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SYNTHESIS AND CHARACTERIZATION OF (PVA-CoO-ZrO_2) NANOSTRUCTURES FOR NANOOPTOELECTRONIC FIELDS[†]

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Nanocomposites have a wide range of applications, including optical integrated circuits, sensors, coatings, and medical devices. As a result, the purpose of this paper is to prepare a new type of nanocomposites made of polyvinyl alcohol (PVA) with different concentrations (0, 1, 2 and 3) wt% of cobalt oxide and zirconium dioxide (CoO-ZrO_2) nanoparticles by using casting method. Microscopic photographs demonstrate the fact that the additive distribution amount of NPs in the polymer was uniform, and (CoO-ZrO_2) NPs formed a continuous network within the polymer when the concentration reached 3wt.%. The outcomes of optical properties indicate that the absorbance of nanocomposites improves as the concentrations of cobalt oxide and zirconium dioxide nanoparticles increase while transmittance and the optical energy gap decrease. On the other hand, optical constants of nanocomposites (refractive index, absorption coefficient, extinction coefficient, real and imaginary the dielectric constants) and optical conductivity are increase with increases in the weight percentages of (CoO-ZrO_2) nanoparticles. These outcomes demonstrate the (PVA-CoO -ZrO_2) NCs use for various optical devices.
Keywords: *Nanocomposites; Optical properties; Cobalt oxide; Zirconium dioxide*
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INTRODUCTION

Metallic nanoparticles differ from bulk metals in their physical and chemical properties (lower melting points, higher specific surface area, specific optical properties, mechanical strength, and specific magnetization). These properties are appealing in a variety of industrial applications thus, nanoparticles are the most fundamental component in nanostructure fabrication. Nanoparticles are intriguing and unique because of their optical properties [1,2]. Nanocomposites have shown great promise in many industries, including microelectronics, Automobiles, drug delivery, sensors, injection moulded products, membranes, packaging materials, aerospace, coatings, adhesives, fire retardants, medical devices, consumer goods and many more [3,4]. Polymer matrices can be tailored to meet not only specific technological requirements, but also size and shape nanostructures dependant features that can be exploited, opening up exciting prospects for the creation of polymer-based nanocomposites with antimicrobial activity. The physical properties of polymer nanocomposites, which are polymer matrices doped with nanosized phases such as nanoparticles, nanofibers, nanosheets, and nanotubes, etc., depend largely on the interaction between polymer molecules and nanofillers [5,6]. Polyvinyl alcohol (PVA) is a type of polymer that has excellent Optical, mechanical, physical, and electrical characteristics are examples of properties. The best way to incorporate metal oxides is as Al_2O_3, CoO, TiO_2, ZnO, and ZrO_2 greatly improves its characteristics. In particular, ZrO_2 possesses excellent wear and chemical resistance, exceptional mechanical strength, fracture toughness, and hardness, as well as decent ionic characteristics [7,8]. Cobalt nanoparticle powders (CoO) have been discussed of intensive studies and development recently because of their promising applications in fields as diverse as rechargeable batteries, ceramic pigments, catalysts, magnetic materials, gas sensors, and solar energy absorbers [9,10] . Nanocomposites are an emerging class of materials that incorporate nanoscale fillers. The term "organic/inorganic hybrid" refers to the combination of inorganic nanoparticles with organic (polymer) materials, because of the strong interfacial connection between organic and inorganic materials that occurs when CoO is incorporated into a polymer, the latter takes on improved optical and mechanical properties. Polyvinyl alcohol (PVA) occurs naturally as a biodegradable and water-soluble substance, making it a model example of a green material. It is possible that oxide can be used to make thin films with a useful natural functionality [11].

