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## Effect of Different Concentrations of Nanoparticles on the Optical Parameters of Biopolymer Blend

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Solution casting is used to create the PVA–PEG–Ag nanocomposites of silver (Ag), polyethylene glycol (PEG), and polyvinyl alcohol (PVA) with varying weight ratios of Ag nanoparticles: 0, 2, 4, and 6 wt.%. The results show that the index of refraction, the extinction coefficient, real and imaginary parts of the dielectric constant, and the optical conductivity all increase with increasing of concentration of Ag nanoparticles. These results could be crucial for the use of PVA–PEG–Ag nanocomposites in a variety of photonics applications and optoelectronic devices.

Для створення нанокомпозитів ПВС–ПЕГ–Ag зі срібла (Ag), поліетиленгліколю (ПЕГ) та полівінілового спирту (ПВС) з різним ваговим співвідношенням наночастинок Ag: 0, 2, 4 та 6 мас.% було використано метод лиття з розчину. Результати показують, що показник заломлення, коефіцієнт екстинкції, дійсна й уявна частини діелектричної проникності та оптична провідність зростають зі збільшенням концентрації наночастинок Ag. Ці результати можуть мати вирішальне значення для використання нанокомпозитів ПВС–ПЕГ–Ag у різноманітних застосуваннях фотоніки й оптоелектронних пристроїв.

**Key words:** polyvinyl alcohol (PVA), polyethylene glycol (PEG), silver (Ag), extinction coefficient, dielectric constant, optical conductivity.

**Ключові слова:** полівініловий спирт, поліетиленгліколь, срібло, коефіцієнт екстинкції, діелектрична проникність, оптична провідність.

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### 1. INTRODUCTION

A novel synthetic material with potential applications in the field of

nanoscience is called a nanocomposite. Along with these qualities, it demonstrated the outstanding benefits of optical, structural, electrical, biodegradable, and biocompatible properties [1, 2]. Because of their remarkable qualities such as low cost, ease of synthesis, stability, *etc.*, polymers are widely used in a variety of applications. Polymer-based composites have advantages of being inexpensive and having straightforward manufacturing procedures [3, 4]. Furthermore, flexible electronics that are lightweight might be produced primarily from polymer matrix composites, which would be advantageous given consumer demands [5, 6]. The usage of nanocomposite materials in scientific research has increased recently, with modifications in energy storage technologies and the advancement of physical qualities being crucial elements for real-world applications [7]. Now, nanocomposites (NCs) are being used in gas sensors, UV filters, optoelectronics, high-energy batteries, fuel cells, and microwave absorbers. Stretchable, lightweight, dielectric/conductive polymer materials are needed for many microelectronic devices [8, 9].

Better optical and thermal characteristics can result from the successful formation of electrical conduction networks in insulating polymers with the addition of a small number of nanofillers [10, 11]. When building network co-ordination polymers, polyvinyl alcohol (PVA) anions make good bridge ligands. Because of bioinertness, it has drawn more interest in the biomedical arena [12, 13]. Hydrophilic and non-toxic, polyethylene glycol (PEG) possesses remarkable attributes such as electron-acceptor nature, biocompatibility, chain flexibility, and a broad molecular weight range [14, 15]. PEG is frequently used to improve the flexibility and ductility of stiff polymers [16]. Ag has the highest SPR peak in the visible range, which increases its demand across a variety of sectors, including electronic fields, optical sensors, and cosmetics [17, 18]. Because of their unique chemical and physical properties, silver nanoparticles are being used more and more in commercial, industrial, health care, and medical applications [19, 20].

## 2. EXPERIMENTAL PROCEDURE

Casting process was used to create films of PVA/PEG/Ag NCs with different Ag concentrations of 0, 2, 4, and 6 wt.%. PVA and PEG were dissolved in 40 ml of distilled water by using a magnetic stirrer for 45 min at temperature of 70°C to create a more uniform solution. Ag nanoparticles were added to the polymer blend. A Shimadzu UV-1800 dual-beam spectrophotometer was used to analyse optical properties of nanocomposite films at wavelengths ranging from 190 nm to 800 nm.

One may find coefficient of extinction ( $k$ ) by Refs. [21, 22] as follows:

$$k = \frac{\alpha\lambda}{4\pi}; \quad (1)$$

$\lambda$  is wavelength.

