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A Study of Electrical Properties of (PVA-PEG / RB) Composite

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ABSTRACT

In this study, (PVA-PEG-RB) composites were fabricated through the casting process with varying amounts of Rhodamine B (RB) dye (0, 1.3, 1.5, 1.7, and 2 wt %). The findings revealed that the dielectric constant and dielectric loss of (PVA-PEG-RB) organic dye composite decrease when the applied electrical field frequency rises, whereas the dielectric loss increases as the organic dye additive concentration increases. The increase in frequency and concentration of the (RB) organic dye both contribute to an increase in the electrical conductivity. From the study the polymeric films have been prepared doped with organic dye have a suitable electrical property that can be using in optical applications such as optical limiting and solar fluorescent concentrates.

Key words

Electrical properties, Organic dye, Dielectric constant, Conductivity, Rhodamine B.

الخلاصة

في هذه الدرا سة ، تم ت صنيع مركبات (PVA-PEG-RB) من خلال عملية الـ صب بكميات متفاوتة من صبغة رودامين B (RB)، 0 ، 1.3 ، 1.5 ، 1.7 ، و 2٪ بالوزن). أوضحت النتائج أن ثابت العزل وفقد العزل لمركب الصبغة العضوية (PVA-PEG-RB) يتناقص عندما يرتفع تردد المجال الكهربائي المطبق ، بينما يزداد الفقد العازل مع زيادة تركيز المادة المضافة للصبغة العضوية. ت ساهم الزيادة في تواتر وتركيز الـ صبغة الع ضوية (RB) في زيادة التو صيل الكهربائي. من هذه الدرا سة ، تم تحـ ضير الأغ شية البوليمرية مخدرة بصبغة عضوية لها خاصية كهربائية مناسبة يمكن استخدامها في التطبيقات البصرية مثل الحد البصري ومركزات الفلورسنت الشمسية.

الكلمات المفتاحية

الخواص الكهربائية ، صبغة عضوية ، ثابت عازل ، موصلية ، رودامين ب.

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INTRODUCTION

The need to create and comprehend new types of plastics, rubber, fibers, and coatings sparked the birth of polymer science in the world's industrial laboratories. Natural resources, including cotton, starch, proteins, and wool, were the first polymers employed. The first important polymers, bakelite and nylon, demonstrated the new materials' enormous potential. However, the scientists of the time found that they did not comprehend a number of the links between the chemical structures and the resulting physical characteristics [1]. In general, the majority of polymers were utilized to produce low-cost items that were employed for basic tasks. Rapid technological advancement has required replacing some industrial materials with higher-quality ones. In the previous years, investigations of the electrical and optical characteristics of polymers have received great attention due to their use in electronic and optical equipment. Optical absorption spectra can reveal the band structure and energy gap of crystalline, semi-crystalline, and monocrystalline polymers [2 and 3]. Later, the improvement of polymer science began to accelerate dramatically. Today, scientists strive to develop polymers that may be utilized in a variety of industrial applications [4].

- **Electrical Properties**

The electrical properties of a material depend not only on its chemical makeup, but also on how its atoms are arranged in a solid and whether or not it has any flaws. The electron states in the energy gap also have an effect on the material's electrical properties. There are many ways to fix this flaw, such as the annealing process [5]. Preparation methods and deposition circumstances have a significant impact on the electrical characteristics [6].The materials can be classified according to their conductivity to: conductive, semi-conductive, and insulator [7]. The conductor has a conductivity of (10^{3}-10^{8}) $\Omega^{-1}cm^{-1}$ at ambient temperature, a semiconductor conductivity of (10^{-8}-10^{3}) cm-1, and an insulator conductivity of (10-18-10-8) $\Omega^{-1}cm^{-1}$ [8].

