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Research Article

Improving the Structural and Morphological Characteristic of Carboxymethyl cellulose (CMC) Via Additive ZnSe Nanoparticle

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Abstract:

The present study focuses on the preparation of Zinc selenide (ZnSe) doped Carboxymethyl cellulose (CMC) for utilization in various optoelectronic applications. X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and field emission scanning electron microscopy (FESEM) were employed to analyze the structural and morphological characteristics. The XRD results indicated an amorphous nature for CMC, which transitioned to a polycrystalline structure upon the addition of high loading (8 wt.%) ZnSe nanoparticles. FTIR spectra confirmed a physical interaction between the ZnSe nanoparticles and the CMC polymer matrix. FESEM analysis revealed a uniform distribution of ZnSe nanoparticles throughout the CMC polymer matrix. These findings suggest that the CMC/ZnSe composite is appropriate for optoelectronic device applications.

1. Introduction

Nanotechnology is a new area of science that is still growing. The current age is having a big effect on the world economy by coming up with new, high-yield products, making better use of existing products, and using more efficient ways to make things. Metallic, metal oxide, doped, and undoped metallic and metal oxide particles are some of the nanoparticles that can be made by nanotechnology. Nanoparticles are made up of things that have at least one size between 1 and 100 nanometers. Different materials have different mechanical, chemical, and physical qualities in this limited framework [1].

Polymer nanocomposites have become increasingly significant due to their capacity to achieve distinctive properties [2]. Metal and semiconductor nanoparticles exhibit exceptional optical and electrical properties, rendering them suitable for integration into polymers, which act as effective host materials [3]. Nanocomposites within the inorganic/organic system exhibit notable technological potential in linear and nonlinear optics, as well as in solar cells, due to their unique properties and advanced methodologies [4]. Polymers exhibit properties similar to those of inorganic materials; however, they also offer several advantages, including flexibility, ease of manufacturing, corrosion resistance, cost-effectiveness, and a lightweight structure. Inorganic materials exhibit advantageous properties, such as stability at elevated temperatures and high mechanical strength. Currently, polymer-inorganic blends find application in various domains, including television screens, sensors, and solar cell batteries [5].

A larger variety of global applications make use of carboxymethyl cellulose (CMC), an ionic linear polymer, more than any other water-soluble polymer in use today [6]. The cellulose backbone contains these hydroxyl groups. During the 1930s, Germany became the pioneering nation to successfully synthesize carboxymethyl cellulose. Production in the United States of America has been ongoing since 1947. The synthetic version of laundry detergent was developed using this

material. During this period, CMC started to be utilized across a diverse range of other sectors [7]

The II-VI semiconductor zinc selenide (ZnSe) shows considerable promise. The material demonstrates a considerable direct band gap of 2.7 eV, accompanied by high visual transmittance, an impressive refractive index, and a remarkable exciton binding energy. The distinct properties of ZnSe make it suitable for a variety of applications, including thin-film solar cells, blue-light emitting diodes, gas sensors, and photocatalysts [8].

This study focuses on the synthesis of CMC/ZnSe nanocomposites and examines their structural and morphological properties for potential applications in various optoelectronic devices.

2- Experimental Part

The (CMC/ZnSe) nanocomposites were synthesized by dissolving 1 g of CMC. A total of 50 ML of deionized water was maintained at 70°C for 30 minutes with continuous stirring via a magnetic stirrer to achieve a homogeneous solution. The solution was placed on a clean glass Petri dish and permitted to dry at room temperature for 240 hours until complete solvent evaporation occurred. Zinc selenide (ZnSe) nanoparticles were integrated into polymethyl methacrylate (CMC) at varying weight ratios of 2%, 4%, 6%, and 8%. The crystal structures were analyzed utilizing an X-ray diffractometer (XRD Bruker D8, Germany) that included an environmental and temperature control stage. Cu Kα1 radiation (λ = 1.5406 Å) was employed at 40 kV and 100 mA. The structural analysis at room temperature utilized FTIR (Bruker, model Vertex-70 spectrometer, Germany), spanning the range of 4000-500 cm−1. The distribution of ZnSe nanoparticles in the CMC medium was examined using a Hitachi SU6600 variable pressure field emission scanning electron microscope (FESEM).

