

A Study of FTIR and Some Mechanical Properties of Sodium Iodide (NaI) Salt Filled Polymer Polyvinyl Alcohol (PVA) Films

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Abstract. The effect of Sodium Iodide (NaI) salt on mechanical properties of polyvinyl alcohol (PVA) was studied in this work. The interaction between (NaI) salt and polymer (PVA) was investigated by (FTIR) spectroscopy. The effect of (NaI) salt on the mechanical properties of the polymer (PVA) was studied by hardness and tensile tests. FTIR spectra analysis of pure and (NaI) filled (PVA) films showed that the vibrational modes have changed due to the effect of filler salt in the polymer (PVA). Hardness test showed that the hardness increases unsystematically with increasing the weight ratio of added sodium iodide salt except the weight ratio of (16 wt %) compared with pure (PVA) film, while the experimental results of the tensile test for (PVA-NaI) composite films showed unsystematic change of tensile strength, elongation at break and Young's modulus after filling with different weight ratios of (NaI) salt compared with pure (PVA) film.

Introduction

Polyvinyl alcohol (PVA) has wide applications because of its high dielectric strength, high elasticity, high tensile strength, flexibility, hydrophilic characteristics and its ability to form good films via solution casting [1, 2]. (PVA) is a water soluble synthetic polymer and due to its characteristics of easy preparation, good biodegradability, excellent chemical resistance and good mechanical properties, the polymer (PVA) has been used in many biomaterial applications [3]. (PVA) has a carbon chain backbone with hydroxyl groups that can act as a source of hydrogen bonding to enhance the formation of polymer complexes [1]. The hydroxyl group of (PVA) can also interact with the inorganic compounds. Recently, several types of inorganic metal salts were used as fillers into (PVA) films and a strong effect of these metal salts on the mechanical properties of (PVA) was observed [4]. A significant improvement in mechanical, thermal, optical, electrical, and other properties of polymers can be achieved by adding different inorganic fillers [5]. The fillers are widely used in the plastics industry to cheaply achieve the same levels of performance that would otherwise require much more expensive engineering plastics; also they facilitate surface bonding because the surface of the filler can be easily wetted by a polymer [6].

The study of mechanical properties of polymer matrix composite materials is very important because these properties determine the behavior of the materials under the influence of stress and the influence of various external conditions such as pressure, temperature, time of stress, speed of stress, nature of chemical solvents, and other factors. The study of the mechanical properties is a very complex matter due to the multiple variables affecting each property. Knowing each property would help in selecting the suitable material for a specific practical [7]. Analysis of polymers is one of the most important application fields for (IR) spectroscopy. This type of spectroscopy can be used for the determination of chemical structures, chain conformation, orientation and crystallinity, identification of complex polymeric systems and monitoring reaction processes [8]. In the present work, polymer composite films (PVA-NaI) were synthesized by using solution casting method. The (IR) spectral characterization of composites was carried out by conventional techniques; and some mechanical properties were investigated and compared with the pure (PVA) film.

Materials and Methods

The polymer (PVA) powder (M.W. = 14000 g/mol) supplied by (Central Drug House Ltd. New Delhi - INDIA) and (NaI) salt (M.W. = 149.89 g/mol) supplied by (Modex - Germany) were used to prepare (PVA) films with different weight percentages of (NaI) salt (0 %, 4 %, 8 %, 12 %, and 16 %). The composite films were prepared by dissolving (PVA) powder and (NaI) salt in (15 ml) of distilled water and using magnetic stirrer to mix the solution for (2 hour) at (80 °C) to obtain homogeneous solution. The solution then was casted in a glass plate and left to dry to produce film samples.

Characterization

(a) Fourier transform infrared (FTIR):

The infrared spectra of pure and (NaI) filled (PVA) films were measured by using (IR Affinity-1 spectrophotometer) in the range of (400-4000 cm^{-1}).

(b) Hardness Test

The hardness of pure and (NaI) filled (PVA) films were tested by using (Shore D) device type (Check-line-dd-100).

(c) Tensile Test

The tensile strength, elongation at break and Young's modulus of pure and (NaI) filled (PVA) films were tested by using (Tinius Olsen- H10K) with crosshead speed of (10 mm/min). Rectangular shaped sample of (120 mm \times 4 mm) were taken for the determination of tensile properties.