- **The Electrical Conductivity (A.C)**

Insulators become ideal when placed in low-frequency electrical fields that allow induced or permanent dipoles to follow the changing applied electrical field without leaving behind any residual dielectric constant (ohmic conductivity equals to zero). In contrast, higher frequency electrical fields and frequency-dependent electric polarization make the dielectric constant more difficult to calculate [9]. The dielectric constant is the ratio of a capacitor's capacitance with an insulator material between its conducting plates to its capacitance with a vacuum between the plates. The current flowing through a capacitor (C) filled with an insulator when an alternating voltage is placed across it does so with a phase difference of Π /2, as shown in Figure (1, A), then [10]:

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$$v = v_m e^{jwt} \quad (1)$$

$$I = jwcv \quad (2)$$

Where *w* represents the angular frequency of the applied field (w=2πf) and j represents an imaginary number.

It is experimentally proved that the angle between I and *V* is less than Π/2 as shown in Figure (1, B). This demonstrates that the electric current is the product of the capacitance current (Iq), which has a phase difference of Π/2, and the conduction current (Ip), which has the same phase as *V* [11]: $I = I_p + j\,I_q$ (3)

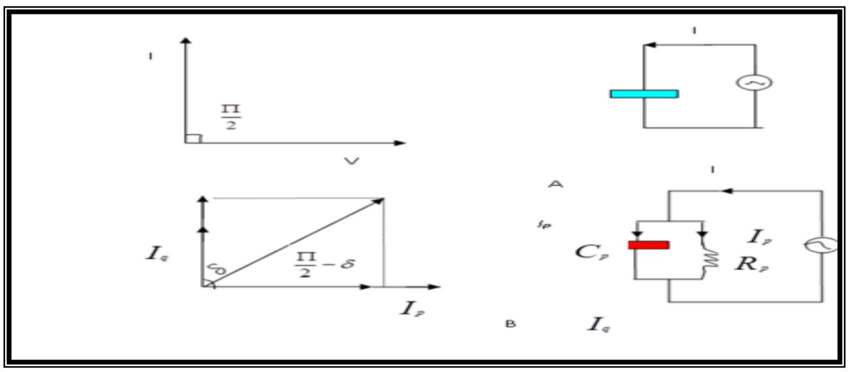

Figure 1. (A). The ideal capacitor circuit and (B). The non-ideal capacitor circuit [13].

The equation below shows, how much a capacitor with two parallel plates can store [12]:

$$c = \varepsilon\, \varepsilon_o \frac{A}{d} \quad (4)$$

By substituting equation (4) in (2), getting [12]:

$$I = j\, w\, \varepsilon\, \varepsilon_o \frac{A}{d} v \quad (5)$$

The permittivity (ε) must be a complex number, consisting of real and imaginary components, just as the electric current is, as stated in equation (6). That is [13]:

$$\varepsilon = \varepsilon' - j\,\varepsilon'' \quad (6)$$

Therefore, we get [12]:

$$I = j\, w\, \varepsilon_o \frac{A}{d} (\varepsilon' - j\, \varepsilon'') v \quad (7)$$

By comparing equation (7) with (3), then [13]:

$$I_p = w\, \varepsilon''\, \varepsilon_o \frac{A}{d} v \quad (8)$$

$$I_q = w\, \varepsilon'\, \varepsilon_o \frac{A}{d} v \quad (9)$$

The loss factor is shown in Figure (1, B) [13]:

مجلــة جـــامعة بــابـل للعلــوم الصـرفـة والتطبيقيـة مجلــة جـــامعة بــابـل للعلــوم الصـرفـة والتطبيقيـة مجلــة جـــامعة بــابـل للعلــوم الصـرفـة والتطبيقيـة

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$$\tan\delta = \frac{I_p}{I_q} = \frac{\varepsilon''}{\varepsilon'} \qquad (10)$$

