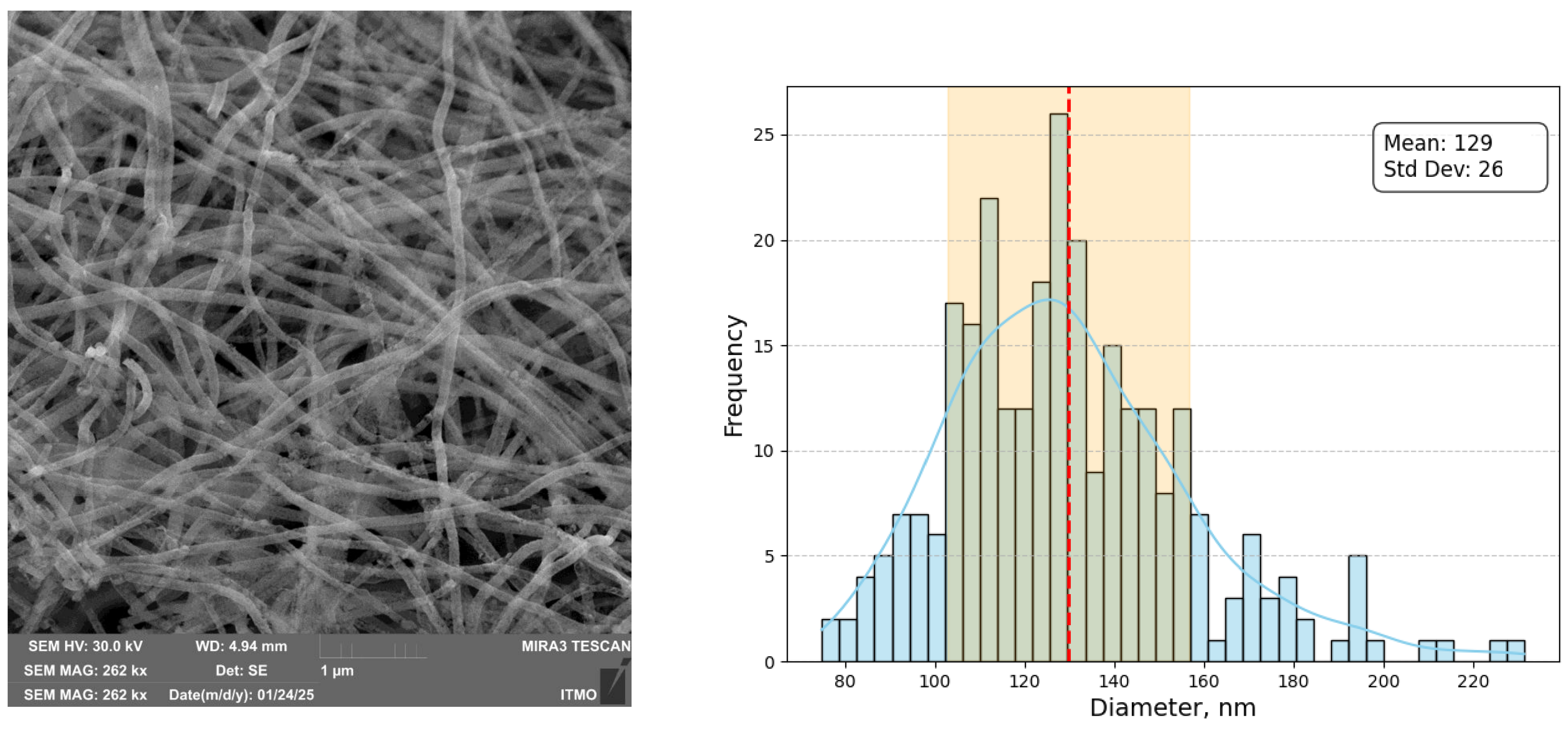

Figure 1. SEM image and diameter distribution histogram of annealed nanofibers electrospun from polymer solution with 2 wt.% Ga. The average diameter is 129 ± 26 nm.

