

Study of the structural and optical properties of electrospun PVA-Cr fibers

Dalia Y. Salahaddin¹, Nadim K. Hassan²

^{1,2} Department of Physics, College of Pure Science, University of Tikrit, Iraq.

Abstract:

Pure polyvinyl alcohol PVA and PVA-Cr PVA/Cr nanofibrous films were prepared by electrospinning with different amounts of Cr(NO₃)₃ solutions (1, 2, and 3 wt%) at room temperature. FE-SEM, XRD, UV and PL characterizations are used to study the morphology, to Structure, and optical properties of materials. In contrast, the PVA-Cr doped nanofibrous films showed a cubic structure with a preferred orientation (100), indicating the presence of Cr NPs in the PVA-Cr nanofibrous films. Measurements were taken on each (SEM) image to determine the average diameter of the fibers obtained. The results showed that the average fiber diameter of electrospun (PVA) was reduced to the (50–350 nm) range without beading. With the increase of Cr(NO₃)₃ concentration, the absorption peak shift to the long wavelength direction, while with the increase of Cr(NO₃)₃ concentration, the energy band gap and absorption edge shifts to the low energy direction.

KEYWORDS: electrospinning, nanofibrous, nanoparticles, electrospun.

دراسة الخواص التركيبية والبصرية لألياف PVA-Cr المغزولة كهربائياً

داليا يوسف صلاح الدين¹ ، نديم خالد حسن²
^{1,2} جامعة تكريت، كلية التربية للعلوم الصرفة، قسم الفيزياء

مستخلص:

تم تحضير الياف نانوية من كحول البولي فينيل PVA النقي وكحول البولي فينيل المشوب بالكروم بنسب مختلفة (1٪، 2٪، 3٪) باستخدام تقنية الغزل الكهربائي عند درجة حرارة الغرفة. تم اجراء فحوصات FESEM, XRD, UV, PL لدراسة الشكل والبنية والخصائص البصرية لجميع العينات، وقد اظهرت اغشية الالياف النانوية المطعمة بالكروم بنية مكعبة ذات اتجاه مفضل (100) يشير الى وجود جسيمات الكروم النانوية على الياف كحول البولي فينيل، واطهرت نتائج SEM ان متوسط قطر الالياف المغزولة كهربائياً قد انخفض الى (50-350 nm) عند تركيز 3%Cr وخالية من الخرز، واخيراً وجد ان ذروة الامتصاص تتحول ذروة الامتصاص باتجاه الطول الموجي الطويل مع زيادة تركيز Cr(NO₃)₃، بينما تتحول فجوة نطاق الطاقة وحافة الامتصاص الى اتجاه الطاقة المنخفضة.

1. Introduction

Electrospinning is the cheapest and easiest way to produce nanomaterials. Structured polymer fibers with diameters ranging from micrometers to tens of nanometers for different types of applications are considered important to the production process for these application. The possibility of producing fibers from biodegradable and renewable products becomes easier due to low-cost and high-strength fiber properties that can be used in different areas of life. Polymer fibers produced by electrospinning process can produce[1]

The diameter range (10-100 μm) is in the micron region, and the diameter range (0.01-0.1 μm) may be decreased to submicron or nanoscale, leading to several desired features, such as B. High surface area to volume ratio (103) times. high porosity, high pore size (nanoscale), and microfibre content [2].

The electrospinning process can be briefly described as follows: Fill the syringe with the polymer solution. The polymer solution is pumped out as soon as an electric field is generated between the tip of the syringe and the

