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Study of thermal and some other physical properties of PVA: PVP: $CuSo_4$ Polymer Compound

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ABSTRACT

In this study, casting method has been used to create films by mixing hydrated copper sulfate $CuSO_4.5H_2O$ with three different concentrations 0.5,1 and1.5 wt% with a combination of PVA/PVP in a 1:1 ratio. The three different samples of different concentration of 0.5, 1 and 1.5 have been denoted as case a, b and c respectively. In order to evaluate and confirm the crystalline quality of the final mixture, PPCu(PVA/PVP/$CuSO_4.5H_2O$), the required physical measurements were carried out, including x-ray investigations. Also, an FT-IR analysis was used to investigate the structure and chemical composition of the mixture for the three cases. The film's morphology was studied by use of SEM equipment, which showed that the PPCu mixture's particle distribution was uneven. The thermal conductivity of the mixture at different temperatures was measured using the hot disk technique. The results showed significant influence of $CuSO_4.5H_2O$ concentration on thermal conductivity.

1. Introduction

Polymer blends have important applications due to their optical, electrical, mechanical properties. PVA is chosen in many industries due to its physical properties and semi-crystalline structure [1]. Because of its higher solubility in casting solutions, less crystalline polyvinyl pyrrolidine (PVP) was used to enhance the properties of polymers by forming polymeric blends. PVA / PVP blends in different proportions [2] drew researchers in order to look into the enhancement of the mixture's physical features and obtain an application similar to that in [3] which search in (Gold nanoparticles (Au NPs) were effectively synthesized from the leaf extract of Chenopodium murale and integrated into a blend of polyethylene oxide and polyvinyl pyrrolidone using a casting technique). Also, it is used to ameliorate the permeability of water-soluble PVP, as in [4]in addition to other applications such as dialysis membranes and water technology [5,6], as well as to maintain suspension stability [7]. To produce a polymer that combines a hydrophilic polymer with another that has adjective

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mechanical capabilities, such as PVA, the resulting mixture improves the ability of the polymer matrix to retain water and preserve carriers in the membranes. To improve the electrical and optical properties of polymers, impurities such as semiconductor particles and metals can be added [8, 9-12].

New materials for optoelectronic devices, such as polymer lasers [13] and LEDs, have been produced with the help of companies with funds allocated to laboratories. Using UV-VIS spectrophotometer, optical and electrical measurements were carried out [14,15-18]. These materials were used in various industries, such as textiles [27] and heating and cooling systems [19-25]. In some researchers, casting techniques were used to produce a mixture of PVA/PVP in different proportions to produce membranes and calculate thermal conductivity coefficients.

To improve the performance of the PVA/PVP mixture, polymers or other materials can be added, as in [29]. T he properties of new polymers can be utilized by mixing several polymers to produce a new homogeneous material [30].

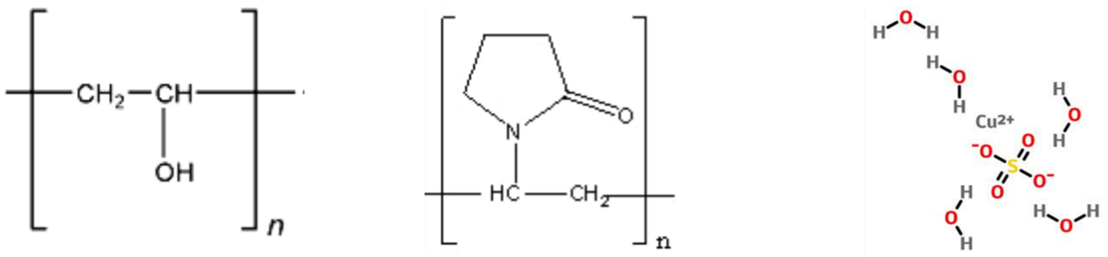
The presence of an OH group in PVA and its ability to form hydrogen bonds with polymers and other metals, as well as the presence of a peptide bond with vinyl, shows semi-crystalline properties for PVP and has flat, polar side groups [31]. Organic, inorganic and synthetic nanomaterials possess special properties that are not found in other materials which are necessary for technology [32].

Because of the excellent conductivity of copper, Cu is used in many electrical and electronic applications [33]. When copper is combined with nanoparticles, it gives many positive qualities, such as high thermal conductivity, which is useful in many applications, such as refrigerant gases, electronic systems, and conductive inks [34]. Also, combining Cu with other metals to create a variety of nanocomposites (NCS) and catalysts, which are possess optical and electrical properties. [35].

