

Study the Morphological and Mechanical Properties of Ultra-high Molecular weight polyethylene UHMWPE: Polytetrafluoroethylene PTFE binary blends

Alyaa H .Abdalsalam

OlfatA.Mahmood

Gaid K.Salman

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Alyaa H .Abdalsalam¹, OlfatA.Mahmood² and Gaid K.Salman³

¹Nano Technology and advanced material Research center-Technology University

²Science College- Diyala University

³Nano Technology and advanced material Research center-Technology University

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Abstract

In this research, it has been investigated the effect of addition High performance polymer Polytetrafluoroethylene (PTFE) on the Ultra-high molecular weight polyethylene (UHMWPE) mechanical and physical properties. It has been prepared three types of blends (95:5, 90:10 and 85:15) of UHMWPE: PTFE by compression method. Stress-Strain curves of polymer blends have been showed that higher ultimate strength and Young modulus were at 95:5 and decreased gradually as wt. % PTFE increased. FTIR inspection has been also accomplished. Finally SEM results showed incompatibility between the polymers with presence of boundaries between the binary polymers phases.

Keywords: Polymer blend, UHMWPE, PTFE, Mechanical properties.

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دراسة الخواص الميكانيكية و المجهرية للخلائط الثنائية لبولي اثيلين عالي الوزن الجزيئي UHMWPE: بولي تترافلورواثيلين (PTFE)

علياء حسين عبد السلام¹ ، الفت احمد محمود² و غيد خلف سلمان³

¹مركز النانوتكنولوجي لبحوث المواد المتقدمة- الجامعة التكنولوجية

²جامعة ديالى-كلية العلوم

³مركز النانوتكنولوجي لبحوث المواد المتقدمة- الجامعة التكنولوجية

الخلاصة

في هذا البحث، قد تم البحث في تأثير أضافة بوليمر عالي الكفاءة وهو بولي اثيلين تترافلورواثيلين على الخواص الميكانيكية والفيزيائية لبوليمر البولي اثيلين عالي الوزن الجزيئي. تم تحضير ثلاثة انواع من الخلائط بنسب وزنية (95:5, 90:10 and 85:15) للبولي اثيلين تترافلورواثيلين: بولي اثيلين عالي الوزن الجزيئي [UHMWPE:PTFE] بواسطة عملية الكبس. ولقد بينت منحنيات الاجهاد-الانفعال للخلائط البوليمرية ان اقصى مقاومة شد ومعامل مرونة كانت عند نسبة 95:5 وتتناقص تدريجيا بزيادة النسبة الوزنية ل PTFE. فحص تحولات فورير بواسطة الاشعة الحمراء (FTIR) تم انجازه ايضا. اخيرا اظهرت صور المجهر الالكتروني الماسح عدم التوافقية بين البوليمرين مع وجود الحدود بين اطوار البوليمر الثنائي. **الكلمات المفتاحية:** الخلائط البوليمرية، بولي اثيلين عالي الوزن الجزيئي، و بولي اثيلين تترافلورواثيلين ، الخواص الميكانيكية.

Introduction

Polytetrafluoroethylene (PTFE) presently discover increasing Using in high performance seals due to its remarkable properties like high chemical resistivity, low coefficient of friction and high temperature stability [1,2]. Yanhong Yan et.al prepared advance composite materials based on PTFE reinforced with expanded Graphite fiber and various nano particles of metal such as Cu and ceramics including (TiO₂, SiO₂ and Al₂O₃). Results of Stress-displacement and stress relaxation revealed that ternary composite materials have viscoelastic behavior and seem to be relatively brittle; finally they have been considered that these materials are useful to be used in severe environments [4]. Jayashree Bijwe et.al investigated the effect of inclusion PTFE in polyether ether ketone (PEEK) polymer. Results showed improvement in PEEK performance [5].