collection electrode. When an electrostatic field strength is applied, the solvent in the atomized polymer solution instantly evaporates and the polymer is stretched by the charge of the solution to generate nanofibers of various shapes. An aluminum foil covering the electrodes was used to collect the fibers that formed. Experimental operating conditions have been reported to have a significant effect on the final fiber[3]. It is believed that over 100 different polymers have been successfully spun into nanofibers to date. Electrospun fibers are typically placed on a solid collector made of a three-dimensional nonwoven membrane structure with different fiber diameters. Extensive studies on electrospinning have shown that fiber trapping capacity, average fiber diameter, fiber diameter distribution, and homogeneity of fiber porosity are strongly influenced by solution properties [4]. Polyvinyl alcohol (PVA) is a water-soluble, biodegradable polyol polymer that has been extensively studied for its excellent thermal stability, biocompatibility, chemical resistance, and low cost. [5]. Especially its aqueous solution, which is colorless transparent and non-viscous. -poisonous. Hong et

al. reported PVA nanocomposite fibers reinforced with Ag nanoparticles as wound dressings [6]. Sajib et al. Nanoscale PVA fibers have been used as reinforcing fillers, filter materials, tissue scaffolds, drug delivery carriers, etc. [7]. His production of PVA-based nanofibers by electrospinning has been widely reported [8]. The effect of inorganic additives on the properties of nanoscale fibers has been reported in several references. [9] However, there are few reports on the effect of salt on fiber morphology. In this study, experiments were performed to fabricate and characterize their PVA/Cr nanofibers using the electrospinning technique. The effect of the concentration of His-Cr nanoparticles on the structural and optical properties of PVA films was mainly analyzed using UV/Vis and PL. These provide clues for understanding the effect of nanoparticles on optical parameters, while the energy band diagram provides the host polymer.

2. Experimental

To prepare spinning solutions, a polyvinyl alcohol PVA was used in this work, which had a molecular weight of 100,000. PVA was dissolved in

distilled water and stirred for 72 min at a temperature of at 60 °C to obtain a homogeneous solution.

Next, to prepare the PVA-Cr solution, dissolve 0.2 g of $\text{Cr}(\text{NO}_3)_3$ in 10 mL of distilled water and mix with a magnetic stirrer for 10 min to form (1,2) and (1,2), and warm to room temperature. 3). Add wt% and mix with a magnetic stirrer for 5 minutes. Finally, To create fibers using the electrospinning system, pour the prepared electrospinning solution into a syringe with a metal needle. A syringe pump, a conductive collector, such as aluminum, and a high-voltage DC power source are the three fundamental parts of an electrospinning system. Electrospinning systems typically come in two flavors: horizontal and vertical. In this experiment, the syringe pump was placed in a horizontal position with the needle pointing towards the floor, as shown in Figure 1. The control range (0~50kV) is set to (DC 20kV) high voltage power supply and flow rate, and the control range is 0.1ml/h~100ml/h. The 0.1 mL/hr syringe and syringe pump are composed of 21 gauge metal. The polymer solution was charged positively by connecting a needle battery to a source

of positive energy. 18 centimeters separate the

from the needle. To disperse the PVA-Cr solution over the glass in three phases, place it in a plastic syringe, add pure PVA solution, and pump. A plastic syringe transmits an electric field to a

Taylor cone, where it flows at a pre-determined flow rate using high voltage, an aluminum current collector, and a hypodermic needle [10]. Surface charges produced by a power source produce the beam [11].

