COMPARATIVE STUDY BETWEEN SPECIFICATIONS OF TWO GROUPS OF THE TERNARY POLYMER BLEND USED IN STRUCTURAL APPLICATIONS

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ABSTRACT :-

In this work, preparation ternary polymer blends, by addition PMMA to the two groups of binary polymer blends (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR). Mechanical properties for all prepared samples were studied. The results of this research showed that the ternary polymer blends which have the ratios (93%Epoxy: 2 %NR: 5%PMMA) or (90%Epoxy: 5 %NR: 5%PMMA) have the best results in fracture strength, young modulus, compressive strength, and hardness and the maximum values were at 5%PMMA, while elongation decreases with the addition PMMA to the blends. Moreover flexural properties values, impact strength and fracture toughness decrease with increasing in PMMA percentage for both groups, these polymer blends were characterized for morphology using scanning electron microscopy (SEM).
Keywords: ternary polymer blends, Epoxy resin; natural rubber; PMMA .

دراسة مقارنة بين مواصفات مجموعتين من الخلائط البوليمرية الثلاثية المستخدمة في التطبيقات الهيكلية

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الخلاصة :-

في هذا العمل ، تم تحضير خلائط بوليميرية ثلاثية بإضافة بولي مثيل ميثا اكريليت (PMMA) الى مجموعتين من الخلائط البوليميرية الثنائية وهي (98%EP:2%NR) و (95%EP:5%NR) . تمت دراسة الخواص الميكانيكية لجميع العينـات المعدة. بينت نتـائج هذا البحث بأن الخلائط البوليميريـة الثلاثيـة بنسب (93%EP:2%NR:5%PMMA) و (90%EP:5%NR:5%PMMA) لديها افضل النتائج في مقاومة الكسر ، معامل يونك، مقاومـة الانضـغاط والصـلادة والقيم القصـوى كانـت عند نسبة (5%PMMA) بينمـا انخفضـت الاستطالة مـع اضـافة البـولي مثيـل اكريليـت (PMMA) الى الخلائط. بالإضافة الى ذلك فإن قيم خصـائص الانحنـاء ،مقاومـة الصـدمة و متانـة الكسر انخفضـت مـع زيـادة نسبة البـولي مثيل ميثا اكريليت (PMMA) لكـلا المجمـوعتين ، هـذه الخلائـط البوليميريـة تميزت مورفولوجياً بإستخدام المجهر الالكتروني الماسح (SEM) .

INTRODUCTION :-

Polymer blends are generated by the mixing of two or more polymer together in order to combine the characteristics of individual polymers. The compatibilazation of the phases in the blends is also achieved by number of physical or chemical, polymer blends are widely used materials in the modern polymer industry owing to their wider range of properties as compared to individual polymers and ease of tailoring of properties. The dispersed phase in certain systems can also acquire a specific morphology beneficial for applications like platy morphology, useful for barrier applications, both solution as well as melt mixing techniques to generate the polymer blends have found their application, though melt mixing is more environmentally friendly as no solvent is required and the melt mixing required the use of high temperature and shear for the generation of blends, which may degrade the heat- sensitive polymers therefore requiring optimum use of mixing conditions (Vikas Mittai, 2012). Blending of chemically different polymers is an important tool in industrial production for tailoring products with optimized material properties. Performance of polymer blends depends on the properties of polymeric components, as well as how they are arranged in space. One of the most basic questions in blends is whether or not the two polymers are miscible or exist as a single phase, most blends of high molecular weight polymers exist as two-phase materials. The morphology of the phases is of great importance in this manner. A variety of morphologies exist such as dispersed spheres of one polymer in another, lamellar structures, and co-continuous phases (Kukaleva N. et. al., 2000). It is well-known that the properties of polymer blends are greatly influenced by the morphology that is developed during the mixing process, the morphology is influenced by the following hierarchy of factors: the size distribution and shape of distributed particles, interfacial tension, viscosity ratio, shear stress. Likewise, the morphology of ternary blends is also influenced by thermodynamics and kinetic factors (L.A.Utracki, 2003; Chen J.H. et. al., 2007; M.A.Huneault and Hongbo Li, 2012). One of the problems associated with blends and alloys is how to make the components adhere together. Studies elsewhere have shown that the uncompatibililzed immiscible polymer blends provide synergy of mechanical properties when the processing and compositional parameters are near optimum values (A.Leclair and Favis B.D., 1996). These polymeric materials must perform under strenuous mechanical, chemical, thermal and electrical conditions imposed by the requirements of a specific application (Samsudin S. A. et. al., 2006; Sayana John et. al., 2009; Altan M. &Yildirim H., 2010; Caliskan M. et. al., 2011; Mudigoudra B.S. et. al.,2012; Sihama E. salih et. al., 2014; Sihama E. salih et. al., 2015). The aim of the work comparative study between specifications of two groups of the ternary Polymer blend (through the mechanical properties and thermal behavior of the preparation of ternary blends) Used in structural applications.