Results and Discussion

Fourier Transform Infrared (FTIR)

The Fourier transform spectra of infrared radiation for pure (PVA) films and (PVA) films filled with different weight ratios of (NaI) salt were studied by recording the transmittance as a function of wavenumber within the range of (400-4000) cm^{-1} as shown in Fig. 1. Table 1 summarizes some stretching and bending vibration bands of (PVA) (OH, C-H, C = O, C = C, CH₂). From the figure, it can be observed that there is no absorption band for the hydroxyl group (-OH) at the wavenumber (3600 cm^{-1}) of (PVA); this suggests that the hydroxyl groups of the (PVA) chains are associated with the intermolecular or intramolecular hydrogen bonding. It can be noticed also the appearance of absorption band that belongs to the hydroxyl group (-OH) of pure (PVA) film within the wavenumber range of (3201-3496) cm^{-1} . Table 1 shows that the hydroxyl group (-OH) of (PVA) is significantly affected by (NaI) salt filler compared to other bonds, where it is found that the band shifts to higher wavenumbers after the filling by (NaI) salt and this result is in agreement with other reports [9,10]. The reason for this change in the absorption frequency value of the hydroxyl group (-OH) is due to the complexes formation between the polymer (PVA) and the added (NaI) salt. Fig. 1 shows also the appearance of a band at the wavenumber (2939 cm^{-1}) which is related to the asymmetric stretching bond (C-H) of pure (PVA) film. The wavenumber of this band is shifted to higher values as the weight ratio of (NaI) increases to reach its maximum value at the wavenumber (2945 cm^{-1}) at the weight ratio of (8 wt%). It can be also noticed the appearance of two bands at the wavenumbers (1710 cm^{-1}) and (1658 cm^{-1}) which are attributed to the stretching vibration of (C = O) and (C = C) bands respectively which are originated from remaining acetate groups of the polymer (PVA) formation process. When (PVA) is filled with (NaI) salt, the wavenumber value of (C = O) band is shifted to higher values, while the value of the wavenumber of (C = C) band is shifted to lower values; this means that the (NaI) salt reacts with the acetate groups of vinyl acetate units of (PVA). Moreover, it can be noticed also the appearance of band at the wavenumber (1419 cm^{-1}) related to the bending vibration band of (-CH₂) and a band at the wavenumber (1332 cm^{-1}) assigned to the wagging vibration band of (-CH₂) of the pure (PVA) film.

These two bands were also affected (change their wavenumber) by the process of filling by (NaI) salt [9, 10].

