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A Study of Structural and Electrical Properties of (PVA_PEG_SrO) Nanocomposites

Submitted to the Council of the College of Education for Pure Sciences of University of Babylon in Partial Fulfillment of the Requirements for the Degree of Higher Diploma Education / Physics of Materials and its Applications

By

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بِسْمِ اللهِ الرَّحْمَٰنِ الرَّحِيمِ

﴿ قَالَ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ

الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَىٰ وَالِدَيَّ وَأَنْ أَعْمَلَ

صَالِحًا تَرْضَاهُ﴾

صَدَقَ اللهُ العَلِيُّ العَظِيمُ

(سورة الاحقاف)

(الآية 15)

Dedication

… to whom I stood at his door begging..

Who called him and he answered me

My Imam and my Master

Ali bin Abi Talib (peace be upon him)

Acknowledgments

Praise is to *Allah*, Mercy and peace are to the Prophet Mohammed and his relatives and companions.

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Last but not the least, I would like to thank my family: my parents, my brother and sisters for supporting me spiritually throughout writing this thesis and my life in general.

Zainab

Supervisor certificate

I certify that this thesis entitled **“A Study of Structural and Electrical Properties of (PVA_PEG_SrO) Nanocomposites”** was prepared by the student **(Zainab Jawad Kadhim Hussein)** under my supervision at the University of Babylon, College of Education for Pure Sciences as partial fulfillment of the requirement the degree of Higher Diploma in Education / Physics.

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Head of the Department Certificate

In view of the available recommendations, I forward this thesis for debate by the examining committee.

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Abstract

Preparing of (PVA-PEG-SrO) nanocomposites by using the casting method with different concentrations (0.5, 1, 1.5 and 2) wt.% of the SrO nanoparticles, with average particle size (20 nm).

The images of the optical microscope showed a continuous network within the polymers of the SrO nanoparticles at the concentrations (0.5-2 wt.%) in a homogeneous and also orderly manner, and this system can allow the passage of charge carriers.

The results of the microscopy of (PVA-PEG-SrO) nanocomposites show the addition of (SrO) nanomaterial distributed through the polymeric blend with homogenous and ordered shape. Also, the A.C electrical conductivity of (PVA-PEG-SrO) nanocomposites and dielectric constant and the dielectric loss for all concentrations increases with the increased frequency.

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Chapter One

Introduction and Literature survey

Chapter One

1.1 Introduction

Polymer science was born in the great industrial laboratories of the world of the need to make and understand new kinds of plastics, rubber, fibers and coatings. The first polymers used were natural products, especially cotton, starch, proteins, and wool. The first polymers of importance, Bakelite and nylon, showed the tremendous possibilities of the new materials. However, the scientists of that day realized that they did not understand many of the relationships between the chemical structures and the physical properties that resulted [1]. Generally, the use of most polymers was limited to the manufacture of cheap products which were used for simple purposes. However, the speedy technical development has required the replacement of some materials being used in industry with others having better specifications; consequently, in recent years, studies of electrical and optical properties of the polymer have attracted much attention in view of their application in electronic and optical devices. The optical absorption spectra of polymers provide essential information about the band structure and the energy gap in crystalline, semi crystalline and monocrystalline polymers [2,3]. Later, the development of polymer science has started to increase by leaps and bounds. Nowadays, scientists seek to produce polymers that can be used for different industrial applications. [4].

1.2 Polymer Structure

Polymers consist of large organic molecules (macromolecules) of repeating small structural units (monomers) connected together in a process called polymerization [5]. Each molecule is composed of thousands of atoms connected by covalent chemical bonds. Molecules in a polymer attract each other by forces that depend on the type of the polymer. As polymers consist of huge, combined molecules which are hard to control, limited crystal connections can be seen in polymers associated with its low temperature. It is only in limited regions that a linear chain of molecules can arrange themselves in an organized form. In the solid state, polymers are comprised of crystalline and non-crystalline regions [6].

1.3 Classification of Polymers

1.3.1 Polymers Sources

They are two main sources of polymers:

1. Natural Polymers

These compounds come from plant or animal such as timber, cotton, natural rubber, wool, and silk. The natural food which is the natural polymers is starch, protein and cellulose [7].

2. Synthetic Polymers

A polymer is prepared from simple chemical compounds and it represents the most industrial important polymers, including plastics, synthetic leather, nylon fabrics and some other dyes [7].

1.3.2 Thermal Polymers:

Polymers are classified according to the effect of temperature to:

1.Thermoplastic Polymers

Thermoplastics form the bulk of polymers in use. They consist of linear or branched molecules and they soften or melt when heated, so that they can be molded and remolded by heating. In the molten state, they consist of a tangled mass of molecules. On cooling they may form a glass (a sort of ‘frozen liquid’) below a temperature called the glass transition temperature (Tg), or they may crystallize [8]. Examples of this type of polymers are poly vinyl alcohol, polyethylene, polypropylene, poly vinyl chloride polystyrene, and others [8].

2.Thermosets Polymers

Thermosets are network polymers that are heavily cross-linked to give a dense three-dimensional network. They are normally rigid. They cannot melt on heating and they decompose if the temperature is high enough. The name arises because it is necessary to heat the first polymers of this type in order for the cross-linking, or curing, to take place. The term is now used to describe this type of material even when heat is not required for the cross-linking to take place. Examples of thermosets are the epoxy resins, such as Araldites, and the phenol- or urea-formaldehyde resins [8].

1.3.3. Chemical Polymers:

A polymer is formed when a very large number of structural units (repeating units, monomers) are made to link up by covalent bonds under appropriate conditions.The functionality of a molecule is simply its inter linking capacity, or the number of sites it has available for bonding with other molecules under specific polymerization conditions [9]. Polymers are classified depending on the structural composition to:

1. Linear Polymers:

The structural units resulting from the reaction of monomers may in principle be linked together in any conceivable pattern. Bifunctional structural units can enter into two and only two linkages with other structural units. This means that the sequence of linkages between bifunctional units is necessarily linear [9], as shown in Figure (1.1a).

2. Branched Polymers:

The reaction between polyfunctional molecules results in structural units that may be linked so as to form nonlinear structures. In some cases, the side growth of each polymer chain may be terminated before the chain has a chance to link up with another chain. The resulting polymer molecules are said to be branched[9], as shown in Figure (1.1b).

3. Cross Linked Polymers:

In other cases, growing polymer chains become chemically linked to each other, resulting in a cross-linked [9], as shown in Figure (1.1c).

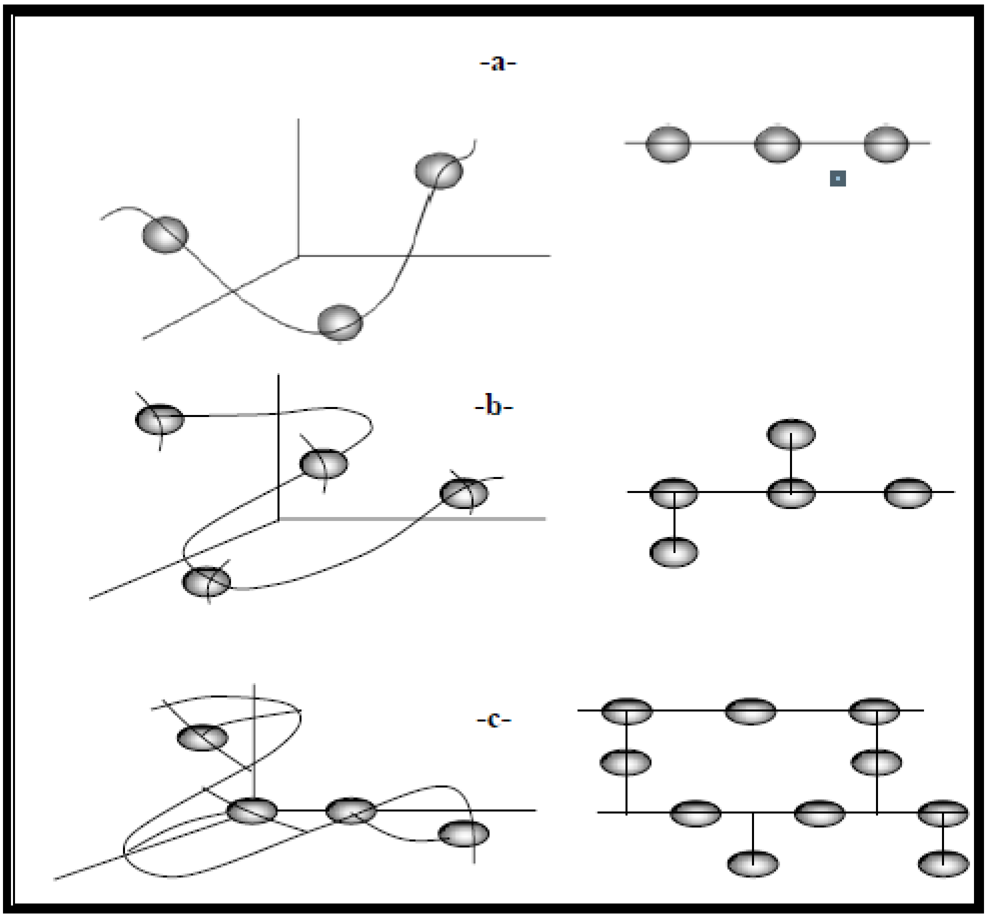


Figure (1.1): Constructivism Authority for Linear polymer, branching polymer chains and cross linked –a– Linear polymer, –b– Branched polymer, –c– Cross linked polymer [10].