EXPERIMENTAL PART :-

Materials used

Epoxy resin type (EUXIT 50 KI) was used as the matrix it was provided from   (Al-Rakaez Building Materials in Amman) made in Egypt Arabic, Epoxy resin of a trade mark (Euxit 50 KI) is a liquid of low viscosity resin and its converted to solid stat by adding hardener (Euxit 50 KII) at ratio of (1:3), which were Supplied by Egyptian Swiss chemical industries company. Natural rubber used in the work, RSS-4 Grade Sheets available from North East India also called India rubber or CaoutchoucHorizon company (ROMIL-SA select Assured solvent) $(C_6H_5CH_3)$. In this work toluene is used as a solvent for the bulk (NR) which is the pieces of (NR) are immerged in toluene for few days then a solution of (NR) is obtained. Poly (methyl meth acrylate) (PMMA) is powder /self-cure

acrylic and (MMA) self-cure liquid use in the research is (Panacryl) type 1-class1-iso 1567 produced in England packaged by Inci Dental in turkey).

Preparation of samples : -

Hand lay-out technique was used to prepare the polymer blend specimens; a mold of size $(250 \times 250 \times 5)$ mm^3 was made from Aluminum. The inner face of the mold was packed with a layer of thermal nylon papers made of a polyvinyl alcohol substance. Weighing the epoxy depending on the weight fraction of NR and PMMA in polymer blend (Epoxy: NR: PMMA)these blend of ternary polymer, it was prepared as follow, at the beginning, a rubber solution it has been added to the base material, then add PMMA powder, according to the selection ratios of the weight fractions (0, 5, 10 and 15%), and taking into consideration the weight of hardener. the polymer blends were thoroughly mixed by using glass rod to remove any entrap gas bubbles that may be found in this mixture, then the mixture was poured into the mold and allowed to cure for 48h at room temperature (27°C). All the specimens were then post cured in an oven at 55°C for 2h by using electrical oven. Then the sheets cut off and machined according to standard specifications to produce samples conforming for mechanical (tensile, flexural, impact and hardness) tests of all the prepared samples.

Mechanical and physical tests

Tensile test samples were cut according to ASTM D 638 (Annual book of ASTM standard, 2003). The machine used for the testing of tensile properties is micro computer controlled electronic universal testing machine (model WDW 200 E) made in China. The test was conducted at a cross head speed of (5mm/min) at ambient temperature. Three specimens where used for most tests and final results represent the average for three specimens it was tested. Bending behavior was tested using a three point test instrument, (model WDW 200 E) made in China, this test is performed according to ASTM D-790-78 (Annual book of ASTM standard, 2003) at room temperature with velocity (5mm/min). **Impact test** is performed at room temperature according to ASTM ISO 179 (Annual book of ISO standard, 2006). Izod charpy tension impact (measurement test machines Inc, Amityville-New York).

Hardness test it has been used (Shore D) hardness test the samples were prepared according to ASTM D-2240 (Anuual book of ASTM standared, 2003). Each specimen was tested five times at different positions at same time, and average values were taken. **The (FTIR) test** is performed according to (ASTM E1252) (Anuual book of ASTM standared, 2002). By using Fourier transform infrared spectrometer, model (TENSOR 27) made in Germany, by (Bruker Optics Company). It is equipped with a room temperature DTGS detector, mid-IR source (4000 to 400) cm^{-1} and a KBr beam splitter. **Scanning Electron Microscope (SEM) test**, analytical (SEM), model (TescanVEGA-SB) made in Belgium are used to examine surface and fracture surface morphology of polymer. To achieve good electric conductivity, all samples are first sputtered with gold from the surface along the edge .