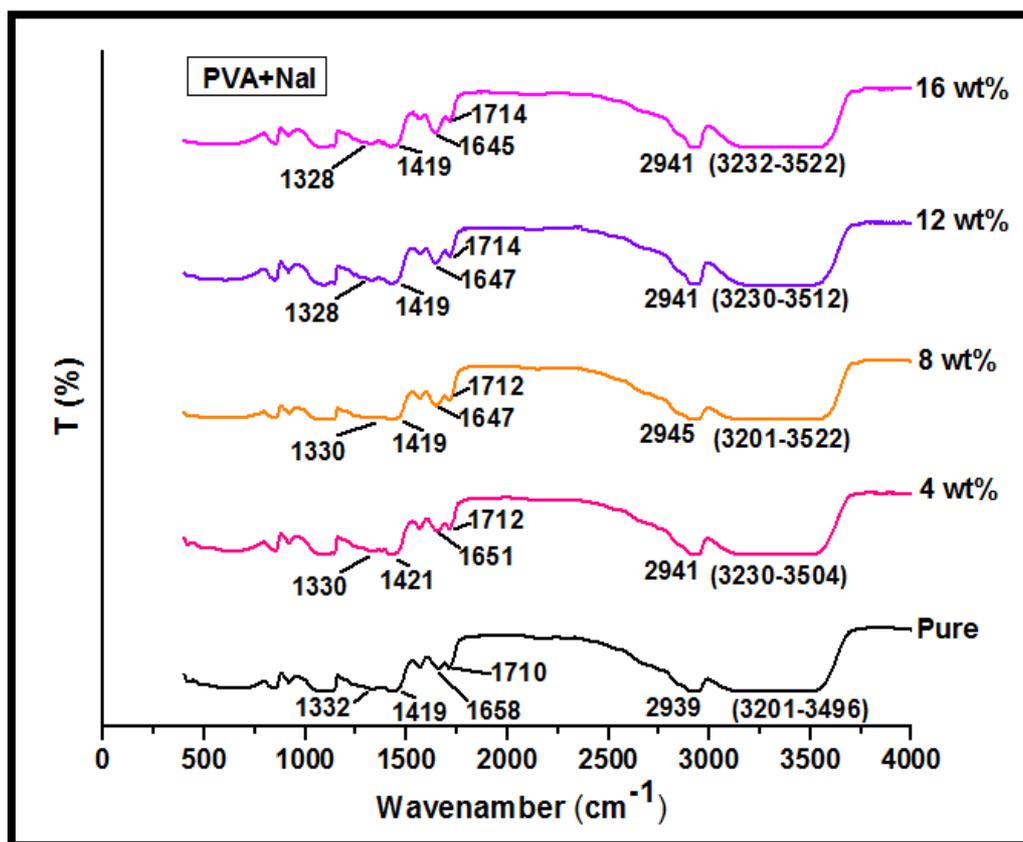


Figure 1. FTIR transmittance spectra of (PVA-NaI) composite films at different weight ratios of (NaI) salt.

Table 1. The values of the wavenumbers of the absorption bands of (PVA-NaI) composite films at different weight ratios of (NaI) salt.

Band	Wavenumbers (cm) ⁻¹				
	(NaI) weight ratio (wt %)				
	Pure (PVA)	4 wt %	8 wt %	12 wt %	16 wt %
O-H Stretching	(3201-3496)	(3230-3504)	(3201-3522)	(3230-3512)	(3232-3522)
C-H Asymmetric Stretching	2939	2941	2945	2941	2941
C=O Stretching	1710	1712	1712	1714	1714
Acetylene C=C Group	1658	1651	1647	1647	1645
Bending of CH ₂	1419	1421	1419	1419	1419
Wagging of CH ₂	1332	1330	1330	1328	1328

Hardness Test

The hardness test was followed the (Shore D) type of pure PVA film and PVA filler by (NaI) salt with different weight ratios (4,8,12,16) wt% as shown in figure (2), The hardness values of the pure PVA are increasing with the increase of the NaI salt, the hardness value began increases at the weight ratio (4wt%), and continues to increase to the weight ratio (12wt%), these results are due to

the bonding between PVA and (NaI) salt, which increases the density of the effective mechanical bond as well as increasing the packing and interlocking, which reduces the movement of the base material molecules, thus increase the resistance to scratching and cutting [11], i.e the addition of salt (NaI) led to a lack of flexibility and increase in the surface resistance to penetration, When attaching at the weight ratio (16wt%) the hardness value decreases significantly, the decrease in the hardness due to the high viscosity gained by the prepared composite material when adding the high weight ratios of the filler materials (NaI) salt inside the (PVA) polymer when it is in a liquid state and that caused the difficulty penetration of sodium salts into the Interfaces distances of polymer (PVA) in the prepared composite material which is due creating many gaps within the prepared composite material at hardened, which was caused a decrease in the value of hardness [7]. Table 2 shows the hardness values of (PVA-NaI) composites films.