1.4 Polymer Blend

A Polymer blend is a mixture of two or more polymers that have been blended together to create a new material with different physical properties. Generally, there are types of polymer blend: thermoplastic blends; thermoplastic–rubber blends; thermoplastic–thermosetting blends and rubber–thermosetting blends all of which have been extensively studied [11]. Moreover, polymers are corrosion-resistant, possess a light weight with good toughness (which is important for good fuel economy in automobiles and aerospace applications), and are used for creating wide range of goods that include household plastic products automotive interior and exterior components, biomedical devices and aerospace applications [12]. The development and commercialization of new polymer usually require many years. However, by employing a polymer blending process, which is also very cheap to operate, it is often possible to reduce the time to commercialization to perhaps two to three years [13]. Controlling the phase behavior and morphology becomes a key factor in determining the performance of polymer blends, which mainly relies on the interface between polymer components. Traditionally, block and graft copolymers are used to strengthen the interface and stabilize the morphology. However, they are system specific, relatively expensive to engineer, and very difficult to produce for systems with more than two components [14].

1.5 Synthesis of SrO Nanoparticles

Strontium Oxide (SrO) nanomaterial with average particle size typically 20-80 nanometers (nm) with specific surface area (SSA) in the 10 - 50 m^2/g range and also available with an average particle size of 100 nm range with a specific surface area of approximately 7- 10 m^2/g. Strontium Oxide nanomaterial are also available in ultra-high purity and high purity, transparent, and coated and dispersed forms. they are synthesized by hydrolysis of single source molecular precursor $SrCl_2*6H_2O$ with potassium hydroxide The Chemical Structure of SrO nanomaterial is shown in figure 1.2 [15].

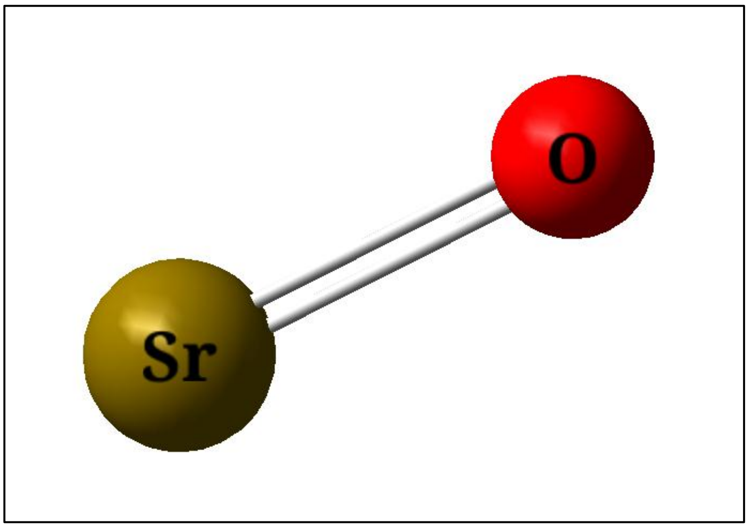


Fig. 1.2 SrO nanomaterial chemical structure.

1.6 Literature Survey

Devi *et al.*, (2002) [16], studied the electrical and optical properties of pure and silver nitrate-doped polyvinyl alcohol films. The electrical conductivity increased with the increasing dopant concentration of silver nitrate. The variation of electrical conductivity with temperature showed activation energies decrease from 0.8 to 0.3eV for undoped to doped films. Optical absorption studies in the wavelength range 190– 600 nm showed additional peaks in the wavelength region 391–417 nm for differently doped films, in addition to the peak at 273 nm for undoped PVA. The optical energy gaps and band edge values shifted to lower energies on doping up to a dopant concentration of 0.5 wt.% showed an increasing tendency for further increase in dopant concentration.

Feng *et al.* (2003) [17] studied the dielectric properties of Ag/PVA nanocomposites. The results showed that the D.C electrical conductivity increases with the increase of the silver nanoparticles concentrations and temperature.

Awasthi *et al.* (2009) [18], studied functionalization effects on the electrical properties of multi-wall carbon nanotube-Polyacrylamide Composites. The results show that the ball milling and functionalization of MWNTs improves the dispersion of MWNTs into the polymer matrix. As the MWNTs loading increases from 0 to 40 wt% electrical conductivity of composite film increases by 7 orders of magnitude whereas the electrical conductivity off functionalized composite film increases only ∼4 orders of magnitude with respect to the pure PAAm film. A model based on power law percolation for the electronic behavior of the above composite has been developed and shows good agreement with the experimental data.

Sengwa *et al.* (2010) [19] studied dielectric characterization of solution intercalation and melt intercalation poly (vinyl alcohol)-poly (vinyl pyrrolidone) blend-montmorillonite clay nanocomposite films. The results show that D.C conductivity increase with increasing the weight percentages of montmorillonite clay nanoparticles . The constant and loss dielectric increase with increasing the weight percentages of nano montmorillonite clay nanoparticles.

Prakash *et al.* (2013) [21], studied the AC electrical conductivity of $CdCl_2$ doped PVA polymer electrolyte. The results show that AC conductivity in these polymer films increases first and then decreases. These observations are in agreement with XRD results. The highest ionic conductivity of 1.68−08 Scm^{-1} was observed in 4% of $CdCl_2$ in PVA polymer blend. Crystallite ellipsoids for different concentrations of $CdCl_2$ are computed here using whole pattern powderfitting (WPPF) indicating that crystallite area decreases with increase in the ionic conductivity.

Manjunath *et al.* (2015) [22], examined the AC electrical conductivity and dielectric properties of PVA/NH_4NO_3 solid polymer electrolyte films. They found that, XRD results show that amorphous nature increases as the amount of the ammonium nitrate salt in PVA is increased. IR-spectra confirm the polymer salt complexes in the range of 3700 - 712 cm^{-1}. Conductance analysis reveals that polymer electrolyte films containing 20 wt% of NH_4NO_3 exhibit the highest ionic conductivity of 1.01×10^{-7} S/cm while pure PVA films give the lowest ionic conductivity of 2.10×10^{-11} S/cm. It was evident from this study that the increase of ionic conductivity depended on the ammonium nitrate salt concentration. The dielectric constant exponentially decreases with increase of frequency for pure PVA and NH_4NO_3 doped PVA film composites. The temperature dependent studies of AC conductivity and dielectric constant also included to understand the conducting property.

1.7 The Aim of the Study

The general aim is a study of the electrical and structural properties of (PVA-PEG-SrO) nanocomposites, which prepared by using casting method.

Chapter Two

Theoretical Part

Chapter Two

2.1 Electrical Properties

The electrical properties of the material are determined not only by chemical composition but also by the arrangement of atoms in the solid, and the existence of defects when giving rise to the electron states in the energy gap which influence the electrical properties of the material. This defect can be reduced by many processes such as the annealing process [23]. The electrical properties depend strongly on the preparation technique and deposition conditions [24]. Materials can be classified according to their conductivity to conductive, semi-conductive, and insulator [25]. At room temperature the conductor has conductivities between (10^3-10^8) Ω^{-1}cm^{-1}, semiconductor between (10^{-8}-10^3)Ω^{-1} cm^{-1}, and insulator between (10^{-18}-10^{-8}) Ω^{-1}cm^{-1} [26]. As shown in figure (2.1).

2.2 The Alternating Current Electrical Conductivity

When an insulator is placed in a low frequency electrical field, where induced or permanent electrical dipoles can go along with the variation of the applied electrical field with no residue, the dielectric constant value becomes equal to its value in a static field; that is, the insulator becomes ideal (ohmic conductivity equals to zero). On the other hand, when the frequency of electric field is greater, where the electric polarization depends on frequency, there will be a complex dielectric constant [27].

The dielectric constant is the ratio between the capacitance of a capacitor containing an insulator material between its conducting plates to the capacity of the same size with a vacuum between the plates. When an alternating potential $V = V_m e^{jwt}$, is applied across a capacitor (C) filled with an insulator, then [28-30]:

