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Study of the evolution of certain electrical properties of a carboxymethyl cellulose by irradiating it and adding different concentrations of materials at different temperatures

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ABSTRACT

There are two parts to this manuscript. In the first part, thin films were prepared by doping carboxymethyl cellulose with Polyanionic cellulose low viscosity, with a concentration of 73% CMCHV and 27% PACLV, then CMC HV/PAC LV thin films were exposed to different X-ray photon doses (0, 200, 400, 600, and 800 cGy). But second Part were prepared the thin films by dissolving 8 g of CMCHV in 50 ml of distilled water, then adding NaCl and ZnONPs in concentrations (0.00, 11, 20, 27, 33 and 38%). The intensity of the direct current I was measured for all samples by changing the potential difference V at different temperatures (T).

The measurement results of all samples studied in this research indicate that the conductivity and current density increase with an increase in the X-ray photon doses in the irradiated samples or with an increase in the concentrations of NaCl, ZnOPNs and also increases with increasing temperature, but the conductivity and current density increase more when NaCl is added than when ZnO PNs are added. By using these results, several areas can benefit, such as industry, scientific research, etc.

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1. INTRODUCTION

This study aims to improve some of the electrical properties of the polymer (CMC HV) through irradiation, as well as by adding materials to its thin films.

Polymers are known to have good insulating properties and are among the most widely used materials in the modern world. However, some polymers have been found to have conductive properties. Conductive polymers are polymeric materials that exhibit metallic and semiconducting characteristics, a combination of properties that no other known material exhibits. A key property of a conductive polymer is the presence of conjugated double bonds along the back bonds of the polymer.

The electrical resistivity of a material is a number that describes that material's resistance to the flow of electricity. Resistivity is measured in units of (W m). If electricity can flow easily through a material, that material has low resistivity. If electricity has great difficulty flowing through a material, this material has a high resistivity [1]. Electrical conductivity is the inverse of resistivity [1,2]. This means that high resistivity equals low conductivity and low resistivity equals high conductivity. [1] Electrical conduction is possible through contact between particles or through the ability of electrons to pass from one CNT to another through a thin polymer layer.[3]

X-ray spectroscopy can provide the energy and transition probabilities to excited states of the electronic Hamiltonian. X-ray absorption results from a transition from an inner shell atomic orbital to an unoccupied or continuum-bound orbital, and X-ray emission occurs when an inner shell vacancy is filled with an electron originating from a valence. Atomic or a shallower inner shell valence orbital 1or 2.The two processes are combined in photon input and output spectroscopy, which provides valuable information about electronics. Structure and therefore the coordination environment of an element.[4] The activation energy(E_a) is the energy necessary to reach the transition state of the complex provided from outside the system. E_a can be used as a reference to determine the minimum amount of energy necessary to activate a reaction after the encounter of molecules during a collision or vibration. It is influenced by several factors, namely temperature, frequency and catalyst. [5] Schottky emission, increase in the discharge of electrons from the surface of a material heated by the application of an electric field that reduces the value of the energy necessary for the emission of electrons.

2. RESEARCH METHOD

2.1 Theoretical Models:

If the charge (q), a numerical density (n) and a drift rate (υ_d) alors the product (n), (q) and (υ_d) are equal to the current density (J) [6]. In ohmic conductors, the drift velocity (υ_d) of the charge carriers is proportional to the electric field (E) in the conductor. This proportionality results from a balance between the acceleration due to the electric field and the deceleration due to collisions between the charge carriers and the network.

At steady state, these two terms balance, leading to a constant drift velocity proportional to (E). This proportionality leads directly to Ohm's microscopic law which states that the current density J is directly proportional to the electric field according to the equation (1) [7, 8]

$$\mathbf{J} = \sigma_{dc}\,\mathbf{E} \qquad (1)$$

Where:

$$\mathbf{J} = \frac{I}{A} \qquad (2)$$

$$\sigma_{dc} = \frac{1}{\rho_{dc}}, \qquad \rho_{dc} = \frac{R\,A}{L} \qquad (3)$$

and I = intensity of the direct current, A = surface area of the sample, σ_{dc} = electrical conductivity (measured in $\Omega^{-1}\,.\,m^{-1}$), ρ = resistivity of the sample, R= resistivity and L= thickness of the sample.[5] The activation energy is calculated from equation (3).[5,9]

$$E_a = \frac{8.6X10^{-5}(ln\sigma_1 - ln\sigma_2)}{\left(\frac{1000}{T_1} - \frac{1000}{T_2}\right) X\ 10^{-3}} \qquad (4)$$

The conventional method for preparing electro conductive polymeric composites involves mixing conductive solid fillers such as metallic particles, carbon black, graphite or carbon nanotubes into the common polymer. Conductive polymers are a suitable substitute for inorganic materials because they exhibit extraordinary electrical properties and wide color variation due to their double-donation conjugated chain structure, which is derived from their conductive or non-conductive form. However, they are inherently insoluble, infusible and non-transformable due to their strong intermolecular interaction. Therefore, high-quality conductive blends can be made with conventional polymers by melt mixing. [10-14]

2.2 Materials and Methods:

2.2.1 Materials and Samples preparation

2.2.1.1 Materials:

ZnO NPs were provided by Sigma-Aldrich GMBH, CMCHV and PAC LV were provided by National Corporation Jowfe Oil Technology. Sodium chloride is a dietary salt.