3. Results and Discussion

The XRD patterns facilitated the determination of the crystallographic structure of CMC polymer and its nanocomposite films. The nanocomposites exhibited different ratios of ZnSe NPs, specifically 2, 4, 6, and 8 wt.%. This study sought to clarify the arrangement of the polymer nanocomposites at ambient conditions, as depicted in Figure 1. The figure demonstrates that the CMC shows broad diffraction peaks at 2θ = 21.39° (strong), indicating its amorphous nature [9]. The nanocomposites containing a significant ZnSe loading of 8 wt.% exhibited distinct XRD peaks at 27.12°, 42.71°, 44.95°, 49.86°, 53.15°, 72.05°, and 73.79°, which align with the Miller indices of (111), (102), (220), (012), (311), (331), and (202). The peaks were mapped out using Powder X software and compared to the standard JCPDS card file No. 37-1463 (space group F43m). This proved that ZnSe formed in a cubic crystal system with a, b, and c values of 5.668 Å [10]. Analysis of the nanocomposite patterns reveals that the incorporation of ZnSe nanoparticles at a loading of 8 wt.% has influenced the structural characteristics of CMC. This change is attributed to the mixing of ZnSe nanoparticles, which transformed the amorphous nature of pure CMC into a polycrystalline structure.

FTIR has been used to study atom-ion interactions in (CMC/ZnSe) nanocomposites. The interactions may change nanocomposites' vibrational modes. In Figure 2, CMC/ZnSe nanocomposite films with different ZnSe nanoparticle ratios show their room-temperature transmittance spectra from 400-4000 cm^{-1}.

The region of hydrogen bonding and OH stretching is indicated by the characteristic transmission band at 3427.85 cm-1 [11]. We can trace the small peaks at 2924.28 cm-1 and 2856.08 cm-1 to the C-H stretching vibration. Due to the stretching of the carboxyl group, the presence of COO-is confirmed by the prominent peak at 1510.79 cm-1 [12]. Bands around 1423.62 cm-1 and 1328.09 cm-1 are associated with the in-plane OH stretching and the symmetric C-H stretching of CMC, respectively, as mentioned in reference [13]. A related spectral band with CH2 group bending is seen at 1267.98 cm-1. The lines at 1113.53 cm-1 and 1061.16 cm−1 in the infrared spectra of the CMC polymer showed that the polysaccharide framework was stretching the C-O bonds. Furthermore, the aromatic ring's out-of-plane bending and the CH2 rocking vibration are matched by the maxima at 720.16 cm-1 and 662.83 cm-1, respectively [14].

Instead of new peaks appearing, the FTIR measurements show that certain bonds are displaced when different concentrations of ZnSe nanoparticles are added to pictures b, c, d, and e. This points to a possible physical interaction between the CMC polymer matrix and the ZnSe nanoparticles.

The impact of the ZnSe nanoparticles on the nanocomposites is assessed after analyzing their distribution in the CMC polymer using field emission scanning electron microscopy (FESEM). Films made from (CMC/ZnSe) nanocomposites, showing different ZnSe nanoparticle concentrations, are shown in Figure 3. Image (a) clearly shows that the polymer is cohesive and uniform in appearance. As shown in pictures b, c, d, and e, the system's surface structure is altered by

adding additional ZnSe NPs to the CMC polymer. At low concentrations of ZnSe nanoparticles, a uniform distribution within the polymer matrix is observed. At a concentration of 8 wt.%, these particles exhibit a tendency to aggregate, resulting in the formation of clusters. The interactions between ZnSe nanoparticles and the CMC polymer matrix likely account for this phenomenon, as evidenced by XRD analysis. This finding aligns with the conclusions reached by researchers [15, 16].