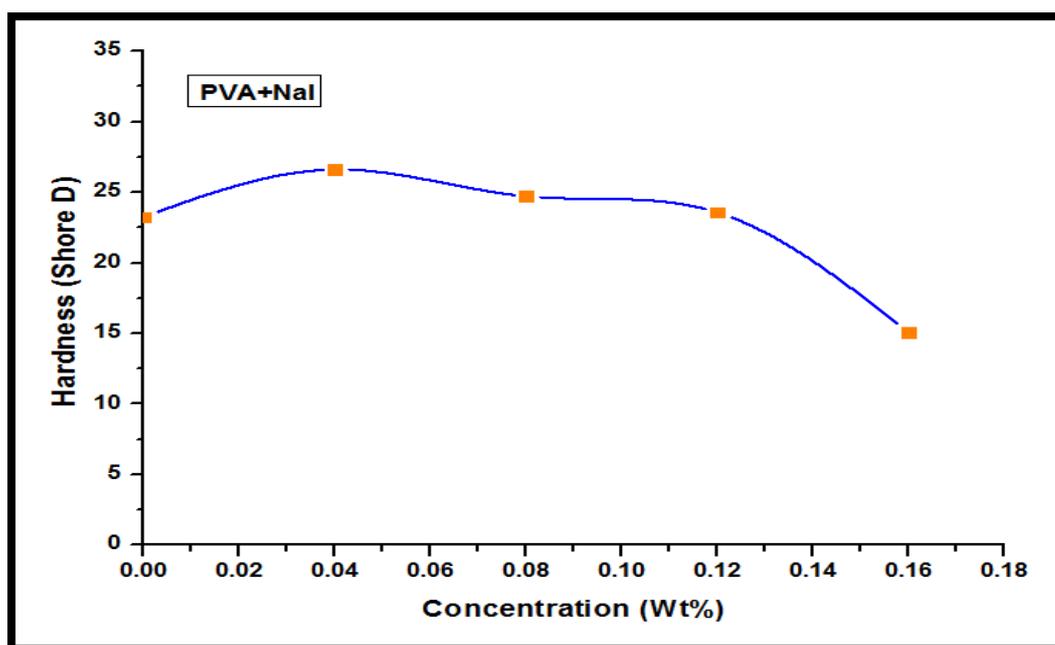


Figure 2. The hardness of (PVA-NaI) composite films as a function of weight ratio of (NaI) salt.

Table 2. The hardness values of (PVA-NaI) composite films at different weight ratios of (NaI) salt.

Concentration (wt%)	(PVA-NaI)
Pure (PVA)	23.25
4	26.525
8	24.725
12	23.575
16	15.075

Tensile Test

The stress-strain curve of pure (PVA) film is shown in Fig. 3 where the plastic deformation region which is expressed by the linear relationship between stress and strain is very clear, and from this region the coefficient of elasticity (Young's modulus) which represents the slope of the straight line was calculated. It is clear that, after filling the pure (PVA) film with (NaI) salt, the stress-strain curve changes and we obtain curves with different characteristics depending on the weight ratio of the added filling material as shown in Fig. 4. Table 3 shows the values of tensile strength (T.S.), elongation at break (E_b) and Young's modulus (Y_m) of (PVA-NaI) composite films which are determined by the stress-strain curves. From Table 3, we can notice that the value of the tensile

strength of pure (PVA) film is (71.1 MPa), the elongation at break value is (170 %) and the value of the Young's modulus is (2200 MPa), whereas after filling (PVA) by (NaI) salt, these values change, where we observe that the behavior of the tensile strength, Young's modulus and elongation at break are unsystematic with respect to the weight ratio of the added (NaI) salt [12]. The maximum value of tensile strength and Young's modulus are (99.6 MPa) and (2830 MPa) respectively, at the weight ratio of (12 wt %) as shown in Figs. 5 and 7 respectively; and the highest value of elongation at break is (280 %) at the weight ratio of (16 wt %) as shown in Fig. 6. The decrease in tensile properties values such as tensile strength, Young's modulus and elongation at break of (PVA-NaI) composite films (at the some weight ratios of NaI salt) compared with pure (PVA) film can be attributed to the weak interaction between molecules, and low interface adhesion between the composite components due to reduce in the tensile properties and fragility of the composite films [2].