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Ultra-high molecular weight polyethylenediffers from the other Polyethylene types in its average molecular weight which is nearly higher than 10^6 , which can be known from measurement of viscosity [6, 7].UHMWPEis a marvelous polymer with excellent physical and mechanical properties such as wear and abrasion resistance, chemical inertness, lubricity, impact toughness [8]. Their Kyu prepared three types of polymer blends from types of polyethylene; blends of different grades of polyethylene have been prepared (Ultra high molecular weight polyethylene, linear low density polyethylene, low density poly ethylene and high density polyethylene). DSC results of blends showed that compatibility between them in the melting stat which indicates that they form miscibility also UHMWPE with linear low density polyethylene (LLDPE) and high density polyethylene (HDPE) showed some co crystallinity this is interpreted to the long chain branching of conventional LDPE. Results of stress-strain of the above blends show some linearity relationship with composition, except in the last blend UHMWPE-LDPE [9].

A new approach in science and technology developed by blending two different polymers in a way to tailor their both properties in a one single material.The developed characteristics of blends depend strongly on morphology which usually defined by size and shape of distributed particles [10]. With above literature it can be found that most of them tries to improve the performance of polymer matrix using reinforcement materials usually ceramics but in this study the goal was to investigate the effect of high performance polymer addition to another matrix polymerthrough mechanical and morphological inspections.

Materials and Experimental procedure

Ultra-high mw polyethylene was acquired in powder form JIUJIANG ZHONGKE XINXING NEW MATERIAL CO., LTD China, model No. XH-804 and the mechanical properties of UHMWPE grade were shown in table (1).Polytetraflouroethylene polymers provided from ZIBO BAINAISI CHEMICAL CO., LTD-China some mechanical and physical properties are shown in table (2).

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Table (1) shows properties of UHMWPE polymer materials.

	Molecular weight (mil/mol)	Density (gm/cm ³)	Grain size > 40 mesh	Granularity > 30	Tensile elongation at break %	Tensile strength (MPa)	Impact strength Izod (KJ/m ²)
UHMWPE (XH-804)	424*10 ⁵ ±20	0.93-0.95	95	99.6%	250	30	70

Table (2) shows properties of PTFE polymer materials.

	Tensile Strength (Mpa)	Elongation at Rupture (%)	Volume Density (g/l)	Moisture Content, (%)≤	Relative Density	Particle Size (µm)
PTFE	28.5	300	400	0.021	2.144	16

Blending and compression

Polymer blends have been prepared by mixing the two polymers in Nano ball mill for 15 minutes to have homogeneous mixture then placed in a stainless steel mold (150*50*4) mm preparing for hot pressing at 190 °C for 45 minutes and pressure 10 MPa for ten minutes to have blocks of polymer blends.

Mechanical test

Samples were prepared for the tensile test in accordance with ASTM D638-87[14]. A computerized universal testing machine model (WDW-200D Jinan Shijin Group company-china) was used to conduct a test at a constant cross head speed of the order 5 mm/min at room temperature. Tensile load was applied till the failure of the sample and stress -strain curve was obtained.

The modulus of elasticity was evaluated using the following equation:

$$E = \frac{\sigma_y}{L - L_0 / L_0} \dots \dots (1)$$

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Where σ_y is the stress at yield, L is the length of sample at yield and L_0 is the initial length.

Scanning Electron Microscope (SEM), model (Tescan VEGA-SB) made in Belgium available in Nanotechnology and Advanced Materials Research Center/ University of Technology is used to examine the morphology of polymer blends.

Finally, FTIR test is performed according to (ASTM E1252) by using Fourier transform infrared spectrometer instrument (available in Material Engineering Department model (TENSOR 27) made in Germany, by (Bruker Optics Company).

Results and Discussion

FTIR results

IR- spectra of Ultra-High Molecular Weight PE shows the main five peaks (2912.87, 2843.92, 1470.46, 729 and 718 cm^{-1}) as shown in fig (1) which indicates to Asymmetric stretching of the $-\text{CH}_2$, symmetric stretching of the $-\text{CH}_2$ aliphatic groups, C-H bending deformation, $=\text{CH}_2$ out-of-plane bending and C-H rocking deformation respectively as shown in table (3)[11].

