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INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 6, Issue, 04, pp.6225-6227, April, 2014

ISSN: 0975-833X

RESEARCH ARTICLE

ELECTRICAL PROPERTIES OF POLYVINYL ALCOHOL (PVA) FILMS DOPED WITH $CoCl_2$ SALT

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ARTICLE INFO

Article History:
Received 26th January, 2013
Received in revised form
24th February, 2014
Accepted 10th March, 2014
Published online 23rd April, 2014

Key words:
Polyvinyl alcohol films,
Casting method,
Electrical properties,
$CoCl_2$ doping effect.

ABSTRACT

The electrical characteristics of polyvinyl alcohol (PVA) films doped with different concentrations (0, 1, 3, 5, 7 and 10 wt %) of $CoCl_2$ salt powder were studied. The volumetric electrical conductivity σ_v for (PVA-$CoCl_2$) films as a function of the concentration of $CoCl_2$ salt at room temperature and the relationship of volumetric electrical conductivity σ_v for (PVA-$CoCl_2$) films of different concentrations of $CoCl_2$ salt with the temperature are calculated. The activation energy for (PVA-$CoCl_2$) films of different concentrations of $CoCl_2$ salt was calculated also and it is found that it decreases with increasing $CoCl_2$ salt content. It is found that there are two transport mechanisms, giving rise to two activation energies (Ea_1) and (Ea_2). At higher temperatures range (343 – 373) K, the conduction mechanism is due to carriers excited into the extended states beyond the mobility edge and at lower temperatures range (303 – 333) K, the conduction mechanism is due to carriers excited into the localized states at the edge of the band.

INTRODUCTION

Conductive polymers are organic compounds that conduct electricity. Such compounds may be true metallic conductors or semiconductors. It is generally accepted that metals conduct electricity well and that organic compounds are insulating, but this class of materials combines the properties of both. The biggest advantage of conductive polymers is their processability. Conductive polymers are also plastics (which are organic polymers) and therefore can combine the mechanical properties (flexibility, toughness, malleability, elasticity, etc.) of plastics with high electrical conductivities. Their properties can be fine- tuned using the exquisite methods of organic synthesis (Herbert, 2002). Different additives are usually added to polymer in order to modify and improve its properties. Inorganic additives such as transition metal salts have considerable effect on the optical and electrical properties of PVA (polyvinyl alcohol) polymer (Mohamed and Gadou, 2000; Abdul-Aziz, 2011). A polyvinyl polymer, namely polyvinyl alcohol (PVA) has several interesting physical properties, which are very useful in material science and technical applications. (PVA), as semi crystalline water soluble material exhibits certain physical properties resulting from crystal-amorphous interfacial effects (Vijaya and Chandramani, 2008). (PVA) is a polymer with carbon chain backbone with hydroxyl groups attached to methane carbons. These OH- groups can be a source of hydrogen bonding and hence assist in the formation of polymer (Balaji et al., 2007).

EXPERIMENTAL

The raw materials used in this work were as a powder of commercial polyvinyl alcohol (PVA) doped by Cobalt chloride ($CoCl_2$) salt with weight percentages (0, 1, 3, 5, 7 and 10 wt %). The films were prepared using the conventional casting method by dissolving the powders with the appropriate percentages in distilled water. The powders were completely dissolved by using magnetic stirrer for about 1hour and then placed in Petri dish (5 cm diameter). The thickness of the dried samples was found to be ~ 0.045 cm by measured by digital micrometer. The method of the three-electrode cell (the method of Teflon-isolated circular electrodes) was used according to ASTM D66-257 recommendations to study the effect of additives and temperature on the volumetric conductivity of polymeric systems. The input electrical power was regulated by using a (D.C.) power supply of Phillips Harris Limited type having a voltage of (3-7) kV, the highest voltage used in this study was (1000) V. The current was measured by a Digital Solid State Electrometer (616) with sensitivity of (10^{-15}) and full gradation. The temperature was changed in the range of (303-373) K by using an electrical oven of Yamato (DP61) type.