The lost electrical energy is transformed to thermal energy in the insulator. The determining of power factor is very useful in electrical applications and excessive power factor would cause heat in the insulator at high frequencies, leading in an electrical failure. At low frequencies, the capacitor can be represented by an ideal capacitor connect in parallel with a resistance (Rp). So [13]:

$$I = I_p + jI_q = \frac{v}{R_p} + jwc_p v \qquad (11)$$

Hence, determine the impedance (Z):

$$\frac{1}{Z} = \frac{1}{R_p} + jwC_p \qquad (12)$$

From equations (8), (9) and (11), we get [13]:

$$R_p = \frac{d}{w\ \varepsilon''\ A\ \varepsilon_0} \qquad (13)$$

$$\varepsilon'' = \frac{1}{w\ R_p\ C_o} \qquad (14)$$

$$C_p = \frac{\varepsilon'\ \varepsilon_o\ A}{d} \qquad (15)$$

Power lost in an insulator is shown by the existence of alternating potential as a function of alternating conductivity (16) [14]:

$$\varepsilon' = \frac{C_p}{C_o} \qquad (16)$$

$$\sigma_{A.C} = w\,\varepsilon''\,\varepsilon_0 \qquad (17)$$

Where: $\sigma_{A.C}$ represents a method for measuring the temperature in an insulating material induced by the rotation of dipoles in their locations (or the vibration of charges) when the field changes.

Materials and Methods

- **The Utilized Materials**

1. Polyvinyl Alcohol (PVA)

Poly vinyl alcohol (PVA) is a poly hydroxyl polymer and the world's largest synthetic, water-soluble polymer by production volume. PVA has a melting point of 230 ^{0}C and a molecular weight of 18000g/mol.

2. Polyethylene Glycol (PEG)

The substance polyethylene Glycol (PEG) is a white powder with a molecular weight of 20,000 g/mol that is available on local markets and has a melting point between (55- 82)^{0}C.

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3. Rhodamine B (RB) Dye

The laser dye has been used in this study is the (Rhodamine B) dye, and it is supplied by the Lambda Physics company (Germany). The molecular weight is 479.02 g/mol.

- **The Utilized Instruments and Measurements**

1. Optical Microscope

Samples of (PVA-PEG-RB) composite films are studied using an optical microscope supplied with a light intensity-controlled camera type of (Top View, Nikon -73346) under magnification (10x).

2. Measurement of (A.C) Electrical Conductivity

The measurement of (A.C) electrical conductivity has been measured in University of Babylon's College of Education for Pure Sciences/Department of Physics by using LCR meter (HIOKI 3532-50 LCR Hi TESTER) from Japan. Figure (2) shows a diagram for the system of (A.C) electrical measurement. The capacity and the dissipated factor have been recorded for all the samples at frequency ranging between ($5\text{-}100\times10^{6}$) Hz at room temperature.

- **Preparation of (PVA-PEG-RB) Composite**

The (PVA-PEG-RB) composite films are made by dissolving 1 gm of polymers in 50 ml of distilled water at varied concentrations (75wt. percent PVA at 700C and 25 wt. percent PEG at 500C) and mixing the polymers for 1 hour with a magnetic stirrer to achieve a more uniform solution. The (RB) dye is added each one to polymers mixture with different weight ratios, which are (1.3, 1.5, 1.7 and 2). In the template, samples of (PVA-PEG-RB) composite film are prepared using the casting process (petri dish has diameter 10 cm).

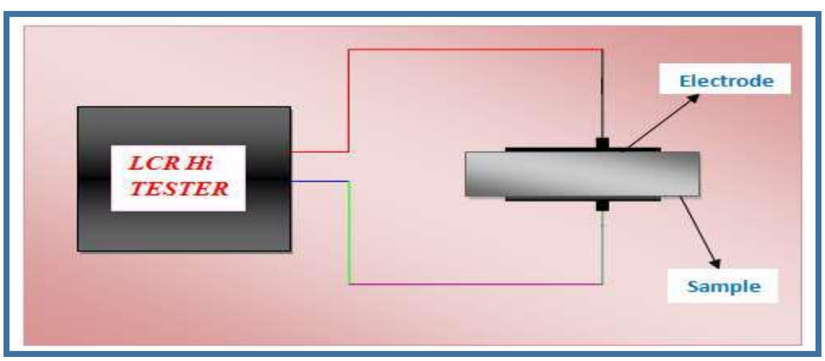

Figure 2. Diagram of electrical system measurement of (A.C) electrical conductivity