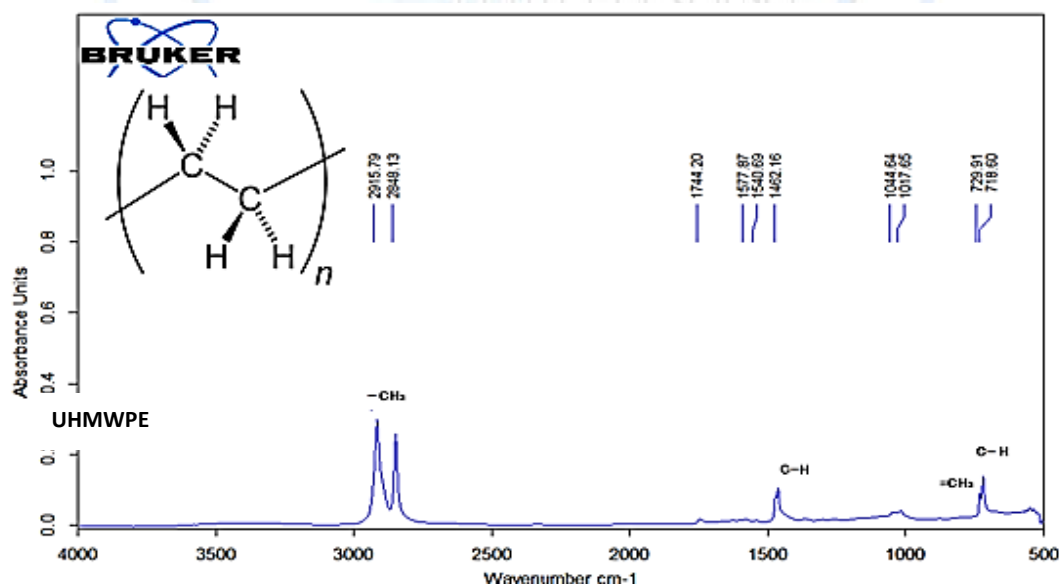


Figure (2) shows FTIR results of UHMWPE.

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As for polytetrafluoroethylene which contains four fluorine atoms and its basic assignments which based on the formula of PTFE: $[-CF_2 -CF_2-]_n$ are 1251, 1155, 705, 632, 511 cm^{-1} belong to the different modes of CF_2 groups as shown in fig (2) and table (3)[12,13]. Moreover the blend FTIR shown in fig (3) showed that there was no new bonds have been appeared and most UHMWPE absorption peaks have been appeared and without shifting, Still some peaks of PTFE have been appeared in the blend [UHMWPE: 15PTFE] with small shifting which may belong to the high percentage of PTFE as compared with the other blends as shown in table (3).

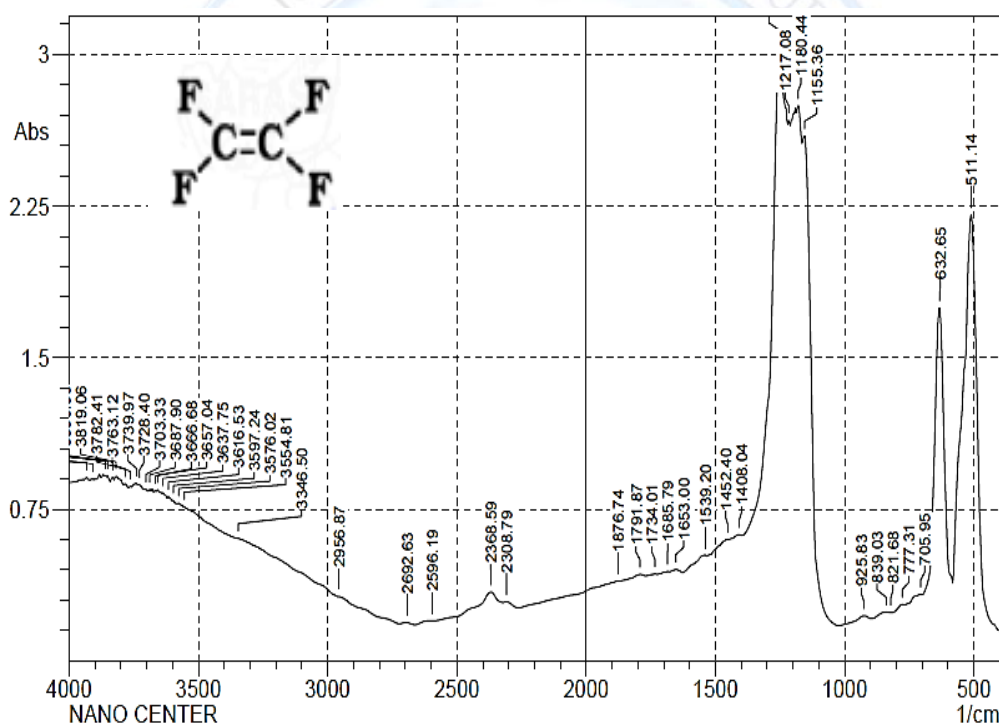


Figure (2) shows FTIR results of PTFE.