EXPERIMENTAL PART

In this analysis, samples create from polyvinyl alcohol and (cobalt oxide- zirconium oxide) NPs with different concentrations (0, 1, 2 and 3) wt% using the casting technique, which involved dissolving polyvinyl alcohol in (40 ml) of distilled water for 45 minutes while stirring with a magnetic stirrer at temperature 70 ^{0}C to achieve a more homogeneous solution. In a petri dish, the solution was kept. After three days of progressive drying at room temperature, polymer mix nanocomposites were formed. The NCs from the petri dish (PVA-CoO-ZrO_2) were cut out and measured. Nanocomposites were tested in various concentrations utilizing a light microscopy of the kind Nikon-73346 made by Olympus a magnification of (10×) and a microscopic photography camera. The UV-1800 from Shimadzu was used to assess the optical properties of (PVA-CoO-ZrO_2) NCs in the range 220 to 1100 nm. The formula below is used to calculate absorbance [12]

$$A = \frac{I_A}{I_O} \quad (1)$$

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(I_A) is the amount of the substance's absorption of light, and (I_O) is the magnitude of the incident light.
The formula is utilized transmittance [13]

$$T = I_T/I_O \quad (2)$$

(I_T) the amount of beam transmitted through a substance, and(I_O) the brightness of the light that is incident
We can measure the absorption coefficient (α) from these equation [14]

$$\alpha = 2.303\, A/d \quad (3)$$

Absorbance is represented by (A), and film thickness is represented by d
The energy gap was formed by applying the connection [15]

$$\alpha\, h\upsilon = B\,(h\upsilon - E_g)r \quad (4)$$

(r = 2) for allowed indirect transitions and (r = 3) for forbidden indirect transitions. ($h\upsilon$) incidental photon energy, (B) constant, and optical energy band gap (E_g)
Relation can be used to determine the refractive index (n) [16]

$$n = (1+R^{1/2})/(1-R^{1/2}) \quad (5)$$

R is reflectance. Equation below can be used to determine the extinction coefficient (k) [17]

$$k = \alpha\,\lambda/4\pi \quad (6)$$

The incident light's wavelength is (λ).
The real (ε_1) and the imaginary (ε_2) components of the dielectric constant are determined by the subsequent mathematical calculations [18]

$$\varepsilon_1 = n^2 - k^2 \quad (7)$$

$$\varepsilon_2 = 2nk \quad (8)$$

The following equation is used to determine the optical conductivity (σ) [19]

$$\sigma = \alpha\, n\, C\, /4\pi \quad (9)$$

Light velocity is denoted by (C)

RESULTS AND DISCUSSION

Figure (1) shows optical microscope images of (PVA-CoO- ZrO_2) nanocomposites taken at a magnification power of 10× at various concentrations of nanoparticles. From this figure we can see that the images (A, B, C, D) when the combination of (CoO-ZrO_2) When nanostructures reach 3 wt.%, Inside the polymer, they form a unified network. the nanoparticles are linked in this network includes routes for charge carriers to travel through, causing a shift in the material properties [20,21].