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RESULTS AND DISCUSSION

Figure (1) shows the volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films as a function of the concentration of $CoCl_2$ salt at room temperature. The increase in electrical conductivity with increasing concentration of $CoCl_2$ salt is due to the increase in the charge carrier ions which increase with increasing filler content (Zihlif and Ragosta, 2003; Srivastava and Mehra, 2003).

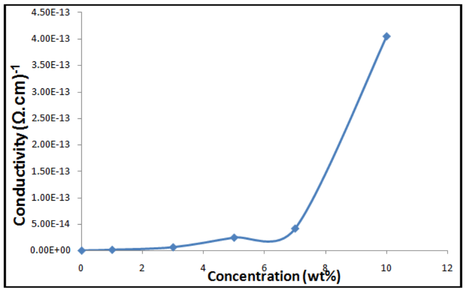


Figure 1. The volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films as a function of the concentration of $CoCl_2$ salt at room temperature

Table (1) shows the values of volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films with concentration of $CoCl_2$ salt at room temperature.

Table 1. The values of volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films with concentration of $CoCl_2$ salt at room temperature

($CoCl_2$) wt %	σ_v $(\Omega.\ cm)^{-1}$
Pure (PVA)	1.47E-16
1	1.61E-15
3	6.41E-15
5	2.46E-14
7	2.47E-14
10	4.05E-13

The volumetric electrical conductivity is calculated using the equation below (Ahmed et al., 2007).

$$\sigma = \sigma_O \exp(-E_{act}/k_B T)$$

Where (σ) is electrical conductivity at temperature (T), (σ_o) is electrical conductivity at absolute zero temperature, (k_B) is Boltzmann constant and (E_{act}) is activation energy. Figure (2) shows the volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films of different concentrations of $CoCl_2$ salt as a function of temperature.

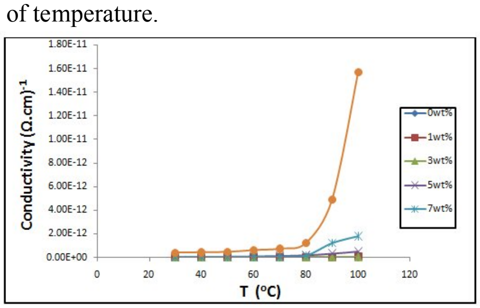


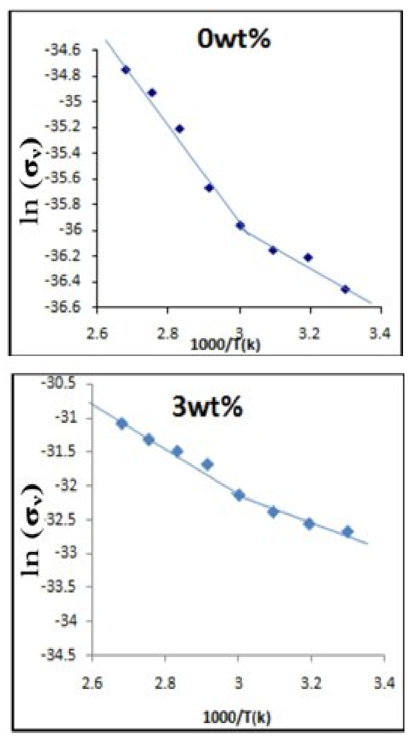
Figure 2. The volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films of different concentrations of $CoCl_2$ salt as a function of temperature

It is clear that the electrical conductivity increases with increasing the temperature. The increase in electrical conductivity with the temperature is attributed to two main parameters, charge carriers and mobility of these charges (Gabur, 2010; Al-Ramadhan, 2008; Majdi and Fadhal, 1997). Table (2) shows the values of the volumetric electrical conductivity σ_v of ($PVA-CoCl_2$) films at different concentrations of $CoCl_2$ salt with the temperature.

