Photo-sensitive electrodes based on NiO: SnO_2 Nano-composites prepared by chemical method

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In the beginning, NiO/SnO_2 nanocomposite thin film was prepared of nickel nitrate (1.5213) gm that was weighed and dissolved in distilled water to obtain a specific molar concentration at room temperature and prepared as nanoparticles and mixed with half mount (0.5121) gm of SnO_2, in addition to other steps to obtain on the nanocomposite to study some features it. The structural properties of nanocomposite thin films using the chemical technique studied, such as XRD, FE-SEM, and AFM, were found that NiO/SnO_2 Nano-composite crystallizes are hexagonal structures with an average crystallite size of 16.30nm. also, the FE-SEM images study the morphology of the NiO: SnO_2 thin films, it catches sight of the nanostructure thin films of the NiO: SnO_2 Clearly, the surface roughness of nanocomposite according to AFM noted that gets better as a result of the radical's mobility. The FT-IR spectrum of the synthesized composite has been studied. UV-Spectral absorption of NiO: SnO_2 where peak range of wavelength (225-550) nm and notice an increase in the absorption range towards the red wavelength after adding nickel oxide, and use the prepared sample in applied as photosensitive electrodes, voltage characteristics of chemical synthesized: SnO_2 nanoparticles shows the current vs voltage plot of chemical-synthesized NiO: SnO_2 nanoparticles coated onto glass substrates using dip coating method where add SnO_2 due to increasing the conductivity of the nanocomposite.

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Keywords: Nano-composite, Thin film, Light-sensitive electrodes, NiO/ SnO_2

1. Introduction

Nanocomposites are composites in which at least one phase or multi-phases have morphology at the nanoscale like lamellar nanostructure, nanotubes, or nanoparticles. so the phases of these materials should have at least dimensions between 10–100 nm. Nowadays consider the nanocomposites the best alternatives due to the limitations of the different engineering materials, also can be categorized depending on dispersed phase materials and their dispersed matrix [1] as results develop rapidly in this field, it can generate novel materials have exciting novel features by innovative routes in the modern industry. The properties of the so-called found not only depended on the properties of their originals, where the new properties are not related to their origin, it is based on morphology and interfacial characteristics. sometimes the new feature is different from the original material [2, 3]. then, the reason behind fabricating the nanocomposite on the Nanoscale belong to create and design novel materials that have matchless flexibility and enhancement in the physical characteristics. These metal oxides or metal has been synthesized as nanoparticles to be used in different applications, like biomedicines, energy storage devices, catalysis, and dye-based solar cells, [4,5, 6– 7]. SnO_2 and NiO NPs one of them n-type and p-semiconductor respectively, have wide energy gaps of 3.6–4.0 eV of NiO while SnO23.6 eV, Where NiO has electrochemical and exclusive optical properties and has high conductivity [8, 9], used NiO in numerous applications like fuel cells, gas sensor photocatalytic agent and adsorbent [10]

. Various routes are used to prepare it such as green methods, sol–gel methods, spin coating, and pulsed laser deposition [11]. SeO2 NPs have non-toxic nature, various morphologies,

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also strong oxidizing power with photochemical stability is very high; therefore, it the best choices to use for photo-catalysts [12, 13,14] also have electro-catalytic activity, low cost in addition to the conductivity, and the chemical stability is very high so utilized in the electrochemical sensing [15]. Several methods used for the fabrication of SnO2 NPs may be chemical or physical techniques like co-precipitation, the sol–gel method, laser ablation, microwaves, spray pyrolysis, hydrothermal, electrochemical deposition, and Sono-chemical, non-aqueous routes, and solvothermal, [16, 17, 18]. Study the photosensitivity of electrodes of NiO/SeO2nanocompsite besides studying the structural and optical features of the compound