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Results and Discussion

- **The Optical Microscope Images**

The optical microscope images for all films has been taken at magnification power (10x). Figure (**3**) shows, the photographic images of (PVA-PEG) blend and (PVA-PEG-RB) composites with different concentrations. Compared with pure sample picture there are many difference among this sample and composite with addition different concentrations of RB dye ,when RB particles reaches to higher concentration the fillers materials form uninterrupted network inside the polymer blend. This constitutes pathways within the composites of charge carriers, and this system permits charge carriers to traverse the pathways **[15]**.

- **The Electrical Properties of (PVA-PEG-Rhodamine B) Composite**

Figure (4) demonstrates the influence of Rhodamine B on the dielectric constant at 100 Hz and 25C^{o}, respectively. It is obvious that when the concentration on of Rhodamine B rises, the dielectric constant rises as well. As the dipole moment per unit volume increases, so does the dielectric constant. At low concentrations, Rhodamine B forms clusters or separated groups; consequently, the dielectric constant decreases. At higher concentrations, dielectric constant values rise with volumetric rate as particles form a network in the polymer blend.

Due to the types of polarisation, Figure (5) displays that the dielectric constant goes down as the frequency of application goes up (space charge, dipolar, ionic and electronic). When the frequency is low, the space charge polarisation is a big part of why the dielectric constant goes up. As the frequency goes up, it becomes the most important type of polarisation and becomes less important as the frequency goes up. As a result, the values of the dielectric constant would go down for all samples as the frequency of the electric field went up. Higher frequencies show the other kinds of polarisation. The ionic polarisation changes less than the electronic polarisation when the field frequencies change. This is because an ion has more mass than an electron does. As a result, even the highest frequencies of the field vibrations can be felt by electrons. At high frequencies, however, the dipoles will be incapable of pointing in the direction of the applied field. As a result, the value of dielectric constant is nearly constant.

Figure (6) depicts the fluctuation in (A.C) electrical conductivity of (PVA-PEG-Rho B) composites with different concentrations of (Rho B) nanoparticles at 100Hz and 25^{o}C. The conductivity of the pure mix increases as the concentration of Rho B nanoparticles increases. The increase in conductivity may be attributed to charge carrier mobility as well as charge carrier concentration and the influence of space charge. As a result, for Rho B nanoparticle dispersion in polymer mix.

Figure (7) depicts the frequency dependence of (A.C) electrical conductivity for (PVA-PEG-Rhodamine B) composites. The frequency-dependent (A.C) electrical conductivity is the result of charge carrier hopping in the localized state and charge carrier stimulation to higher states in the conduction band. The primary chain motion and ions movements are two variables that determine (A.C) electrical conductivity.