Refractive index ( $n$ ) is defined by Refs. [23, 24] as follows:

$$n = \sqrt{4R - \frac{k^2}{(R-1)^2} - \frac{R+1}{R-1}}; \quad (2)$$

$R$  is reflection.

Real ( $\epsilon_1$ ) and imaginary ( $\epsilon_2$ ) components of the dielectric constant are provided by Refs. [25, 26]:

$$\epsilon_1 = n^2 - k^2, \quad (3)$$

$$\epsilon_2 = 2nk. \quad (4)$$

Optical conductivity ( $\sigma$ ) is defined by Refs. [27, 28] as follows:

$$\sigma = \frac{\alpha nc}{4\pi}, \quad (5)$$

where  $c$  is the velocity of light.

### 3. RESULTS AND DISCUSSIONS

#### 3.3. The Optical Characteristics for PVA/PEG/Ag NCs

Figure 1 depicts how extinction coefficient of PVA/PEG/Ag NCs fluctuates with wavelength. Extinction coefficient is less at low concentrations and increases with increasing Ag nanoparticle concentrations. This is because as the proportion of nanoparticles grows, so, does the absorption coefficient [29, 30]. This study demonstrates that Ag-nanoparticle atoms affect the structure of the host polymers [31, 32].

As the NCs' wavelengths change, Fig. 2 illustrates how the refractive index of PVA/PEG/Ag NCs varies. Figure demonstrates that, when the density of the nanocomposites rises, the concentration of 6 wt.% Ag nanoparticles also rises, as refractive index does with increasing weight percentages of Ag nanoparticles added to the PVA/PEG formulation [33, 34]. In the visible spectrum, high transmittance results in low refractive index values, whereas poor transmittance causes high values in the UV range [35, 36].

Figures 3 and 4 show the real and imaginary dielectric constants

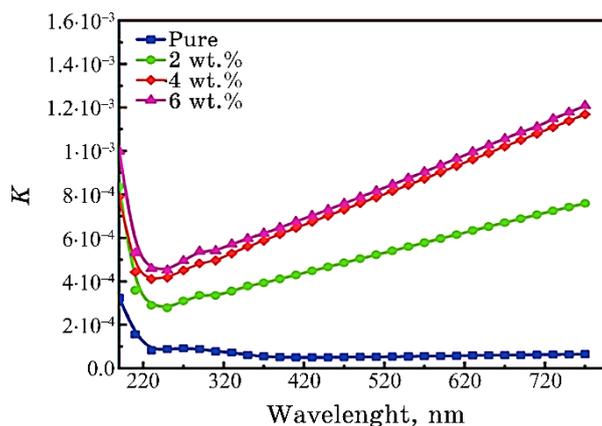


Fig. 1. Extinction-coefficient variation with wavelength for PVA/PEG/Ag NCs.

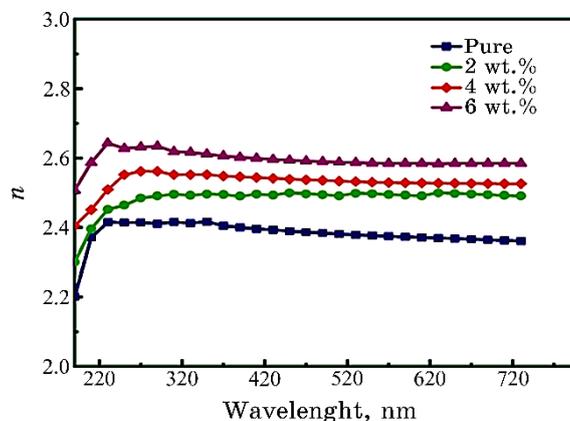
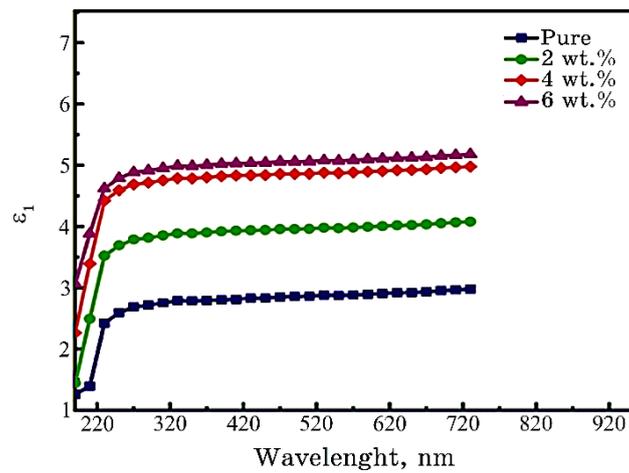


