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Preparation and Study of Some Mechanical Properties of Polymeric Blend Films [PVA: PVP-$CaCl_2.2H_2O$]

Rafid M. A. Rustam, Sabah A. Salman and Rana S. Mahmood

Department of Physics – College of Science – University of Diyala

rafidmahmood26@gmail.com

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Abstract

In the present paper, pure polymeric blend films [PVA: PVP] reinforced by $CaCl_2.2H_2O$ salt have been produced with different weight ratios (10, 20, 30, 40, 50 wt %) by using the solution casting method, where the mechanical properties such as tensile, hardness, and impact were studied. The effects of weight ratio of salt on tensile characteristics of reinforced polymeric blend films have been studied, where we note the increase in the values of the tensile characteristics that are represented by Yung modulus and the maximum tensile strength (at all weight ratios) of the reinforcement by $CaCl_2.2H_2O$ salt in comparison with pure polymeric blend films [PVA: PVP] reinforced by $CaCl_2.2H_2O$ salt. The impact of salt weight ratio on hardness (Shore D) of polymeric blend films was studied, and the experimental results showed that the hardness increased with an increase in salt weight ratio, as well as the effect of salt weight ratio on the impact represented by fracture energy and impact strength of the reinforced polymeric blend films, where it was found that the values of the fracture energy and impact strength increased with an increase of the salt weight ratio.

Keywords: polymeric blend [PVA: PVP], CaCl2.2H2O salt, Hardness (Shore D), Impact Strength, Fracture Energy.

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تحضير ودراسة بعض الخصائص الميكانيكية لأغشية الخلائط البوليمرية [PVA: PVP-$CaCl_2.2H_2O$]

رافد محمود عبد الله رستم، صباح أنور سلمان ورنا سعد محمود

جامعة ديالى – كلية العلوم – قسم الفيزياء

الخلاصة

تم في هذه الدراسة تحضير اغشية الخلائط البوليمرية [PVA:PVP] النقية والمدعمــة بملح $CaCl_2.2H_2O$ بنسب وزنية مختلفة(10,20,30,40,50)wt%) باستخدام طريقة صب المحلول. حيث تمت دراسة الخصائص الميكانيكة (الشد والصلادة والصدمة)، وتم دراسة تأثير النسبة الوزنية للملح على خصائص الشد لأغشية الخلائط البوليمرية المدعمة، حيث نلاحظ الزيادة في قيم خصائص الشد المتمثلة بمعامل يونك و متانة الشد القصوى (عند كل النسب الوزنية) للـتدعيم بـملح $CaCl_2.2H_2O$ بـالمقارنة مع غشاء الخليط البوليـــمري [PVA:PVP] النقي. وتم دراسة تأثير النسبة الوزنية للملح على الصلادة (Shore D) لأغشية الخلائط البوليمرية المدعمة، وأظهرت النتائج العملية بأن الصلادة تزداد مع زيادة النسبة الوزنية للملح المضاف. وتم دراسة تأثير النسبة الوزنية للملح على الصدمة المتمثلة بطاقة الكسر ومتانة الصدمة لأغشية الخلائط البوليمرية المدعمة، حيث وجد ان قيمة طاقة الكسر وقيمة متانة الصدمة تزدادان بزيادة النسبة الوزنية للملح المضاف.

الكلمات المفتاحية: الخليط البوليمري[PVA:PVP] ، ملح CaCl2.2H2O ، الصلادة ، طاقة الكسر، متانة الصدمة.

Introduction

The history of polymers is linked to human development, as they were used in the clothing industry and the manufacture of dyes and glues, and were later used in water prevention, as in the asphalt used in boating [1]. The beginnings of laboratory studies of polymers, it dates back to the beginning of the twentieth century, specifically to the studies of the scientist (Staudinger) (1920) who pioneered the study of long molecular chains involved in the structure of the polymer to be the cornerstone in building of the polymers science [2]. The topic of polymerization and polymers has received the attention of the scientific and industrial

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community, where many researchers have diagnosed polymers and the means to study their properties and manufacture them, which has led to their improvement and increase in use in various aspects of life. Polymers have entered into the production of most industrial materials, from toys, car structures, and aircraft [3]. The use of polymers has also emerged in the manufacture of solar cells and chemical cells, and a number of polymers have been classified as insulators [3], as they have been used in the field of electronic industries to produce useful materials such as electronic circuit boards, electrical insulation materials, electrical wire wrapping and electrical connections, which are uses that fit the insulating nature of most polymers. Polymers have become an alternative to many traditional building metals, due to the high temperatures and stress that a number of polymers are characterized by, while the use of reinforced polymers has emerged in prefabricated construction, good thermal and sound insulation, and resistance to weather conditions [3].