4. Conclusions

The films of (CMC/ZnSe) nanocomposites were synthesized in this study using the casting method. The XRD analysis revealed that the CMC exhibited an amorphous nature, which transitioned to a

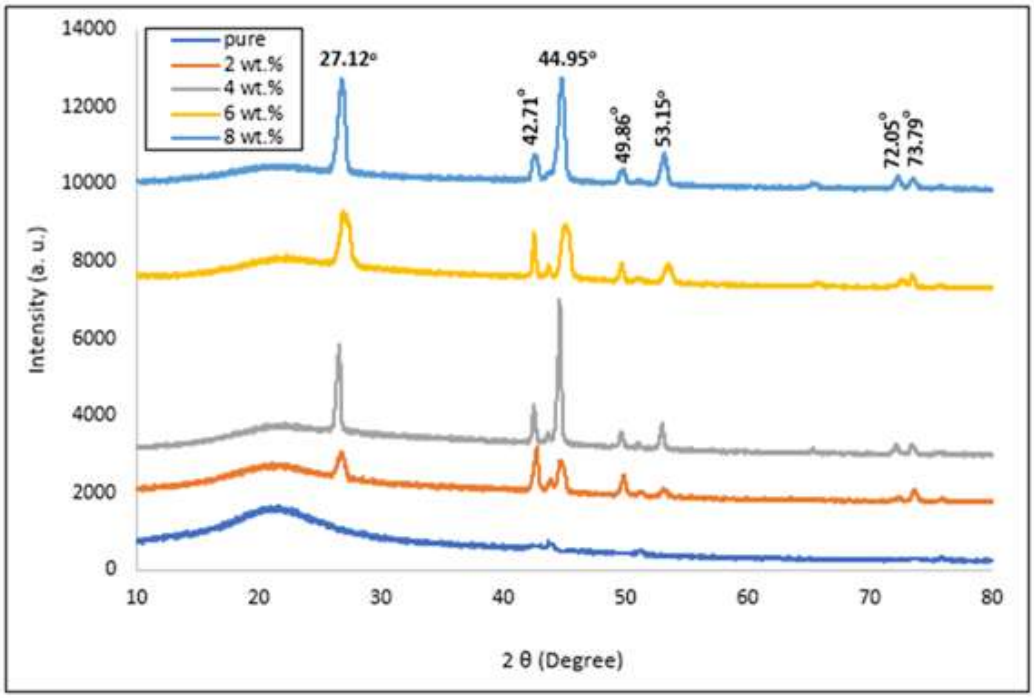
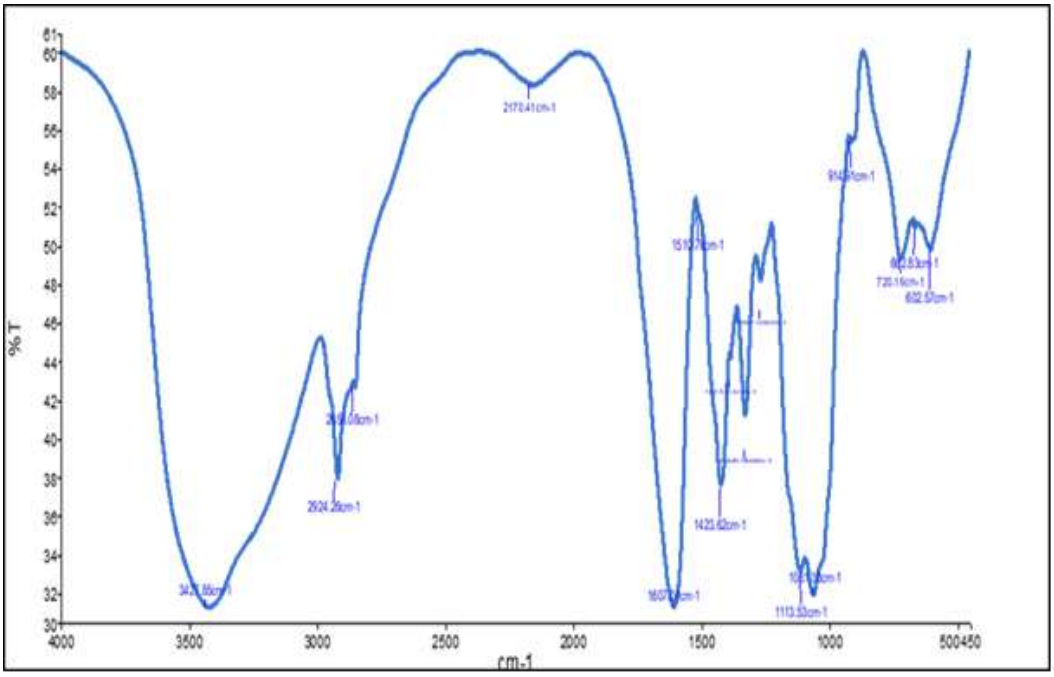
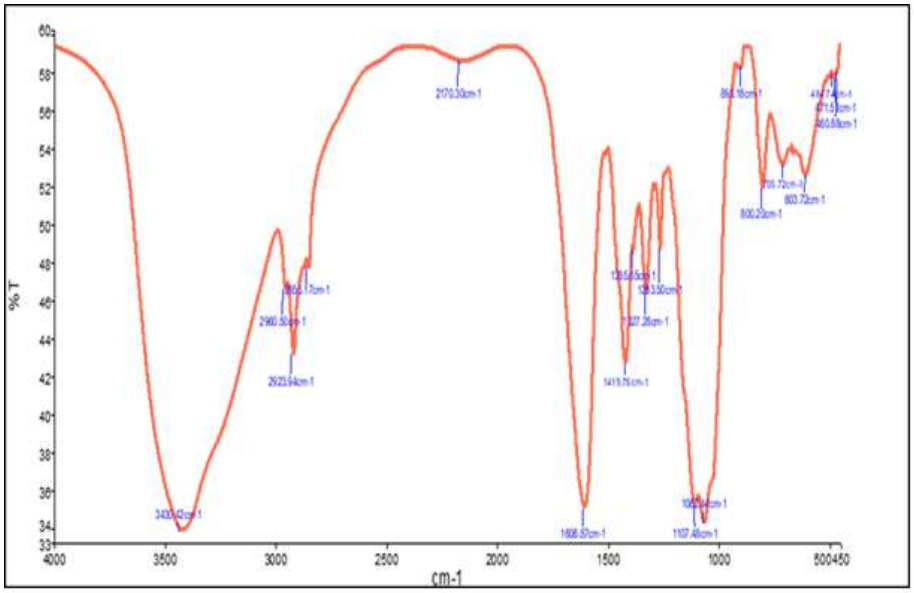