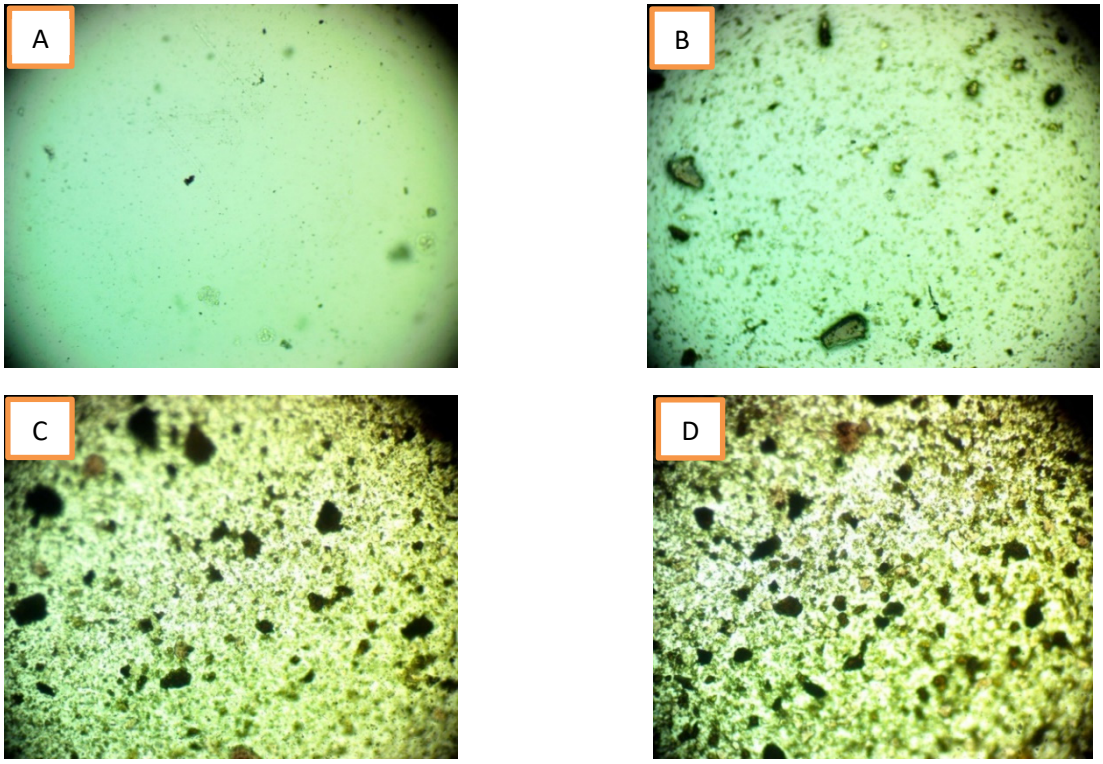

Figure 1. Photomicrographs (×10) for (PVA-CoO-ZrO_2) nanocomposites
(A) PVA, (B) 1wt.% CoO-ZrO_2 nanoparticles, (C) 2 wt.% CoO-ZrO_2 nanoparticles, (D) 3 wt.% CoO-ZrO_2 nanoparticles

Figure (2) shows the optical absorbance of (PVA-CoO-ZrO_2) nanocomposites varies with wavelength. from this figure, absorption has increased in the ultraviolet region while decreasing in the visible and infrared regions. the incident photon has a high wavelength and the photon is not transmitted because there is not enough energy to communicate with atoms. The photon-material interaction occurs and the photon absorbs as the wavelength decreases. The absorbance increases as the concentration of CoO-ZrO_2 NPs increases. This is due to free electrons absorbing incident light [22,23].

The relationship between transmittance and wavelength for (PVA-CoO-ZrO_2) nanocomposites is shown in Fig. 3. The transmittance decrease with increase of added concentration of (CoO-ZrO_2) nanoparticles. The method is not followed by emission from the radiation because the transferred electrons in its outer orbits have occupied vacancy positions of the energy bands, absorb part of the light incident that does not exceed a material dosage which is induced by (CoO-ZrO_2) electrons on their outer orbs and transmits them to higher energy levels [24,25].

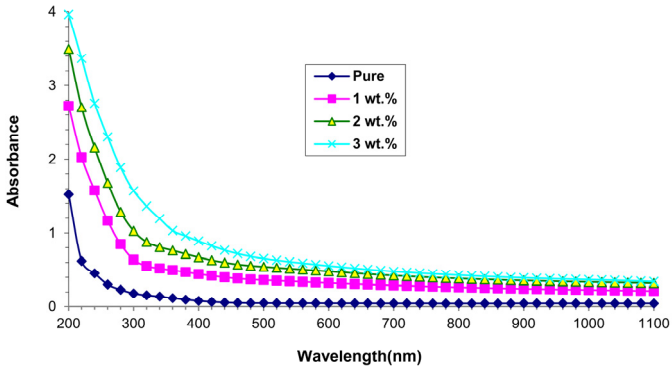

Figure 2. Absorbance spectra with photon wavelength of (PVA-CoO-ZrO_2) nanocomposites

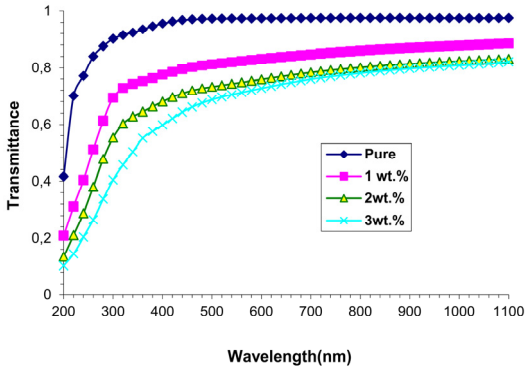

Figure 3. Transmittance spectra of (PVA-CoO-ZrO_2) NCs as a function of wavelength