$$I=jwcv \tag{2.1}$$

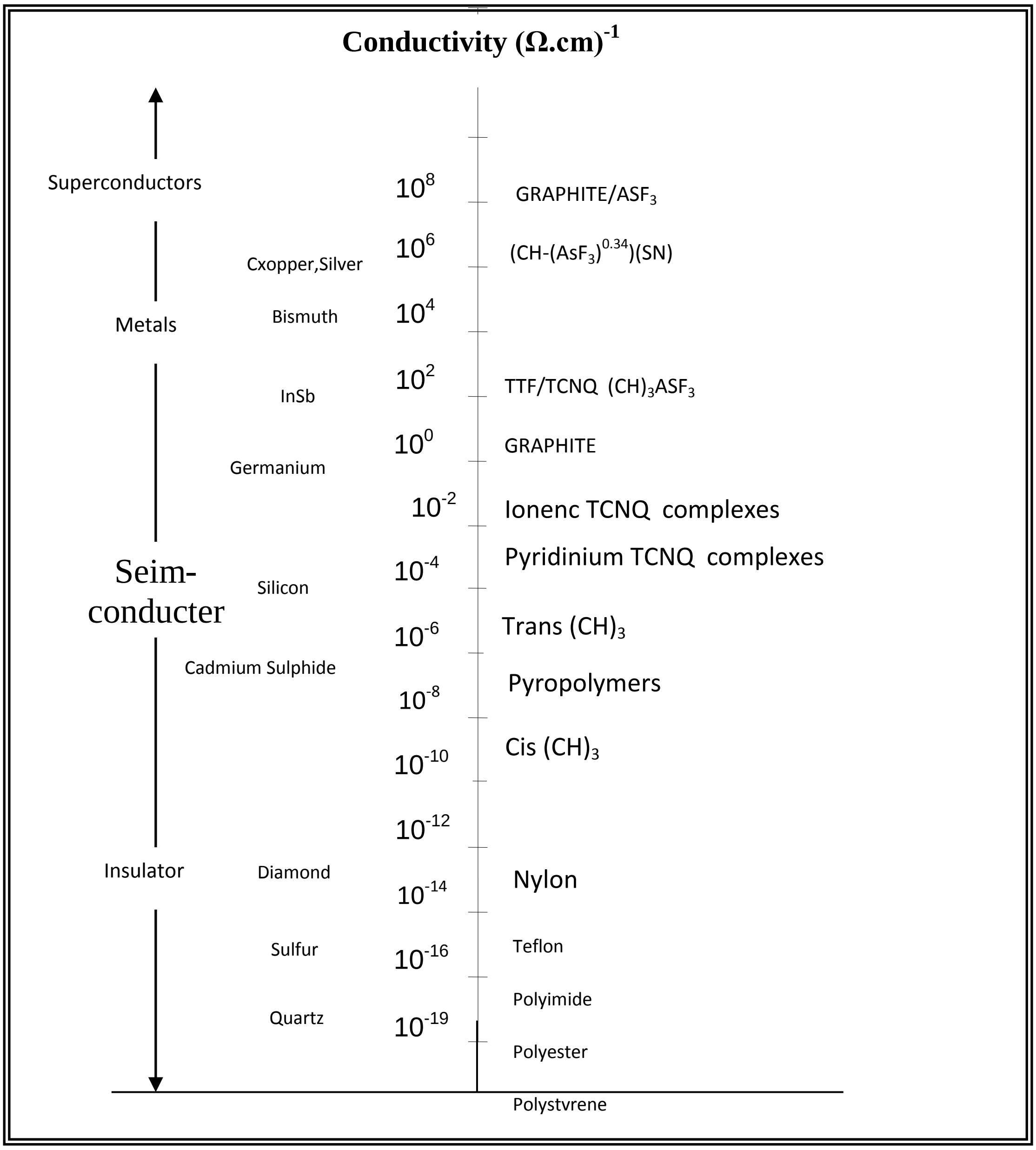


Figure (2.1) : The conductivity of material (including polymers) [26].

Where w is the angular frequency of the applied filed ($w=2\pi f$) , j is imaginary number $j=\sqrt{-1}$ and V_m is the voltage maximum .

This emphasizes the fact that the electric current is the sum of the conduction current Ip which is in the same phase with V and I_q with a phase difference of $\Pi/2$, that is, the current is represented by the equation:

$$I = I_P + jI_q \tag{2.2}$$

The capacitance of a capacitor constructed of two parallel plates is given by the equation:

$$C = \varepsilon\varepsilon_{o}\frac{A}{d} \tag{2.3}$$

By substituting equation (2.3) in (2.1), getting :

$$I = jw\varepsilon\varepsilon_{0}VA/d \tag{2.4}$$

The permittivity (ε) must be a complex quantity, it is consist of real and imaginary parts, so that the electric current be a complex quantity, as cited in equation (2.5). That is [31] :

$$\varepsilon = \varepsilon' - j\varepsilon'' \tag{2.5}$$

Where ε'' is the dielectric loss

So, we get :

$$I = jw\varepsilon_{o}\frac{A}{d}(\varepsilon' - j\varepsilon'')V \tag{2.6}$$

By comparing equation (2.6) with (2.2), then:

$$I_{p} = w\varepsilon''\varepsilon_{o}\frac{A}{d}V \tag{2.7}$$

$$I_{q} = w\varepsilon'\varepsilon_{o}\frac{A}{d}V \tag{2.8}$$

The loss factor (tanδ) is:

$$\tan\delta = \frac{I_{p}}{I_{q}} = \frac{\varepsilon''}{\varepsilon'} \tag{2.9}$$

And this represents the lost electrical energy which is transformed to thermal energy in the insulator. The importance of determining the power factor is very useful in electrical applications. Excessive power factor would cause heat in the insulator at high frequencies, resulting in an electrical failure [32].

The capacitor (c) can be represented by an ideal capacitor connected in parallel with a resistance R_p at low frequencies. So:

$$I = I_p + jI_q = \frac{v}{R_p} + jwc_pV \tag{2.10}$$

Hence, get the impedance (Z):

$$\frac{1}{Z} = \frac{1}{R_p} + jwc_p \tag{2.11}$$

From equations (2.7), (2.8), and (2.10), we can write :

$$R_p = \frac{d}{w\varepsilon'' A\varepsilon_\circ} \tag{2.12}$$

$$\varepsilon'' = \frac{1}{wR_pC_\circ} \tag{2.13}$$

$$C_p = \frac{\varepsilon'\varepsilon_\circ A}{d} \tag{2.14}$$

$$\varepsilon' = \frac{C_p}{C_\circ} \tag{2.15}$$

The dissipated power in the insulator is represented by the existence of alternating potential as a function of the alternating conductivity, using equation (2.5) :

$$\sigma_{a.c} = w\varepsilon''\varepsilon_\circ \tag{2.16}$$

$\sigma_{a.c}$ is a measurement for the generated temperature in the insulating material resulting from the rotation of the dipoles in their positions, (or the vibration of the charges) as a result of the alternating of the field.

Chapter Three

Experimental Part

Chapter Three

3.1 Introduction

This chapter includes the preparation process, devices and measurement techniques. A general description of materials (polyvinyl alcohol, Polyethylene glycol, strontium oxide) used in this work.

3.2 The Utilized Materials

The utilized materials in this study are:

3.2.1 Matrix Material

Polymers: two types of polymers are used in this work:

3.2.1.1 Polyvinyl Alcohol (PVA)

PVA is one of the earliest and best known polymers [33], with the formula $(C_2H_4O)_n$, as shown in Figure (3.1). It was seen to use in a variety of applications and is currently used extensively in semiconductors applications [34]. As shown in Figure (3.1).

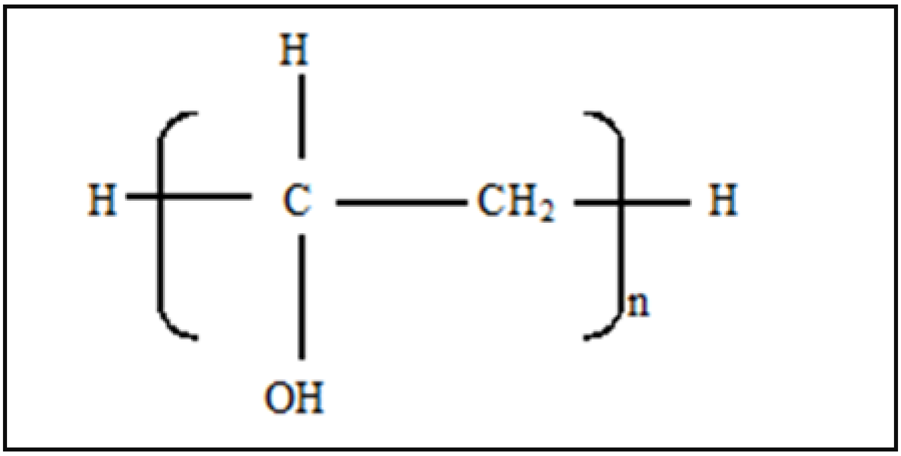


Figure (3.1): The Chemical Structure of PVA [34].

PVA is a water-soluble synthetic polymer and is an odorless, translucent, tasteless, white or cream colored granular powder, because with the existence of many hydroxyls, PVA is easily soluble in water and soluble in hydroxyl-contained organic compounds. The prominent properties of PVA are its biodegradability in the milieu and biocompatibility. PVA has high tensile strength and flexibility, high oxygen and aroma barrier properties. It also has admirable film forming, blending and adhesive properties [35]. The transmission of visible light is very high. Polymeric composites of PVA are known for their importance in technical applications [36]. PVA has unique properties, good chemical stability, eco-friendly, optical and electrical properties. The significant feature of polyvinyl alcohol its semi crystalline nature which is the presence of both amorphous and crystalline regions causing interfacial effects which increases the physical properties [37].

Table (3.1): Physical and chemical properties of polyvinyl alcohol (PVA) [38].

Property	**Description**
Appearance	White to ivory white granular powder
Molecular formula	$(C_2H_4O)_n$
Density g/cm3	1.3
Solution PH	5- 6.5
Refractive index	1.55
Glass transition temperature (T_g)	85 ^oC
Melting temperature (T_m)	230 ^oC

3.2.1.2 Polyethylene Glycol (PEG)

The chemical formula is [H $(OCH_2CH_2)_n$ OH]. Chemical name is [a hydro-o-hydroxypoly (oxy-1, 2-ethanediyl)]. Solubility in all grades of polyethylene glycol is soluble in water and miscible in all proportions with other polyethylene glycols (after melting, if necessary). Aqueous solutions of higher molecular-weight grades may form gels. Liquid polyethylene glycols are soluble in acetone, alcohols, benzene, glycerin, and glycols. Solid polyethylene glycols are soluble in acetone, dichloromethane, ethanol (95%), and methanol; they are slightly soluble in aliphatic hydrocarbons and ether, but insoluble in fats, fixed oils, and mineral oil. PEG is used to make emulsifying agents and detergents, and as plasticizers, humectants, and water-soluble textile lubricants. The wide range of chain lengths provides identical physical and chemical properties [39]. Figure (3.2) shows the chemical structure of Polyethylene glycol**.**

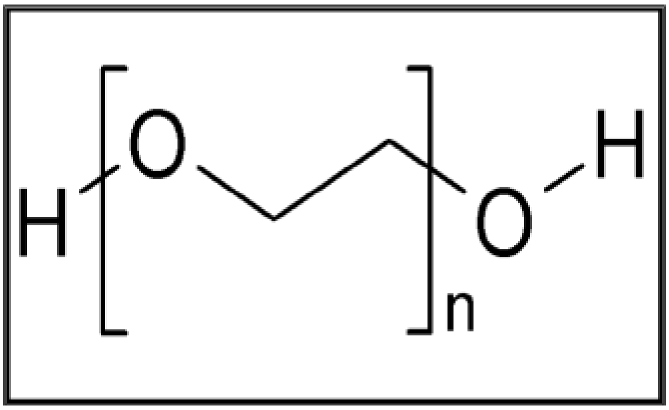


Figure (3.2): The chemical structure of polyethylene glycol [40].