2.2.1.2 Samples preparation

There are two parts to this manuscript. In the first part, thin films were prepared by doping CMC HV with PAC LV, with a concentration of 73% CMC HV and 27% PAC LV. The solution of CMC HV and PAC LV was prepared by dissolving CMC HV and PAC LV in double-distilled water for three hours with stirring at room temperature (293.15ºC), and then the solutions were poured into a plate. of flat glass and let it rest. dry at room temperature. A thin film almost 50 µm thick was formed.

CMC HV/PAC LV thin films were exposed to different X-ray photon doses (0, 200, 400, 600, and 800 cGy) at the National Cancer Center, Benghazi, Libya, but samples from the second Part were prepared by dissolving 8 g of carboxymethyl cellulose in 50 ml of distilled water, then adding NaCl and ZnO NPs in concentrations (0.00, 11, 20, 27, 33 and 38%) and stirring for three hours, then poured onto a plate and left until thin films of thickness (0.05 nm) are formed.

2.2.2 Measurements:

The intensity of the direct current I was measured for all samples by changing the potential difference V at different temperatures T, starting from room temperature (293.15°k) to temperature (353.15°k) with a change of 10 degrees. Then the resistance was calculated for each sample at all temperatures, while the conductivity was the reciprocal of the resistances, and from there the current density was calculated using equation (2) and the electric field was calculated from the equation (1). Using electrical conductivity and temperature, the activation energy is calculated by equation (4).

3. RESULTS AND DISCUSSIONS

3.1 The non-irradiated and irradiated CMC HV/ PAC LV thin films

The current density and electric field for irradiated CMC HV/ PAC LV thin films with different X- ray photons doses were calculated at temperatures ranging between room temperature (293.15°k) and (353°k) using equations (1 and 2), then plotted as in figure (1), observe in this figure the direct proportionality between the electric field and the current density, as well as the direct proportionality between the X- ray photons doses and the current density.[15]