RESULTS AND DISCUSSION :-

Fourier Transform Infrared Spectrometers (FTIR) test results for ternary polymer blends (Epoxy: NR: PMMA).

The effect of addition PMMA to binary (98%EP: 2%NR) on the FTIR spectrum are shown in Figure (1). This figure show infrared spectrum of polymers blends (98%EP: 2%NR) , (93%EP: 2%NR: 5%PMMA) and (88%EP: 2%NR: 10%PMMA) as a function of PMMA content in the blend, it is clear from infrared spectrum of the neat

Epoxy resin and ternary polymer blend (EP: 2%NR: X%PMMA),do not reveal any new peak or peak shifts as compared with epoxy resin, there is only decrease in peak intensity for all the characteristic peak, and that may be related to the increase in degree of cross link of epoxy polymer blend (Sagar T. cholake et. al., 2014; Sihama E.salih et.al.,2015). The Characterization absorptions of epoxies by three locations of the oxirane ring (epoxy groups) bands. The first one is located at 3050 cm^{-1}approximately and is attributed to the C-H tension of the methylene group of the epoxyring. The second band is located at 915 cm^{-1}, is attributed to the C-O deformation of the oxirane group, The third band is located at 1181.42 cm^{-1} which is due to C–O stretching of aromatic ring (Sihama E.salih et. al.,2015; Sagar T. cholake et. al., 2015) . The C=O stretching usually lies in the region between 1500 to 2000 cm^{-1}.PMMA shows a band at 1722.32 cm^{-1} assigned to C=O stretching. C-O stretching frequency is one of the intense bands that appear at 1181.42 cm^{-1}. Another group of ternary polymer blends which are (98%EP: 2%NR), (93%EP: 2%NR: 5%PMMA) and (90%EP: 5%NR: 5%PMMA) as a function of NR content in the blend, the infrared spectrum of these groups blend, are shown in Figure (2).Too it is clear from infrared spectrum of the neat Epoxy resin and ternary polymer blend (EP: X%NR: 5%PMMA), do not reveal any new peak or peak shifts as compared with epoxy resin, there is only decrease in peak intensity for all the characteristic peak, and that may be related to for previously mentioned reasons. And this related to the nature of the chains structure of natural rubber which are long chain, entangled, and coiling of this chains is attributed to the steric hindrance of the methyl group and the hydrogen atom on the same side of the carbon-carbon double bond and this make the polymer blend (Epoxy: 2 %NR: X%PMMA) have the flexible structure, on the contrary of this, the molecular chain of PMMA, have meth and methacrylate groups on every other carbon atom of the main carbon chain of PMMA provides considerable steric hindrance and this makes polymer blend (Epoxy: 2 %NR: X%PMMA) rigid and relatively strong (Sihama E.salih et.al.,2015; Smith W.F and Hashemi J.,2006).

Tensile test results of Ternary (Epoxy-NR-PMMA)polymer blends:

The behaviour of (stress-strain) curves of ternary blends (Epoxy:2%NR: X%PMMA) and (Epoxy: 5%NR: X%PMMA) are shown in Figures (3) and (4) respectively. It was found from theses curves that is behaviour of (stress-strain) changes from hard and tough to hard and brittle for the (Epoxy: 2 or 5%NR: X%PMMA) with increasing percentage ratios of PMMA in blend, moreover, it was shown the maximum values of the fracture strength reach to (36MPa) and (24MPa) with an elongation (8.71%) and (9.46%) for the samples(93%Epoxy:2%NR:5%PMMA) and (90% Epoxy:5%NR:5%PMMA)respectively as compared to samples of other ratios, and these curves showed the elastic behaviour untile fracture.Figures (5), (6), (7), show the comparison between the samples of the ternary polymer blends (Epoxy: 2%NR: X%PMMA) and (Epoxy: 5%NR: X%PMMA) in terms of the Fracture strength, Young's modulus and Elongation at break respectively. The results of these figures it is showed that the addition of (5%PMMA) to the binary polymer blends (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR) gives the higher values of fracture strength and Young's modulus except the elongation at break which was lower as compared with the binary polymer blend (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR). That may be related to the molecular chain of PMMA the substation of the meth and methacrylate groups on every other carbon atom of the main carbon chain of PMMA provides considerable satiric hindrance and this makes polymer blend (Epoxy: 2 or 3%NR: X%PMMA) rigid and relatively strong (Sihama E.salih et. al.,2015;William D.callister et.al., 2012). From these figures it can be seen that increasing the weight percentage of PMMA at ratios more than 5% decreased the values of fracture strength