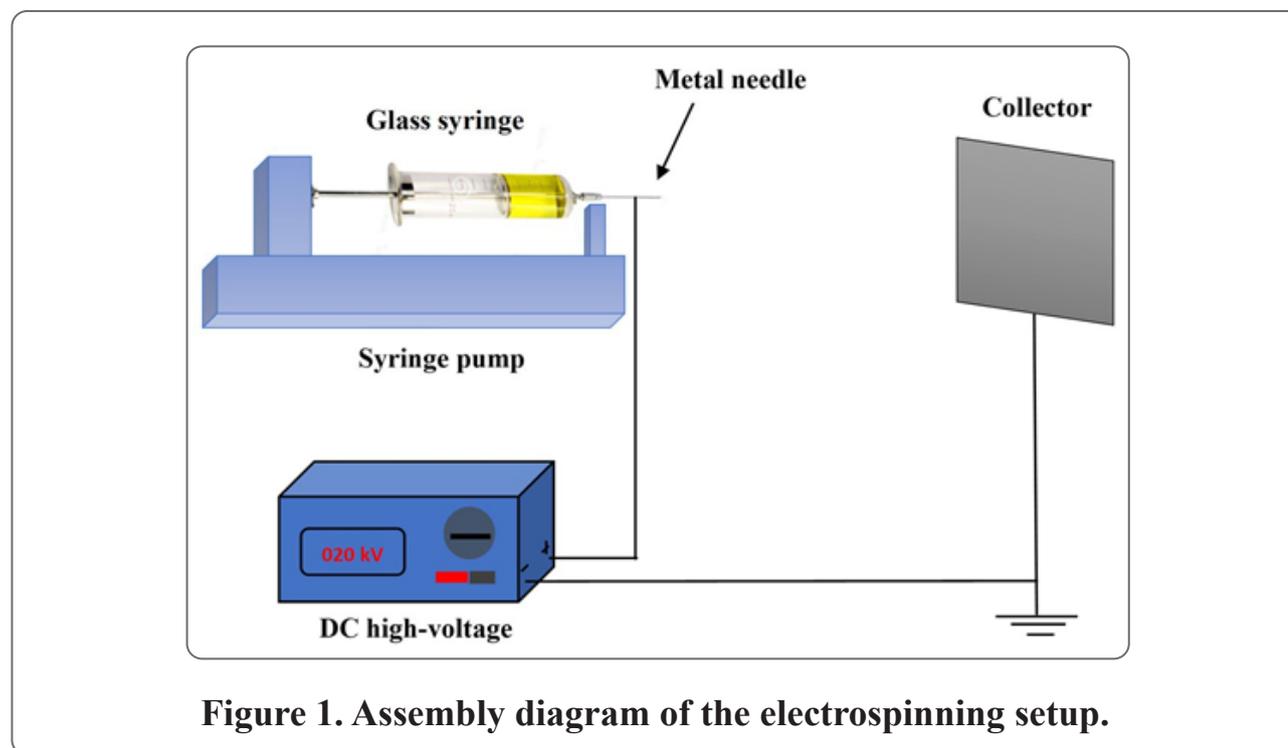


Figure 1. Assembly diagram of the electrospinning setup.

Layer by layer, the nanofibers are created when the solvent evaporates as it travels to the collecting plate. Based on their impact on the structure and morphology of nanofibers, the optimal operating conditions and associated factors impacting electrospinning were identified [12]. This study looked at how Cr affected fiber diameter, shape, and optical characteristics. to guaran-

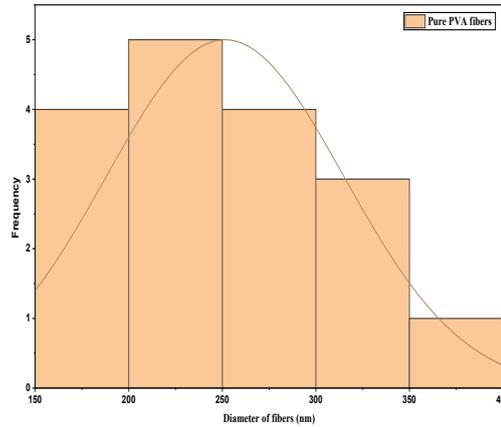
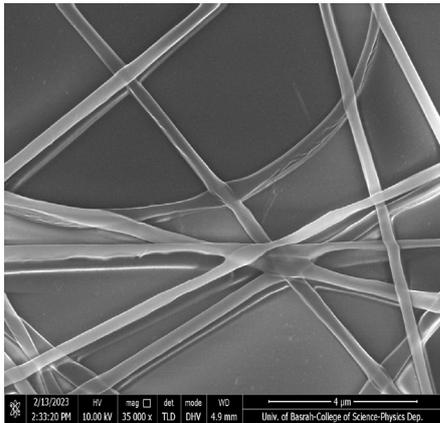
tee the correctness of the outcomes. The structural morphology of the resultant nanofibers was examined using (FE-SEM). X-ray diffraction was used to confirm the observed structure. Using a UV-VIS spectrophotometer (model Sp-8001), determine the optical absorption spectra of the deposition nanofibers as a function of wavelength in the range (300-1100 nm).