Materials

1-The basic material

A- Polyvinyl alcohol (PVA): It is in the form of grains of a white color and is quick to dissolve in distilled water. It is a product of the Indian company HIMEDIA, and its molecular weight average is (13000–23000) g/mol.

B- Polyvinyl pyrrolidone (PVP): It is in the form of a white, slightly yellowish powder that dissolves quickly in distilled water. It is a product of the Indian company HIMEDIA, and its molecular weight is about (40000 g/mol). Figure (1) shows the structural formula of the above polymers [4].

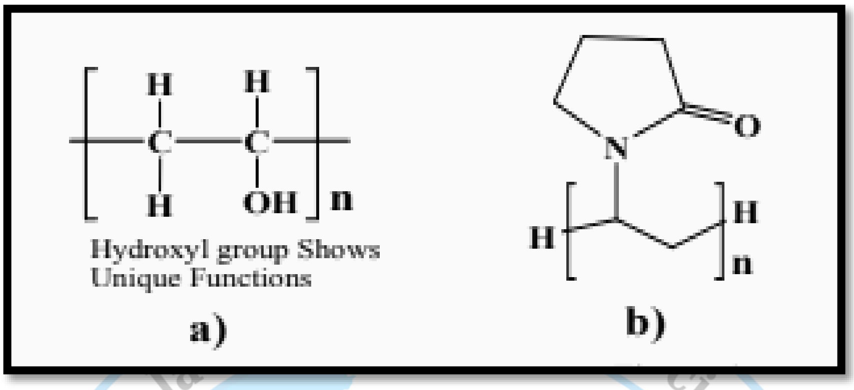

Figure 1: Structural Formula of Polymers [4]
(a) Polyvinyl alcohol polymer (PVA).
(b) Polyvinyl pyrrolidone polymer (PVP).

2 – The reinforcement material

A- Hydrated calcium chloride: It is white crystalline material, soluble in water at (30 ^oC), and has the chemical formula $CaCl_2.2H_2O$. The most prominent properties are its molar mass (110.98g/mol), its density (2.15g/cm3) and its melting point (772^{o}C).

Preparation of Composites

The [PVA: PVP] polymeric blend is prepared using the casting method, a certain weight ratio of PVA was mixed with a certain weight ratio of PVP, and distilled water was added to them at an amount of 15 ml by using a magnetic stirrer for 1 hour at a temperature of 60 ^oC for the purpose of obtaining a homogeneous solution. The solution is cast afterwards into special glass mold that is placed on flat surface and left the solvent evaporates and we get the required sample.

As for preparing a polymeric blend [PVA: PVP] reinforced by $CaCl_2.2H_2O$ salt using the casting method, Certain weight ratios of PVA polymer were mixed with certain weight ratios of PVP polymer and certain weight ratios of $CaCl_2.2H_2O$ salt (10,20,30,40,50 wt%), and then distilled water was added to them in an amount of (15 ml) using a magnetic stirrer for 1 hour at a temperature of (60°C) to obtain a homogeneous solution, after which the solutions are cast in special glass molds that are placed upon flat surface and left to the point where the solvent evaporates and required samples are obtained.

In order to conduct a tensile test of the pure polymeric blend film [PVA: PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt, a device of the type (Tinius Olsen-H10K) of English origin was used, In order to conduct the hardness test of the pure polymeric blend film [PVA:PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt, a Shore D device of the type (Check-line dd100) of American origin was used, In order to conduct the impact test of the pure polymeric blend film [PVA: PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt, an impact resistance tester was used for plastic films and paper clips (Filling Darte Impact Tester) type (FDI-01) of Canadian origin.