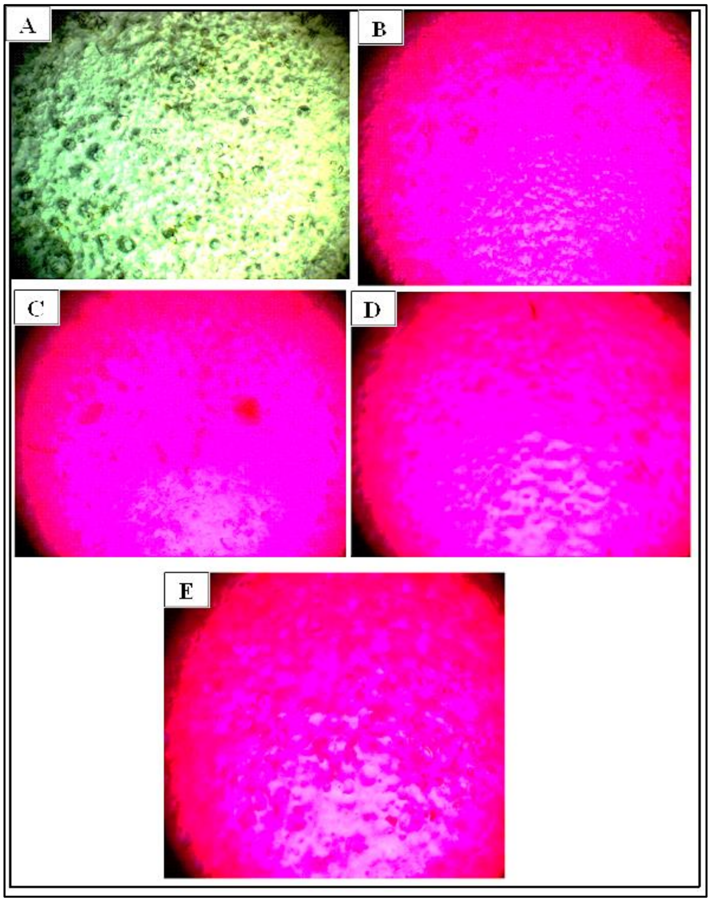

Figure 3. Photomicrographs (10 X) of (PVA-PEG-RB) composites, (A): (PVA-PEG) blend, (B): (PVA-PEG-RB 0.013 wt %) composite, (C): (PVA-PEG-RB 0.015 wt %) composite, (D): (PVA-PEG-RB 0.017 wt %) composite and (E): (PVA-PEG-RB 0.020 wt %) composite.

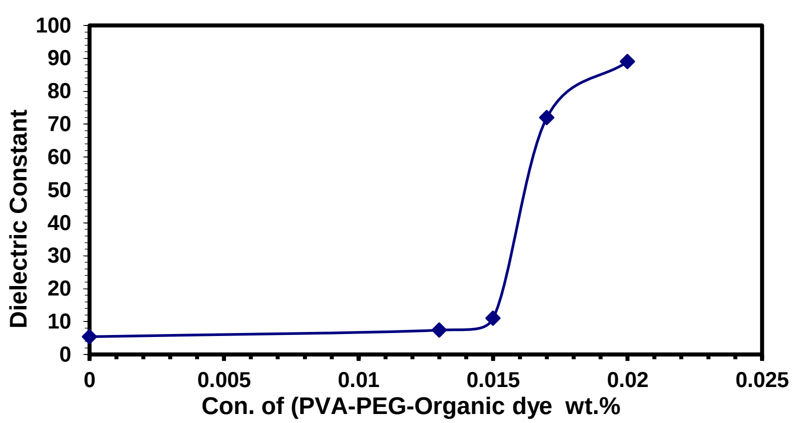

Figure 4. Variation of dielectric constant of (PVA-PEG-Rhodamine B) composites with concentration.

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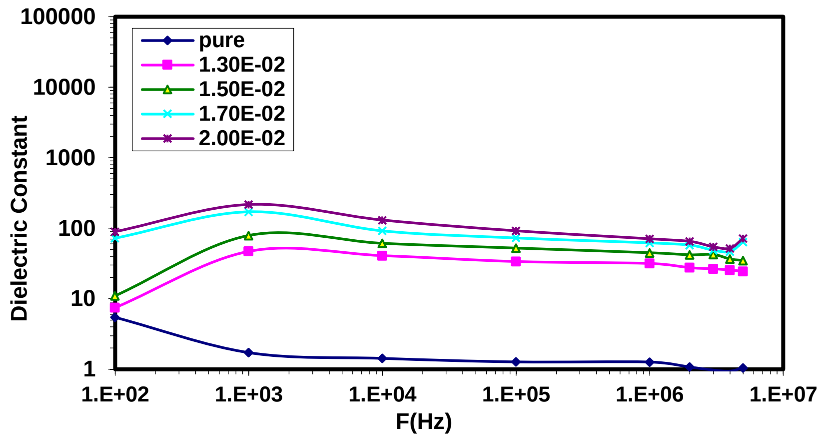

Figure 5. Variation of the dielectric constant of (PVA-PEG-Rhodamine B) composites with frequency.