The aim of this work is to study the thermal conductivity of PVA/PVP mixture with different concentrations of $CuSO_4.5H_2O$ because of its unusual physical properties of copper nanoparticles, its ability to weld and its high melting point [36].

2. Materials and sample preparation

We blended PVA(1g) and PVP(1g) films via the solution casting process. The average molecular weights of the compounds they utilized were 14000 g/mol for PVA, 40000 g/mol for PVP, and 249.685 g/mol for copper sulfate pentahydrate. At the beginning, the polymer powders were mixed with distilled water at 90 °C to create bulk solutions. The mixture was stirred for 3 hours. Then, the bulk concentrations of PVA and PVP were blended in a 1:1 ratio with constant stirring until clear solutions were formed. After combining $CuSO_4$. $5H_2O$ with distilled water and adding it to the mixer set the temperature to 60°C and then add the appropriate viscosity PVA/PVP. Then slowly add $CuSO_4$. $5H_2O$ drop by drop over two hours while mixing to fully combine the ingredients. The recommended ratio of $CuSO_4$. $5H_2O$ to PVA/PVP blend should be 0.5 to 1.5 weight percent. The structure of PPCu is as in Figure 1.

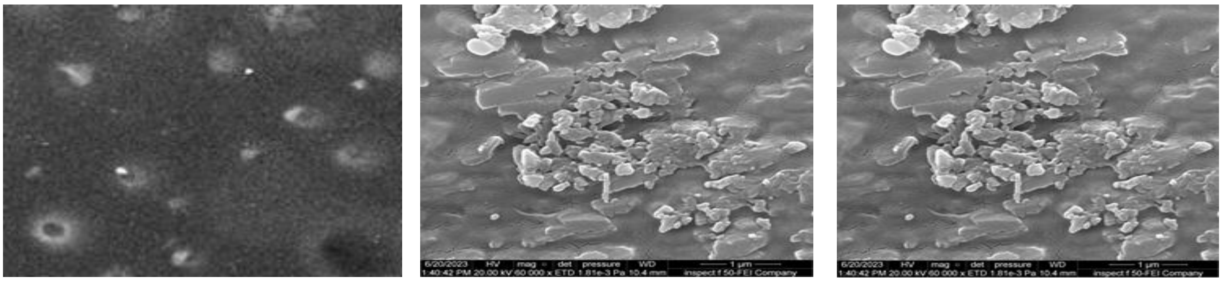


a b c

Fig. 1. Depicts the structure of (a) PVA, (b) PVP, and (c) copper sulfate pentahydrate $CuSO_4.5H_2O$.

3. SEM OF PPCu (0.5:1:1.5)

SEM is frequently employed to examine morphologies surface for better understanding how various polymer film elements is behave. The analysis of Figure 2a shows that in the PPCu(0.5), the resin appears broken with more dimples and wavy structures. The waviness seen in the SEM image of PPCu(0.5) is belong to the contribution of its soft molecular properties, while the SEM image of PPCu(1.0) shows uniform-sized spherical particles. The SEM image of PPCu(1.5) displays contrast between dark and bright regions in certain micrometer areas. The dark part is belonging to the PVA/PVP polymer, while the bright part represents $CuSO_4.5H_2O$.



a b c

Fig. 2. (a,b,c) shows the SEM of the combination PPCu (0.5,1,1.5)

4. X-ray diffraction Analysis

X-ray diffraction analysis is a necessary method for examining different structural aspects of materials, such as the thickness of the layer, favored orientation, strain, crystal size, and crystal structure. It is commonly employed by material scientists to explore a variety of materials, such as powders, thin films, nanomaterials, and solid objects. The X-ray diffraction patterns for PPCu(0.5, 1 and 1.5) shown in Figure 3 demonstrating the crystalline characteristics of the materials. The XRD analysis showed that PPCu(0.5) has peaks at 22.30, 24.0, 25.90, and 32.70 on the axis of 2θ angles. For PPCu(1.0), peaks were seen at 22.20, 32.70, and 47.70 2θ angles. PPCu(1.5) had peaks at 20.20, 27.60, 36.20, and 39.80 2θ angles.