Young's modulus, as well as decreases the elongation percentage at break for ternary polymer blends samples.From the results of tensile test, it is found that the ternary polymer blends which have the ratios (93%Epoxy: 2%NR: 5%PMMA) have the best result in tensile properties compared to other ratios of ternary polymer blends. Furthermore the ternary polymer blends (Epoxy: 2%NR: X%PMMA) have the higher values of the Fracture strength, Young's modulus as compared with their counterparts of the other group samples of (Epoxy: 5%NR: X%PMMA), whereas the elongation percentage at break values are on the contrary, and this related to the nature of the chains structure of natural rubber which are long chain, entangled, and coiling of this chains is attributed to the steric hindrance of the methyl group and the hydrogen atom on the same side of the carbon-carbon double bond and this make the polymer blend (Epoxy: 2 %NR: X%PMMA) have the flexible structure, on the contrary of this, the molecular chain of PMMA, have meth and methacrylate groups on every other carbon atom of the main carbon chain of PMMA provides considerable steric hindrance and this makes polymer blend (Epoxy: 2 %NR: X%PMMA) rigid and relatively strong(Sihama E.salih et.al.,2015; Smith W.F and Hashemi J.,2006) .

Flexural test results of (Epoxy:NR:PMMA)polymer blends

Figures (8, 9 and 10)show the comparison between the samples of the polymer blends (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR) before and after addition PMMA to this polymer blends, in terms of the Flexural strength, Flexural modulus and Maximum shear stress respectively.Fromthese figures it was show that there is decrease in the flexural properties with addition of PMMA to the polymers blend, as compared with the epoxy resin and binary polymer blends, which is related to the nature of constituents of polymer blend so the wide range of engineering properties is due to the contributing properties of each of its components. Furthermore from These figures, it was observed that the ternary polymers blend (Epoxy: 2%NR: X%PMMA) got the highest values of flexural strength, flexural modulus and maximum shear stress as compared with their counterparts of the other group samples of ternary polymers blend (Epoxy: 5%NR: X%PMMA) samples. These results are due to the nature of the interaction reaction and interface between the components of the polymers blends (William D.callister et. al., 2012).

Impact test results of (Epoxy: NR: PMMA) polymer blends

The Impact test represents one of important dynamic mechanical tests, where the specimen exposed to very fast moving load. From this test the impact strength and fracture toughness of composite materials can be calculated by depending on the energy needed to fracture of specimen. Figures (11 and 12) show the effect of addition PMMA to the two binary polymer blend (98%Epoxy: 2 %NR) and (95%Epoxy: 5%NR) on the impact strength and fracture toughness respectively. The results show decrease in the impact strength and fracture toughness for both types of ternary polymer blend (Epoxy: 2 or 5%NR: X%PMMA), moreover the ternary polymer blend (Epoxy: 5%NR: X%PMMA) have the higher values of impact strength, on the contrary the ternary (Epoxy: 2%NR: X%PMMA) have the higher values of fracture toughness, as compared with their counterparts of the other group samples of ternary polymers blend. This may be linked with rubber particles can act as plasticizer when some amount of rubber goes into the epoxy matrix or act as flexibilizer when rubbers incorporated into epoxy matrix. Both of these effects can increase toughness of the matrix during the deformation under shear occur (Rohani Abu Bakar and M.S.Fauzi J., 2012).