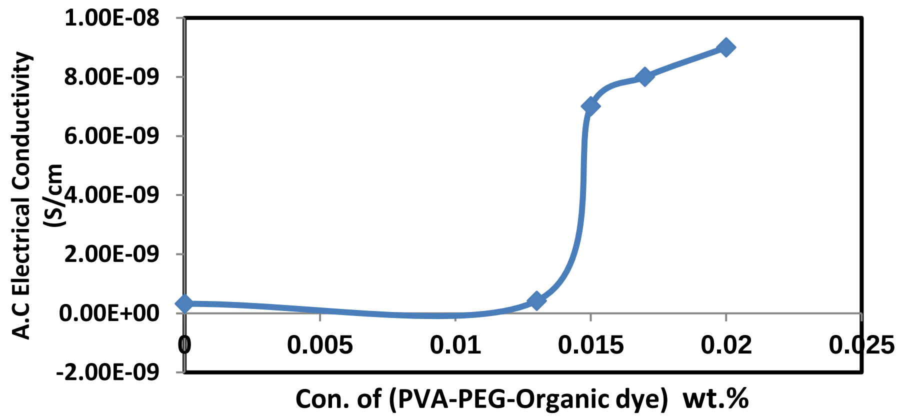

Figure 6.Variation of (PVA-PEG-Rhodamine B) electrical conductivity with Rhodamine B nanoparticle concentration in weight percent at 100 Hz.

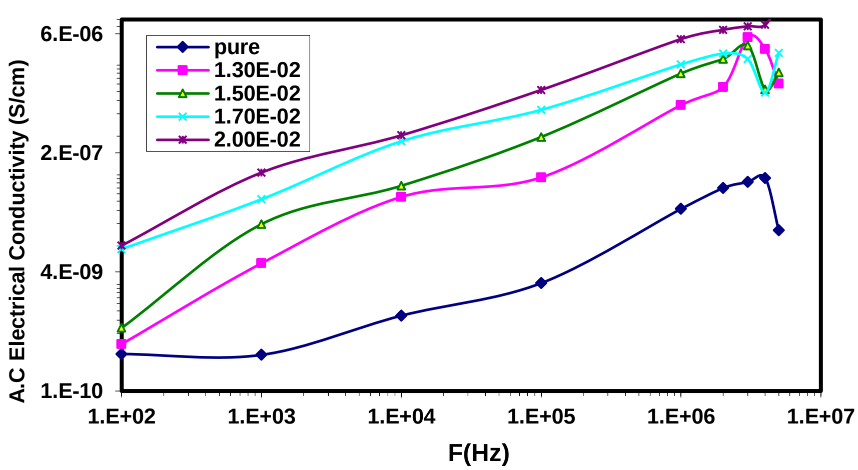

Figure 7. Variation of (A.C) electrical conductivity of (PVA-PEG-Rhodamine B) composites with frequency.

Conclusions

The results of the optical microscopy of (PVA-PEG-RB) composites show that, the addition of organic dyes distributed through the polymeric blend with homogenous and ordered shape as well as the apparent of dyes network inside the polymer blend. When the frequency of the electric field applied to (PVA-PEG-RB) composites is increased, the dielectric constant and dielectric loss decrease while the alternating current electrical conductivity increases. Increasing RB concentrations increase the alternating current electrical conductivity, dielectric constant, and dielectric loss of (PVA-PEG-RB) composites at all concentrations.

Conflict of interests.

There are non-conflicts of interest.

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