Наносистеми, наноматеріали, нанотехнології
Nanosistemi, Nanomateriali, Nanotehnologii
2022, т. 20, № 3, сс. 761–767

PACS numbers: 78.20.Ci, 78.40.Fy, 78.67.Sc, 81.07.Pr, 82.35.Np, 85.60.Dw, 88.40.hj

Synthesis and Optical Characteristics of PVP/NiO Nanocomposites for Optoelectronics Applications

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Synthesis of polyvinyl pyrrolidone (PVP)/nickel oxide (NiO) nanocomposites' films and their optical properties are investigated. The films are prepared with various ratios of PVP and NiO nanoparticles. The absorption of PVP/NiO nanocomposites in UV region is high. With increasing the concentration of NiO nanoparticles, the PVP absorbance is increasing too; so, it is possible to use it in different applications such as transistors and solar cells. By increasing the concentration of NiO nanoparticles, the PVP optical conductivity is increasing, but the energy gap and transmittance are decreased.

Досліджено синтезу плівок нанокомпозитів полівінілпіролідон (ПВП)/оксид Ніклю (NiO) та їхні оптичні властивості. Плівки готуються з різними співвідношеннями ПВП та наночастинок NiO. Вбирання нанокомпозитів ПВП/NiO в ультрафіолетовій зоні є високим. Зі збільшенням концентрації наночастинок NiO вбирання ПВП також збільшується; тому його можна використовувати в різних сферах застосування, таких як транзистори та сонячні елементи. Збільшенням концентрації наночастинок NiO оптична провідність ПВП збільшується, але енергетична щілина та коефіцієнт пропускання зменшуються.

Key words: polyvinyl pyrrolidone, NiO, nanocomposites, optical constants, absorption, energy gap.

Ключові слова: полівінілпіролідон, оксид Ніклю, нанокомпозити, оптичні константи, вбирання, енергетична щілина.

(Received 8 October, 2021; in revised form, 11 October, 2021)

1. INTRODUCTION

There are many exceptional features, which make polymers attractive in most researches because of the broad application fields. It can be used in several applications for example in scientific field because of its low cost, easy to product, processability and durability.

Also, some characteristics should be taken into account for choosing the suitable polymers in practical field such as chemical constancy, hydrophilic & hydrophobic equilibrium, bio-harmonizing, optoelectronic activities, and other functionalities (for example, wettability, solvability, templates). Maintaining the above-mentioned properties and improving them assure features similar to heat resistance, strength and modulus, while increasing the application means that these materials are the maximum challenges in the field of polymers in many instances. Furthermore, polymers can tolerate better shaping and easier processing of the composites.

Due to the reality, polymer medium carries the features of the host polymer medium and the guest nanoparticles; it can be used in the construction of nanoparticles (NPs). Inorganic metal-oxide semiconductor NPs formed in the polymer matrices had attracted significant attention, due to the outstanding characteristics of the materials. The NPs fabricated in such manner exhibited interesting properties such as optical, electrical, magnetic, catalytic, and mechanical features, which were distinct from those observed in their molecular and bulk materials counterparts [1].

Generally, the polymers are the material of great interest because of their low cost, easy processability, low weight, high quality surfaces and easy fabrication of thick and thin samples. The most valuable property of polymer is that they have the capacity to inhibit electrical conductivity as an insulator. In addition to these, the PVP is known to have pharmaceutical importance and possesses good electrical storage capacity, dopant-dependant electrical and optical properties. Due to these remarkable characteristic features, it has drawn a special attention among the conjugated polymers [2].

Nickel oxide (NiO) is a *p*-type semiconductor with wide optical band gap energy of 3–4 eV, and it exhibits a cubic crystallographic structure as a dominated structure. NiO has attractive applications such as sensors, batteries, memory devices, solar cells, and energy storage [3].

NiO has a large exciton binding energy and having a large band gap ranging from 3.6 to 4.0 eV. NiO nanoparticles have many unique optical, chemical, electrical and magnetic properties. Nanometer-size NiO is expected to possess many better properties than those of bulk NiO. NiO nanoparticles are much more effective catalysts than commercial NiO powder for catalytic reduction of carbon dioxide to methanol. NiO nanoparticles have applications in the field of ceramic materials, electronic components, sensors, magnetic data-storage materials and catalysts. NiO has many applications in solar thermal absorber, catalyst for oxygen evolution, photo electrolysis and electro chromic device.