It is widely used in a variety of pharmaceutical formulations including parenteral, topical, ophthalmic, oral and rectal preparations. Polyethylene glycol has been used experimentally in biodegradable polymeric matrices used in controlled-release systems. PEG or polyethylene glycols are used in great variety of applications because of their chemical structure, their low toxicity, their solubility in water and their lubricating properties. They provide flexibility in choosing properties to meet the requirements of many different applications. In the rubber industry, they serve as heat transfer agents, mold release agents, rubber compounders, lubricants, and pigment carriers [41]. Table (3.2) shows the physical properties of PEG.

Table (3.2): Physical Properties of (PEG) [41].

Physical properties	Units	Result
Molecular weight	g/mol	4000
Solution PH	-------	4.5-7.5
Viscosity at 99 ^oC	mm^2/s	110-158
Viscosity at 25 ^oC	mm^2/s	solid at specified temp.
Melting point	^oC	50-58
Density	g/cm^3	1.09
Refractive Index at 25 ^oC		1.456
Solubility in Water % by weight	-------	50
Surface Tension at 25 ^oC	N/m	solid at specified temp.
Glass transition temperature T_g	^oC	53-55
Liquid specific heat at 30-60 ^oC	kJ/kg/K	2.25
Coefficient of thermal expansion at 20 ºC	$^oC^{-1}$	solid at specified temp.
Thermal conductivity at 26 ºC	W/m.K	solid at specified temp.

3.2.2 Additive Material Strontium oxide (SrO)

Strontium oxide is an inorganic compound with the formula SrO that exists in both anhydrous and octahydrate forms, both of which are white solids. The anhydrous form adopts a structure similar to that of calcium carbide. Strontium oxide is an alkaline oxide, interacts with water with a hydrolysis reaction and diffuse heat to give strontium hydroxide:

$SrO + H_2O \rightarrow Sr(OH)_2$

It can be reduced by cutting from aluminum metal to metal strontium in an oxygen-free medium [41,42]. Table (3.3) shows the physical properties of SrO

$3SrO + 2Al \rightarrow Al_2O_3 + 3Sr$

Table (3.3) : Physical Properties of SrO [43-45].

Chemical formula :	**SrO**
Molar mass :	119.619 g/mol
Appearance :	white powder
Odor :	odorless
Density :	4.56g/cm3 (anhydrous) , 1.91 g /cm3 (octahydrate)
Melting point :	215 ºC
Solubility in water :	slightly soluble

3.3 Preparation of (PVA-PEG-SrO)

The nanocomposites of (PVA-PEG-SrO) are prepared by dissolving 1 gm of polymers in 50 ml of distilled water with different concentrations which are 0.90wt.% PVA and 0.10wt.% PEG by using magnetic stirrer to mix the polymers for 1 hour to obtain more homogeneous solution. The SrO nanoparticles are added to nanocomposites mixture with different concentrations which are (0.01, 0.02, 0.03 and 0.04) wt.%. as shown in table (3.4). The casting method is used to prepare the samples of (PVA-PEG-SrO) nanocomposites in the template (petri dish has diameter 10 cm).

Table (3.4): Illustrate samples no. and (PVA-PEG-SrO) nanocomposites wt.%.

Sample No.	**PVA Wt.%**	**PEG Wt.%**	**SrO Wt.%**
0	0.90	0.10	0
1	0.90	0.095	0.005
2	0.90	0.090	0.010
3	0.90	0.085	0.015
4	0.90	0.080	0.020

3.4 Measurements of Structural Properties for (PVA-PEG-SrO) nanocomposite by Optical Microscope

The sample of (PVA-PEG-SrO) are examined by using the optical microscope, which is supplied from Olympus name (Toup View) type (Nikon - 73346) and equipped with light intensity automatic controlled camera. Under magnification (10x), this measurement was implemented in the University of Babylon /College of Education for Pure Sciences, as shown in Figure (3.3).

Figure (3.3): Optical Microscope.

Chapter Four

Results and Discussion

Chapter Four

4.1 Introduction

This chapter include results and discussion of the structural and electrical properties of (PVA-PEG-SrO) nanocomposites.

4.2 The Optical Microscope

Figures (4.1) shows the images of (PVA- PEG-SrO) nanocomposites with different concentrations of SrO nanoparticles at magnification power (10x).

The optical microscope gives the change of surface morphology of nanocomposites. Compared with pure sample images, there are many differences among this sample and both nanocomposites with adding different concentrations of SrO nanoparticles, both figures show the addition of SrO nanoparticles distributed through the polymeric blend with homogenous and ordered shape as well as the appearance of SrO nanoparticles network inside the polymer blend. This constitutes paths inside the nanocomposites of charge carriers, this system can allow charge carriers to pass through the paths. In our opinion, these results agree with [46].

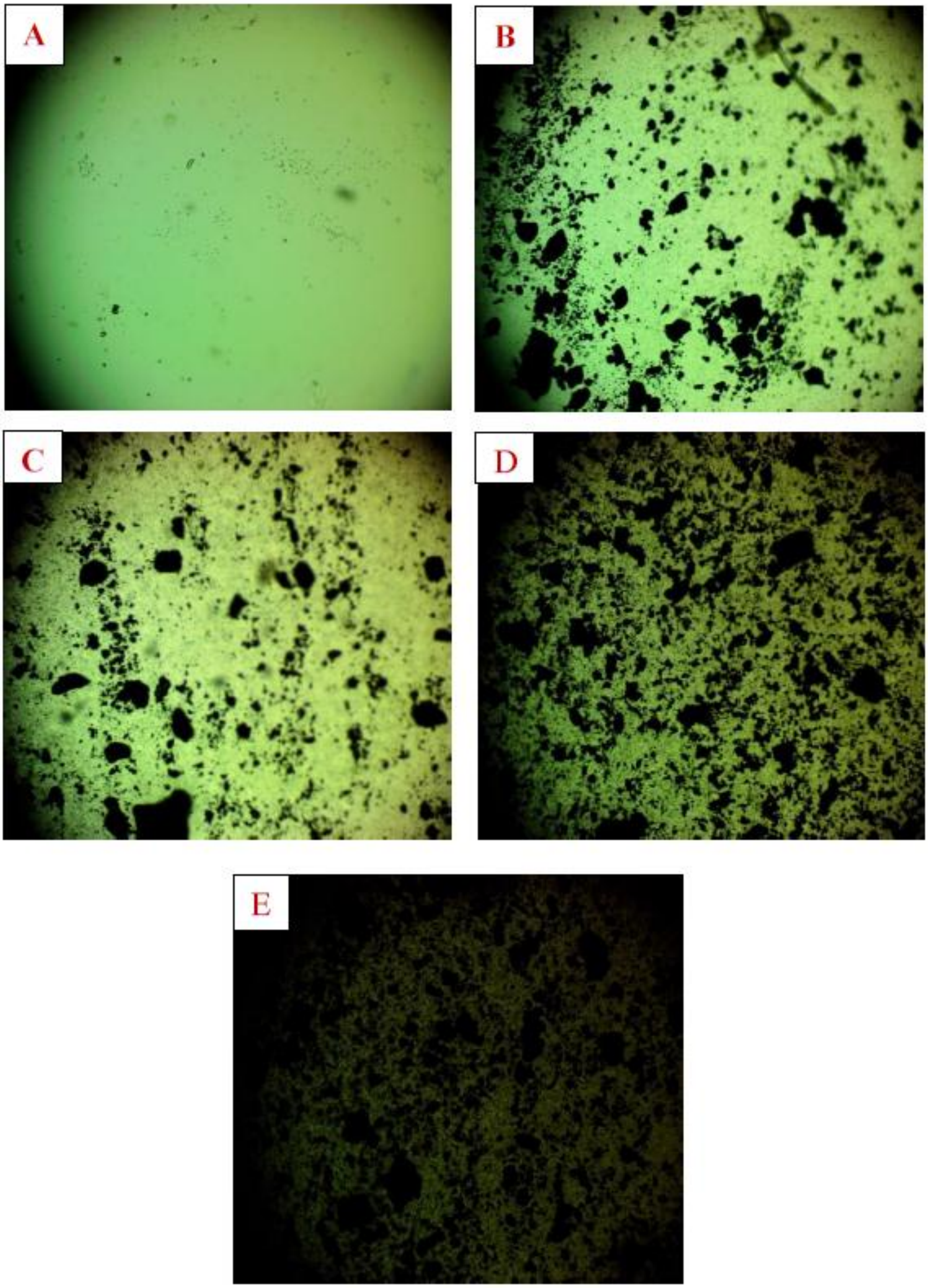


Figure (4.1) : Photomicrographs (10x) for (PVA-PEG- SrO) nanocomposites

(A) (PVA- PEG) blend (B) 0.5wt% (C) 1wt% (D) 1.5wt% (E) 2wt%.