Key findings revealed that a gallium precursor concentration of 2 wt% in the PVP solution yielded stable electrospinning and, post-annealing at 900 °C, nanofibers with an average diameter of 129 ± 26 nm.

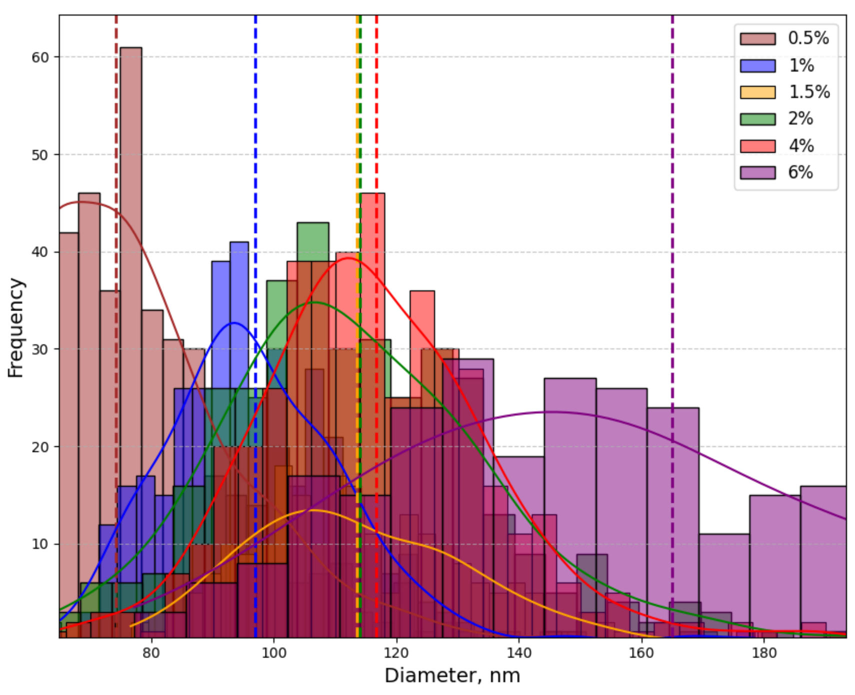

Figure 2. Diameter distribution histograms of the annealed Ga_2O_3-based nanofibers.

Lower precursor levels (0.5–2 wt%) produced finer fibers (74–129 nm) with narrower size distributions, indicative of enhanced uniformity, whereas higher concentrations (4–6 wt%) resulted in diameters of 100–132 nm with broader spreads. Compared to pre-annealed polymeric fibers (270–316 nm), annealing consistently reduced diameters due to polymer pyrolysis and oxide consolidation.

EDS confirmed near-stoichiometric Ga_2O_3 composition (O: 60 at%, Ga: 38.9 at%) with uniform elemental distribution across the fiber surfaces.

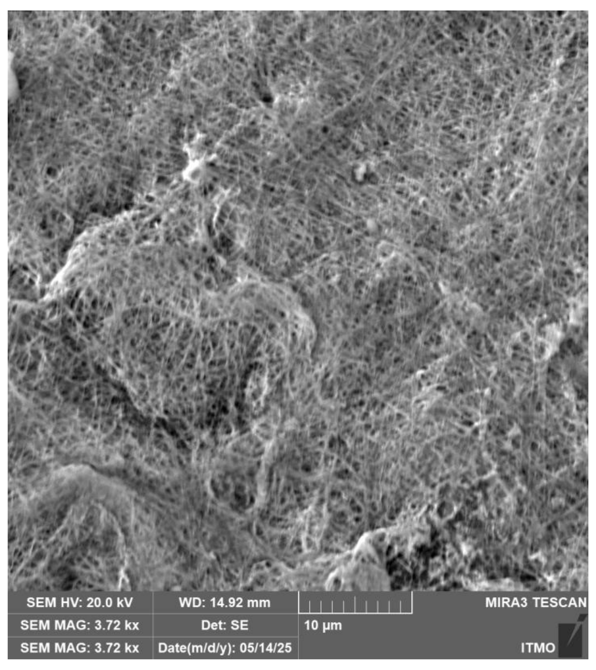

Figure 3. SEM images of electrospun Ga_2O_3 nanofibers doped with 10 wt.% In.