Composites have excellent properties such as high hardness, high melting point, low density, low coefficient of thermal expansion, high thermal conductivity, good chemical stability and improved mechanical properties such as higher specific strength, better wear resistance and specific modulus and have good potential for various industrial fields [4].

The composites and nanocomposites materials have many modern applications like thermal energy storage and biomedical fields [5–10]. This work deals with the effect of NiO NPs on PVP optical property for using it in diverse optoelectronics fields.

2. MATERIALS AND METHODS

The PVP/NiO nanocomposites films were synthesized by using casting technique on glass slides. The solution of PVP was prepared by dissolving 0.5 gm of PVP in the distilled water (20 ml). The nickel oxide nanoparticles (NiO NPs) were added to PVP solution with various ratios: 1.5, 3 and 4.5 wt.%. The optical properties PVP/NiO nanocomposites were measured in range of wavelength from 300 nm to 900 nm by spectrophotometer (UV/1800/Shimadzu). The absorption coefficient (α) of nanocomposites is determined by Ref. [11]:

$$\alpha = (2.303A)/t, \tag{1}$$

A and t are the absorbance and thickness of sample, respectively. The non-direct transition model for amorphous semiconductors is given by following equation [12]:

$$\alpha h\upsilon = B(h\upsilon - E_g)^r, \tag{2}$$

where B is constant, E_g is photon energy. The optical conductivity can be determined by the following equation [13]:

$$\sigma = \alpha nc/(4\pi)\,. \tag{3}$$

3. RESULTS AND DISCUSSION

Figures 1, 2 represent the variation of absorbance and transmittance spectra for PVP/NiO nanocomposites' films with photon

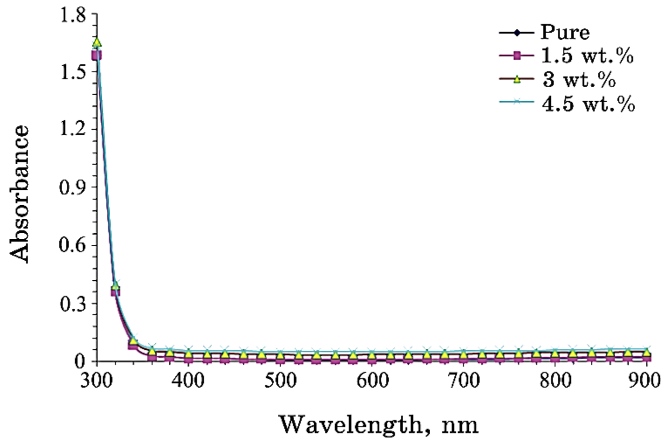

Fig. 1. Variation of absorbance spectra for PVP/NiO nanocomposites with photon wavelength.

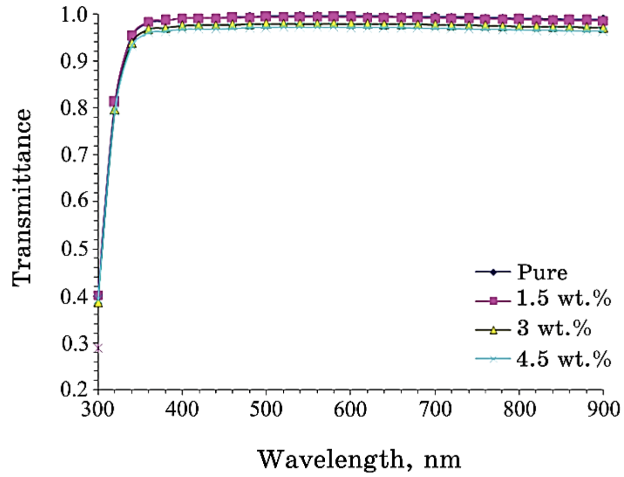

Fig. 2. Variation of transmittance spectra for PVP/NiO nanocomposites with photon wavelength.