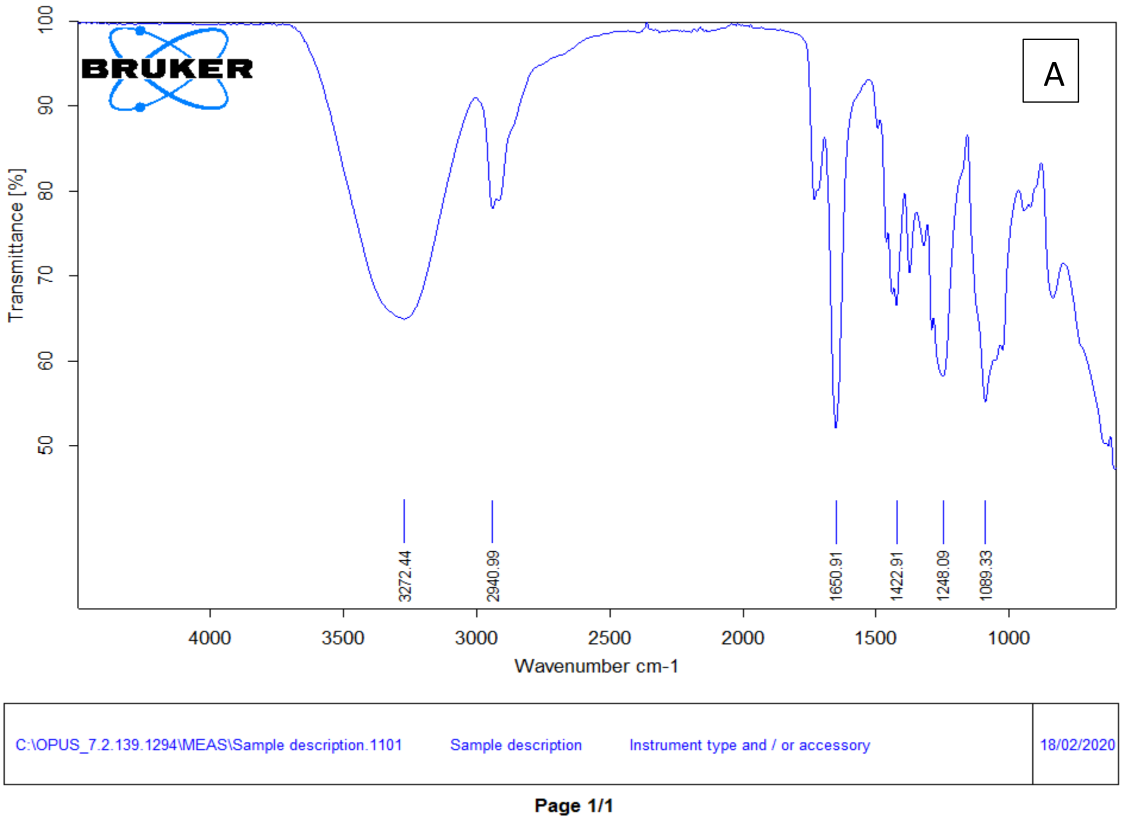
4.3 Fourier Transform Infrared Radiation (FTIR) of (PVA-PEG-SrO) nanocomposites.

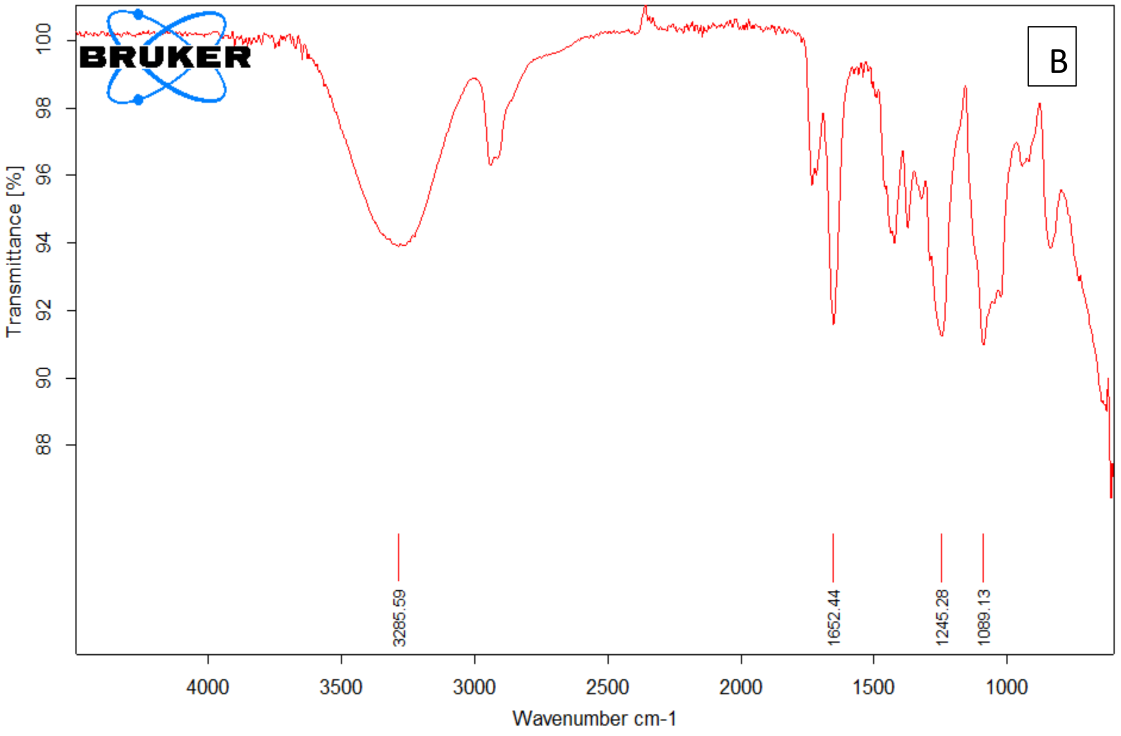
Figure (4.2) shows the FTIR spectra of (PVA-PEG-SrO) nanocomposites with different concentrations of (SrO) nanoparticles recorded at room temperature in the region (600-4000) cm^{-1}.pure blend (PVA-PEG) where wave number (cm^{-1}) (3401-3480) O-H stretching, (1607-1694) C=C stretching, (2910-2996) CH_2 asymmetric stretching, (1708-1760) C=O stretching, (1607-1694) C=C stretching, C-N stretching, (1469-1484) CH2 bending or bending O-H, (1038-1078) C=O stretch, C-H and OH bending, (907-943) CO= symmetric stretching. Table (4.1) exhibited the spectra characteristic bands of stretching and bending vibrations of the functional groups formed in nanocomposites.

Table (4.1): FTIR-characteristic for (PVA-PEG- SrO) nanocomposites

Active band	0wt%SrO	0.5wt% SrO	1wt% SrO	1.5wt% SrO	2wt% SrO
(C-H) Stretching Vibration (3000-3300) cm^{-1} (≡C-H, SP-1S), (3300 cm^{-1})	**3272**	**3285**	**3272**	**3273**	**3273**
(CH2) Asymmetric Stretching (2910-2996) cm^{-1}	**2940**		**2939**	**2940**	**_**
(C=C) Stretching Aromatic (1607-1694)cm^{-1}	**1650**	**1652**	**1650**	**1651**	**1653**
(CH2) bending Or bending (O-H) (1469-1483)cm^{-1}	**1422**	**_**	**1422**	**1422**	**_**
(CH2) wagging, Twisting(out-of-plane) Bending vibrations1250 cm^{-1}	**1248**	**1245**	**1245**	**1245**	**1245**
(C-O) Single band (1100 cm^{-1})	**1089**	**1089**	**1088**	**1088**	**1088**

FTIR spectra show a shifting in peak position as well as the change in shape and intensity compared with pure (PVA-PEG) and (PVA-SrO) films and it can be noticed that there is a decrease in transmittance at the concentration increasing of SrO nanoparticles. So far the density increment of the films means that there is increasing in atoms and ions in the light path.





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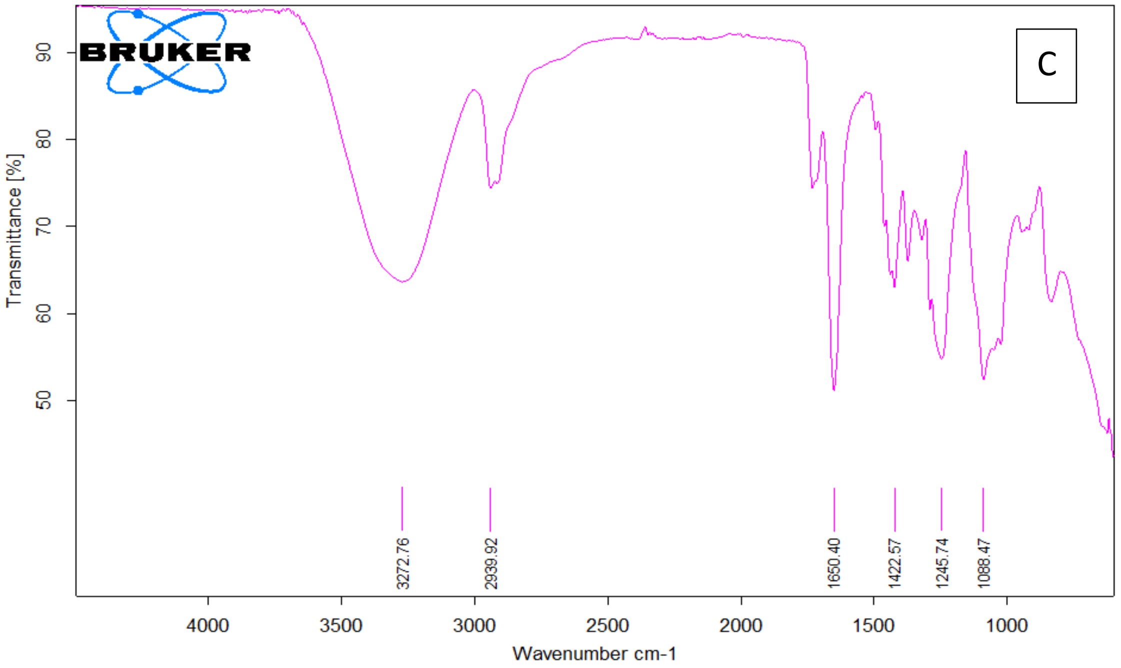

