GERMANIUM(II) SULFIDE THIN FILMS FOR VISIBLE-LIGHT PHOTODETECTORS

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The growing demand for ultra-low-light, high-gain, and energy-efficient visible-light photodetectors in imaging, sensing, and optoelectronic systems exposes fundamental limitations of conventional silicon-based CMOS technologies, particularly in the red and low-photon-flux regimes, where limited absorption depth and carrier collection efficiency restrict responsivity. Achieving high photoconductive gain at low operating voltages remains a key challenge, motivating the exploration of alternative semiconducting materials and device architectures. In this context, layered and quasi-two-dimensional materials offer enhanced light–matter interaction and tunable carrier transport, although scalable fabrication and defect control remain major obstacles. [1,2]

Polycrystalline germanium(II) sulfide (GeS) emerges as a promising low-toxicity, air-stable p-type semiconductor with a suitable bandgap (1.6 eV) for visible-light detection, enabling efficient photon absorption in the visible spectrum. In this work, GeS thin films are synthesized by rapid thermal evaporation (RTE), a simple and scalable deposition technique compatible with large-area device fabrication. [3] Thin films are deposited on quartz and interdigitated electrode substrates, followed by controlled post-deposition annealing to induce crystallization, grain growth, and defect redistribution. Furthermore, intentional doping is employed to modulate carrier concentration, trap density, and Fermi-level position, directly impacting photocarrier lifetime and transport.

Structural and morphological characterization using X-ray diffraction and scanning electron microscopy confirms the formation of homogeneous and reproducible polycrystalline GeS films after annealing. The optoelectronic performance of GeS-based photodetectors is evaluated through current–voltage measurements under visible-light illumination. Enhanced responsivity and specific detectivity are achieved through the combined effects of doping and thermal post-treatment, attributed to improved carrier mobility, reduced recombination, and increased photoconductive gain arising from trap-assisted charge transport.

These results demonstrate that rapid thermal evaporation, combined with post-deposition electronic structure engineering, provides a viable pathway toward low-power, high-gain visible-light photodetectors based on scalable polycrystalline GeS thin-film technology.

[1] Audrius Drabavičius et al., “High-Performance GeS Thin Film Photodetectors Obtained via Sulfurization and Boron Doping,” ACS Applied Optical Materials, vol. 3, no. 9, pp. 2232–2240, Sep. 2025, doi: https://doi.org/10.1021/acsaom.5c00312.
[2] E. Sutter, B. Zhang, M. Sun, and P. Sutter, “Few-Layer to Multilayer Germanium(II) Sulfide: Synthesis, Structure, Stability, and Optoelectronics,” ACS Nano, vol. 13, no. 8, pp. 9352–9362, Jul. 2019, doi: https://doi.org/10.1021/acsnano.9b03986.
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