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Topic of Research: Synthesis and Study of Metal based Chalcogenides and their Electrical and Photo-induced properties

Findings

The present research work has yielded comprehensive insights into the synthesis, structural, optical, electrical, photoelectrical, and photocatalytic properties of metal-based chalcogenide materials in both amorphous thin film and nanostructured forms. The study systematically investigated the influence of compositional modification and elemental doping on selenium- and tellurium-based chalcogenide systems with the objective of tailoring their properties for optoelectronic and energy-related applications.

Thermally evaporated amorphous $\text{Se}_{88}\text{Zn}_{10}\text{Bi}_2$ thin films were successfully synthesized, and structural analysis using X-ray diffraction confirmed their amorphous nature. Raman spectroscopy revealed characteristic vibrational modes associated with Se-based networks, while SEM analysis showed a uniform and homogeneous surface morphology. Optical studies demonstrated a suitable optical bandgap with high absorption in the visible region, indicating the potential of the material for photonic applications. Temperature-dependent DC conductivity measurements confirmed thermally activated conduction, and the electrical transport was found to be governed by localized states within the mobility gap.

In Bi-modified $\text{Se}_{85}\text{Ga}_{15}$ alloy thin films, bismuth incorporation led to significant enhancement in both DC conductivity and photoconductivity. Structural and microstructural analyses indicated improved network connectivity and increased defect states with Bi addition. Optical investigations showed a systematic reduction in the optical bandgap with increasing Bi concentration, attributed to the formation of additional localized states and enhanced polarizability. Electrical studies revealed a decrease in activation energy and an increase in photosensitivity, confirming that Bi doping effectively improves charge carrier generation and transport. The rise and decay behavior of photocurrent indicated trap-assisted recombination mechanisms, highlighting the role of defect states in governing photoresponse.

The study of Sb- and In-doped Se-Te amorphous thin films further demonstrated the strong dependence of optical and photoelectrical properties on compositional tuning. XRD and SEM analyses confirmed the amorphous nature and uniform surface morphology of the deposited films. Optical bandgap analysis showed a noticeable bandgap narrowing upon Sb and In incorporation, accompanied by an increase in Urbach energy, indicating enhanced structural disorder. Temperature-dependent photoconductivity measurements revealed non-linear

behavior with light intensity, confirming the presence of multiple trapping and recombination centers. Transient photoconductivity analysis suggested that carrier transport is dominated by trap-controlled recombination processes, making these materials suitable for photodetector and switching applications.

In addition to thin film studies, CuCdS₂ nanoparticles were successfully synthesized using the solvothermal method. XRD and Raman analyses confirmed the formation of a crystalline phase with good structural quality, while FE-SEM images revealed nanoscale morphology with high surface area. Optical studies indicated strong visible light absorption, making the material suitable for photocatalytic applications. Photocatalytic degradation experiments using methylene blue dye under solar irradiation demonstrated high degradation efficiency, following first-order reaction kinetics. Time-resolved photoluminescence measurements supported efficient charge carrier separation, which contributed to enhanced photocatalytic performance.

Overall, the findings of this research highlight that controlled elemental doping and compositional engineering play a crucial role in tuning the optical bandgap, electrical conductivity, and photo-induced properties of metal-based chalcogenides. The synergistic improvement in photoconductivity, photosensitivity, and photocatalytic response demonstrates the versatility of these materials for applications in optoelectronic devices, photodetectors, solar energy conversion, and environmental remediation. The systematic correlation between structure, composition, and functional properties established in this work provides a strong foundation for the development of next-generation chalcogenide-based devices.