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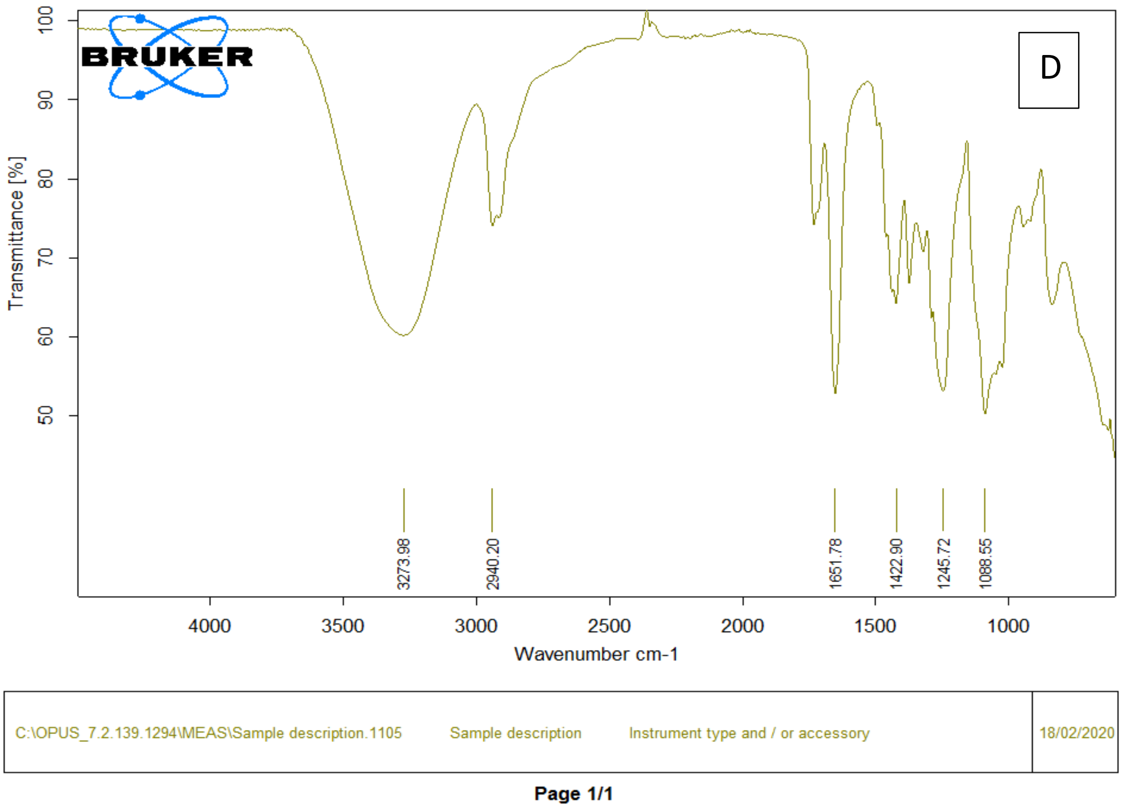

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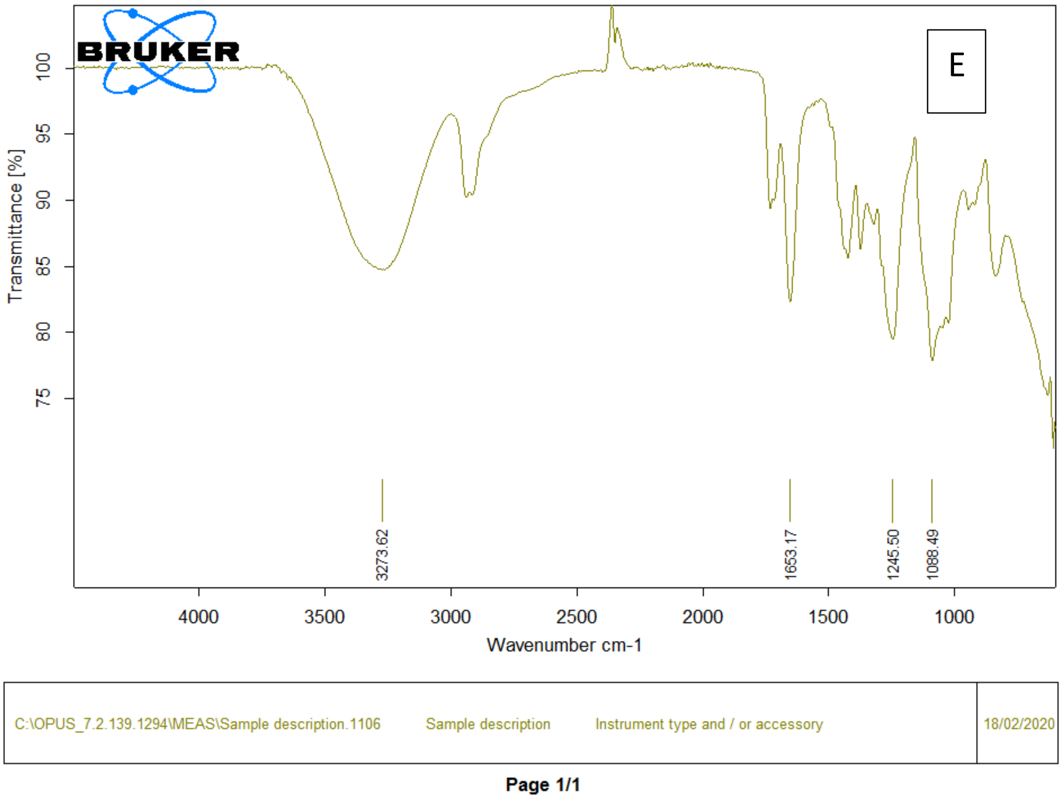

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Figure (4.2): FTIR spectra for (PVA-PEG-SrO) nanocomposite: (A) (PVA-PEG) blend, (B) 0.5wt% SrO, (C) 1wt% SrO, (D) 1.5wt% SrO, (E) 2wt% SrO.

4.4 Alternating Current Electrical Properties of (PVA-PEG-SrO) nanocomposites

The A.C electrical properties of (PVA-PEG-SrO) nanocomposites were studied with frequency range (100Hz-5MHz) at room temperature. The dielectric constant was calculated by using the equation (2.32). The dielectric loss was calculated by using equation (2.26); using the measured dielectric constant and $tan\delta$, while the A.C electrical conductivity ($\sigma_{A.C}$) was calculated by using equation (2.33) after substituting the measured values of ε'.

4.4.1 The Dielectric Constant of (PVA-PEG-SrO) nanocomposites

Figures (4.3) show the effect of adding the (SrO) nanoparticles on the dielectric constant at 100Hz and 25^{o}C. From this figure, notice that, the dielectric constant increases with the increase of the concentration of (SrO) nanoparticles.

The possible reason behind the increase of dielectric constant values in the formation of a continuous network of (SrO) nanoparticles inside the nanocomposites. At low concentrations, the nanoparticles take place to form the clusters or separated groups; hence, the dielectric constant becomes approximately low, and at high concentrations, (SrO) nanoparticles form a continuous network inside the nanocomposites and because the of (C_p) increment for the storage charges, and so the value of dielectric constant reduces with the volumetric rate of the (SrO) nanoparticles. This is similar to the results reached by the researchers [47].

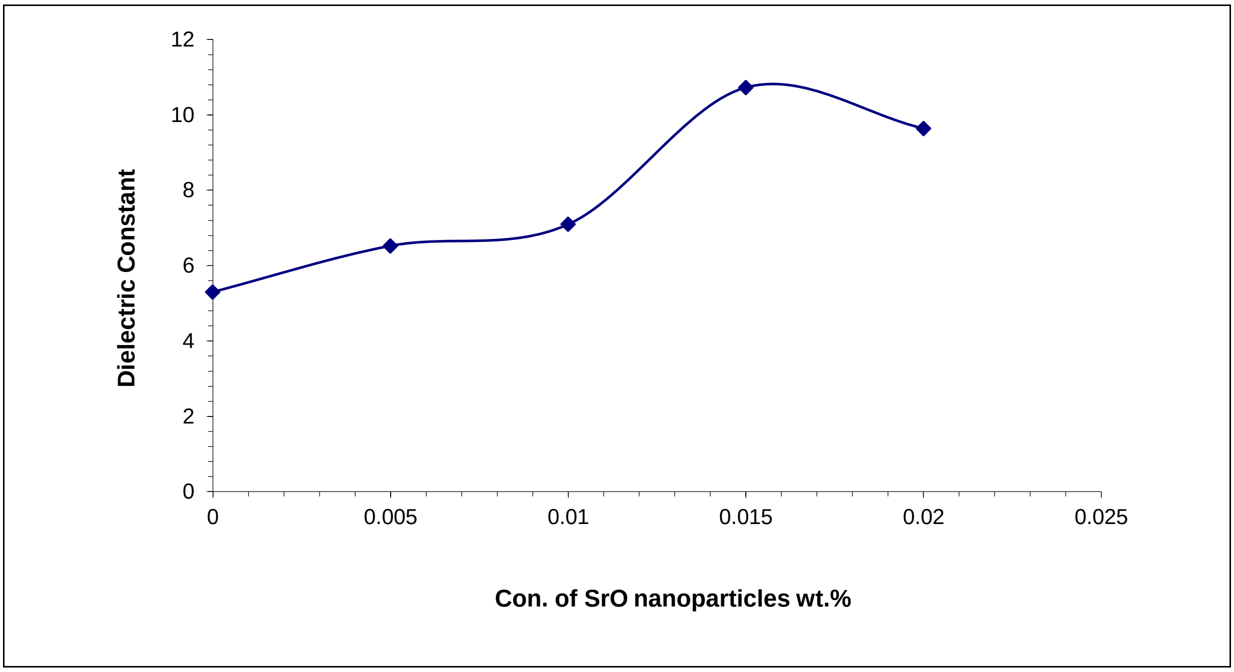

Figure (4.3): Variation of dielectric constant with concentration of (SrO) nanoparticles at 100Hz of (PVA-PEG-SrO) nanocomposites.