3. Results and discussion

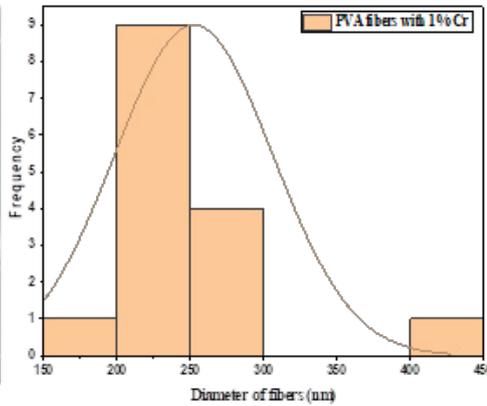
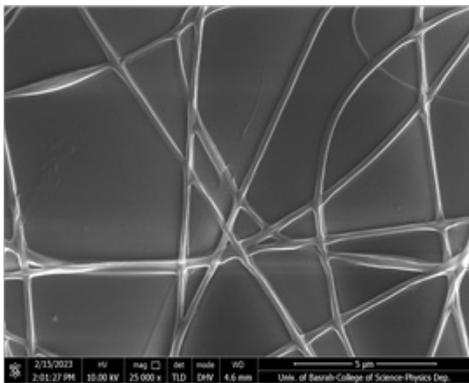
3.1 field emission scanning electron microscopy (FESEM) result

Figures (2-a, b, c, and d) show the obtained FE-SEM images of the nanofibers and the fiber diameter distributions (1%, 2%, and 3%) of the bare PVA film and the Cr-doped PVA film. (PVA film - film) It shows. % When using a glass substrate. For pure PVA nanofibers, the average length is (258.5 nm). For PVA/Cr nanofibers containing 1% Cr, the manufactured nanofibers had diameter values between 150 and 450 nm, with an average diameter of 251.6 nm. At a Cr mass concentration of 2%, the average diameter (292.8 nm) ranged from 150 to 650 nm, while a maximum Cr mass concentration of 3% in the polymer matrix produced PVA/Cr nanofibers with diameter values of the results are as follows: (2-a,b,d). The average diameter is 50-350 nm (177.6 nm). The 1%, 2% and 3% Cr-doped PVA/Cr nanofibers have a regular shape without beads. Beadless fibers are preferred due to their high surface area to volume ratio and excellent mechanical properties. [13]. In addition, it is characterized by the absence of structural

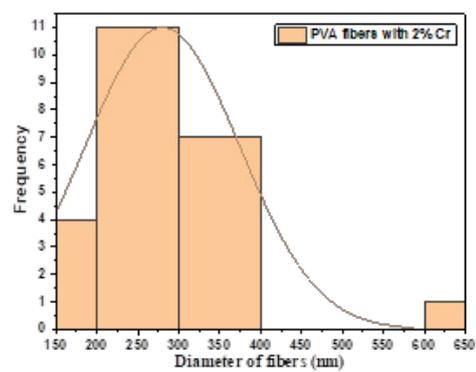
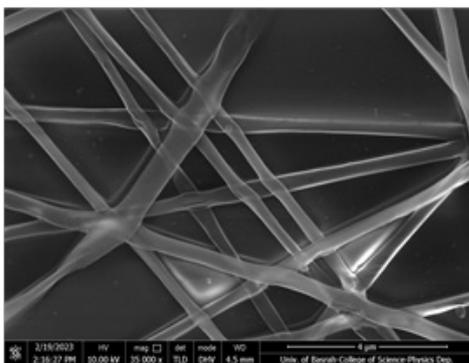
defects over the entire fiber length. The increasing amount of material added to the polymer solution may be the cause of the observed change in the diameter values of the composite nanofibers, which changes the charge density and solution viscosity of the solution. A suitable Cr content is 3%, which enables the production of fine-diameter fibers.