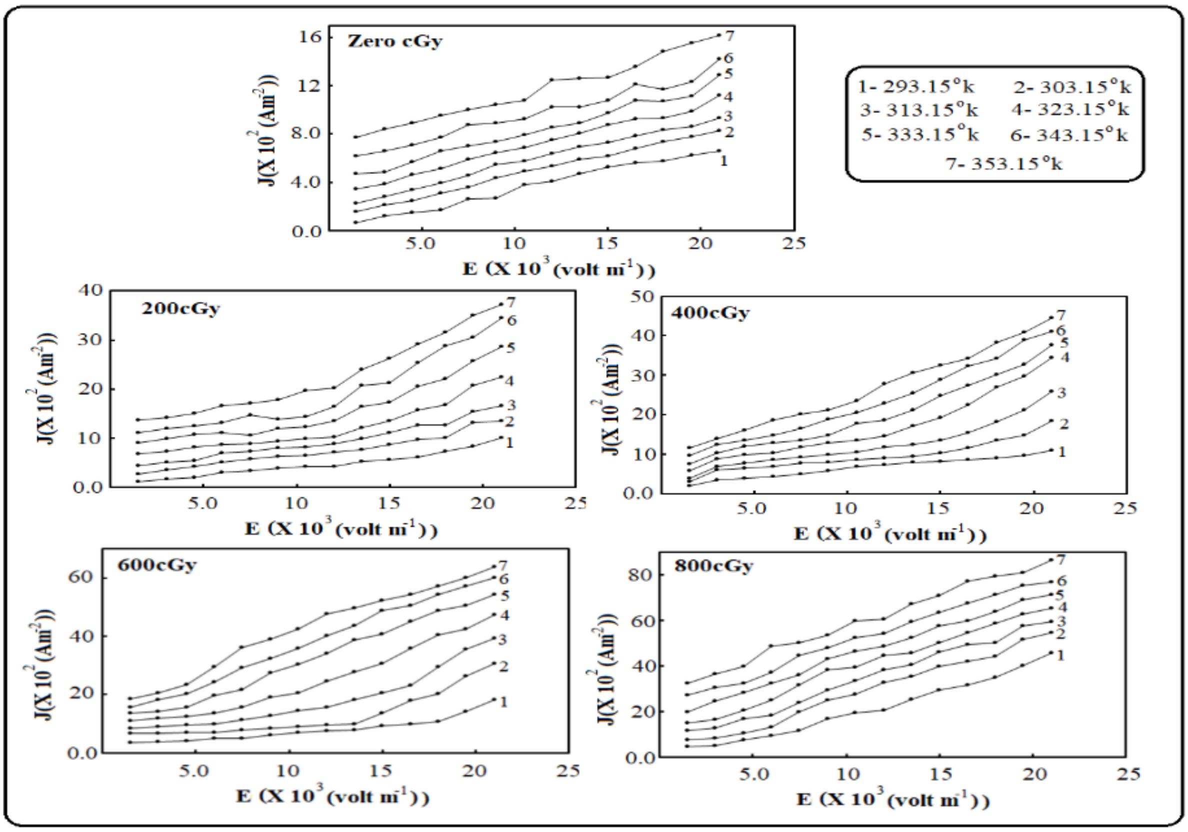

Fig. 1 Variation of J with E for CMC HV/ PAC LV thin film samples at different X- ray photons doses and different temperatures.

The relationship between the square root of the electric field and the log(J) representative in figure (2). Schottky emission can be expressed as log (J), where the current density is proportional to the square root of the applied electric field (E). The current shows the behavior of Schottky emissions. [16]. There are direct proportionality between square root of the electric field and the logarithm of the current density, as well as the direct proportionality between the X- ray photons doses and the logarithm of the current density.

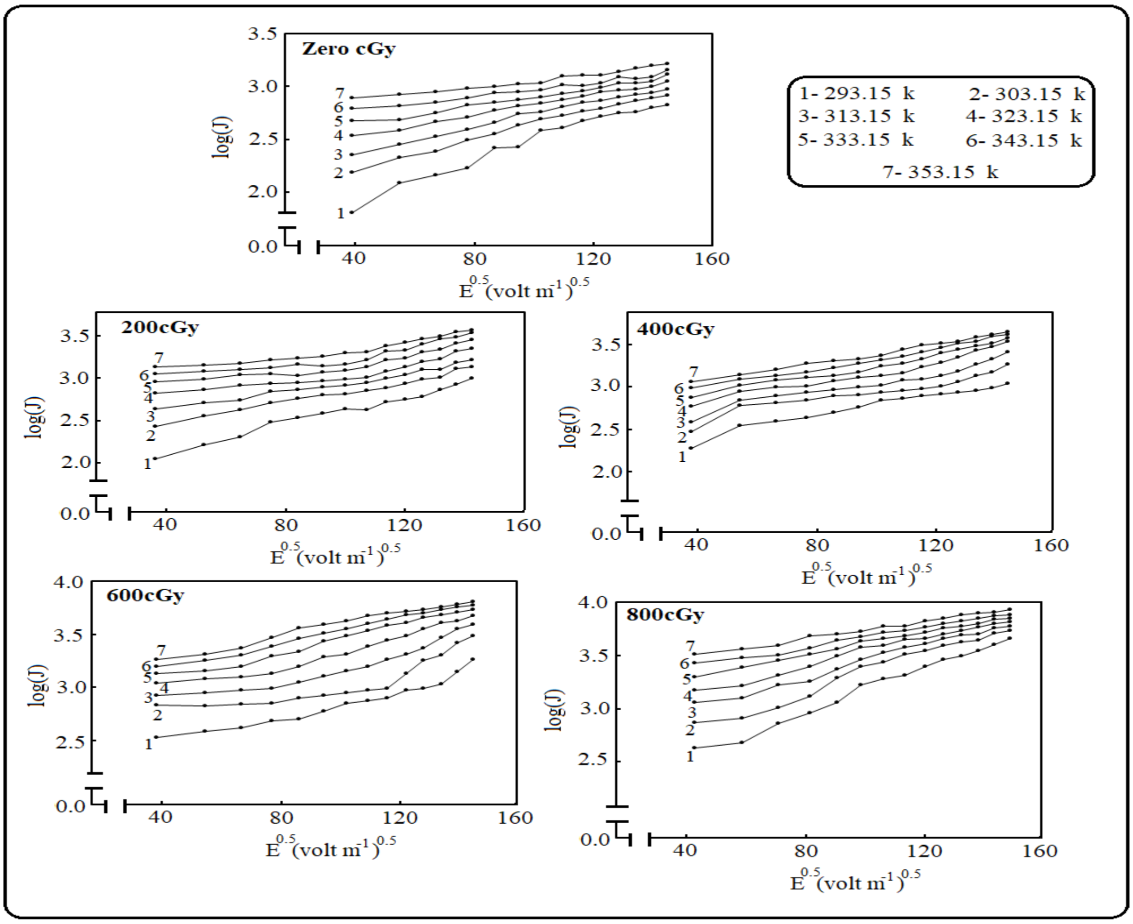

Fig. 2 Variation of log (J) with $E^{0.5}$ for CMC HV/ PAC LV thin film samples at different X- ray photons doses and different temperatures.

