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Analyzing the Thermal Behavior and Phase Transitions of $ZnSnO_3$ Prepared via Chemical Precipitation

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INTRODUCTION & AIM

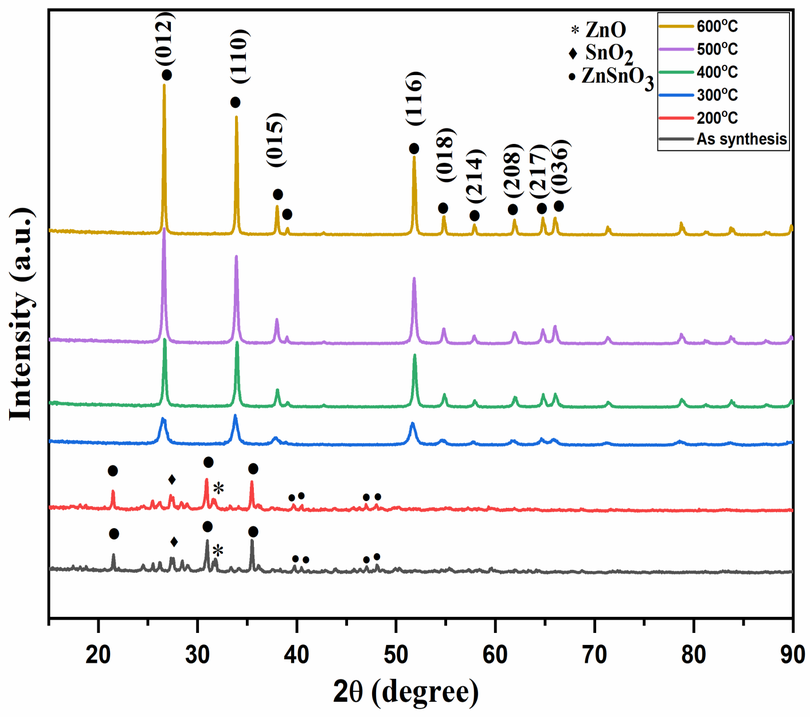
Zinc stannate ($ZnSnO_3$), also known as zinc tin oxide (ZTO), is especially noteworthy for its remarkable physical and chemical properties such as high electron mobility and excellent electrical conductivity [1,2].$ZnSnO_3$ is less extensively studied than its counterpart Zn_2SnO_4, primarily due to the latter's greater thermodynamic stability, which allows it to withstand a wider range of conditions without decomposition. In contrast, $ZnSnO_3$ is thermodynamically unstable at elevated temperatures, posing challenges in its synthesis and limiting its research focus. Nevertheless, $ZnSnO_3$ offers unique characteristics, including a wide bandgap of approximately 3.72 eV and high thermal stability. These attributes make it a promising candidate for optoelectronic, energy storage, and gas sensing applications [3]. This study synthesized $ZnSnO_3$ via the chemical precipitation method, with annealing at various temperatures (As-synthesis, 200°C to 600°C).

METHOD

$ZnSnO_3$ nanoparticles were synthesized using the chemical precipitation method, employing zinc chloride ($ZnCl_2$) and stannous chloride dihydrate ($SnCl_2 \cdot 2H_2O$) as precursor salts for the respective zinc and tin ions. A solution of the precursor salts was prepared by dissolving both in 50 mL of distilled water at a 1:1 molar ratio, which was stirred at room temperature until a clear solution was obtained. Concurrently, a surfactant solution of sodium hydroxide (NaOH) was prepared by dissolving it in 10 mL of distilled water at a ratio of 1:1. The NaOH solution was then added to the zinc and tin chloride solution and stirred vigorously for three hours at room temperature. Following the reaction, white precipitates were collected through filtration. The as-synthesized $ZnSnO_3$ nanoparticles were air-dried for 24 hours. Subsequently, the dried nanoparticles were calcined at varying temperatures (0°C, 200°C, 300°C, 400°C, 500°C, and 600°C) for three hours in an oven. The resultant products were then utilized for further characterization.

RESULTS & DISCUSSION

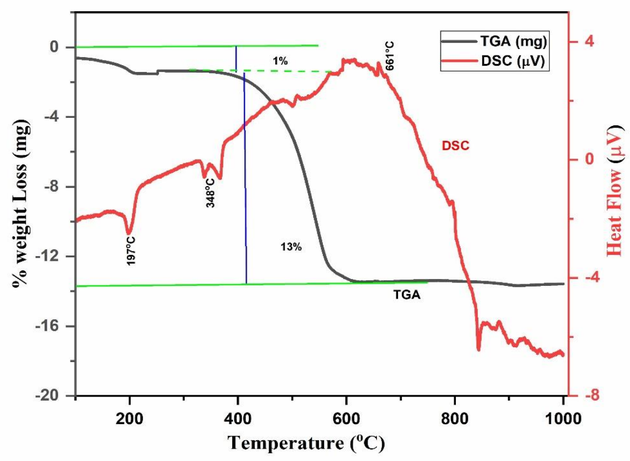
X-Ray diffraction:



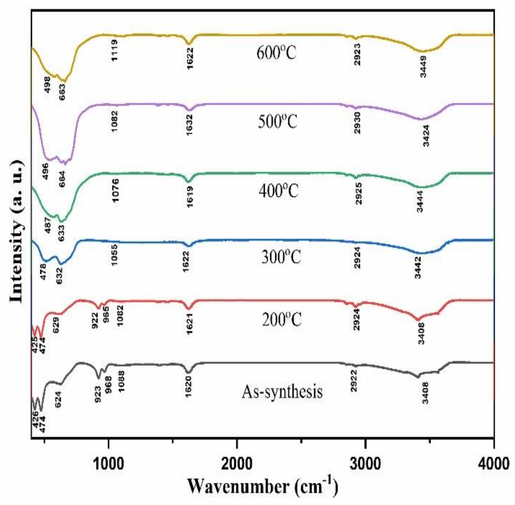
JCPDS card No : 28-1486
Crystal structure : Orthorhombic phase
Space group : Pnma

Temperature (°C)	Average Crystalites Size (nm)	Dislocation density $\delta \times 10^{-3}$ (nm^2)	Average microstrain $\varepsilon \times 10^{-3}$
As-synthesis	48.222	0.43004	2.75381
200°C	45.4542	0.48401	2.93693
300°C	12.778	6.12456	8.30086
400°C	29.2528	1.1686	3.49989
500°C	30.0335	1.10863	3.82756
600°C	43.1629	0.53676	2.38373

TGA-DSC:

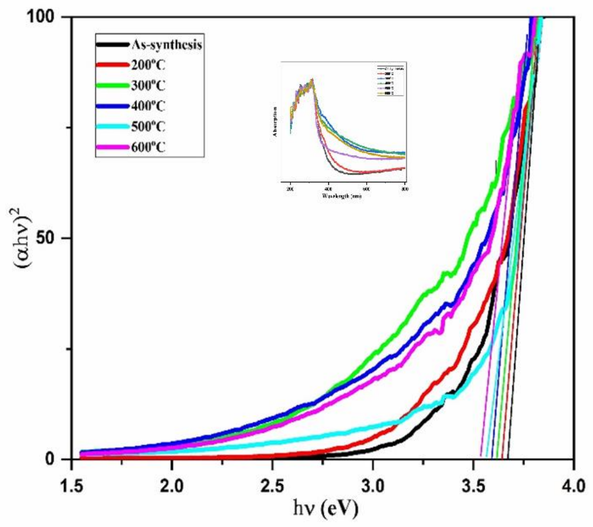


FT-IR Spectroscopy:



Transmittance band (cm^{-1})						Band assignment (Functional Group)
As-synthesis	200°C	300°C	400°C	500°C	600°C	
3408	3408	3442	3444	3424	3449	O-H stretching vibration
2922	2924	2924	2925	2930	2923	C-H stretching vibration
1620	1621	1622	1619	1632	1622	C=O stretching vibration
1110	1096	1055	1069	1082	1119	C-O bond vibration
474	474	478	487	496	498	O-Zn-O bending vibration
624	629	632	633	664	663	O-Sn-O stretching

UV-Vis spectroscopy:



Annealing temperature (°C)	Band gap energy (eV)
As-synthesis	3.67
200°C	3.64
300°C	3.62
400°C	3.59
500°C	3.57
600°C	3.53

CONCLUSION

The analysis of $ZnSnO_3$ confirms its structural integrity and thermal stability, as supported by JCPDS: 28-1486. The TGA-DSC analysis demonstrates that $ZnSn(OH)_6$ decomposes to $ZnSnO_3$ at temperatures above 348°C confirming the thermal stability and transformation of the precursor compound. FTIR spectroscopy successfully identified the relevant functional groups, enhancing the understanding of its chemical properties. UV-Vis spectroscopy revealed a band gap range of 3.67 eV to 3.54 eV with increasing temperature, indicating the impact of thermal variations on its electronic structure, which is significant for applications in electronics and photonics. In summary, $ZnSnO_3$ exhibits promising characteristics that adapt with thermal processing, making it a suitable candidate for applications in energy storage, photocatalysis, and gas sensing. The comprehensive understanding of its structural and optical properties paves the way for further exploration and development of $ZnSnO_3$ in advanced material applications, likely contributing to innovations in next-generation electronic and photonic devices.

FUTURE WORK / REFERENCES

[1] J. Mater. Sci.: Mater. Electron., 2023, 34, 215, DOI: 10.1007/ s10854-022-09600-z.
[2] Talanta, 2013, 105, 327–332, DOI: 10.1016/j.talanta.2012.10.051.
[3] J. Sol-Gel Sci. Technol., 2024, 112, 703, DOI: 10.1007/s10971-024-06550-2.