Results and discussion

Mechanical characteristics

Tensile Test

Tensile test has been carried out and (stress-strain) curves have been obtained for the pure polymeric blend film [PVA: PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt, with different weight ratios. Figure2 shows stress-strain curve of pure polymeric blend film [PVA:PVP], as we find that it consists of an elastic deformation region represented by linear correlation between the stress and the strain, and from this region, the elasticity modulus (also referred to as Young's modulus) has been estimated, which represents the slope of straight line, where the polymeric material suffers an elastic deformation within the limits of this region resulting from the tension and polymeric chains' elongation without breaking bonds, then this curve is deviated from the linear behavior because of the generation of cracks inside polymeric materials those cracks grow and aggregate with the increase of stress, forming larger cracks and continue growing with the applied stress to the point where the fracture happens in the sample [5]. In other cases, fracture starts at the outer surfaces at sites of deformations or defects like the scratches, notches, or internal cracks, acting as sites of stress concentration, leading to an increase in stress value to limits where internal bonding strength is exceeded, and thus the fracture occurs. When adding the reinforcement material ($CaCl_2.2H_2O$ salt) to the base material (polymeric blend [PVA: PVP]), the (strain-strain) curve changes and we get curves with various properties depending upon type of reinforcement added and its weight ratio, as can be seen from Figure (2).

Table 1 shows the values of young's modulus (Ym) and the ultimate tensile strength values of all polymeric blend films that have been determined from stress - strain curves. We note from the table that young's modulus value of the pure polymeric blend film [PVA: PVP] is (132 Mpa), but when reinforced with $CaCl_2.2H_2O$ salt with different weight ratios, value of Young's modulus is increased with increasing the weight ratio of added $CaCl_2.2H_2O$ salt until it reaches its maximal value of 3300MPa at weight ratio (40 wt%) of reinforcement, then the value of the Young's modulus is decreased with increasing weight ratio of added $CaCl_2.2H_2O$ salt.

The decrease in the value of young's modulus of the polymeric blend film [PVA: PVP] at the weight percentage (50 wt%) of the reinforcement with $CaCl_2.2H_2O$ salt is due to weak interaction between the molecules as well as the lack of the interfacial adhesion between composite's components, which leads to a reduction in the tensile properties (Young's modulus).

As well as the composite's brittleness [6], We also note from the table that the ultimate tensile strength value of pure polymeric blend film [PVA: PVP] is (7.88 Mpa), but when reinforced with $CaCl_2.2H_2O$ salt with different weight ratios, the value of ultimate tensile strength is increased with the increase of weight ratio of added $CaCl_2.2H_2O$ salt until it reaches the maximal value of (123Mpa) at weight ratio of (40 wt%) of reinforcement, then the value of the ultimate tensile strength is decreased with increasing weight ratio of added $CaCl_2.2H_2O$ salt.

The increase in the values of the tensile properties that are represented by Young's modulus and the ultimate tensile strength of all polymeric blend films (at all weight ratio values of the reinforcement with $CaCl_2.2H_2O$) compared to the pure polymeric blend film [PVA: PVP] indicates that the additive reinforcement material reacts physically with the polymeric blend [PVA: PVP] and the reinforcement material chain is dispersed in the polymeric blend [PVA: PVP] and the additive reinforcement material corresponds to the additive copolymerization[7], which effects the mechanical properties.

Figures (3) and (4) show the behavior of young's modulus and ultimate tensile strength as weight ratio function of $CaCl_2.2H_2O$ salt, respectively.

Table1: Young's modulus value and ultimate tensile strength of [PVA: PVP]- $CaCl_2$ composite films with weight Percentage of $CaCl_2.2H_2O$ salt.

Weight Percentage wt (%) of Salt	[PVA: PVP]-$CaCl_2$ Young's Modulus (Y_m) (Mpa)	[PVA: PVP]-$CaCl_2$ Ultmate Tensile Strength (U.T.S) (MPa)
Pure [PVA:PVP] Blend	132	7.88
10	1120	22.6
20	1270	27.4
30	2080	71.4
40	3300	123
50	837	21.4