2. Experimental part

2.1. Preparation of:(NiO: SnO2) nanocomposites

In the beginning, (1.0120) gm of nickel nitrate and was weighed of (0.121) grams of polyethylene (PEG) were taken in 60 ml of deionized water to obtain a specific molar concentration. After that, it puts on a magnetic mixer for 30 min at 50°C, an amount of sodium hydroxide (NaOH)(0.5102) gm add it dropwise to the solution and it is considered for reaction fuel, and adjusting the alkalinity at pH 8. And 0,121 gm of PEG and put on a magnetic stirrer and start increasing the temperature gradually till 100 C for 3 hours then decreasing the temperature gradually then filtration the solution to obtain on NiO2 Nanoparticle, then take 2 ml of NiO2 NPs and half mount (0.5121) gm of SnO2 mixed on magnetic stirrer to get on solution white colour, the solution was filtered and the liquid was taken from it and deposited by dip-coating on a glass substrate, after that the material is ready for testing and application. A percentage of ethanol was added to the material and mixed well to obtain nickel oxide in a liquid form

3. Results and discussions

3.1. The crystal structure

Figure 1 and Table 1. show The NiO: SnO_2 Nanocomposite, diffraction peaks pattern through 2-theta of NiO 37.20,43.20,62.70, 69.10,72.40can be well-matched with the miller indices (hkl) at (111), (200), (220),(301)and (222) While SnO_2 260,330,370,510, 650,790 (110), (101), (211),(112), and (321) respectively. This result matches the Crystallography Open Database (COD) card numbers [96-153-4786 and 96-101-0094]. Here, NiO: SnO_2 Nanocomposite with an average crystallite size of 16.30 nm

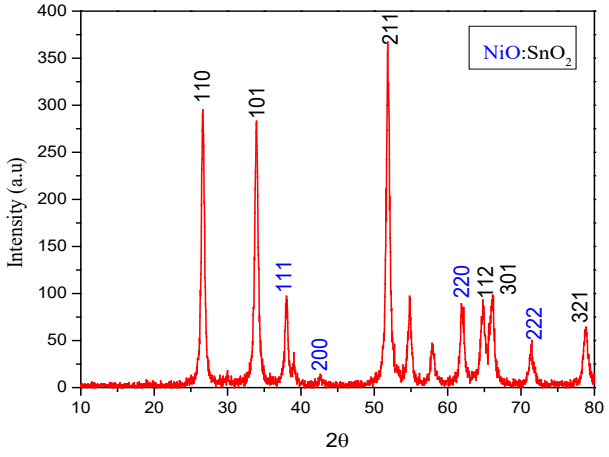

Fig. 1. XRD pattern of NiO: SnO_2 nanocomposite.

Table 1. Structural properties of NiO: SnO2 nanocomposite.

2θ (Deg.)	*FWHM (Deg.)*	*d_{hkl} Std.(Å)*	*d_{hkl} Exp.(Å)*	*The crystallite size (nm)*
26.641	0.551	3.4	3.34	14.80
33.935	0.606	2.53	2.64	13.69
38.031	0.525	2.36	2.36	16.00
42.679	0.198	2.12	2.12	42.99
51.87	0.63	1.72	1.76	14.02
54.82	0.67	1.53	1.67	13.44
61.99	0.70	1.50	1.50	13.24
64.80	0.80	1.52	1.44	11.77
66.03	0.79	1.45	1.41	11.99
71.42	0.72	1.53	1.32	13.57
78.82	0.74	1.21	1.21	13.84

3.2. Scanning Electron Microscope (SEM)

the morphology of the surface NiO: SnO2 Nano-composite can be seen by SEM after depositing the nanocomposite on the glass as shown in Fig. 2. Through the images of morphology, it can see nanostructure of the NiO: SnO2 nanocomposite thin films are fully identical excluding that there is a small diminishing in the size of the particle, in addition to exists some crystalline forms and structures that formed by the grains agglomerations, it is clear that samples of nanocomposite have the smallest grain size, where using (Image J software), to known NiO: SnO2 nanocomposite thin films that are about (36nm).