Fig. 4 shows the connection between incident radiation and absorption coefficients for (PVA-CoO-ZrO2) nanostructures. As in our view, this absorption coefficient is lowest at wavelength with energy high, indicating there being isn't much possible electron transition because the force of the input photon is insufficient for the electron to be able to move from the V.B. to the C.B. (hv> Eg). This shows how the absorption coefficient influences the type of electron transfer that takes place. When the absorption coefficient is extremely high (>10^4 cm^{-1} at high speeds), an electron is expected to undergo a direct transition, and the electrons and photons retain this same energy and moment. However, because absorption coefficients at low energies are small, ($10^4 cm^{-1}$) This is anticipated in which an electron will undergo a deceptive transition, so that its electronic traction shall be preserved through to the adsorption process. The coefficient of absorption intensity of PVA-CoO-ZrO_2 nanocomposites is less than (>10^4 cm^{-1}), indicating that the transition of the electron in these nanocomposites is indirect [26,27].

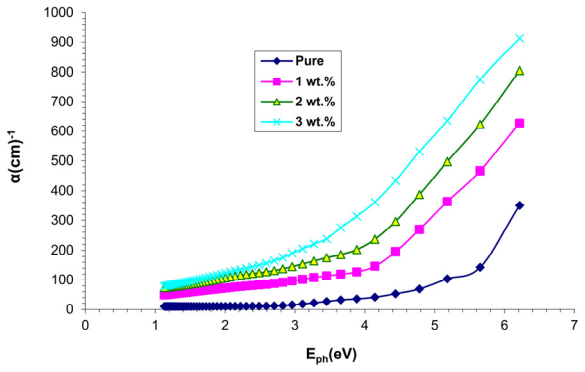

Figure 4. Variation of absorption coefficient with photon energy for (PVA-CoO-ZrO_2) nanocomposites

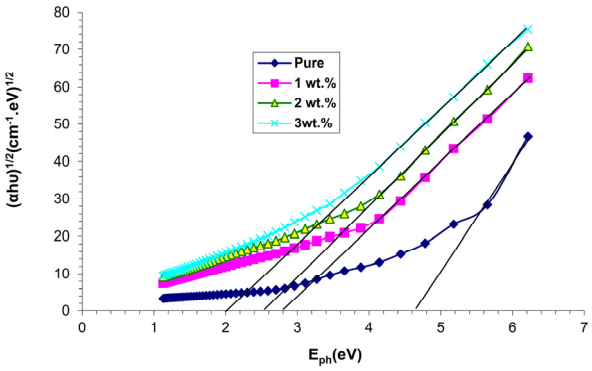

Figure 5. The connection between $(\alpha hv)^{1/2}$ $(cm^{-1}\cdot eV)^{1/2}$ and photon energy of (PVA-CoO-ZrO_2) NCs

Figure (5) demonstrates the relationship between $(\alpha hv)^{1/2}$and photon energy. This figure indicates energy gap decreased by an increase in (CoO-ZrO_2) concentration for (PVA-CoO-ZrO_2) nanocomposites, this is because the material has risen in disruption, which means that the secondary excitation within the band can be made possible and the width of these levels increases with increasing concentrations of CoO-ZrO_2) NPs, that minimize the energy gap [28,29]. Figure 6 illustrates the relationship between $(\alpha hv)^{1/3}(cm^{-1}\cdot eV)^{1/3}$ and photon energy of (PVA-CoO-ZrO_2) nanocomposite. This graph clearly shows the energy gap values for forbidden transition.

The change in the coefficient of attenuation is shown in Figure (7) as a function of wavelength. With an increase in (CoO-ZrO_2) nanoparticles we have noticed that the coefficient of attenuation increases. This is because the absorption value is enhanced and the (CoO-ZrO_2) nanoparticles weight percentage is increased[30,31]. The extinction coefficient varies with wavelength (PVA-CoO-ZrO_2) nanocomposites there is an effect of the geometric structure of the material on the tops extinction coefficient, when the percentage of nanomaterial increases, the proportion of geometric deformation increases in the crystal lattice [32,33].