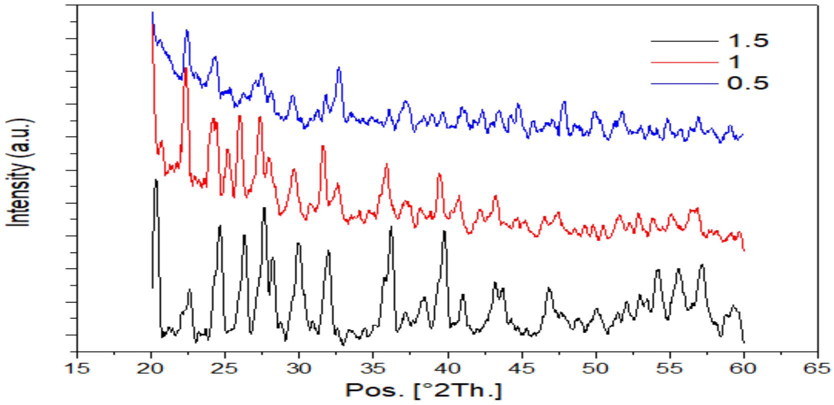
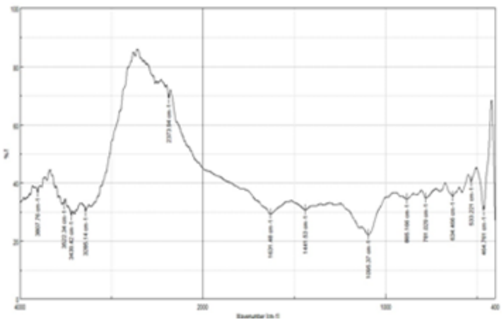


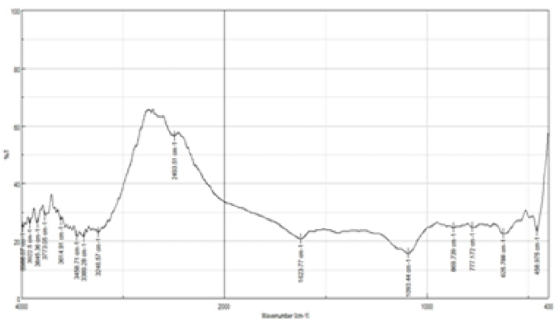
Fig. 3. (a,b,c). The XRD of PPCu(0.5,1,1.5) .

5. FT-IR spectroscopy

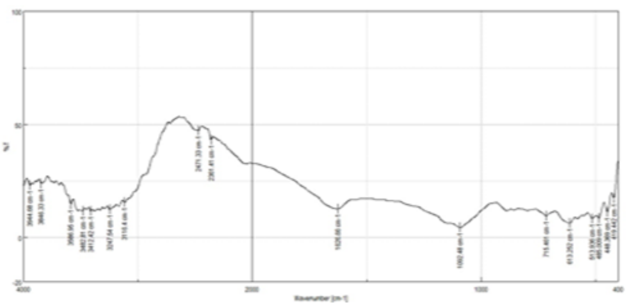
FTIR spectroscopy was used to study how atoms and ions interact within the polymer blend and electrolyte systems. The FTIR spectra of the PVA/PVP(1:1) blend and different concentrations of CuSO4.5H2O were measured at room temperature, as shown in Figure 4.The specific data about the FTIR transmission bands, their locations, and what they represent for each of the polymer electrolytes are prepared in Table 1. The peaks seen at 3,087, 1,484, and 943 cm-1 in Figure 4a are linked to the stretching of O-H bonds, bending of O-H and C-H bonds, and symmetric stretching of C-O bonds in pure PVA. Moreover, the bands observed at 1,083 and 837 cm-1 were found to be related to the stretching of C-O bonds and bending of CH2 groups in pure PVP, respectively [38]. Upon the introduction of CuSO4.5H2O to the PVA:PVP blend (shown in Fig. 4a-c), these PVA and PVP bands experienced shifts, indicating the formation of complexing between the polymer blends and CuSO4.5H2O.



a



b



c

Fig. 4. (a,b,c). the FTIR spectra of PPCu (a- 0.5, b-1.0, c-1.5).

Table 1. presents the FTIR transmission bands, positions, and assignments of all polymer electrolytes which were prepared.