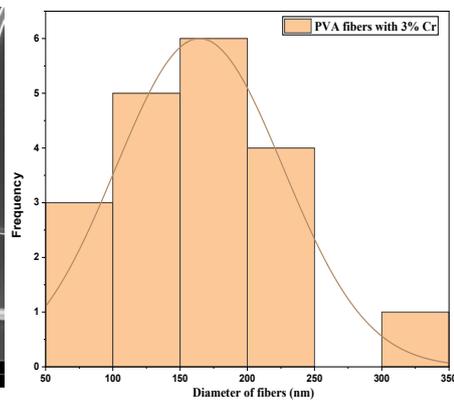
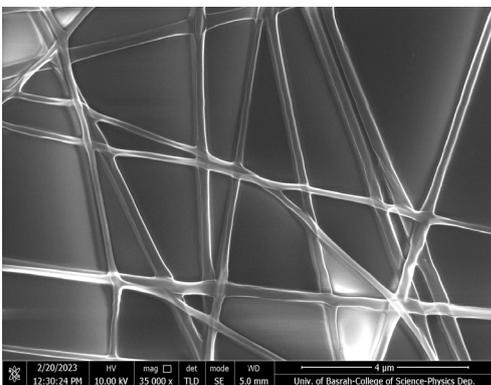
(a)



(b)



(c)



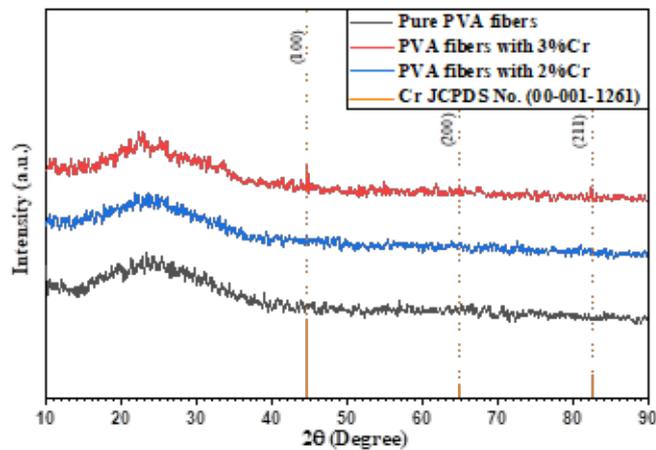
(d)

Fig(2-a.pure PVA,b.PVA/1%Cr,c.PVA/2%Cr,d.PVA/3%Cr)

3.2 X-ray diffraction results

XRD was performed to confirm the phase structure of the resulting pristine PVA and PVA/(1.2.3 wt% Cr) nanofibers. Figure 3 shows the XRD patterns of PVA and PVA/(2.3 wt% Cr) nanofibers. It can be seen from the XRD pattern of PVA that there is no trend peak for PVA. In addition, a mixture diffraction scan of PVA and elemental chromium shows chromium peaks at cubic (FCC) angles (100, 200, 211) and angles (44.6085° , 64.6771° , 82.3500°). This is because the molecular chains

of PVA polymer and chromium are strengthened by rotation and alignment during electrospinning [14]. Calculate the particle size (D) using the formula " $D_{avg} = (0.9)/(\cos \theta)$ ". where θ is the span angle, $\Delta 2\theta$ is the entire width of the FWHM intensity in radians, and λ is the X-ray beam's wavelength. This is better than average. The particle sizes (D) of the PVA/(2%, 3%) Cr nanofibers were calculated as (59.63 nm and 65.32 nm, respectively). This indicates a slight increase in particle size with increasing concentrations of (Cr) nanoparticles.