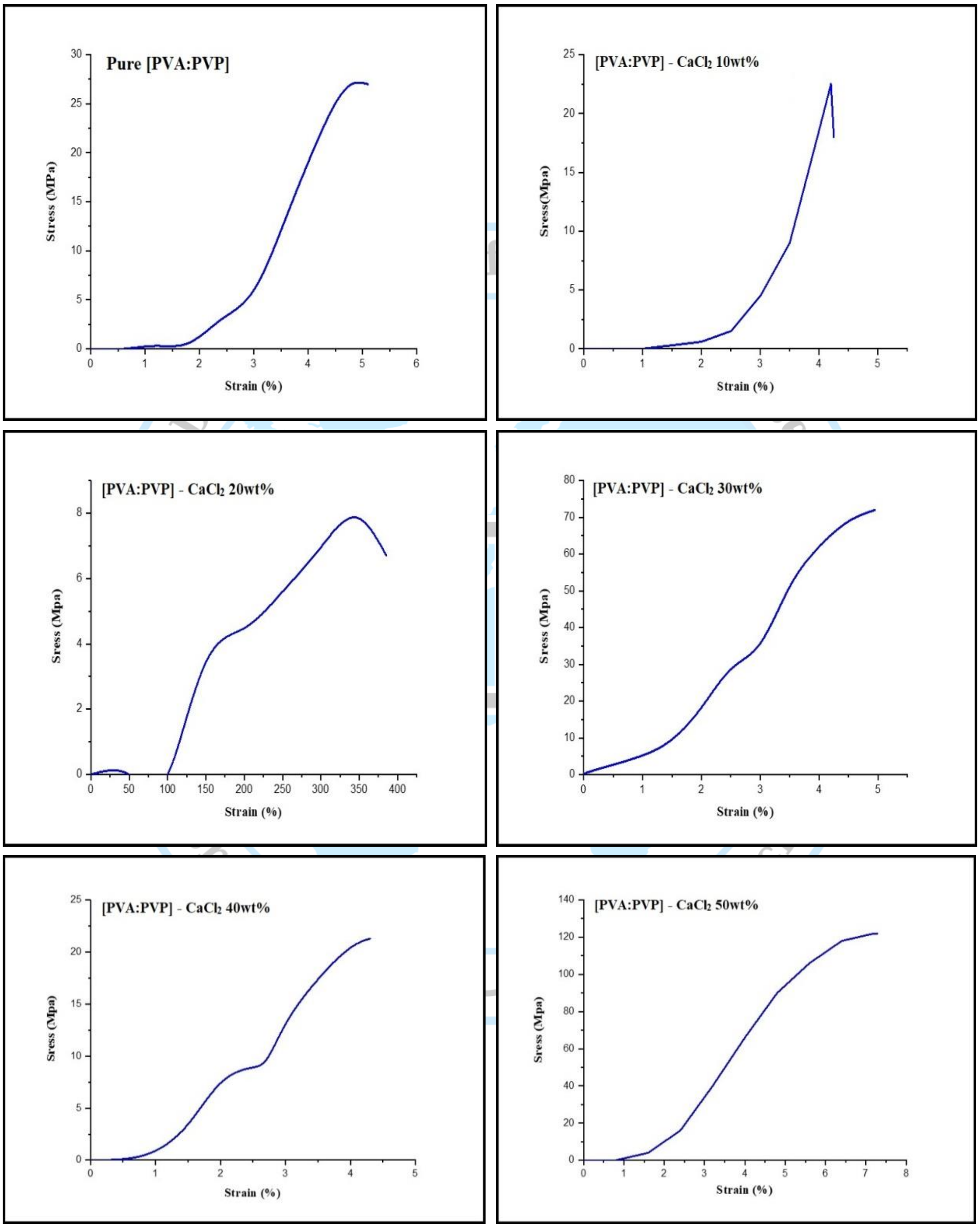

Figure 2: (stress-strain) curve of the [PVA: PVP]- $CaCl_2$ composite films with various weight ratios of $CaCl_2.2H_2O$ salt.