Figure 1. *X-ray diffraction for (CMC/ZnSe) nanocomposites*

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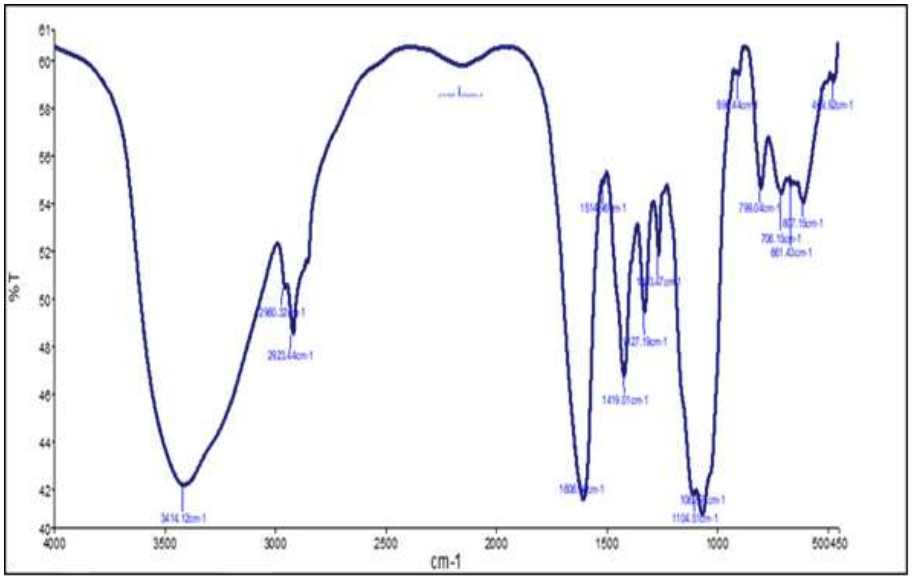
603.72cm-1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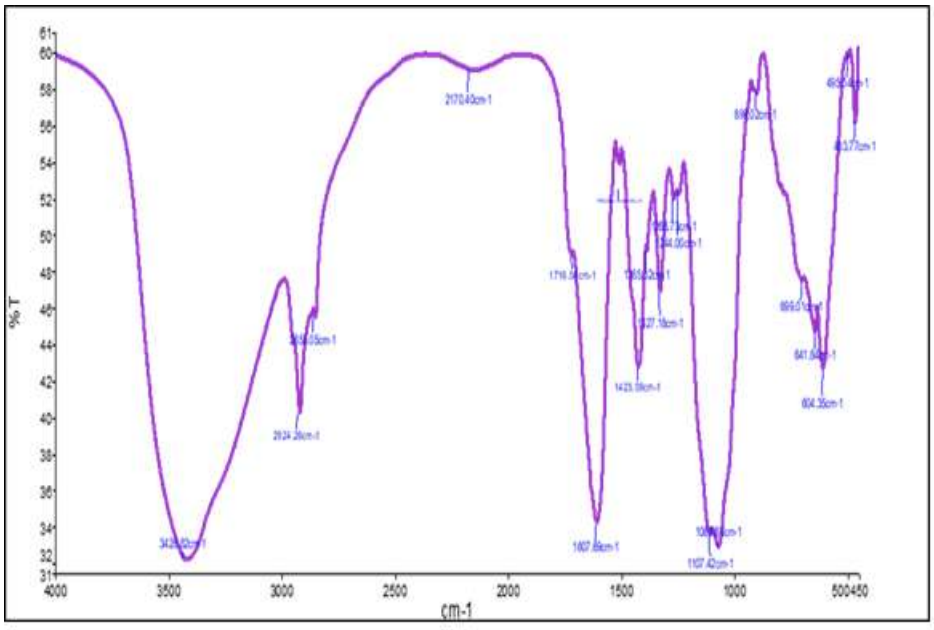
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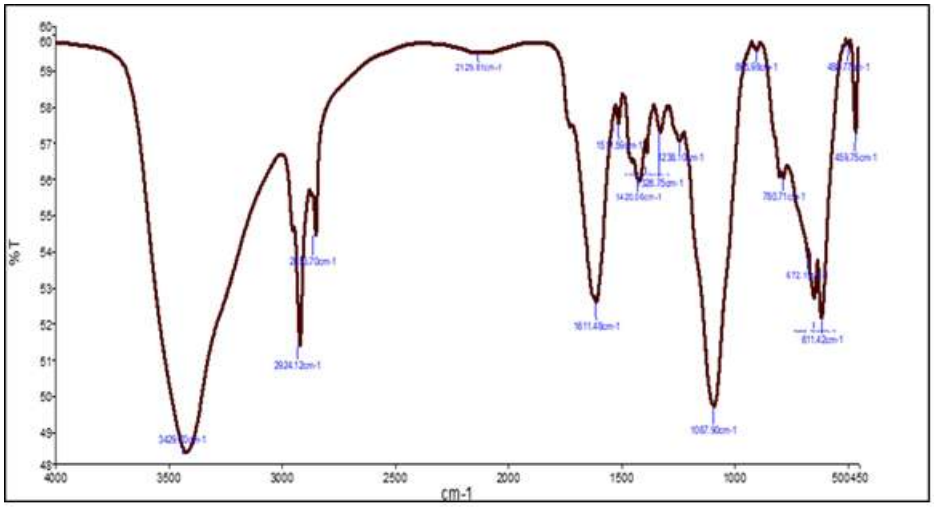

Figure 2. *FTIR spectrum for (CMC/ZnSe) nanocomposites:(a) for (CMC) pure, (b) for 2 wt.% ZnSe, (c) for 4 wt.% ZnSe, (d) for 6wt.% ZnSe, (e) for 8 wt.% ZnSe.*