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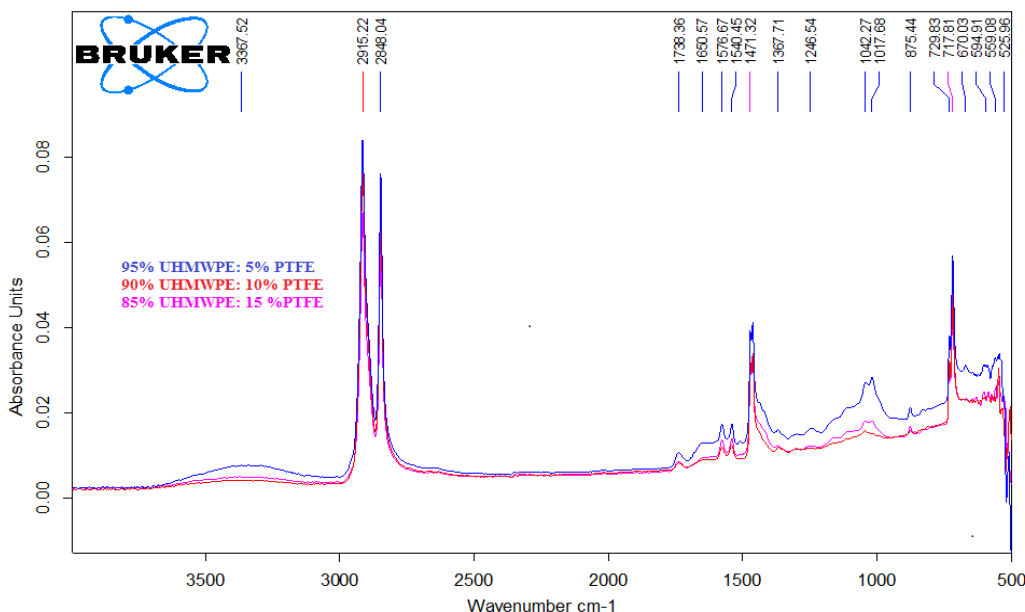


Figure (3) shows FTIR of (UHMWPE and PTFE) polymer blends.

Table (3) shows IR- spectrum of UHMWPE,PTFE and their blends.

Association	UHMWPE	PTFE	UHMWPE 5% PTFE	UHMWPE :10%PTFE	UHMWPE: 15%PTFE
CF ₂ asymmetric stretching	-	1251	-	-	-
CF ₂ symmetric stretching	-	1155.36	-	-	1152.91
CF ₂ scissoring	-	705.95	-	-	-
CF deformation	-	632.65	-	-	638.55
CF ₂ bending	-	511.36	543.64	545.70	545.86
Asymmetric stretching of -CH ₂	2912.87	-	2915.30	2915.22	2915.23
symmetric stretching of -CH ₂	2843.92	-	2848.04	2847.93	2847.88
C-H bending deformation	1470.46	-	1462.35	1471.33	1471.32
=CH ₂ out-of-plane bending	729	-	729.83	730.03	729.88
C-H rocking deformation	718	-	717.54	717.49	717.81

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SEM results

Scanning electron microscope photographs of UHMWPE: PTFE polymer blend are shown in fig (4 a, b and c). Results interpreted the reasons of the in improvement in mechanical properties, which is the incompatibility that led to the segregation that shown below which corresponding with MohdAmran research [14] in the immiscibility between PP and PTFE. Also it may be seen that PTFE flakes imbedded in UHMWPE matrix and tries to expand to be mixed and united with the other polymer phase without melting since the difference in melting point between the two polymers, still the need for copolymers is necessary to enhance the compatibility and strengthening the boundaries between them. Moreover, it should be noted that some PTFE particles are deformed into a fibrous shape owing to the applied squeeze flows as well as the localized shear deformation and this can be seen in photograph (4.c) below.