Fig(3) X-ray diffraction PVA and PVA-(2%,3%Cr)

3.3 The UV-vis absorption spectra for PVA nanofiber thin film doped with Cr

Figure (4) displays the UV-Vis absorption spectra of pure PVA and PVA that has been doped with Cr. It is found that the addition of Cr nanoparticles to

the PVA matrix increases absorption. It can be seen that all the NCP films show similar trends in the wavelength range from 300 to 1200 nm. While a strong absorption band is seen at about 347 nm and abruptly decreases at about 550 nm. The higher absorption shows

that the light photons' energy is being absorbed by the NP medium's atoms. Electronic shifts from lower to higher energy levels underpin the interaction approach. The ($\pi \rightarrow \pi^*$) transition explains why this is the case. Other authors suggested that the locally stimulated transition ($n \rightarrow \pi^*$) of the lone pair on the carbonyl bond, which typically happens in PVA structures, was the cause of the enhanced absorption. [15]. This is related to the degree of conjugation between adjacent benzene rings within the polymer chain [16] [17]. Moreover, the increased absorption is believed to result from the en-

ergy transfer of the incident radiation, leading to the emergence of new classes of chemicals. This might possibly be a result of the extra negative charges that create new internal bonds inside the PVA film, causing in-band energy levels [18]. Because of their tiny size, nanoparticles (NPs) are more likely to establish new bonds, which reduces their atomic volume of occupancy, raises their density, and increases their absorption [17]. Moreover, the absorption values of the PVA blends increased with increasing Cr content associated with the formation of charge-transfer complexes. [19]

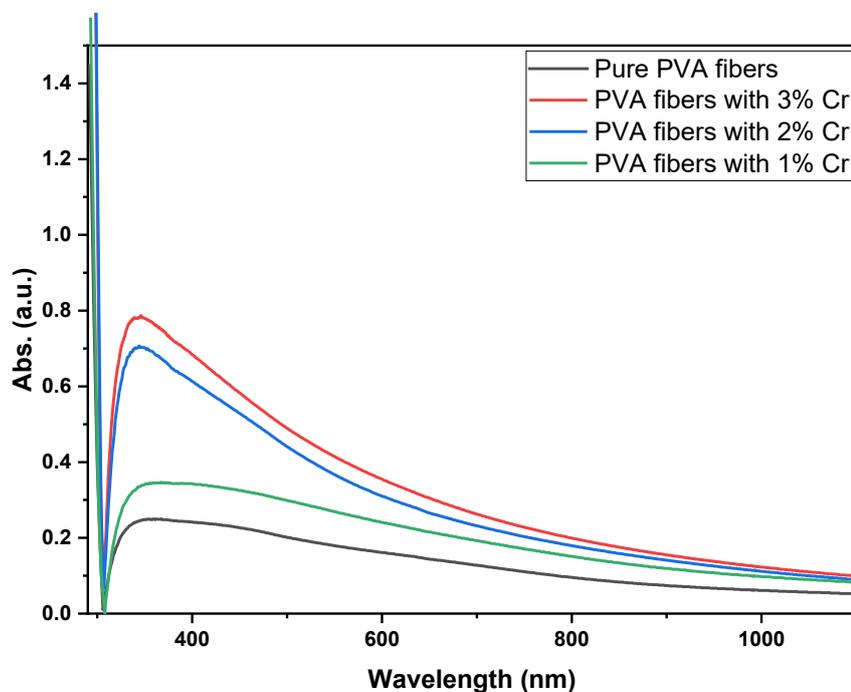


Fig.(4). Spectrum of pure PVA and PVA-(1,2,3%wt Cr) nanofiber

3.4 Optical energy band gap for PVA/Cr

As shown in Figure 5. The E_g value of pure PVA is 4.17 eV. For Cr-doped films, E_g is 4.16, 4.14, and 4.12 eV at 1 wt %, 2 wt %, and 3 wt %, respectively. For Cr-doped PVA. The data obtained show that the optical bandgap decreases with increasing nanochromium concentration. The decrease in E_g after adding Cr to PVA can be attributed to the increased occurrence of interactions between metal ions and the OH groups of PVA [20]. Moreover, the energy bandgap of PVA with an increasing Cr-NP ratio, This has to do