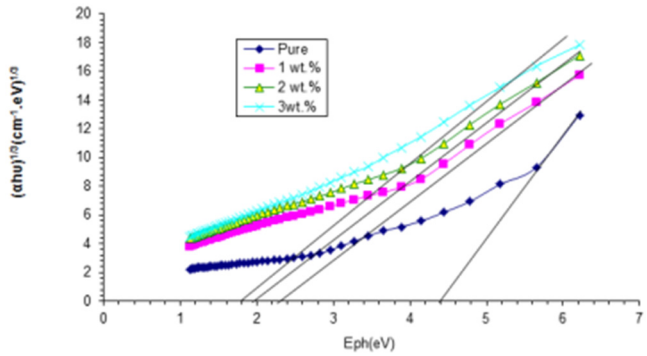

Figure 6. The relationship between $(\alpha h\nu)^{1/3}(cm^{-1}\cdot eV)^{1/3}$ and photon energy of (PVA-CoO-ZrO_2) nanocomposites

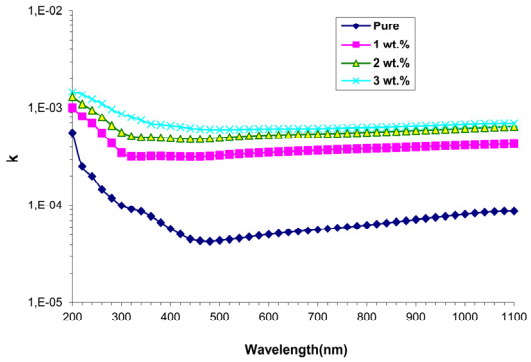

Figure 7. Deference of extinction coefficient of (PVA-CoO-ZrO_2) nanocomposites with wavelength

Figure (8) demonstrates the relationship between refractive index and wavelength for (PVA-CoO-ZrO_2) nanocomposites. The graph demonstrates that as density increases, (CoO-ZrO_2) nanoparticle concentration to (PVA) nanocomposites' refractive index increases. Due to its low transmittance, the UV region has high refractive index values, while the visible range has little values because of its high transmittance [34,35].

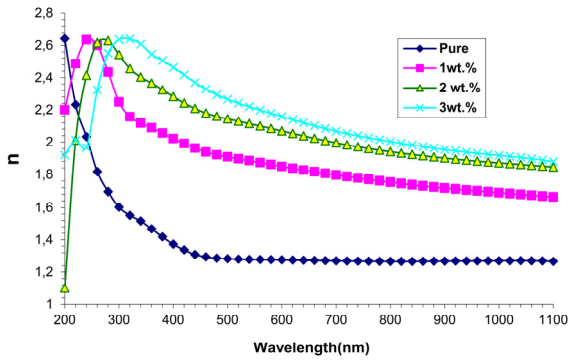

Figure 8. Refractive index (n) for (PVA-CoO-ZrO_2) nanocomposites as a function of wavelength

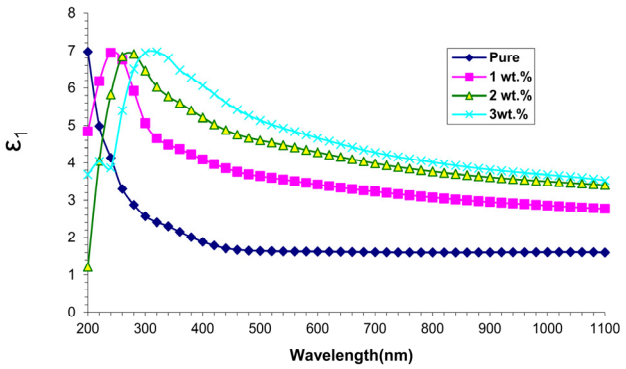

Figure 9. Actual dielectric constant (ε_1) as a function of incident wavelength for (PVA-CoO-ZrO_2) nanocomposites

Figure (9) the difference between ε_1 and wavelength. It is concluded that there is a variation of ε_1 is primarily, depends on the n^2 because of little k^2 values. The relationship amid the imaginary part of the dielectric constant and wavelength of PVA-CoO-ZrO_2 nanocomposites as shown in fig. (10). We can see the (ε_2) values that vary due to the absorption coefficient are dependent on (k) because of their relationship between (ε_2) with (k) [36,37,38]