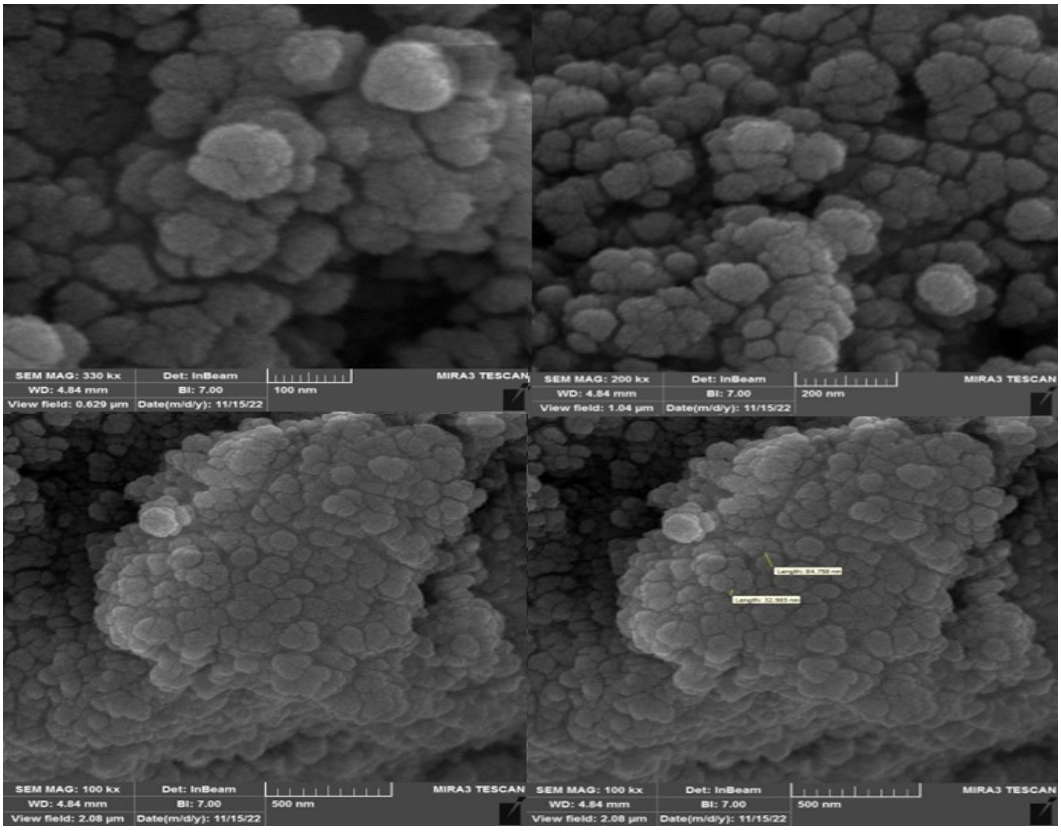

Fig. 2. NiO/SnO_2 Nano-composite (FE-SEM) Analysis shows the surface morphology.

3.3. Energy dispersive X-ray spectroscopy (EDS)

This test was used to analyze elements of nanocomposite after deposition of NiO/SnO2 nano-composite samples on the glass in Figure (3) notes at room temperature that the amount elements of Tin, Nickel with the oxygen of the prepared samples the least from the other prepared samples where these results are matching with X-ray diffraction analysis and FE-SEM. Also been proven that the goodness of these thin films in terms of sizes of grain, crystallite or particle, and porosity are the best from the other samples that were prepared in other conditions.

