

# Photoluminescence Material Based on Arsenic Sulfide Cluster Impregnated in Porous Glasses for Sensing and Detection Applications

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## Summary:

We study the photoluminescence of new nanocomposite material consisting of arsenic sulfide doped in porous glasses and the effect of photoinduced structural transformations on it. Strong photoluminescence signal was observed in the samples when excited with lasers with excitation wavelengths of 405 and 532 nm. Also, the effect of laser irradiation on the photoluminescence of the samples was studied using confocal microscope with two different operating lasers 405 and 514 nm. It was observed that laser irradiation influences photoluminescence differently depending on the irradiation wavelength. Also, it was recording photonic structure on this material. Thus, the material combines the properties of photonic crystals and luminescent materials, allowing for both optical recording and luminescence emission, making it versatile for a range of sensing applications.

**Keywords:** Arsenic sulfide, photoinduced structural transformations, porous glasses, photoluminescence, photonic structure

## Background, Motivation an Objective

Kolomiets' research group was the first to observe photoluminescence (PL) in arsenic sulfide glasses, which has since been widely studied by others [1, 2], taking into account factors such as composition, temperature, and excitation spectra. This paper focuses on the investigation of PL in arsenic sulfide doped in porous glasses (As<sub>2</sub>S<sub>3</sub>-PG nanocomposite) using various excitation wavelengths. The effects of gold nanoparticles on the intensity of PL are also presented, along with the influence of irradiating the samples using different lasers on their PL, as well as effects when recording photonic structure on a material. Synthesis and characterization of the optical properties of materials especially at a nanoscale and at a photonic structures is considered as important tasks for the engineering of photonic devices and systems.

## Description of the New Method or System

The As<sub>2</sub>S<sub>3</sub> doped porous glasses were prepared by dissolving As<sub>2</sub>S<sub>3</sub> in propylamine and adding the porous glasses to the solution, followed by annealing. Here the photoinduced changes in the PL emission observed in the As<sub>2</sub>S<sub>3</sub>-PG composite were utilized for the recording of optical structure – a grating using TEM grating mask and a laser with 532 nm

wavelength. Thus, a new As<sub>2</sub>S<sub>3</sub>-PG composite material was obtained that combines the properties of photonic crystals and luminescent materials, allowing for both optical recording and luminescence emission.

## Results

The photoluminescence (PL) spectra of the As<sub>2</sub>S<sub>3</sub>-PG samples were measured under excitation with 405 nm and 532 nm lasers. To obtain more detailed information about the PL centers, deconvolution was performed due to the presence of multiple Gaussian peaks in the PL spectra. The peaks obtained from the deconvolution process and the PL spectra are shown in Fig. 1. The results indicate the presence of a broad and intense band at 511 nm when excited with a wavelength of 405 nm (Fig. 1a). The PL spectrum excited with 532 nm is dominated by a broad emission band centered around 596 nm with shoulder around 630 nm. The PL observed in the As<sub>2</sub>S<sub>3</sub>-PG samples investigated in this research does not conform to the established EPL  $\approx$  Eg/2 rule that typically characterizes the intrinsic properties of chalcogenide glasses [2]. This could be attributed to the fact that the observed PL emission is originating from arsenic sulfide nanoparticles rather than its bulk form.