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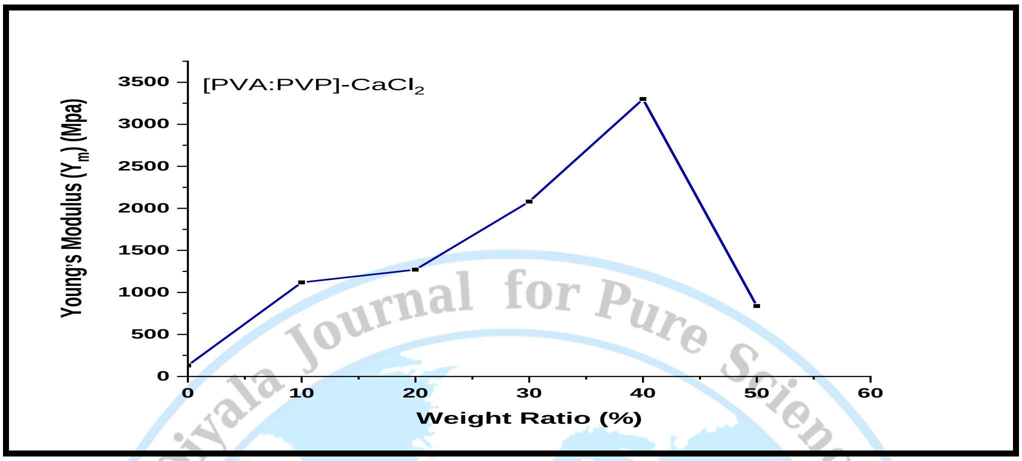

Figure 3: Young's modulus of the [PVA: PVP]- $CaCl_2$ composite films as function of the weight ratio of $CaCl_2.2H_2O$ salt.

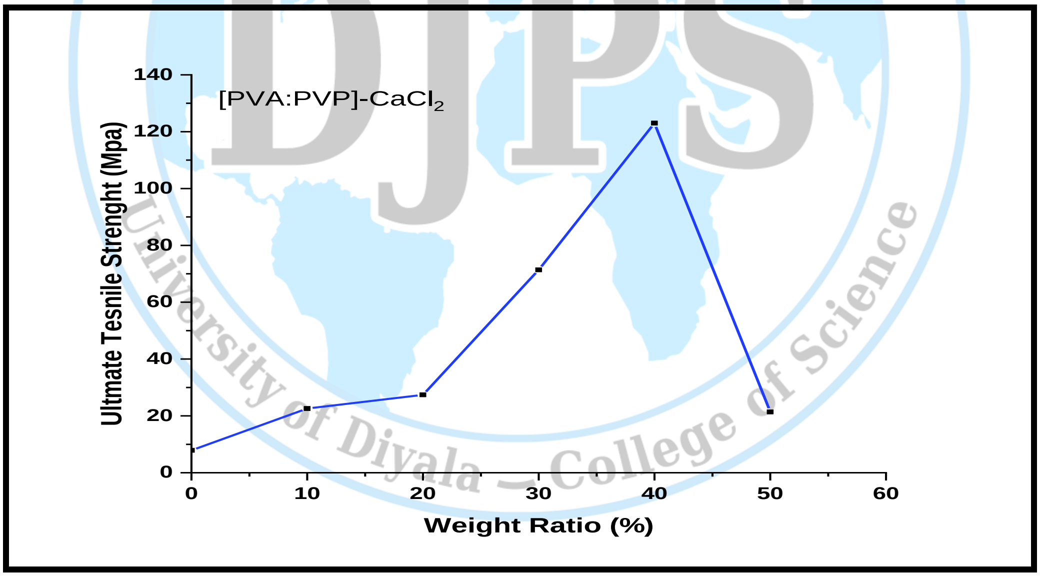

Figure 4: Ultimate Tensile Strength of the [PVA: PVP]- $CaCl_2$ composite films as function of the weight ratio of $CaCl_2.2H_2O$ salt.

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Hardness Test

The (Shore D) hardness test was carried out on the pure polymeric blend film [PVA: PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt with different weight ratios, as shown in Figure (5), from the figure, it is clear that the hardness of pure polymeric blend film [PVA: PVP] is (17), and after reinforced by $CaCl_2.2H_2O$ salt with different weight ratios, we notice that hardness is increased with the increase in weight ratio of $CaCl_2.2H_2O$ salt. From the concept of hardness, it can be considered as plastic deformation measure where a material can suffer under impact of the external stresses. Thus, the addition of reinforcing material to base material results in increasing the material hardness as a result of increasing its resistance to plastic deformation [8], as well as the penetration of the reinforcing material into the base material within the interspaces and vacancies results in an increase in contact area and therefore a link between the base material and the reinforcing material, which leads to strengthening of the composite and after that, an increase in hardness [9]. Table (2) illustrates hardness values of all of the polymeric blend films.

