TEMPLATE SYNTHESIS AND PHOTOLUMINESCENCE OF ZnTe NANOCRYSTALS

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This work presents the synthesis of zinc telluride (ZnTe) nanostructures using a template-assisted chemical deposition method. The process is based on preliminary ion modification of the substrate, followed by chemical treatment, enabling nanocrystal formation at room temperature without thermal annealing. This approach is compatible with various substrates and suitable for the development of multilayer optoelectronic structures. The photoluminescence (PL) properties of ZnTe nanostructures were studied as a function of deposition time. PL spectra, recorded at room temperature, revealed broad visible-range emission with distinct peaks associated with excitonic recombination, localized states, and intrinsic defects. The variation in synthesis conditions influenced both the position and intensity of these emission bands, indicating the possibility of tuning optical behavior through controlled growth parameters. The results confirm the effectiveness of the proposed synthesis technique for producing ZnTe nanostructures with adjustable photonic properties. The material exhibits high sensitivity to structural modifications, making it a promising candidate for use in photonic devices, sensors, and hybrid nanoscale systems. The low-temperature and scalable nature of the method further supports its applicability in the development of functional nanomaterials for advanced optoelectronic applications.

Keywords: zinc telluride; nanostructures; chemical deposition; photoluminescence; optoelectronics.

Introduction

Zinc Telluride (ZnTe) is a II–VI group semiconductor material with unique optical and electronic properties. This compound can crystallize in either a cubic (sphalerite) or hexagonal (wurtzite) structure, which contributes to the anisotropy of its physical characteristics [1-2]. ZnTe has a band gap of 2.26 eV at room temperature, making it a promising material for optical devices operating in the visible and near-infrared spectral regions [3]. Its high refractive index, low effective mass, and pronounced excitonic effects broaden the scope of its application in quantum and optoelectronic devices [4].

ZnTe can be synthesized by various methods, including chemical deposition, molecular beam epitaxy, hydrothermal synthesis, and laser ablation, all of which are widely utilized [5]. Moreover, the use of template-assisted techniques enables the fabrication of ZnTe nanostructures with controlled morphology. This approach, based on track-etched membranes, porous oxides, carbon nanotubes, or polymer matrices, allows for precise control over the geometry of the resulting nanostructures [6].

Materials based on ZnTe are extensively used in various technological domains. Specifically, in solar energy applications, ZnTe serves as a buffer layer in CdTe-based solar cells, enhancing their efficiency [7]. In the field of optoelectronics, it is employed in the fabrication of light-emitting diodes (LEDs), lasers, and photodetectors. ZnTe-based quantum dots are considered a promising material for lasers operating in the visible spectrum [8]. In terahertz radiation sources and detectors, ZnTe's pronounced nonlinear properties enable efficient operation in the THz frequency range [9]. In biosensing technologies, ZnTe nanostructures demonstrate high sensitivity in biological and chemical analyses, making them suitable for medical diagnostics and environmental monitoring applications [10]. Furthermore, ZnTe quantum dots and multilayer nanostructures hold promise for implementation in quantum computing systems and high-efficiency optoelectronic devices [11, 12]. ZnTe nanocrystals offer a tunable platform for nanoscale optical applications due to their controllable structure and luminescent properties.

Materials and Methods

In this work, the results of template-assisted synthesis of ZnTe nanocrystals within track-etched structures are presented. A SiO_2/Si structure was irradiated with 177 MeV Xe ions at a fluence of 10^8 ions/cm^2, followed by chemical etching in a 4% hydrofluoric acid (HF) solution. The etchant composition included: m(Pd) = 0.025 g.

The chemical deposition of zinc telluride (ZnTe) was carried out at a temperature of 25 °C for a duration of 30 minutes. The composition of the solution used for deposition was as follows: $ZnCl_2$ – 0.36 g/L, TeO_2 – 0.4 g/L, HCl – 3 mL. The deposition was performed for durations of 30, 60, and 90 minutes.

Results and Discussion

After chemical deposition, the surface morphology and cross section were examined using a JSM-7500F scanning electron microscope (SEM) (Figure 1).

SEM studies showed that nanopores with diameters between 363-368 nm (Figure 1 - b), most of the nanopores of the sample were filled, and the chemical deposition method was suitable for synthesizing highly ordered materials with controlled morphology.

Further, to determine the structure of nanocrystals, an X-ray structural analysis was carried out on an X-ray diffractometer Rigahu miniflex 600.

After the calculations, a hexogonal crystal structure was determined with the Space Group P3121. And the Miller indices (100) (003) (012) have been observed.

Photoluminescence (PL) spectra of ZnTe material were measured using a CM2203 spectrofluorimeter. For PL excitation, Xe-lamp radiation with a wavelength of 450 nm was employed. PL spectra of $ZnTe/SiO_2/Si$ samples obtained via chemical deposition for 30 minutes were recorded at room temperature and exhibited a broad emission band in the range of 2.0 to 2.4 eV.