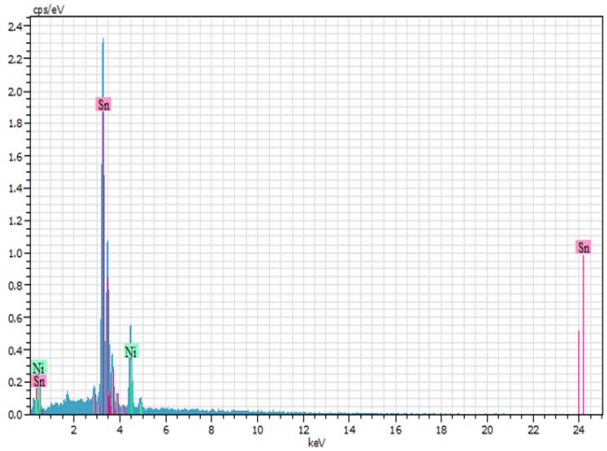

Fig. 3. EDS analysis of NiO: SnO2 Nano-composites by chemical technique at room temperature.

3.4. Atomic force microscopy AFM

To see the morphology of the surface of nanocomposites used Atomic Force Microscopy (AFM). Observe from images of AFM, that there raising in the growing size and an improvement in crystallinity after adding NiO to the substrate, also observed that the roughness of surfaces may improve due to the mobility of radicals at the surface of the sample, where note that 3D images of (AFM) surface may enhance of thin films NiO: SnO_2 nanocomposite that deposited on substrates of the glass at different temperature of substrates as in Figure.4

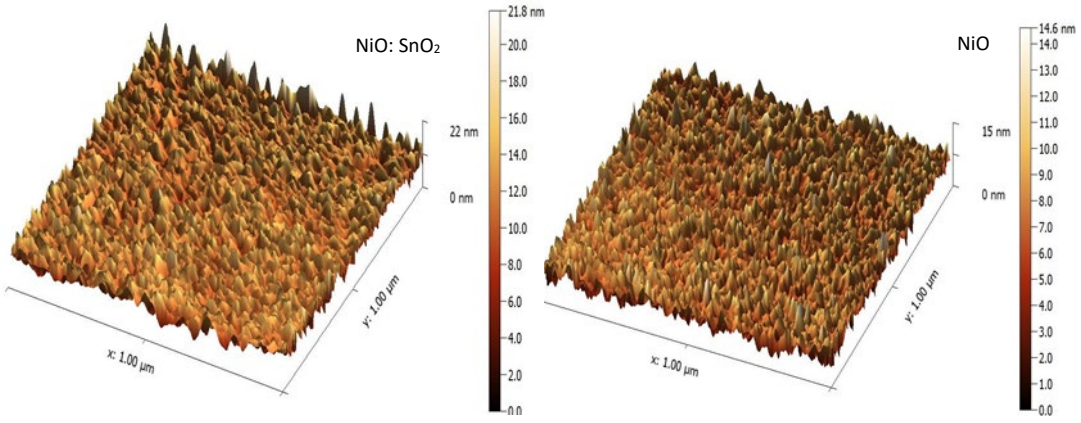

Fig. 4. The AFM of NiO: SnO_2thin films as a function of the substrate at 3D images.

3.5. FT-IR analysis

The FT-IR spectra of NiO: SnO2 nanocomposite thin film as Fig. 5 where hydroxyl groups located at 3848.77 and 680.97 cm−1 that consider the exemplary stretching vibration, While the peaks at 2078.70 cm−1 pointed to symmetrical stretching vibrations and the typical

asymmetrical of bond C-O because the groups of C-O-H. whereas the peaks at 3848.77 cm−1 represent the peaks double weaker that belong to the symmetrical stretching vibrations of bond C-O-C, whilst the peaks at 680.97 and 1637.57 cm^{-1} belong to stretching of Sn-O-H due to impurities of the Sn(OH)2. , in Figure.5. shows The peaks he Sn-O-Sn stretching at t<1000 cm−1 [10, 11].in addition to the peak of Ni-O located at 460 cm^{-1} at standard conditions while observed at 680.97 cm^{-1} as a broad absorption band of stretching vibration for NiO: SnO2 in case the nanocomposite. One of the authors found that FT-IR spectra of SnO_2 around 468 and 609 cm−1, which refer to bonds of stretching vibration for O—Sn—O and Sn—O, respectively [8]