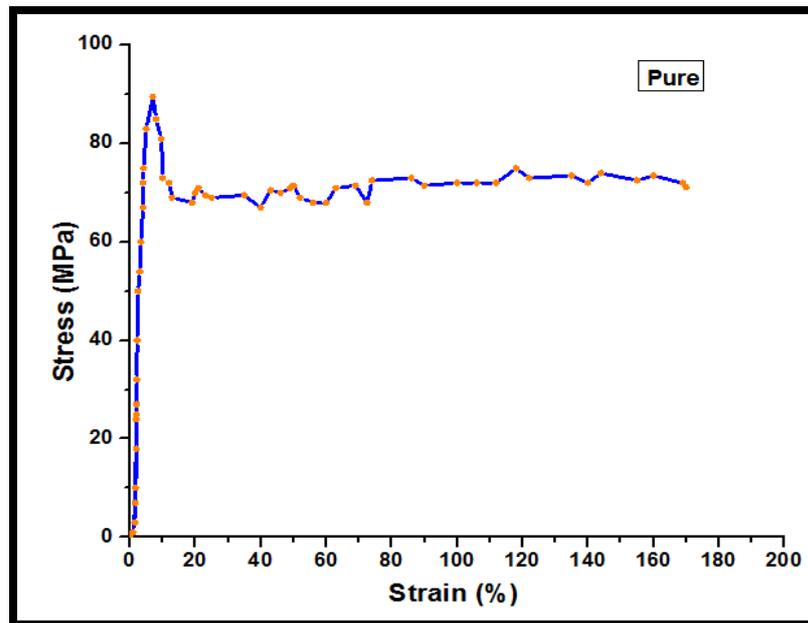


Figure 3. Stress-strain curve of pure (PVA) film.

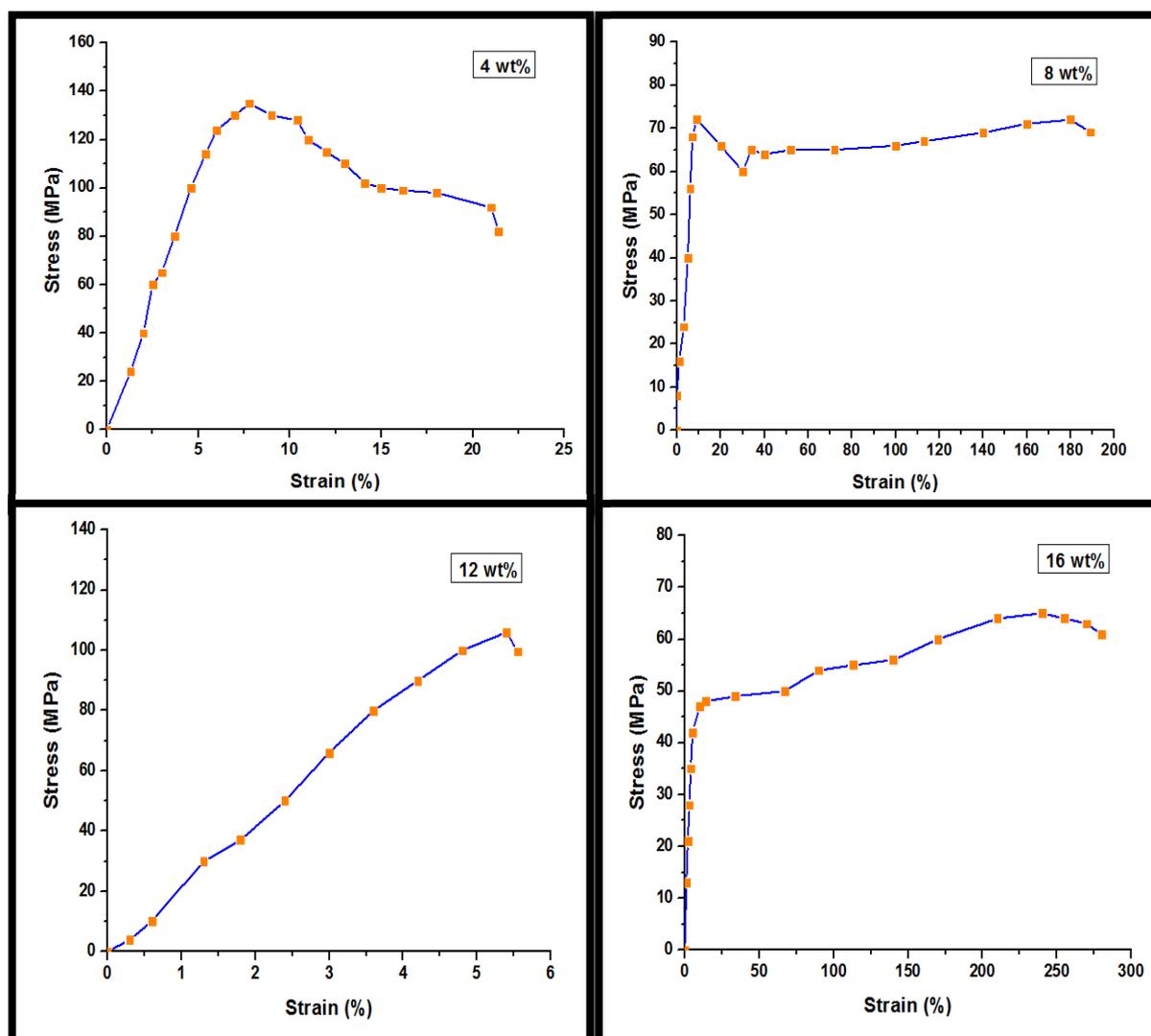


Figure 4. Stress-strain curves of (PVA-NaI) composite films at different weight ratios of (NaI) salt.