Using equation (3), the continuous conductivity values were calculated and then representative of the relationship between the values of $\frac{1000}{T}$ in Kelvin^{-1} and the logarithm of continuous conductivity in Figure (3). There was an inverse proportion between them.[17] This figure also illustrates the direct proportion with the X-ray photons doses, demonstrating that irradiation increases the continuous conductivity.

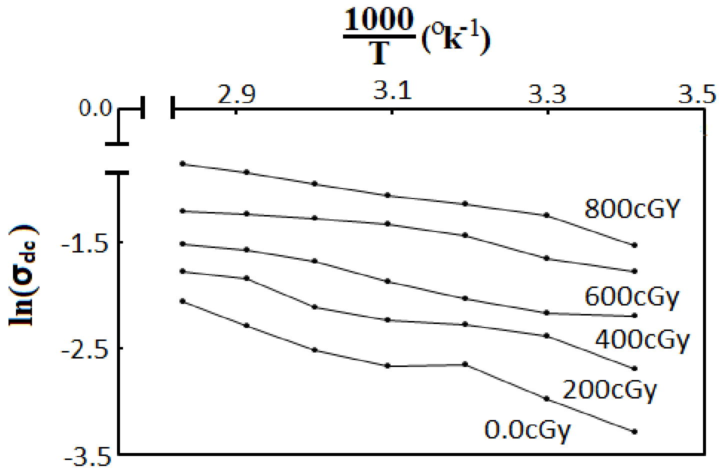

Fig. 3 Temperature dependence of σ_{dc} for CMC HV/ PAC LV thin film samples at different X- ray photons doses.

The dependence of the activation energy of CMC HV/ PAC LV thin films on different X- ray photons doses were calculated using equation (4) and is shown in figure (4). The value of (E_a) can be used to view the characteristics of the charge stability rate mechanism passing through a conductive polymeric material under the influence of temperature. The higher the activation energy, the slower the rate of stability of the charge passing through the conductive polymer material with changes in temperature. On the other hand, the lower the activation energy, the faster the stability rate of the charge passing through the conductive polymeric material with changes in temperature. [5] Activation energy decreased with the increase of the X- ray photons doses.[18]

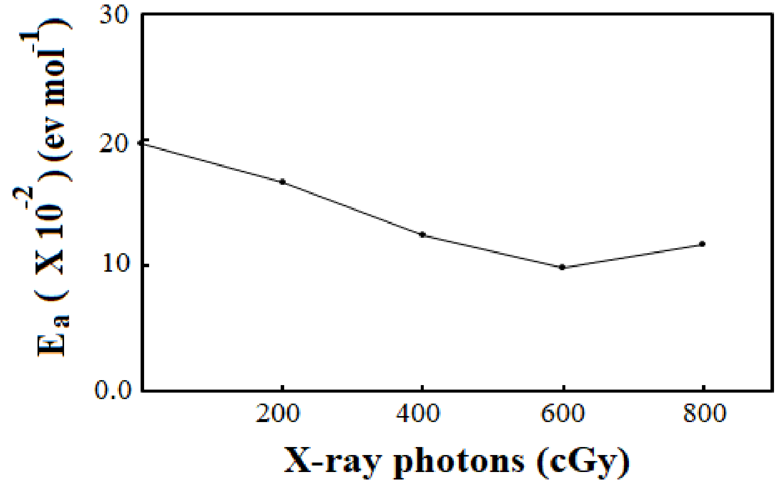

Fig. 4 Dependence of activation energy of CMCHV/ PACLV at different X- ray photons doses.

3.2 CMCHV thin film samples with different concentrations of sodium chloride

In figure (5), there is a relationship between the electric field and the current density at different temperatures, from room temperature (293.15 ok) to (353.15 ok). There is a direct proportionality between the electric field and the current density, as well as a proportionality between the NaCl concentration and the current density. [15]