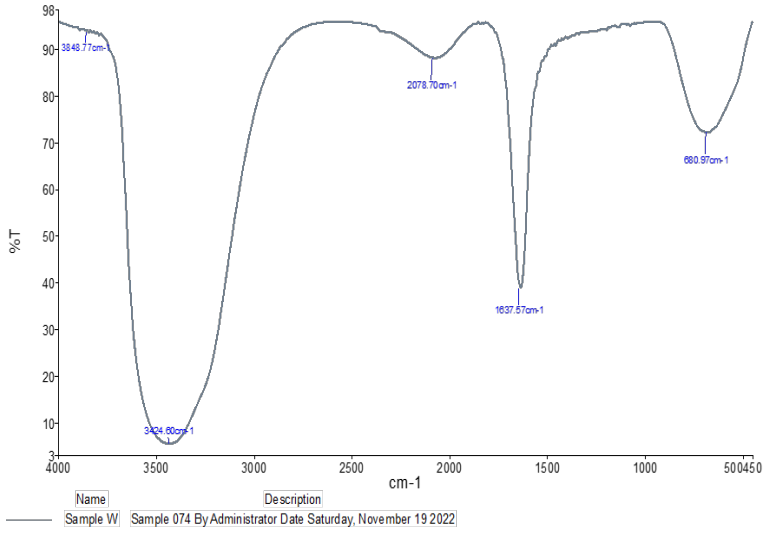

Fig. 5. FT-IR spectrum of NiO: SnO2 Nano-composite thin film.

Table 3. The peak of NiO: SnO2 nanocomposite from FTIR spectrum.

Peak Number	*X (cm^{-1})*	*Y (%T)*
1	3848.7	93.82
2	3424.6	5.43
3	2078.7	88.41
4	1637.5	38.99
5	680.9	72.41

3.6. Absorbance Spectra Measurement

It is seen that the maximum peak range of wavelength the UV-Spectral absorption (200-300) nm as Figure shows the UV-Spectra of NiO/SnO_2 nanocomposite located at wavelengths (225-550) nm and notices an increase in the absorption range towards the red wavelength after adding nickel oxide, and this phenomenon is called red-shifting. This phenomenon is clear in Figure 6 which shows the improvement in the susceptibility of the resulting material from adding nickel oxide to tin oxide by improving the extent of absorbance in the aforementioned sample.

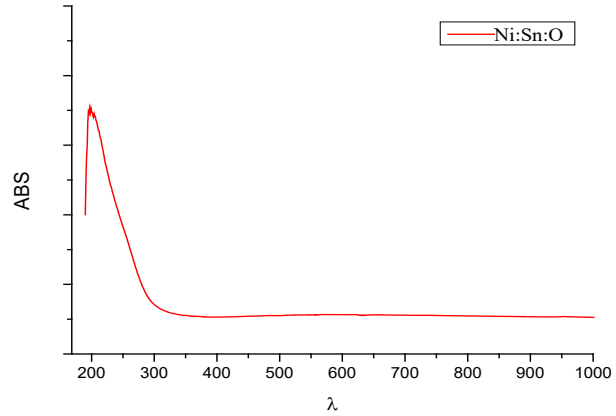

Fig. 6. Shows the absorption of UV-Spectra of SnO_2: NiO nanocomposite.