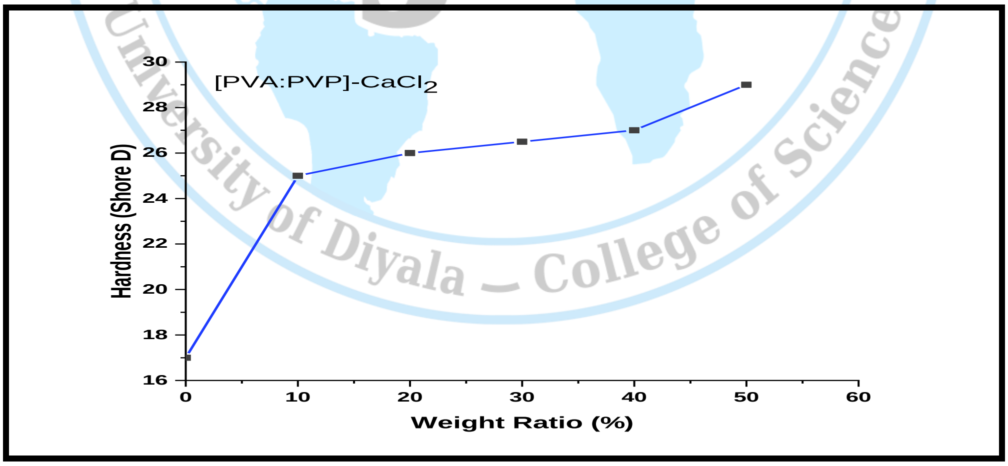

Figure 5: Hardness of the [PVA: PVP]- $CaCl_2$ composite films asfunction of the weight ratio of $CaCl_2.2H_2O$ salt.

Table 2: Hardness value of [PVA: PVP]- $CaCl_2$ composite films with weight ratio of $CaCl_2.2H_2O$ salt.

Weight Ratio wt (%) of Salt	[PVA: PVP]-$CaCl_2$ Hardness
Pure [PVA: PVP] Blend	17
10	25
20	26
30	26.5
40	27
50	29

Impact Test

This test represents one of the significant mechanical tests, which is utilized in order to show resistance of the material to collapse under an influence of impact forces at work conditions, where it represents the measurement of the actual energy that is needed for breaking sample [10]. Fracture energy and impact strength were calculated for the pure polymeric blend film [PVA: PVP] and polymeric blend films reinforced by $CaCl_2.2H_2O$ salt at different weight ratios. We note from Figures (6) and (7) that the fracture energy value and impact strength value of pure polymeric blend film [PVA: PVP] are (0.392 $kg.m^2/sec^2$) and (0.135 kg/sec^2), respectively, and when reinforced with $CaCl_2.2H_2O$ salt with different weight ratios, we note that the fracture energy value and the impact strength value increases with the increases weight ratio of the $CaCl_2.2H_2O$ salt. It is noticed from the two figures that the absorbed energy required for the fracture and the impact strength increases with the increase of the weight fraction in a linear relationship, where the $CaCl_2.2H_2O$ salt works to impede the crack growth and this will lead to a change in the crack and its direction. This change in the crack shape had led to increasing the fracture's surface area and energy expended, all of which led to increasing material resistance, i.e. adding of $CaCl_2.2H_2O$ salt to the pure polymeric blend [PVA: PVP] led to an improvement in the mechanical characteristics. Also, the reason for increases in the fracture energy and impact strength with increasing weight ratio of the added $CaCl_2.2H_2O$ salt, where the large impact energy part that has been applied to the sample has been decreased by $CaCl_2.2H_2O$ salt, increasing resistance of the material [11,12]. Table3 lists values of the fracture energy and impact strength of all polymeric blend films.