For indium-doped variants, electrospinning parameters were adjusted to a solution flow rate of 0.02 ml/min, maintaining other conditions. SEM images displayed homogeneous morphologies with diameters around 100–130 nm.

EDS spectra showed prominent Ga and O peaks with clear indium incorporation. Elemental mapping confirmed uniform elemental distribution, indicating successful homogeneous doping.

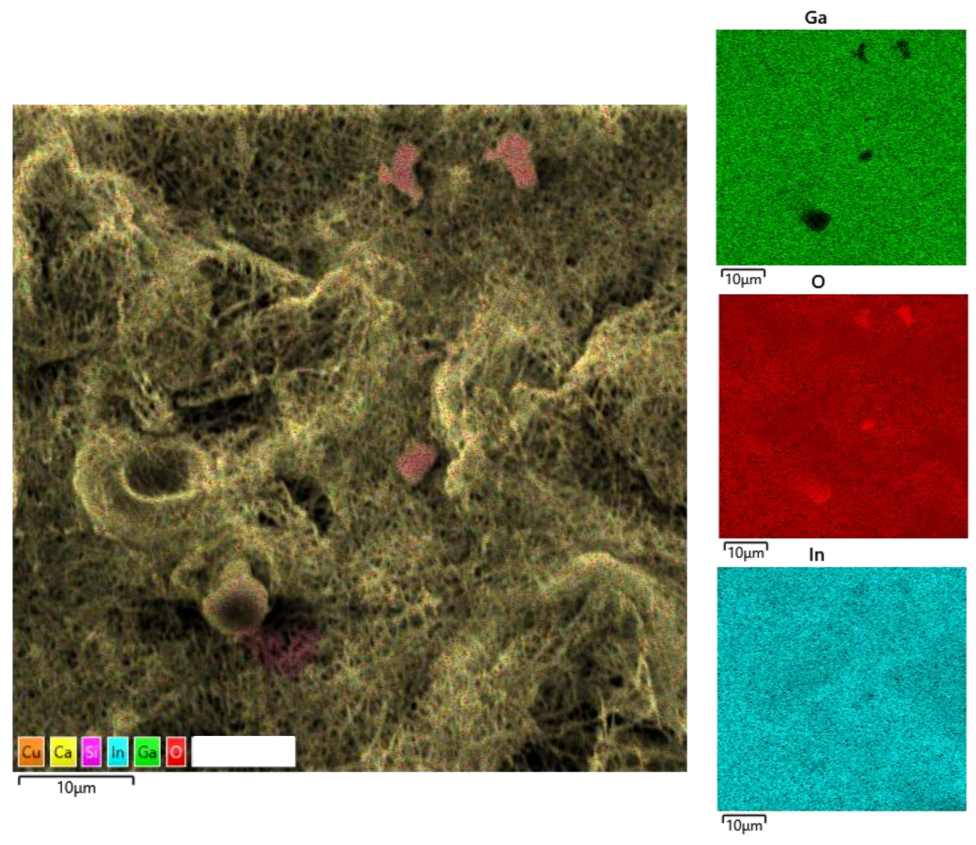

Figure 4. EDS elemental maps of Ga_2O_3 nanofibers doped with 10 wt% In.