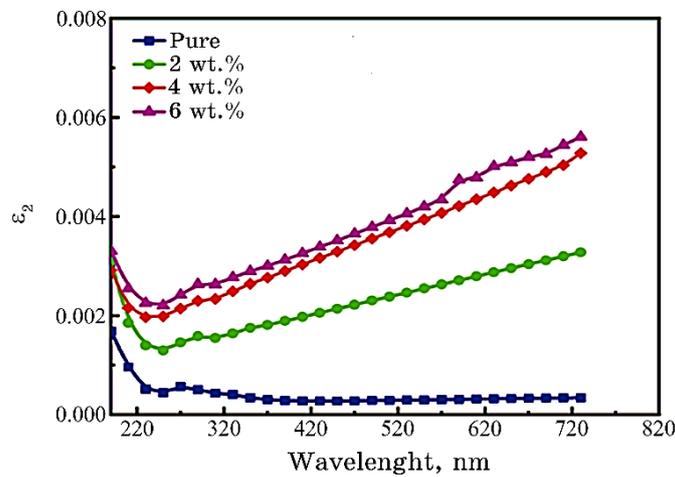
Fig. 2. Refractive index of PVA/PEG/Ag NCs varying with wavelength.

as both components for PVA/PEG/Ag NCs. Figure 3 illustrates how  $\epsilon_1$  varies in relation to wavelength. Because of the low  $k^2$  value,  $\epsilon_1$  is heavily dependent on  $n^2$ . Furthermore, the real dielectric constant rises as the Ag-nanoparticle concentration does. The wavelength-dependent fluctuation of  $\epsilon_2$  is seen in Fig. 4. As demonstrated, value of  $k$  fluctuates with absorption coefficient [37–40].

The relationship between wavelength and optical conductivity is depicted in Fig. 5. This figure demonstrates that, when the Ag content of the PVA/PEG mix rises (6 wt.%), the optical conductivity rises as well. Electrons may more easily transit from valence band to these lower levels and the conduction band thanks to this elevation in band gap, which is result of new-levels' forming. Conse-



**Fig. 3.** The wavelength effects on the actual dielectric constant for PVA/PEG/Ag NCs.

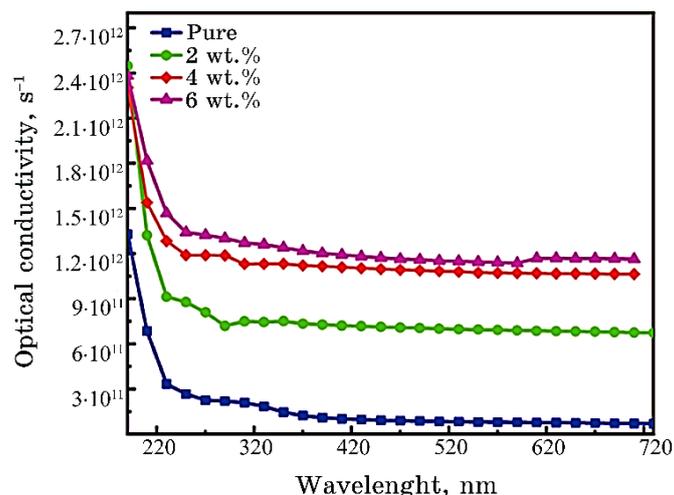


**Fig. 4.** Imaginary component of the dielectric constant changes with wavelength for PVA/PEG/Ag NCs.

quently, conductivity rises and band gap narrows [41, 43].

#### 4. CONCLUSION

Solution-casting technique is used to make films of PVA/PEG/Ag NCs. The optical measurements showed that the refractive index, extinction coefficient, dielectric constant (both real and imaginary



**Fig. 5.** Variance of optical conductivity of PVA/PEG/Ag NCs with wavelength.

ones), and optical conductivity all increase with increasing numbers of Ag nanoparticles until they reach a weight of 6% compared with pure; these results are much better than pure. Furthermore, the results used in this study showed that the PVA/PEG/Ag-NCs' films have superior optical properties compared to the pure mixture. These results indicate the possibility of using PVA/PEG/Ag NCs in photonic and optical applications.

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