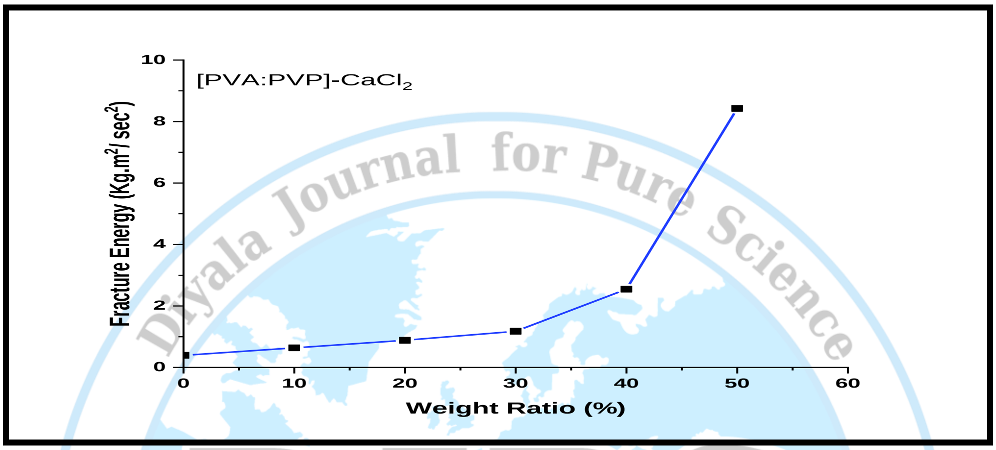

Figure 6: Fracture Energy of the [PVA: PVP]- $CaCl_2$ composite films as function of the weight ratio of $CaCl_2.2H_2O$ salt.

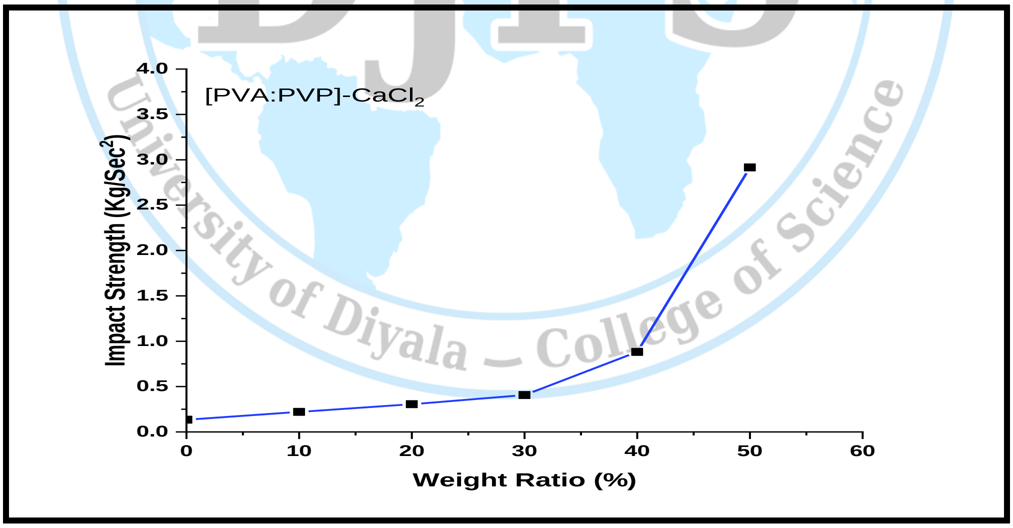

Figure 7: Impact Strength of the [PVA: PVP]- $CaCl_2$ composite films as a function of the weight ratio of $CaCl_2.2H_2O$ salt.

Table3: Fracture Energy and Impact Strength values of [PVA: PVP]- $CaCl_2$ composite films with weight ratio of $CaCl_2.2H_2O$ salt.

Weight Ratio wt (%) of Salt	[PVA: PVP]-$CaCl_2$ Fracture Energy (J)	[PVA: PVP]-$CaCl_2$ Impact Strength (J/m^2)
Pure [PVA: PVP] Blend	0.392	0.135
10	0.637	0.2204
20	0.882	0.3051
30	1.176	0.4069
40	2.548	0.8816
50	8.428	2.9162

Conclusions

After conducting the study and research on the films of the pure polymeric blend films [PVA: PVP] and reinforced by $CaCl_2.2H_2O$ salt with different weight ratios (10,20,30,40,50) wt % - we notice the increase in the values of the tensile characteristics that are represented by Young's modulus and ultimate tensile strength of the polymeric blend films reinforced (at all weight ratios) by $CaCl_2.2H_2O$ salt compared to the pure polymeric blend films [PVA: PVP], and that the hardness (Shore D) is increased with increasing weight ratio of added $CaCl_2.2H_2O$ salt. And the value of both fracture energy and impact strength is increased with the increase in weight ratio of added $CaCl_2.2H_2O$ salt.

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