Indium doping progressively narrowed the bandgap—from 4.82 eV (undoped) to 4.63 eV (5 wt% In) and 4.47 eV (10 wt% In), giving a total reduction of 0.35 eV at the higher concentration. This redshift, approximately 0.035 eV per wt% In, shifts the absorption edge toward the near-UV and visible region, which is advantageous for photocatalysis and photodetection.

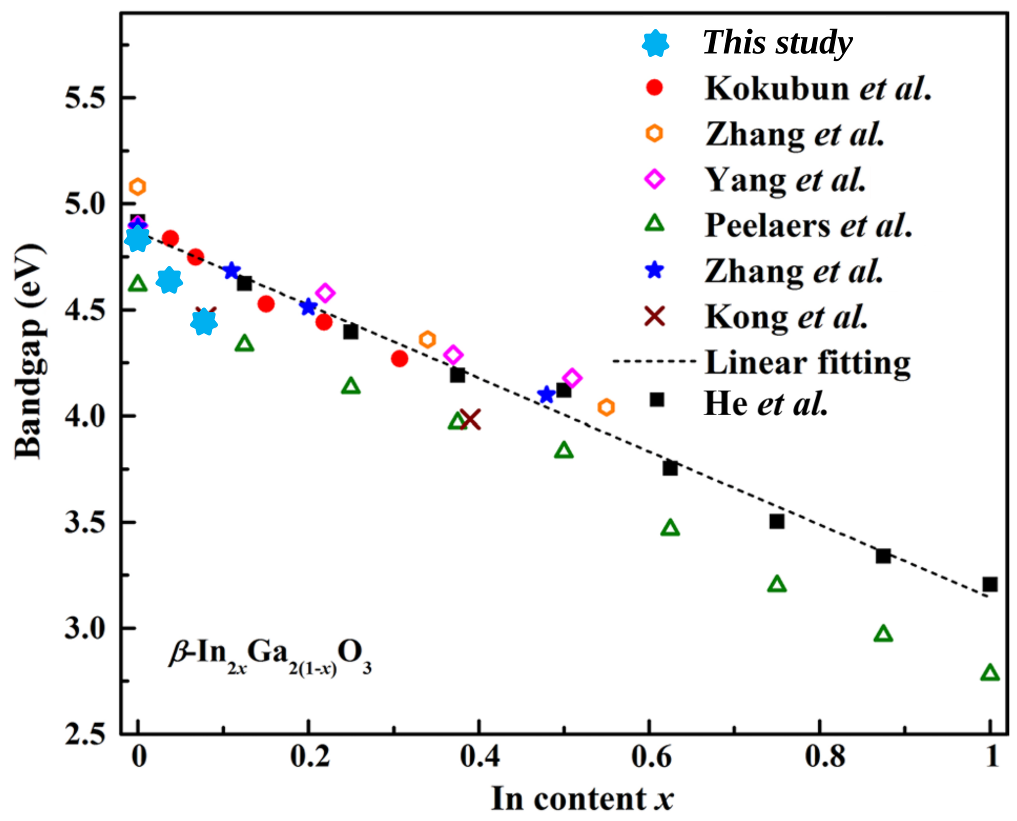

Figure 5[1]. Bandgap dependence on the indium content. Experimental data are represented by solid symbols, and numerical simulations – by open symbols.

Sample	Bandgap, eV
Ga_2O_3	4,82
Ga_2O_3 (In 5 wt.%)	4,63
Ga_2O_3 (In 10 wt.%)	4,47

Table 1. The effect of indium doping concentration on the optical bandgap of Ga_2O_3 nanofibers.

CONCLUSION

Optimal synthesis conditions (2 wt.% Ga, 900 °C) provided uniform and stoichiometric Ga_2O_3 nanofibers with enhanced conductivity and spectral response. After establishing these conditions, the fibers were doped with indium, which enabled effective tuning of the bandgap. Together, these findings advance the design of Ga_2O_3-based nanomaterials for optoelectronic and sensing devices.

ACKNOWLEDGEMENTS

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