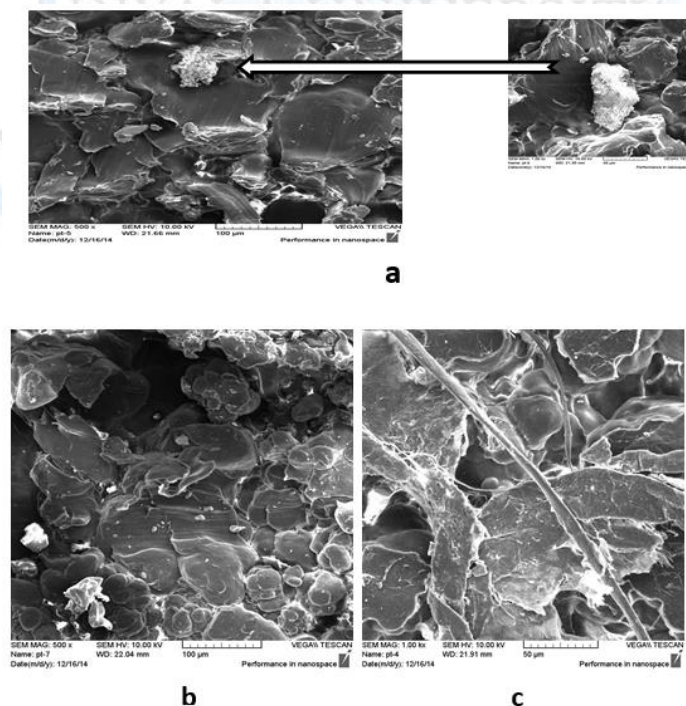


Figure (4a,b and c) shows SEM images of polymer blends.

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Tensile results

It has been noticed the change in the behavior of the neat polymer (i.e. Ultra high molecular weight polyethylene) as polytetrafluoroethylene added as shown in fig (5). Results showed how UHMWPE converted from soft and tough into hard and brittle but still tensile strength of the pure polymer higher than all ratio of UHMWPE: PTFE polymer blends as shown in fig (6), this may attributed to the weak compatibility between UHMWPE and PTFE which may lead us to think about copolymers that strengthen the interfacial areas. The same can be seen in Young modulus property (i.e. values of E blends less than the UHMWPE) further more they decreases as wt. % PTFE increased as shown in fig (7) and the reason also will be the same .Table (4) shows ultimate strength and young modulus values of the blends.

Table (4) shows the mechanical properties of polymer blends.

	Ultimate tensile strength (MPa)	Young modulus (MPa)
UHMWPE	22.8	618
UHMWPE:5PTFE	19	400
UHMWPE:10PTFE	15	300
UHMWPE:15PTFE	12	208

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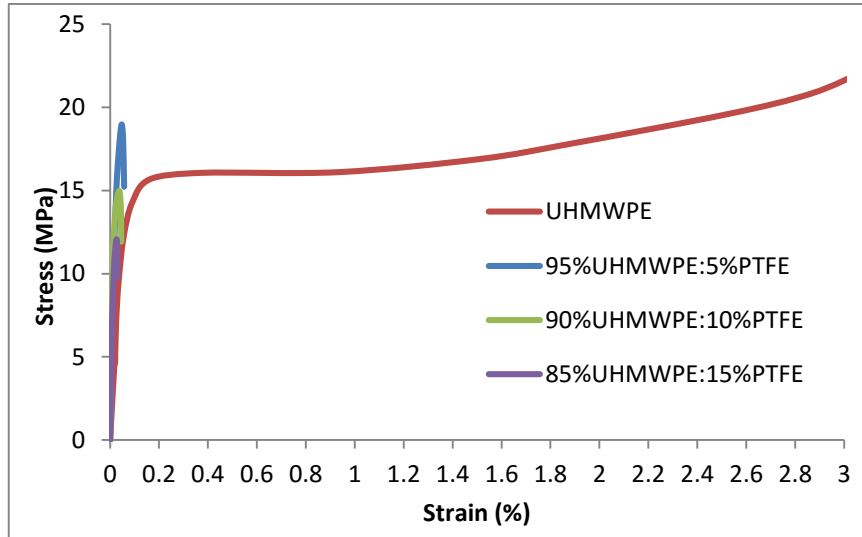


Figure (5) shows stress-strain behavior of UHMEPE-PTFE polymer blends.