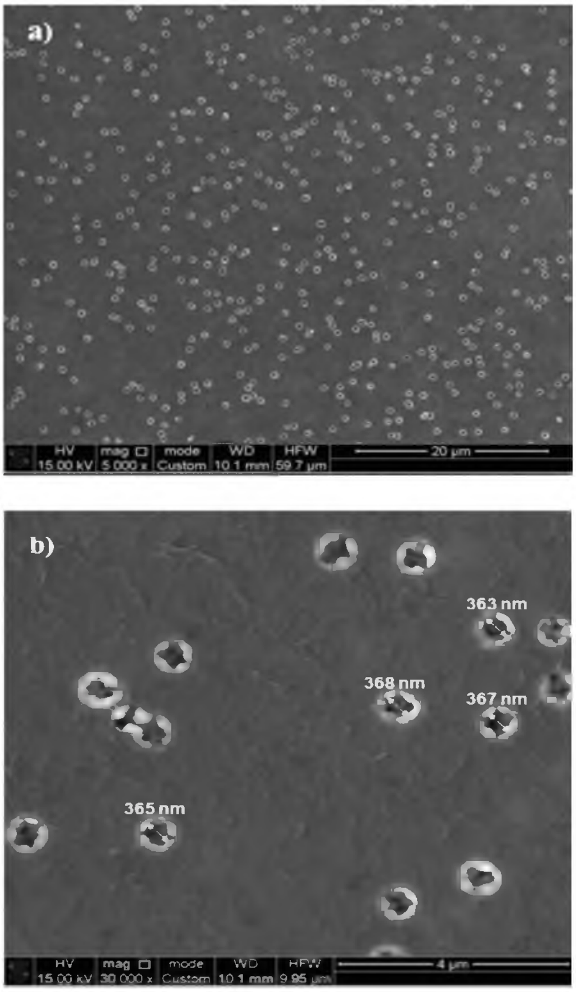

Fig. 1. SEM image of the surface after 30 minutes of chemical deposition: a) - total number of nanochannels, b) - nanochannel diameters

The differential PL spectra of the samples after 30 minutes of chemical deposition are presented in Figure 2.

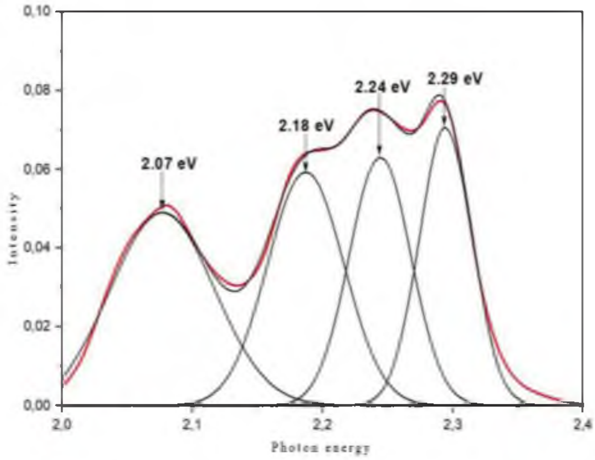

Fig. 2. Differential PL spectra of ZnTe nanocrystals after chemical deposition

The photoluminescence of ZnTe nanocrystals is observed within the energy range of 2.0–2.4 eV. Within this interval, four distinct peaks can be identified.

The first peak appears at 2.07 eV. This emission is likely associated with transitions involving deep defect states or transitions between bound excitons and free charge carriers [13].

The transition observed at 2.18 eV is attributed to energy levels related to specific defects within the ZnTe crystal lattice [14].

The emission at 2.24 eV may originate from an unknown defect acceptor, potentially formed spontaneously, and is likely linked to a transition from a free state [15].

The 2.29 eV peak may be associated with excitonic transitions or transitions induced by minor structural defects in the material [16].

Conclusions

ZnTe nanocrystals were successfully synthesized using a template-assisted chemical deposition method on ion-irradiated SiO_2/Si structures. The synthesis was carried out at room temperature using a well-defined chemical solution composition, and different deposition durations were explored. The resulting nanostructures exhibited photoluminescence in the 2.0-2.4 eV energy range, with clearly distinguishable peaks attributed to various radiative transitions involving excitonic states and defect levels in the ZnTe lattice.

The combination of ion-track technology and chemical deposition proved to be an effective approach for fabricating ZnTe nanostructures with controlled morphology and promising optical characteristics. These findings demonstrate the potential of ZnTe for applications in optoelectronics, photonics, and sensor technologies, particularly in the visible and near-infrared spectral regions. Future studies may focus on optimizing synthesis parameters to further enhance luminescence efficiency and tailor material properties for specific device applications.

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