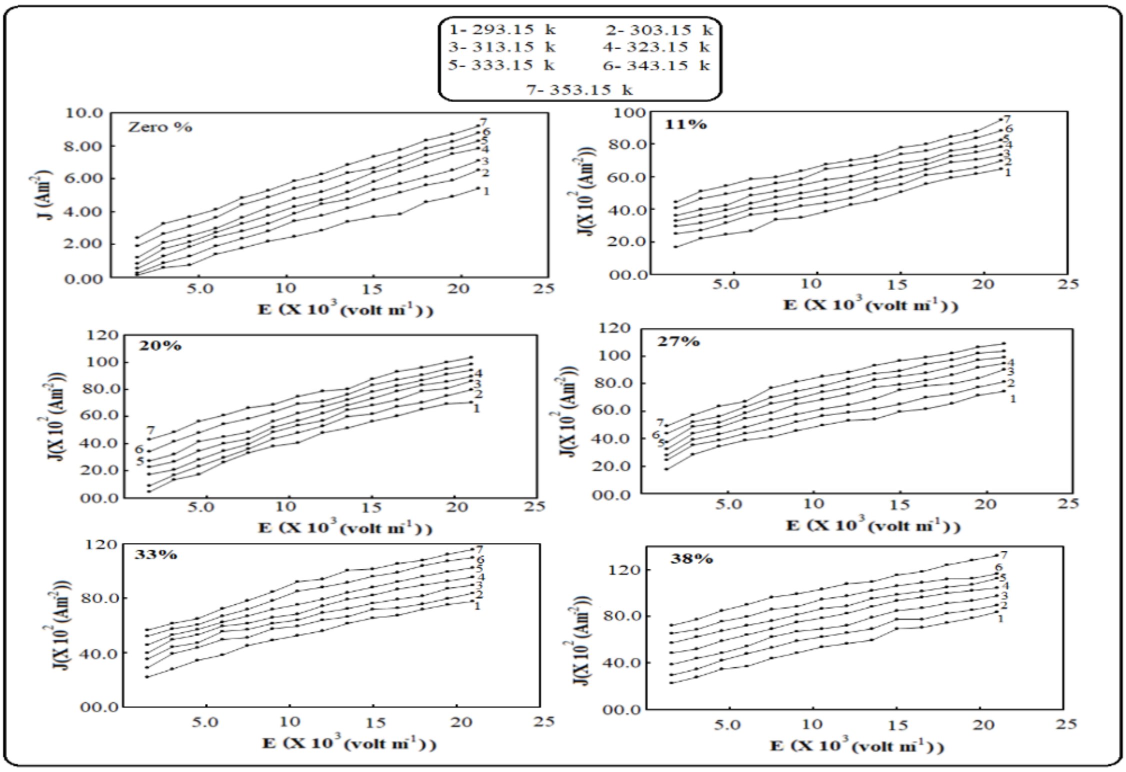

Fig. 5 Variation of J with E for CMCHV thin film samples with different concentrations of sodium chloride at different temperatures.

Figure (6) represents the logarithmic current density versus the square root of the electric field log (J) vs $E^{0.5}$. For high electric field (> 80 volt m^{-1}), a straight line can be obtained for the samples and the leakage current depends very little on the thickness. This provides further evidence for electrode current limiting, which is a Schottky emission (SE). Therefore, the dominant high -field driving mechanism for the samples is determined to be a Schottky emission process. At low field (<80 volt m^{-1}), the leakage current curve deviates slightly from the straight line of the samples. [19]