Concentrations	O-H stretching	O-H & C-H bending	C=O stretch	CH_2 bending	Ref.
PVA/PVP	3087	1484	1083	837	38
PVA/PVP/$CuSO_4.5H_2O$ (1:1:0.5)	…..	……	1092	995	present
PVA/PVP/$CuSO_4.5H_2O$ (1:1:1)	3201	…..	1094	961	present
PVA/PVP/$CuSO_4.5H_2O$ (1:1:1.5)	3201	…..	1094	961	present

6. UV-Vis Measurement

Figure 5 shows the UV-VIS absorption spectrum of PPCu(0.5, 1and 1.5). The peaks seen in the spectrum between 600-800 nm are associated with the π- polaron transition[39]. The main peak in PPCu(0.5, 1and 1.5) appears at 360-370 nm, indicating the presence of the π-π* electronic transition[40] related to unsaturated carbonyl bonds (C=O) in the polymeric blend chains.

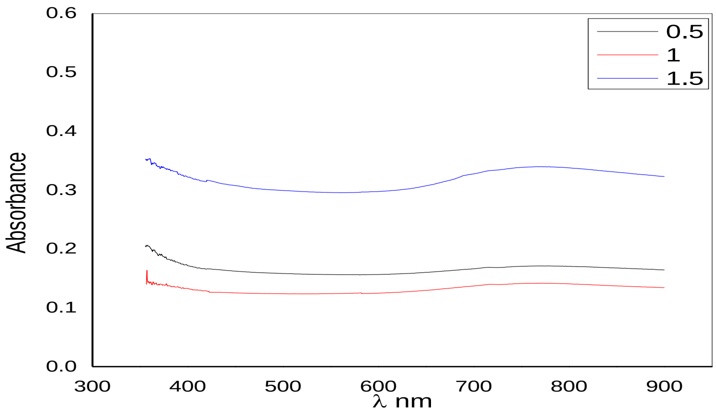


Fig. 5. Absorption spectra of PPCu(a,b,c)(0.5,1 and 1.5).

7. Thermal conductivity

The subject of thermal conductivity is getting more important for physical studies and engineering applications in the last Three decades. The process of moving heat from one area to another in the direction of decreasing temperatures is referred to as heat transfer. Fourier's Law is the important law by which the conduction of heat transfer can be investigated experimentally:

$\dot{Q} = -kA\frac{dT}{dx}$ ……………………………………………………….(1)

$\dot{Q}$ is the heat transfer rate through the body in a given amount of time.

A is denoted by the heat transfer area of the surface.

dT is the temperature differential between the two faces in the heat direction of flow.

dx is the body thickness.

k is the thermal conductivity of the material of the body.

In this study, the hot disk technique has been used to measure the thermal conductivity of the PPCu polymer compound as illustrated in figure 6 [41]. Two similar disks of 5 cm in diameter and 2 cm in thickness have been used, disk 1 and disk 2. The two disk materials were white iron. The sample consisted of the polymer compound which was deposited on a glass disk of 5cm in diameter. The two disks are separated by the sample. An adjustable (controllable) heater has been used to heat Disk 1. The thermocouples were attached to the disks using three small holes: one at the first face of disk 2, right after the sample, and two at the two surfaces of disk 1. The temperatures of the three holes are known and are represented by the letters T1, T2, and T3.It is well known that under steady heat transfer conditions, the rate of heat flow through disk 1 and the sample is equivalent. This fact has been used in Fourier's Law to measure the thermal conductivity of the polymer compound. The thermal conductivity has been measured for a range of temperatures for the compounds of three concentrations, PPCu(0.5,1 and 1.5) as shown in Figure 7. As can be seen the thermal conductivity has been affected by the concentration of the PPCu.

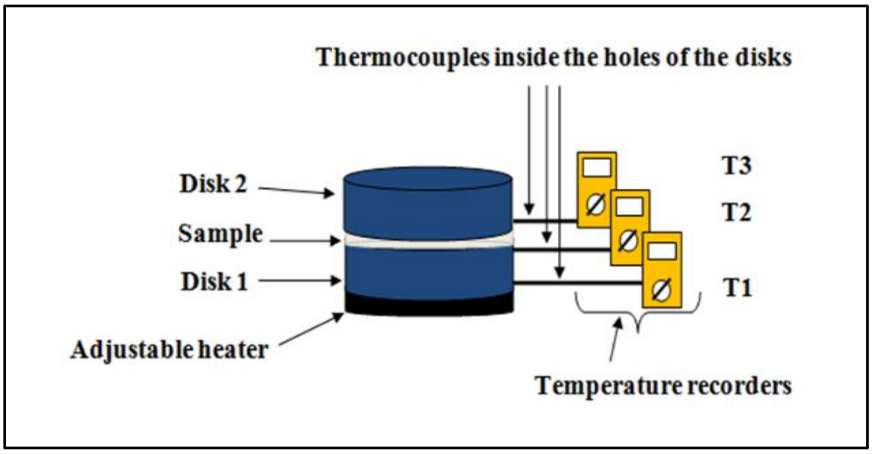


Fig. 6. Sketch of the thermal conductivity measurement.