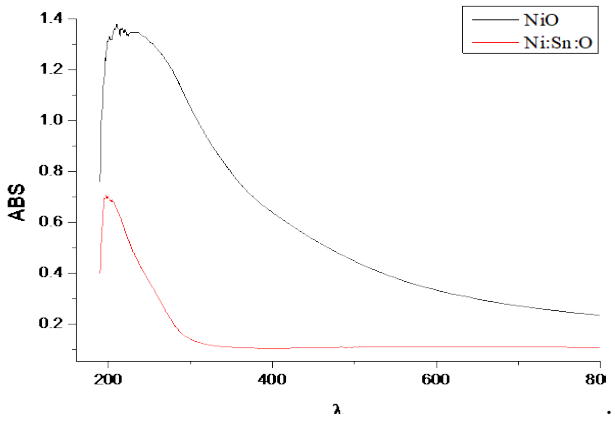

Fig. 6. Comparative NiO NPs of the UV-Spectra with NiO: SnO_2 Nano-composite

3.7. Energy gap estimation

After recording the optical transmittance for nanocomposite NiO/SnO2 thin film in the range(200–1100nm) At room temperature, after that The plot NiO: SnO_2 thin films take $(\alpha h\nu)^2$ and produces a straight line, and the value of the band gap occurs at $(\alpha h\nu)^2 = 0$ as the extrapolation of the straight line. It has been calculated the value of the gap of the NiO: SnO_2 thin films as Figure .7at (3.7 eV).

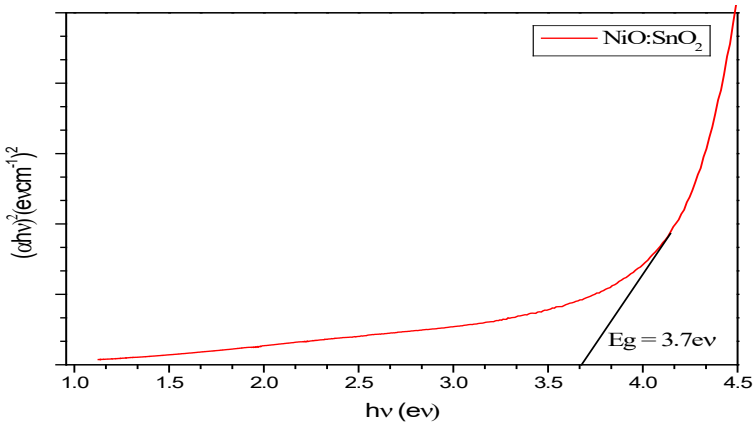

Fig. 7. Energy bandgap (Eg) of the NiO: SnO2 Nanocomposite

The doping of the samples with ten oxides led to a raising in the energy gap, which is associated with a reduction in the size of the nanoparticles. This result is very compatible with the results of the diagnosis using SEM and XRD tests, which confirm the consistency of the results [19-21].

3.8. Photo-sensitive electrodes

Figure 8. shows the Current-Voltage characteristics of the Chemical method: SnO_2 nanoparticles show the current-voltage plot of chemical-method NiO: SnO2 nanoparticles coated onto glass substrates using the dip coating method. From the Figure, it can be seen that the NiO: SnO_2 Nano-composite thin film shows Ohmic nature. The current through the thin film is found to be in Nano Ampere. Also, the value resistance of films was found equal to 288MΩ, it considers very high. This proves that electrodes can be used in solar cells or use as photo-catalysis electrodes in the production of fuel hydrogen cell

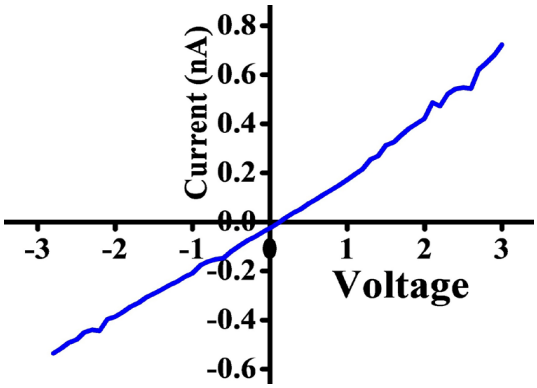

Fig. 8. The Current-Voltage characteristics of the Chemical method: SnO_2 nanoparticles.

4. Conclusion

Nickel Oxide was prepared by Chemical route from its raw materials, as well as preparation of NiO/ SnO_2 compound as nanocomposite by dipping method, and studied the structural tests represented by X-rays, as well as SEM and AFM, were performed, and Optical tests were carried out and were consistent with international research, and then apply it as light-sensitive electrodes

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