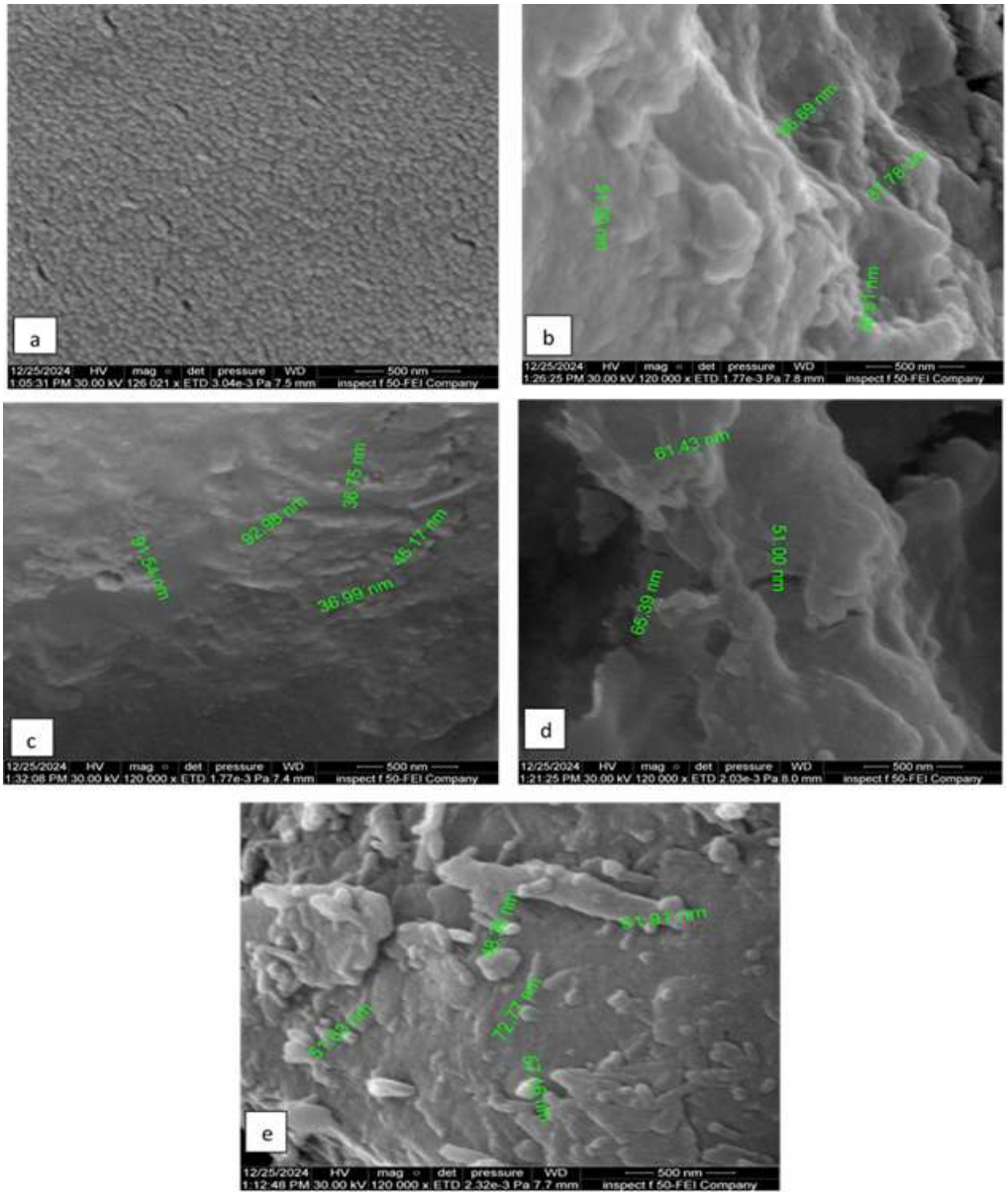

Figure 3. *FESEM images for (CMC/ZnSe) nanocomposites:(a) for (CMC) pure, (b) for 2 wt.% ZnSe, (c) for 4 wt.% ZnSe, (d) for 6wt.% ZnSe, (e) for 8 wt.% ZnSe.*

polycrystalline structure upon the addition of a high loading (8 wt.%) of ZnSe NPs. The FTIR spectrum confirmed a physical interaction between ZnSe nanoparticles and the CMC polymer matrix. The Field Emission Scanning Electron Microscopy (FESEM) analysis indicated a uniform distribution of ZnSe nanoparticles within the CMC matrix polymers. The results suggest that the CMC/ZnSe combination is appropriate for use in optoelectronic devices.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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