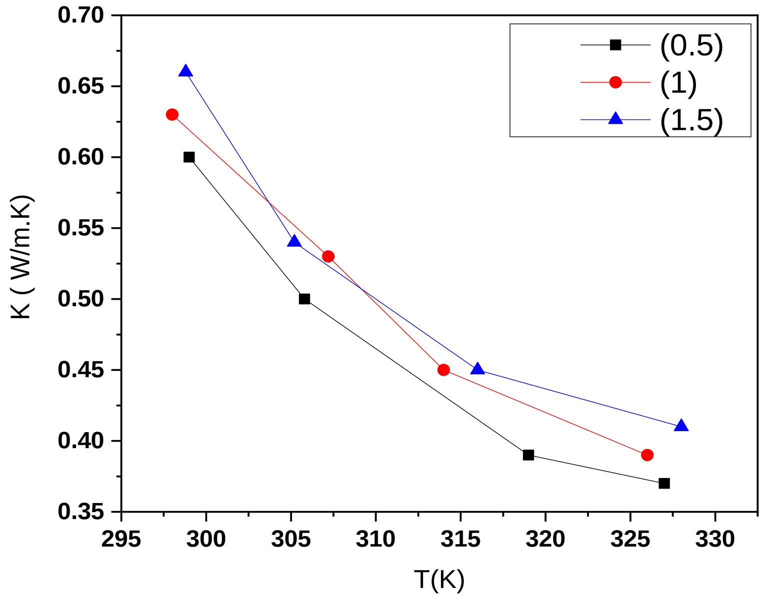


Fig. 7. The thermal conductivity measurement at different temperatures for different PPCu(0.5,1 and 1.5).

8. Conclusion

In this study, PVA:PVP blend (1:1) was doped with CuSO4.5H2O at varying weights (0.5, 1, and 1.5 wt%) using the casting technique. The main objective was to investigate the impact of copper sulphate pentahydrate (CuSO4 .5H2O) on the thermal conductivity of the PVA:PVP mixture. The results showed that the thermal conductivity has been affected by the copper concentration. X-ray diffraction (XRD) analysis revealed the crystalline nature of all ratios of the PPCu blend, while Fourier transforms infrared (FT-IR) investigation confirmed the presence of carbon double bonds in the combination.

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دراسة الخواص الحرارية وبعض الخواص الفيزياوية الاخرى للمركب البوليمري PVA: PVP: $CuSo_4$

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معلومات البحث

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النشر	31 كانون الأول 2024

الكلمات المفتاحية

خليط $CuSO_4.5H_2O$, PVA/PVP, انتقال الحرارة, SEM.

الملخص

في هذه الدراسة ، تم استخدام طريقة الصب لإنشاء أفلام عن طريق خلط كبريتات النحاس المائية $CuSO_4.5H_2O$ من ثلاثة تركيزات مختلفة 0,5 , 1 و 1,5 wt% مع مزيج من PVA/PVP بنسبة 1:1. تم الإشارة إلى العينات الثلاث المختلفة ذات التركيزات المختلفة 0,5 , 1 و 1,5على أنها الحالة a , b و c على التوالي .من أجل تقييم وتأكيد الجودة البلورية للخليط النهائي PPCu ، تم إجراء القياسات الفيزيائية ، بما في ذلك تحقيقات الأشعة السينية .أيضا ، تم استخدام جهاز FT-IR device لفحص الهيكل والتركيب الكيميائي للخليط للحالات الثلاث .تم دراسة مورفولوجيا الفيلم عن طريق استخدام جهاز SEM device والتي أظهرت أن توزيع جسيمات خليط PPCu كان غير متساو. تم قياس التوصيل الحراري للخليط عند درجات حرارة مختلفة باستخدام تقنية القرص الساخن. اظهرت النتائج وجود تأثير كبير لتركيز $CuSO_4.5H_2O$ على التوصيل الحراري.

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