with flaws in the combination. Within the optical bandgap, these defects are confined states [21]. Furthermore, the E_g falls with increased filler content due to the quantity of polarons generated and matrix flaws [22]. This can be explained by the fact that the creation of charge transfer complexes in the host matrix is triggered by the incorporation of minute quantities of dopants. By adding a charge, these charge-transfer compounds improve conductivity. This makes it easier for carriers to transition between localized states and narrows the optical energy bandgap [23].

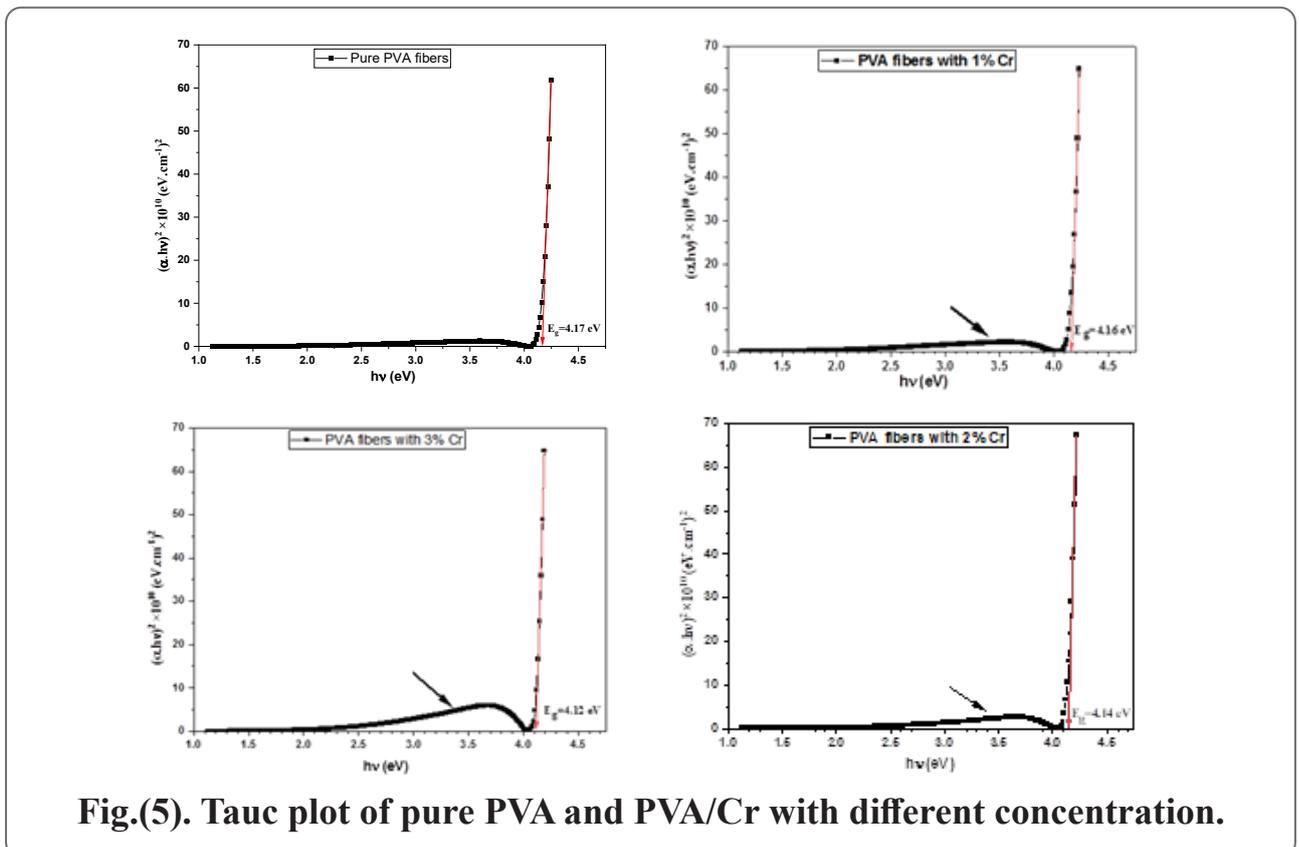


Fig.(5). Tauc plot of pure PVA and PVA/Cr with different concentration.

3.5 The fluorescence spectra for PVA doped with Cr nanofibers

Figure 6). Fluorescence spectra of a pure His-PVA film and a PVA-Cr film made from electrospun nanofibers are shown. For bare PVA and PVA-Cr films, a peak was seen at 396 nm, and the excitation wavelength was 350 nm. Pure PVA film fluorescence was not seen in the 400 nm to 650 nm wavelength range[24]. Furthermore, peaks were observed at 455 nm, 474 nm and 625 nm in the PVA-Cr film. The emission peak of the sample at 655 nm is red-shifted, However, this red-shift is also brought on by additional PVA-Cr interactions, including exciton energy transfer and electronic coupling. Fluorescence intensity increased with 1%