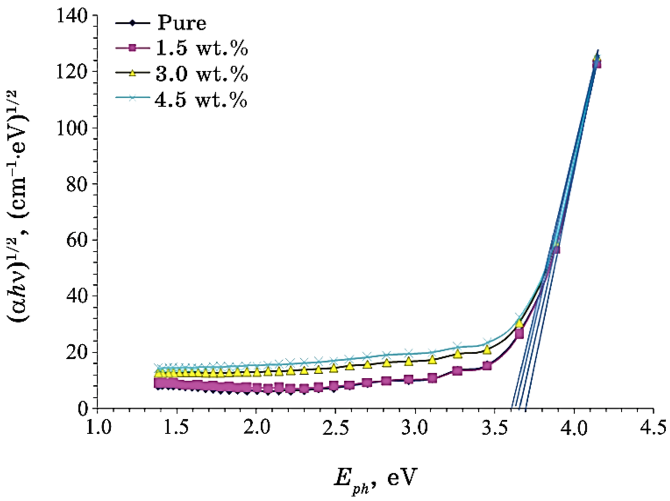

Fig. 3. Energy band gap for allowed indirect transition of PVP/NiO nanocomposites.

wavelength range 300–900 nm. These figures show the absorbance of PVP increases while the transmittance decreases with the increase in NiO nanoparticles' concentration. The increase of the absorbance and decrease of the transmittance are due to the increase of charge carriers' number in the nanocomposite. The increase in absorption is due to charge transfer transitions [14–16].

Figure 3 shows the indirect allowed transition energy gap for PVP/NiO nanocomposites films. As shown in this figure, the energy gap of PVP reduces with the increase in nanoparticles NiO concentrations; also, it is important to remind that this concert caused by forming of levels in the energy gap. There are two steps when the electron moves in this case: first step is taking up the transition in the valence band; second step is in the conduction band and to the confined levels because of increase of the concentration of NiO nanoparticles. The conduction of electrons depends on the concentrations of NiO nanoparticles. From the results, it is obvious the existence of strong intermolecular relations between doping component and composite; this guide to reduce the space between bonding and antibonding molecular orbitals, and a less significant photon energy is necessary to be expecting electrons from π- to π^*-molecular levels compact as well [17].

Figure 4 shows the variant in optical conductivity of PVP/NiO nanocomposites' films and energy of photon. This figure shows that the PVP optical conductivity rises with raises in concentration of NiO nanoparticles; this behaviour is certified to increase of density and absorption coefficient [18, 19].

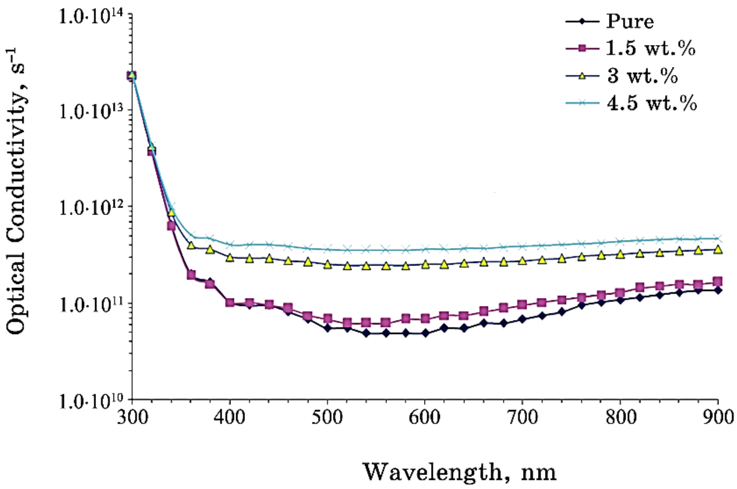

Fig. 4. Variation of optical conductivity of PVP/NiO nanocomposites with energy of photon.

4. CONCLUSIONS

In this work, the optical properties of PVP/NiO nanocomposites' films were studied to use it for different optoelectronics applications. The experimental results showed that the absorbance of PVP increases while the transmittance decreases with the increase in NiO nanoparticles' concentration that make it is useful for various optical and electronic applications. In addition, optical conductivity increases while the energy gap decreases as NiO nanoparticles' concentration increases.

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