The dielectric constant variation for (PVA-PEG-SrO) nanocomposites with frequency for all samples are shown in Figure (4.4). It's obvious from figure the dielectric constant is higher in the low frequency range and with the increasing in frequency; it decreases for all samples. The higher dielectric constant is due to Maxwell-Wagner polarization. This kind of polarization originates from insulator-conductor interfaces. The accumulation of space charges or dipoles at the interfaces leads to this interfacial polarization. At low frequency region, the space charges have plenty of time to react to the applied electric field, whereas in the higher frequency range changes in the electric field is too quick for the space charges to react and the polarization effect does not exist. The other types of polarizations appear at high frequencies. The ionic polarization reacts slightly to the variation in the field frequencies compared to the electronic polarization. This is because the mass of ion is greater than that of the electron. The electrons respond to even the high frequencies of the field vibrations. The low mass of electron makes the electronic polarization, the only type of polarization at higher frequencies. This makes the dielectric constant approximately constant for all samples at high frequencies. [48,49].

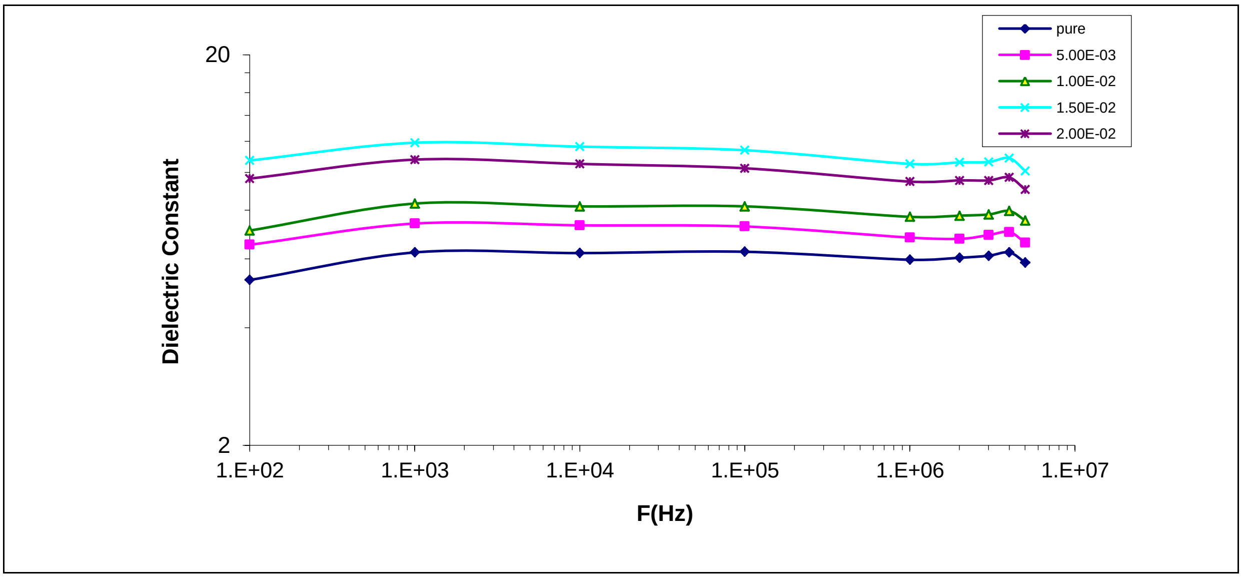

Figure (4.4): Variation of the dielectric constant of (PVA-PEG-SrO) nanocomposites with frequency.

4.4.2 The Dielectric Loss of (PVA-PEG-SrO) nanocomposites

The dielectric loss decreases with increase in frequency as depicted in the Figures (4.5). This is due to the highly mobile charge carriers present in the polymer chain at low frequency. Since the space charges find it difficult to react with the electric field at high frequency, the charge accumulation due to polarization decreases at the higher frequency, so dielectric loss decreases. In general, the loss of power in a dielectric material**.** When the frequency is increasing to 1MHz, the dielectric loss is approximately constant for (PVA-PEG-SrO) nanocomposites. This is attributed to the mechanisms of other types of polarization that occurs at high frequencies. The value of dielectric loss is increasing by increasing the SrO nanoparticles wt.% content ; this is due to the increase of the ionic charge carriers caused by the increase of the SrO concentration, as shown in figure (4.6) [48,49].

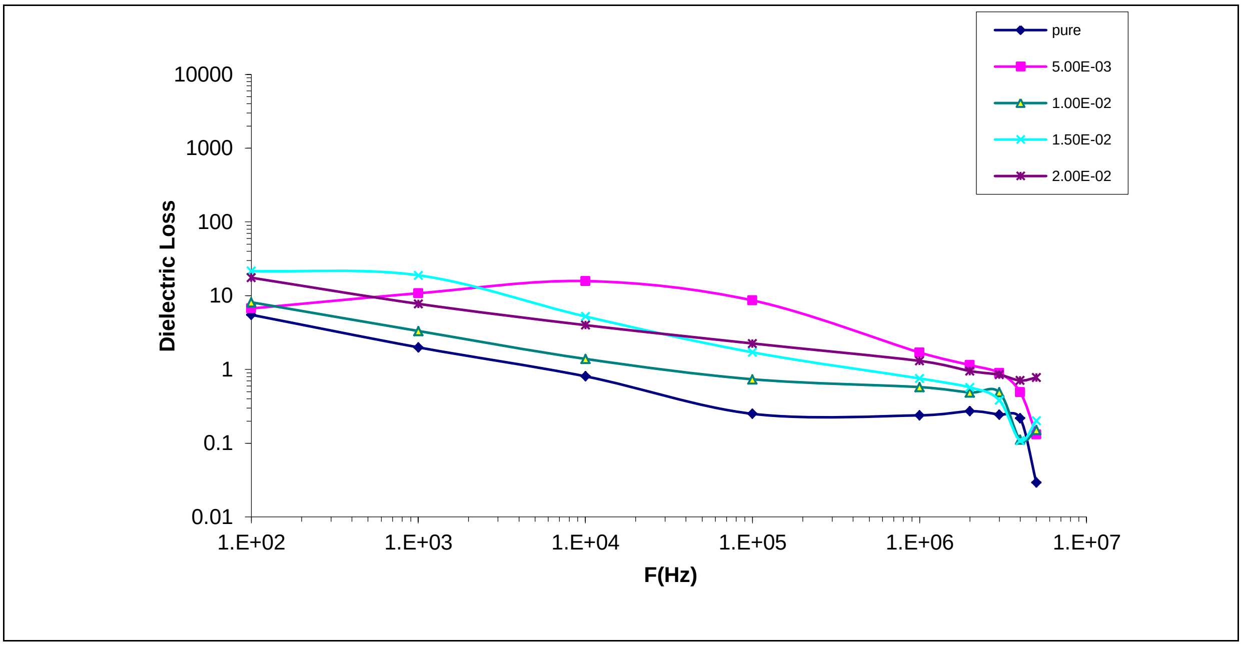

Figure (4.5): Variation of the dielectric loss of (PVA-PEG-SrO) nanocomposites with frequency.