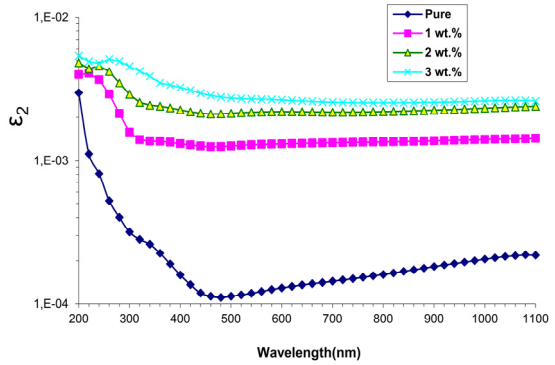

Figure 10. Imaginary dielectric constant (ε_2) as a function of wavelength of (PVA-CoO-ZrO_2) nanocomposites

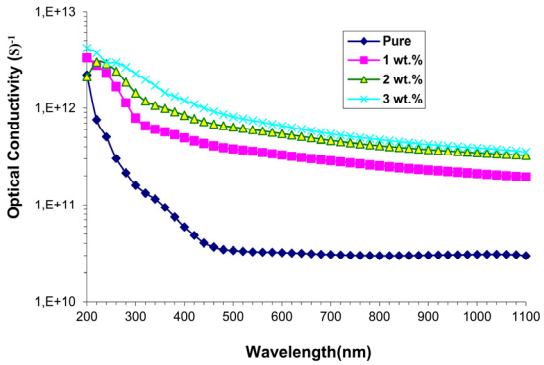

Figure 11. Optical conductivity of (PVA-CoO-ZrO2) nanocomposites as a function of wavelength

Difference of optical conductivity with wavelength for (PVA-CoO-ZrO_2) nanocomposites is shown in fig. (11). As the proportion of CoO-ZrO_2 NPs reached to the (3wt%), the optical conductivity of (PVA) rises. Because of the new levels in this band gap, electrons can move more easily the V.B., followed by the municipal and state levels, and then the C.B. The band gap closes as a consequence, and conductivity rises [39,40,41].

CONCLUSION

1- Optical microscope images show that the additive distribution of nanoparticles in the polymer was homogeneous and (CoO-ZrO_2) nanoparticles form a continuous network inside the polymer

2- The absorbance of (PVA-CoO-ZrO_2) nanocomposites increases with increasing CoO-ZrO_2 nanoparticle concentrations, whereas the transmittance and energy gap of (PVA-CoO-ZrO_2) nanocomposites decreases with increasing CoO-ZrO_2 nanoparticle concentrations.

3- With increasing (CoO-ZrO_2) weight percentage, the absorption coefficient, extinction coefficient, refractive index, real and imaginary parts of dielectric constant, and optical conductivity increase.

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СИНТЕЗ ТА ХАРАКТЕРИСТИКА НАНОСТРУКТУР (PVA-CoO-ZrO_2) ДЛЯ НАНООПТОЕЛЕКТРОННИХ ЗАСТОСУВАНЬ

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Нанокомпозити мають багато застосувань, включаючи оптичні інтегральні схеми, датчики, покриття та медичні пристрої. У зв'язку з цим метою цієї роботи є отримання нового типу нанокомпозитів з полівінілового спирту (ПВС) з різними концентраціями (0, 1, 2 і 3) мас.% оксиду кобальту та діоксиду цирконію (CoO-ZrO_2) наночастинок методом лиття. Мікроскопічні фотографії демонструють, що додаткова кількість наночастинок у полімері була рівномірною, і наночастинок (CoO ZrO_2) утворювали безперервну мережу в полімері, коли концентрація досягала 3 мас.%. Крім того, результати оптичних властивостей вказують на те, що поглинання нанокомпозитів покращується, оскільки концентрація наночастинок оксиду кобальту та діоксиду цирконію збільшується під час пропускання та зменшується розрив візуальної енергії. З іншого боку, оптичні константи нанокомпозитів (показник заломлення, коефіцієнт поглинання, коефіцієнт екстинкції, дійсна та уявна діелектричні константи) і оптична провідність зростають зі збільшенням масових часток (CoO-ZrO_2) наночастинок. Ці результати демонструють використання наночастинок PVA-CoO-ZrO_2 для різних оптичних пристроїв.

Ключові слова: *нанокомпозити; оптичні властивості; оксид кобальту; діоксид цирконію*