and 2% Cr additions and decreased with 3% Cr additions. The fluorescence intensity of the 2% Cr film is higher. The stability of electron density in molecular orbitals can be enhanced by doping PVA with Cr atoms. The electron density becomes extremely stable and the number of useful transitions rises as the filler concentration rises within a certain threshold, resulting in an increase in fluorescence intensity [25]. Electron-donating centers are known to increase fluorescence, Fluorescence efficiency is decreased by electron-withdrawing centers [26]. This explains why the intensity of the fluorescence has decreased. When the Cr content is raised to 3w%.

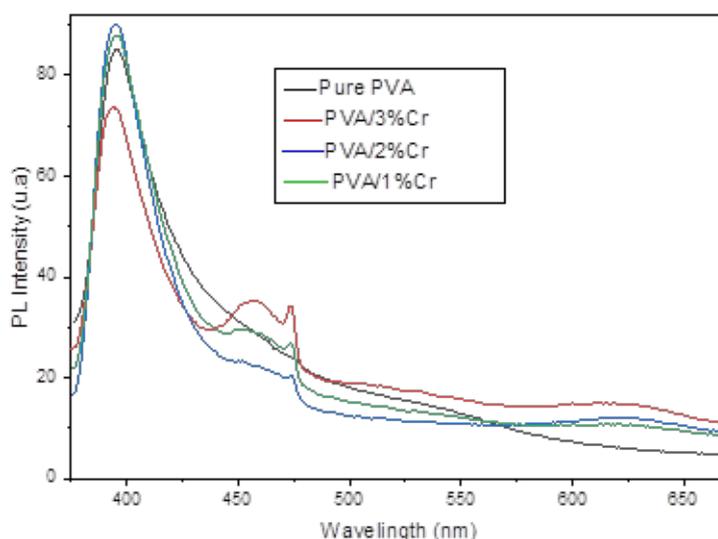


Fig.(6). Fluorescent Emission Spectra of pure PVA and PVA doping thin films with different ratios of Cr

4. Conclusions

In this study, PVA and PVA/(1.2.3 wt%) Cr nanofibers were successfully prepared by electrospinning. According to XRD, the high-quality PVA/Cr fibers produced by the electrospinning process had a uniform structure and smooth surface, and FESEM measurements showed that the addition of 3% Cr reduced the fiber diameter. Compared with the pure PVA nanofiber film, the absorption spectrum of PVA/Cr nano fibers increases, and the optical energy gap shifts from 4.17 eV to 4.12 eV. The fluorescence intensity increased with the addition of 1% Cr and 2% Cr but decreased with the addition of 3% Cr.

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