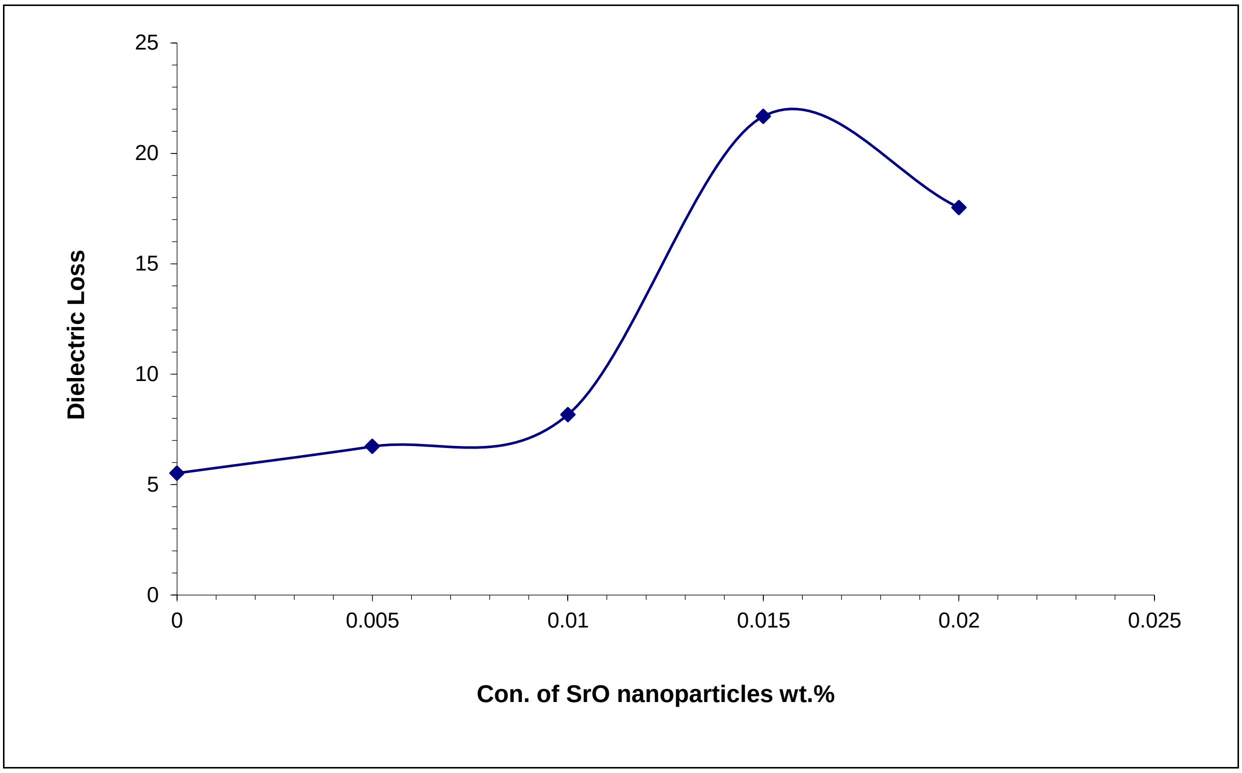

Figure (4.6): Variation of dielectric loss with concentration of (SrO) nanoparticles for (PVA-PEG-SrO) nanocomposites.

4.4.3 Alternating Current electrical conductivity

The variation of AC electrical conductivity as a function of frequency for (PVA-PEG-SrO) nanocomposites at 100Hz, 25 ^{o}C is depicted in Figure (4.7). The figure shows that at (low, intermediate and higher) frequency regions, the electrical conductivity of nanocomposites increases with frequency which is due to the hopping of charge carriers through the conducting networks formed as a result of polarity. Furthermore, the increase in AC electrical conductivity with angular frequency at low frequency region can be attributed to the interfacial polarization while at intermediate and higher frequencies, the increase in conductivity is due to the motion of electrons or atoms, tunneling or hopping between two equilibrium sites. In general, the AC conductivity decreases with increasing in frequency in case of the band conduction, while it increases with increasing in frequency in case of hopping conduction. From figure (4.7), it can be shown that the conductivity of nanocomposites was increased with the increasing of (SrO) nanoparticles concentrations as a result of the increase of the ionic charge carriers and the formation of a continuous network of (SrO) nanoparticles ions inside the composites [48,49].

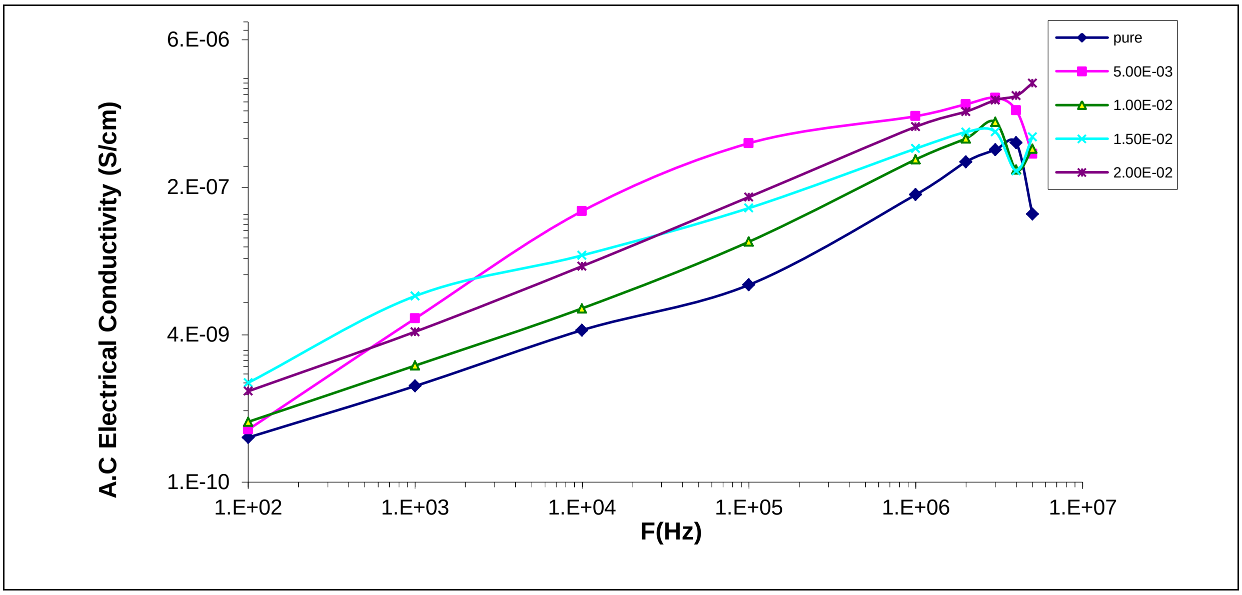

Figure (4.7): Variation of the A.C electrical conductivity with frequency for (PVA-PEG-SrO) nanocomposites.

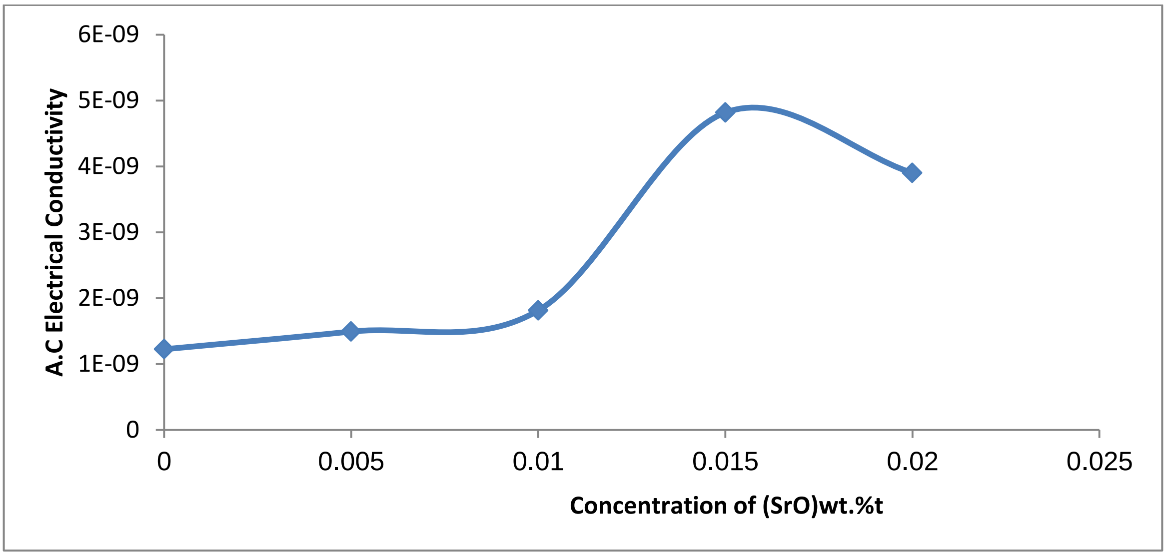

Figure (4.8): Variation of the A.C electrical conductivity with different concentration for (PVA-PEG-SrO) nanocomposites.

Chapter Five

Conclusions and Future Works

Chapter Five

5.1 Conclusions

1. The results of the optical microscopy of (PVA-PEG-SrO) nanocomposites show the addition of (SrO) nanomaterial distributed through the polymeric blend with homogenous and ordered shape.
2. The A.C electrical conductivity of (PVA-PEG-SrO) nanocomposites and dielectric constant and the dielectric loss for all concentrations increases with the frequency.

5.2 Future works

1. Study of the thermal properties of the (PVA-PEG-SrO) nanocomposites.
2. Study of the mechanical properties of the (PVA-PEG-SrO) nanocomposites.
3. Study of the optical properties of the (PVA-PEG-SrO) nanocomposites.

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الخلاصة

تحضير المتراكبات النانوية (PVA–PEG–SrO) باستخدام طريقة الصب بتراكيز مختلفة (0، 0.01، 0.02، 0.03، 0.04) بالوزن٪ من جسيمات SrO النانوية بمتوسط حجم حبيبي (20) نانومتر. وأظهرت صور المجهر الضوئي شبكة مستمرة داخل بوليمرات الجسيمات النانوية SrO بطريقة متجانسة ومنظمة، وهذا النظام يمكن أن يسمح بمرور حاملات الشحنة.

أظهرت نتائج الفحص المجهري البصري للمتراكبات النانوية (PVA–PEG–SrO) انه عند إضافة مادة متناهية الصغر من (SrO) موزعة داخل الخليط البوليمري بشكل متجانس ومرتّب.

وبينت أيضاً تزداد الموصلية الكهربائية للتيار المتردد للمركبات النانوية (PVA–PEG–SrO) وثابت العزل الكهربائي وفقد العازل لجميع التركيزات مع زيادة التردد.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية التربية للعلوم الصرفة
قسم الفيزياء

دراسة الخصائص التركيبية و الكهربائية للمتراكب النانوي (PVA-PEG-SrO)

بحث مقدم
إلى مجلس كلية التربية للعلوم الصرفة في جامعة بابل
وهي جزء من متطلبات نيل درجة الدبلوم العالي / فيزياء المواد وتطبيقاتها

من قبل الطالبة

زينب جواد كاظم حسين

بكالوريوس علوم فيزياء
(جامعة القادسية 2015 م)

بأشراف

أ. د. علي رزاق عبد الرضا

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