Table 2. The values of volumetric electrical conductivity σ_v for ($PVA-CoCl_2$) films of different concentrations of $CoCl_2$ salt with the temperature

T(ºC)	σ_v $(\Omega.cm)^{-1}$ for (PVA- $CoCl_2$)					
	Pure	1wt %	3wt %	5wt %	7wt %	10wt %
30	1.47E-16	1.61E-15	6.42E-15	2.46E-14	2.47E-14	4.05E-13
40	1.88E-16	1.92E-15	7.20E-15	3.44E-14	4.55E-14	4.31E-13
50	2.00E-16	2.70E-15	8.58E-15	4.52E-14	2.83E-13	4.58E-13
60	2.41E-16	3.28E-15	1.47E-14	7.13E-14	3.32E-13	5.30E-12
70	3.23E-16	3.64E-15	1.73E-14	4.37E-13	3.78E-13	9.26E-12
80	5.12E-16	4.51E-15	2.10E-14	4.81E-13	4.20E-13	3.73E-11
90	6.80E-16	5.28E-15	2.50E-14	5.54E-13	5.06E-13	3.90E-11
100	8.13E-16	7.77E-15	3.16E-14	5.05E-13	6.26E-13	4.37E-11

Figure (3) shows the relation between (ln $\boldsymbol{\sigma_v}$) and the inverse of absolute temperature for ($PVA-CoCl_2$) films at different concentrations of $CoCl_2$ salt. It is clear from this figure that there are two transport mechanisms, giving rise to two activation energies (Ea_1) and (Ea_2). At higher temperatures range (343 – 373) K, the conduction mechanism is due to carriers excited into the extended states beyond the mobility edge and at lower temperatures range (303 – 333) K, the conduction mechanism is due to carriers excited into the localized states at the edge of the band (Al-Ramadhan, 2008). It is also noted that the activation energy decreases with increasing $CoCl_2$ salt content as a result of the increase of local centers (Gabur, 2010; Ahmed and Zihilif, 1992).



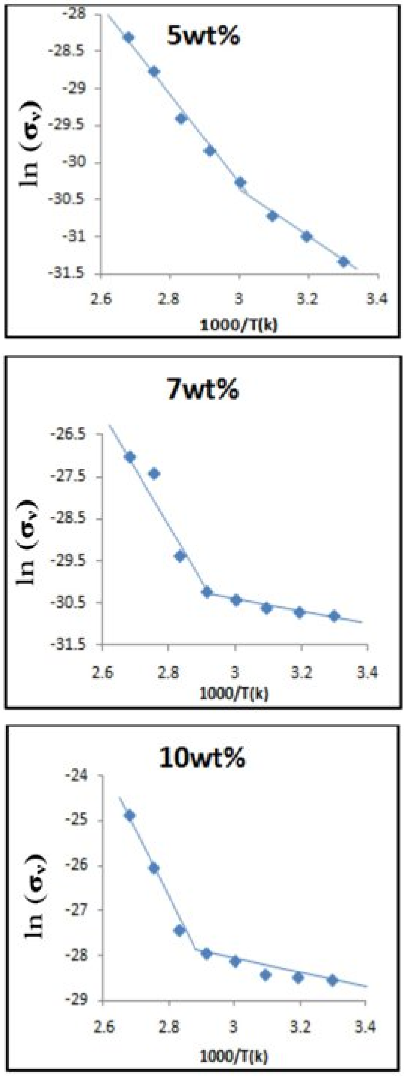


Figure 3. The relation between ($ln\sigma_v$) and the inverse of absolute temperature for (PVA-$CoCl_2$) films at different concentrations of $CoCl_2$ salt

Table 3. The values of activation energies in (eV) for (PVA-$CoCl_2$) films at different concentrations of $CoCl_2$ salt

($CoCl_2$) Wt %	(303 – 333)K	(343 –373)K
	E_{a1} (eV)	E_{a2} (eV)
Pure (PVA)	0.51	1.33
1	0.17	0.38
3	0.12	0.35
5	0.10	0.28
7	0.09	0.188
10	0.05	0.182

CONCLUSIONS

Based on the experimental results the following conclusions can be drawn:

- The D.C. electrical conductivity for (PVA-$CoCl_2$) films increases with increasing of temperature and filler content (wt %).
- From the results, it is concluded that there are two transport mechanisms, giving rise to two activation energies. At higher temperatures range (343 – 373) K, the conduction mechanism is due to carriers excited into the extended states beyond the mobility edge and at lower temperatures range (303 – 333) K, the conduction mechanism is due to carriers excited into the localized states at the edge of the band.
- The activation energy for (PVA-$CoCl_2$) films decreases with increasing the filler content percentages.

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