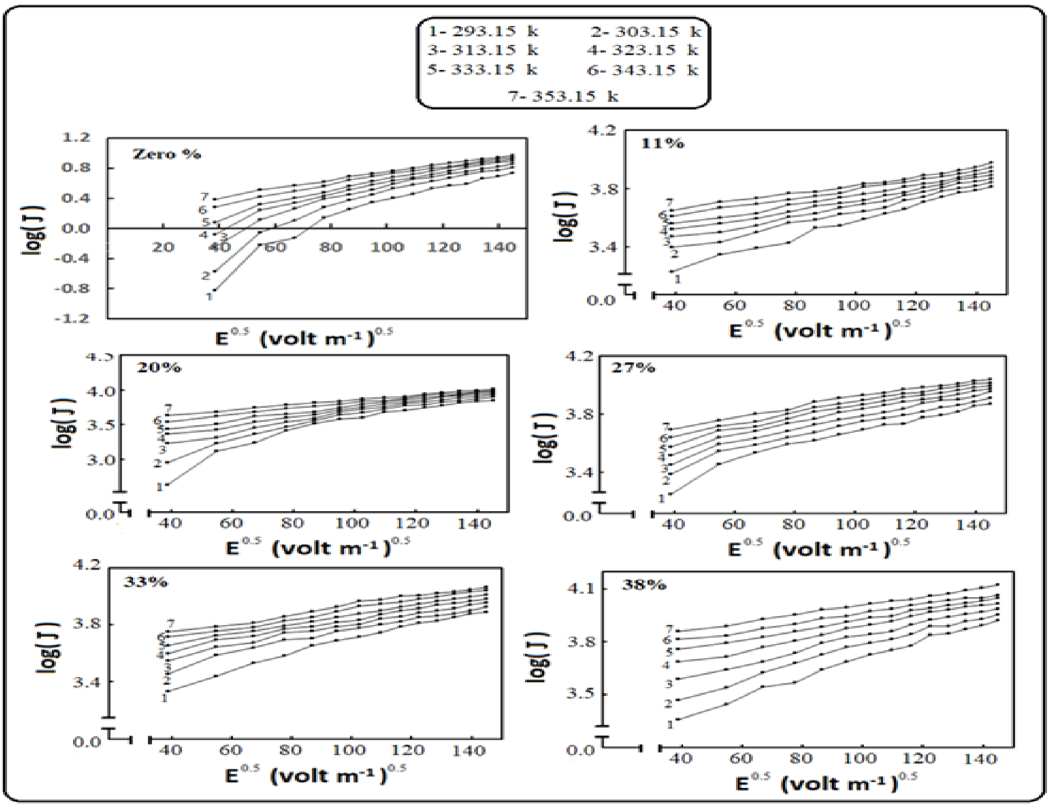

Fig. 6 Variation of log (J) with $E^{0.5}$ for CMCHV thin film samples with different Concentrations of sodium chloride at different temperatures.

The continuous conductivity values were calculated using equation (3) and are then representative of the relationship between the $\frac{1000}{T}$ values in $Kelvin^{-1}$ and the continuous conductivity record in figure (7). There was an inverse proportion between them.[17] This figure also illustrates the direct X-ray photon dose ratio, demonstrating that irradiation increases dc conductivity.

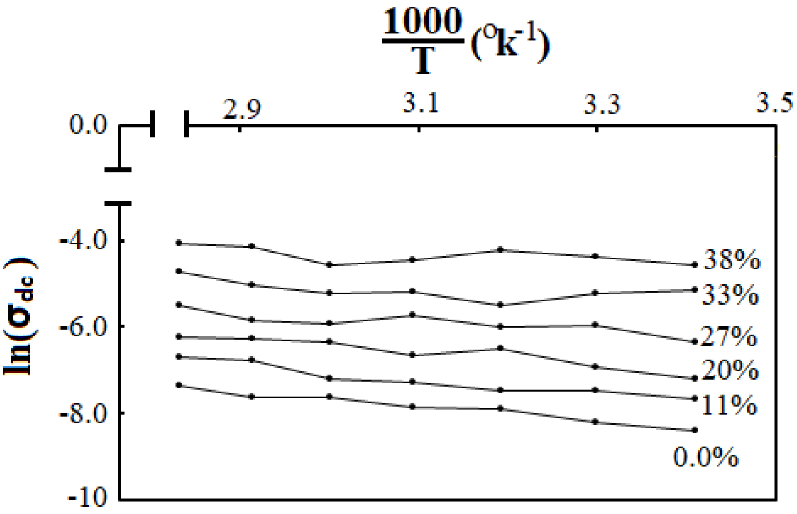

Fig. 7 Temperature dependence of σ_{dc} for CMCHV/NaCl thin film samples at different concentration of NaCl.

3.3 CMCHV thin film samples with different Concentrations of zinc oxide nanoparticles

In the figure (8), there is a relationship between the electric field and the current density at different temperatures, from room temperature (293.15°k) to (353.15°k). There is a direct proportionality between the electric field and the current density, as well as the proportionality between the concentration of ZnO PNs and the current density.[15]