Table 3. The tensile properties values of (PVA-NaI) composite films at different weight ratios of (NaI) salt.

Concentration (wt%)	Tensile Strength (T.S) (MPa)	Elongation at Break (E_b) (%)	Young's Modulus (Y_m) (MPa)
0	71.1	170	2200
4	86.3	21.3	2500
8	69.1	189	2010
12	99.6	5.55	2830
16	60.9	280	1110

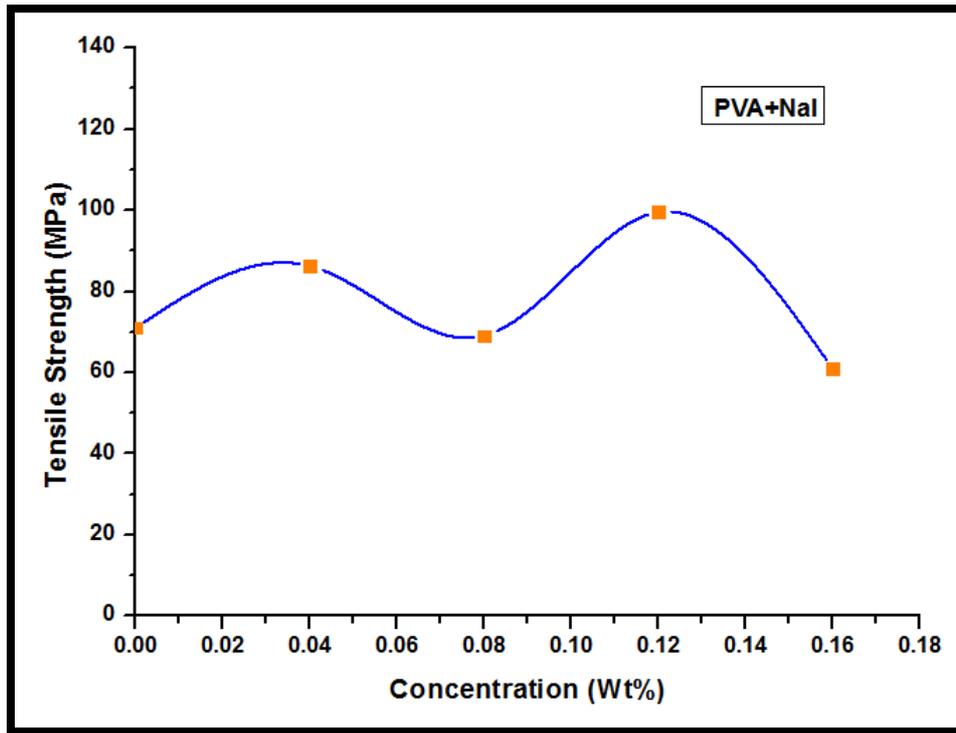


Figure 5. The tensile strength of (PVA-NaI) composite films as a function of weight ratio of (NaI) salt.