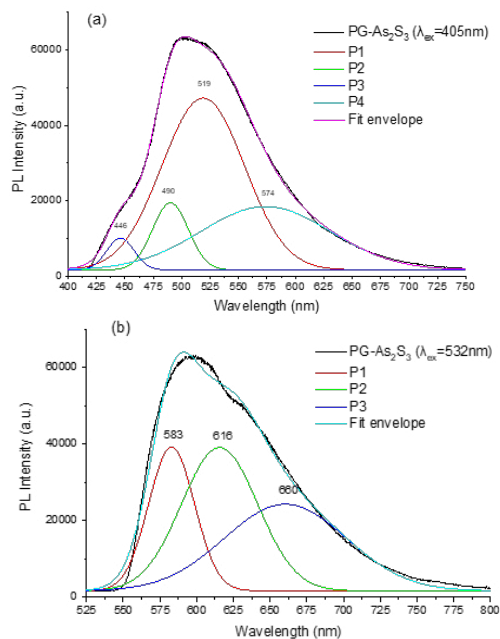


Fig. 1. Deconvoluted experimental PL spectra of  $As_2S_3$ -PG when excited with (a) 405 nm laser and (b) 532 nm laser. Deconvoluted spectra are represented by curves P1, P2, P3 and P4. The resulted sum of the deconvoluted spectra is represented by curve fit envelope.

The effect of AuNPs on the PL emission of  $As_2S_3$ -PG samples was investigated using confocal luminescent scanning microscopy (Fig. 2). Samples with and without AuNPs were analyzed, with both having the same concentration. The results showed that the presence of AuNPs led to a decrease in the PL emission intensity of  $As_2S_3$ -PG by 40% for excitation at 405 nm and by 30% for excitation at 514 nm. This effect was attributed to the strong semiconductor-metal coupling between  $As_2S_3$  and Au, which resulted in the suppression of the plasmonic resonance of AuNPs and the quenching of excited states in  $As_2S_3$ .

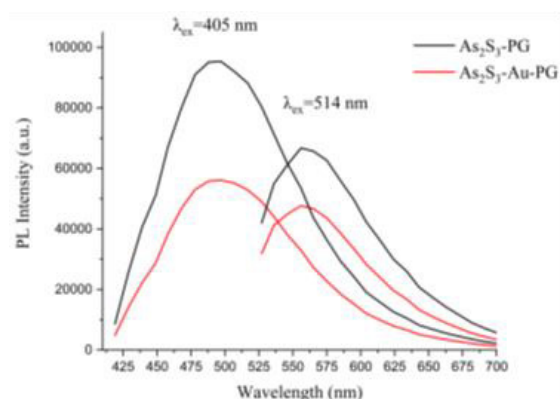


Fig. 2 - PL spectra of  $As_2S_3$ -PG (black curves) and  $As_2S_3$ -Au-PG (red curves) when excited at 405 nm and 514 nm.

The effect of irradiation with different photon energies on the PL emission of the samples was investigated. Under excitation with a 514 nm laser beam, the PL intensity of the samples decreased by 58% and 64% after irradiation with 405 nm and 514 nm lasers, respectively. Irradiation with a 405 nm laser beam resulted in a decrease in PL intensity in the irradiated region by 83% with the same laser but increase by 39% in regions irradiated with 514 nm. This effect is attributed to photoinduced structural transformations dependent on the laser wavelength. The decrease in PL intensity at 514 nm after irradiation can be explained by an increase in the bandgap energy of the samples caused by the irradiation. Increasing the bandgap energy brings the excitation wavelength at 405 nm closer to the resonant absorption-reemission wavelength, resulting in an increase in PL intensity. The formed nanocrystals have a relatively wide bandgap energy and exhibit PL emission in the 490 nm range. The photoinduced changes in the PL emission observed in the  $As_2S_3$ -PG composite were utilized for the recording of optical structure using the former technique and was studied by a confocal microscope (Fig. 3).

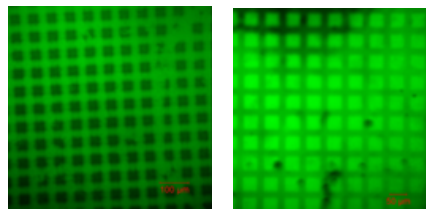


Fig. 3. Confocal microscope image of the recorded TEM grating in the reflected mode, when excited at (left) 514 nm and (right) 405 nm.

It is clear that when viewing the recorded grating with green laser it shows a converted image of what appears with blue laser. The composite material was shown to be effective in utilizing photoinduced changes for optical recording of photonic structures, which makes it suitable for sensing applications [3].

## References

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