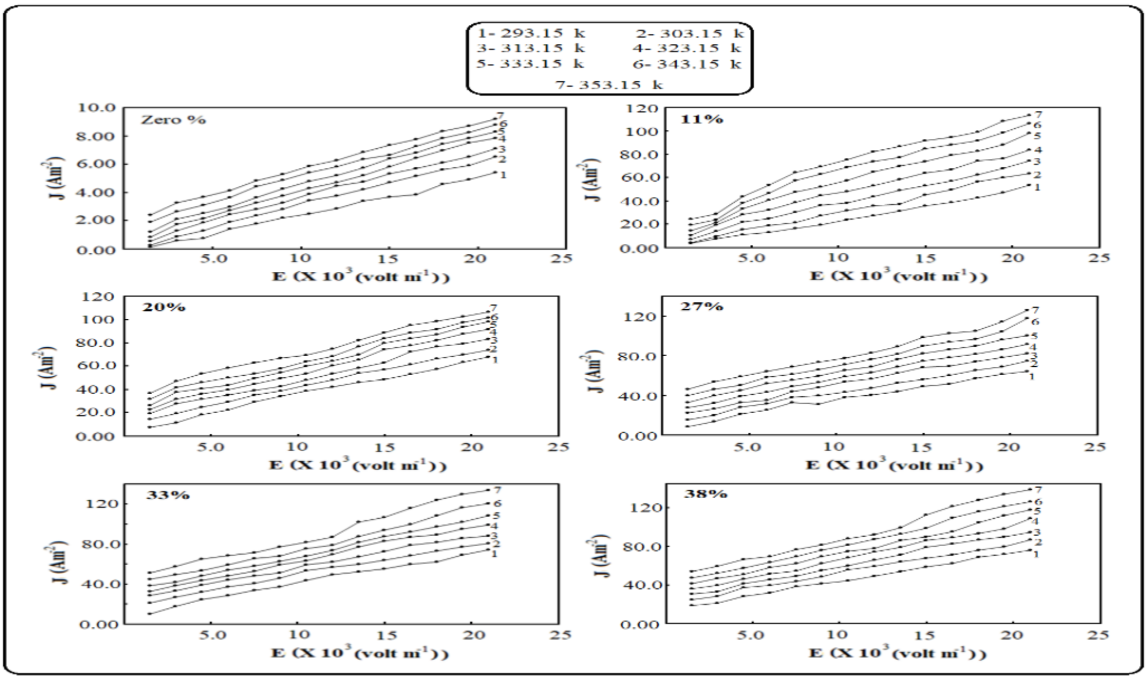

Fig.8 Variation of J with E for CMCHV thin film samples with different Concentrations of zinc oxide nanoparticles at different temperatures.

In figure (9), the current density is plotted logarithmically against the square root of the electric field. As can be seen from the graph, the current density increases logarithmically with the square root of the electric field over a wide current range. [20]

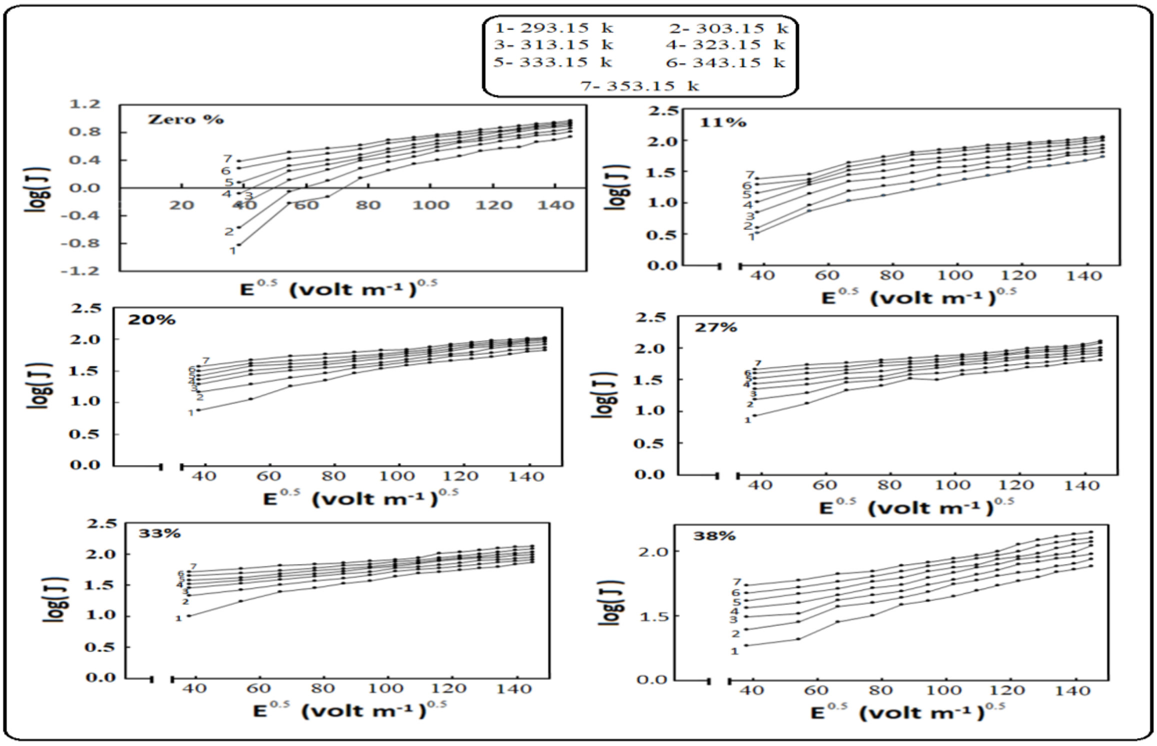

Fig. 9 Variation of log (J) with $E^{0.5}$ for CMCHV thin film samples with different Concentrations of zinc oxide nanoparticles at different temperatures.