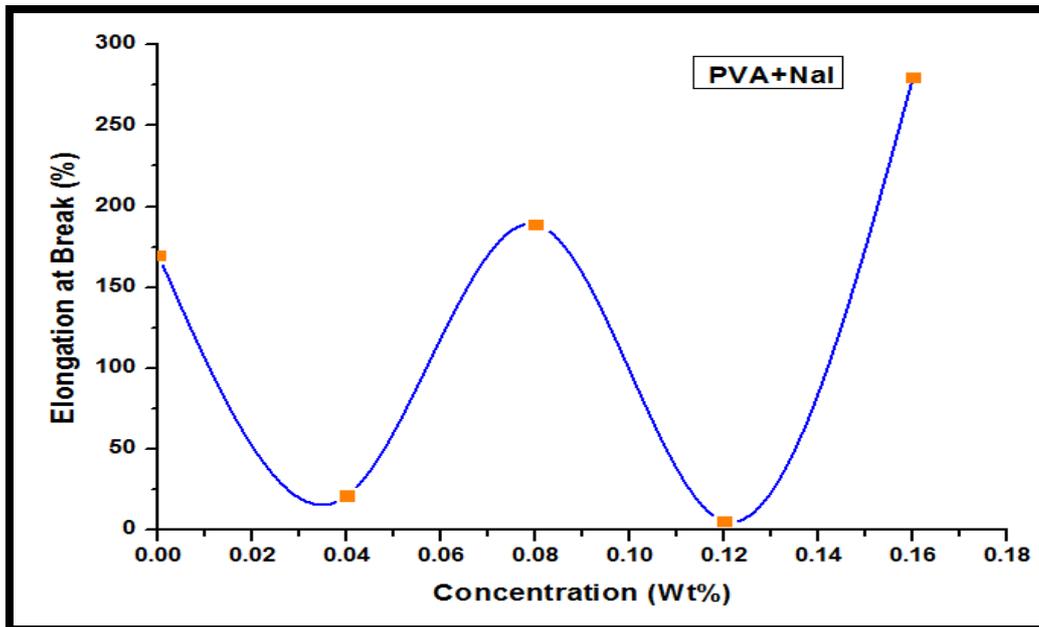


Figure 6. The elongation at break of (PVA-NaI) composite films as a function of weight ratio of (NaI) salt.

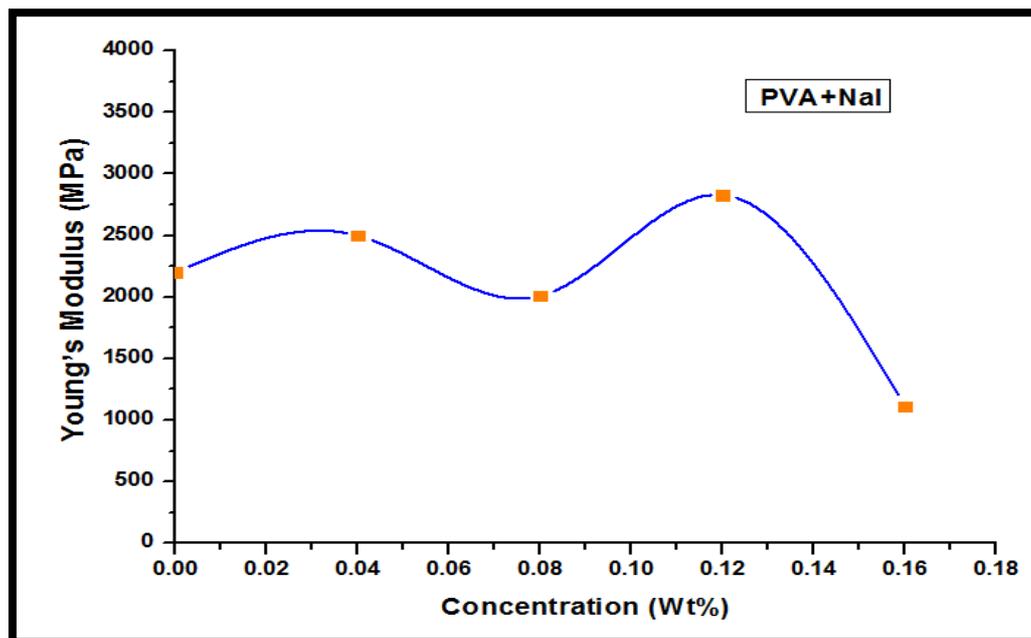


Figure 7. Young's modulus of (PVA-NaI) composite films as a function of weight ratio of (NaI) salt.

Conclusions

At the end of this study, the following points are concluded:

- (NaI) salt could form interactions with (PVA) chains via hydrogen bonding between the ions and the hydroxyl group.
- Significant improvement in some values of hardness, tensile strength, elongation at break and Young's modulus was observed for (PVA-NaI) composite films.
- The value of hardness increases to its highest value at the weight ratio of (4 wt %).
- The results of tensile test show unsystematic change with respect to the weight ratio of the added (NaI) salt.

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