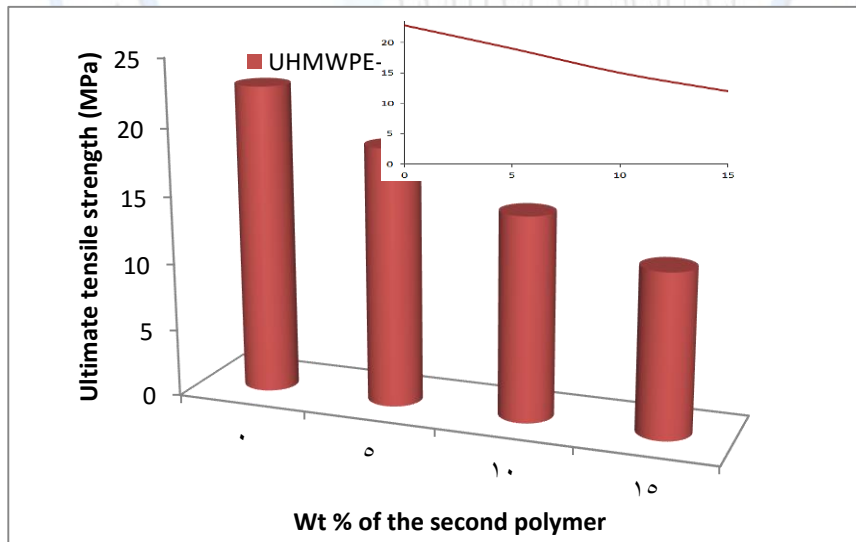


Figure (6) shows Ultimate tensile strength property UHMWPE-PTFE blends.

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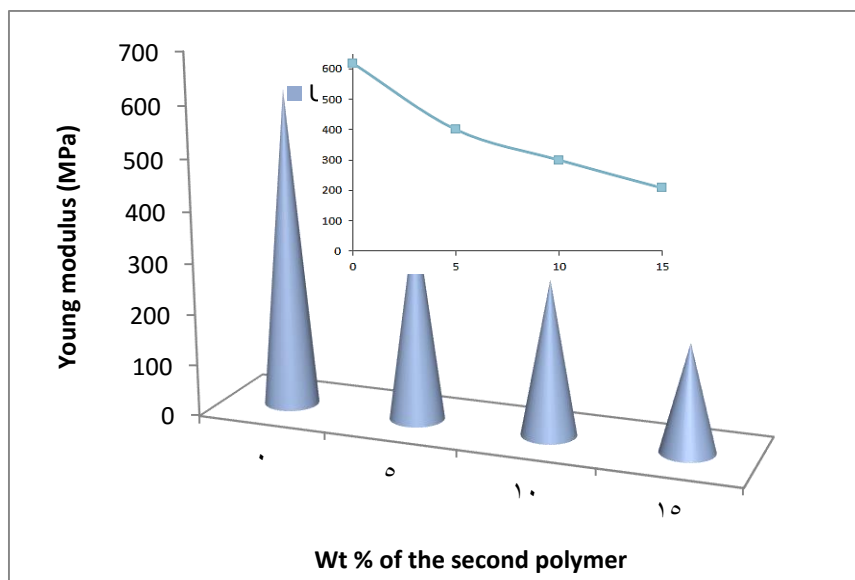


Figure (7) shows Young modulus values of UHMWPE-PTFE blends.

Conclusion

It has been concluded that the effect of PTFE was not so good in improvement the mechanical properties including ultimate strength and Young modulus since there were decrement in both of them which can be interpreted to the incompatibility between the two polymers leading to immiscibility phenomena, which has been proved by SEM.

Still the change in the behavior of UHMWPE from soft and ductile into stiff and brittle is pronounced due to the difference structure of PTFE polymer as compared with simple structure of PE. Moreover FTIR results showed appearance of both polymers peaks with no shifting.

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