The dc conductivity values were calculated using equation (3) and are then representative of the relationship between the $\frac{1000}{T}$ values in Kelvin^{-1} and the log of continuous conductivity in Figure (10). There was an inverse proportion between them.[17] This figure also illustrates the direct proportion to X-ray photon doses, demonstrating that irradiation increases DC conductivity.

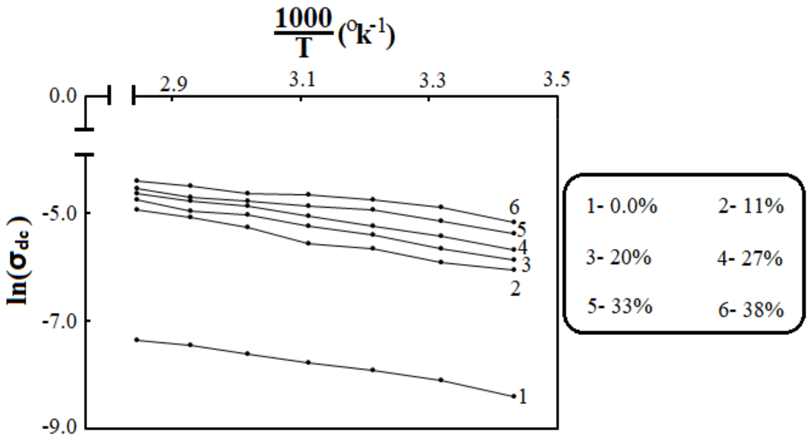

Fig. 10 Temperature dependence of σ_{dc} for pure CMCHV/ZnONPs thin film samples at different concentration of ZnONPs.

The dependence of the activation energy of CMC HV thin films on ZnO NP concentration and NaCl concentration was calculated using equation (4) and illustrates in figure (11). The activation energy decreased with increasing additives concentration. [21] In the figure, we notice that the samples to which ZnONPs is added have a higher activation energy than the samples to which NaCl is added, indicating that the conductivity of the samples to which NaCl is added is higher than the of which ZnONPs is added.[22]

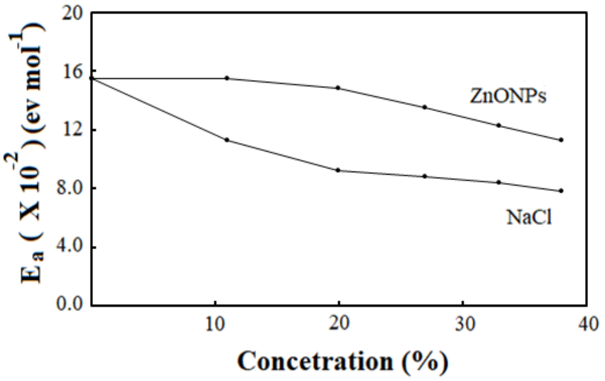

Fig. 11 Dependence of activation energy of CMCHV/ NaCl and CMCHV/ ZnONPs at different concentrations

From the results obtained from the samples to which sodium chloride and zinc oxide nanoparticles were added, it can be seen that the current density and conductivity of the samples increase with increasing concentrations of the two additives, as well as with the temperature increase. It is important to note that the current density and conductivity of the samples increased more by adding NaCl than by adding ZnO PNs

Note: For all figures (**.**) Point represent the experimental measurements. (-) while straight lines represent fitting with linear relation.

4. CONCLUSION

The measurement results of all samples studied in this research indicate that the conductivity and current density increase with an increase in the X-ray photon doses in the irradiated samples or with an increase in the concentrations of NaCl, ZnONPs and also increases with increasing temperature.

The conductivity increases from (0.042667 Ω^{-1}) for the non-irradiated sample to (0.367619 Ω^{-1}) for the sample irradiated with the highest dose (800cGy), while the current density increases from (64 A m^{-2}) for the non-irradiated sample to (8647 Am^{-2}) for the sample irradiated with the highest dose (800cGy), As for the samples to which sodium chloride was added, the conductivity increases from (0.0001Ω^{-1}) for the pure sample to(1.087143 Ω^{-1}) for the sample with a higher concentration of NaCl (38%), while the current density increases from (0.15 Am^{-2}) for the pure sample to (13254 Am^{-2}) for the sample with the highest concentration of NaCl (38%).Finally, by adding ZnO PNs to the samples, the conductivity increases from (0.0001Ω^{-1}) for the pure sample to (0.006614 Ω^{-1}) for the sample with a higher concentration of ZnONPs (38%), but the current density increases by (0.15 Am^{-2}) for the pure sample to (138.9 Am^{-2}) for the sample containing the higher concentration of ZnONPs (38%). However, the conductivity and current density increase more when NaCl is added than when ZnONPs are added.

By using these results, several areas can benefit, such as industry, scientific research, etc.

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