Compression test results of (Epoxy: NR: PMMA) polymer blends

From figure (13), it was observed that compressive strength increase with the addition PMMA to the two groups of the binary polymer blend (Epoxy: 2 or 5%NR), and reach to the maximum values of compressive strength at ratio of 5% PMMA. Whereas the polymers blend with ratios of (10% and 15%) of PMMA gained lower values of compressive strength among the polymers blend samples as compared with ratio (5% PMMA) but more than the matrix of binary polymer blend (Epoxy: 2 or 5%NR). As well as from this figure it was noticed,that the ternary polymer blend (Epoxy: 2 %NR: X% PMMA) gained the higher values of compressive strength as compared with their counterparts of the other group samples of ternary polymers blend (Epoxy: 5%NR: X%PMMA). This is related to the nature of the chemical structure of each of PMMAandNR , as well as the nature of the interaction reaction and interface btween the components of the polymers blends an this acts as an agent to increase the interfacial reaction and provides an effective compatibility btween different phases of polymers blend (Epoxy:Y% NR:5% PMMA) (Sihama E. salih et.al.,2014).

Hardness test results (Epoxy: NR: PMMA) polymer blends

Figure (14) showed clear, a small increase in the hardness value when added 5%PMMA to the polymer blends (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR) as compared with other samples. Also, the hardness decreased with increased of PMMA content to more than 5% ratio of PMMA. And that is related to the nature of the chemical composition and molecular structure of PMMA. From the figure, it is found that the polymer blends which have the ratio (93%Epoxy: 2%NR: 5%PMMA) have the higher values of (shore D) hardness as compared with their counterparts of the other group samples of ternary polymers blend (Epoxy: 5%NR: X%PMMA).

Thermal characteristics results of (Epoxy:NR:PMMA) polymer blends

The effect of PMMA addition to the base polymers blends (98%Epoxy:2%NR) and (95%Epoxy:5%NR) on the thermal conductivity is shown in figures (15) respectively. From this figure it's clear that the thermal conductivity decrease when PMMA add to the two base polymer   blends (Epoxy:2%NR) and (Epoxy: 5%NR).While the polymer blend (80%Epoxy:5%NR:15%PMMA) gets   the lower valus of thermal conductivity and. Moreover the polymer blends (Epoxy: 5%NR: X%PMMA) have the lower values of thermal conductivity as compared with their counterparts of the other group of ternary polymer blend (Epoxy: 2%NR: X%PMMA). The thermal conductivity of a polymer blends is affected by the interface adhesion between components of the blends , since the conductivity may be impaired by the presence of an interficial layer of some sort , or by voids or micro cracks in the vicinty of the interface .

Density test results of ternary polymer blends (Epoxy:NR:PMMA)

Figure (16) showed increasing in the bulk density with added PMMA to the (98%Epoxy: 2%NR) and (95%Epoxy: 5%NR) polymer blends. The addition of PMMA at different ratios the bulk density slightly increased as compared to the base polymer blend this attributed to the high density of the PMMA. The bulk density increase with increasing PMMA content in the polymer blend and the polymer blend (83%Epoxy: 2%NR: 15%PMMA) has high value of bulk density than other polymer blends samples .

(DSC) test results for ternary polymer blends (Epoxy: NR: PMMA)

The glass transition temperature (Tg) either somewhat increases or decreases depending on the type of components of polymer blend, its morphology the interfacial reaction and compatibility between different components and the inter crystallites distance. Figure (17)shownthat in the case of epoxy that the glass transition temperature mid-point is 59.414 ^{o}C adding 2%NR to the epoxy, the glass transition temperature is slightly decreased from 59.414^{o}C to 54.56 ^{o}C as mid-point when As well as when the ratio of NR increased to 5% leads to slightly decrease in the (Tg) value to 53.99 ^{o}C. When the addition of 5% PMMA to these two groups of binary polymer blend, the (Tg) values for the binary polymer blend (epoxy: 2%NR) increased from (54.56 ^{o}C to 66.69^{o}C) and for (epoxy: 5%NR) increased from (53.99 to 63.87), and this related to the molecular chain of PMMA the substation of the meth and methacrylate groups on every other carbon atom of the main carbon chain of PMMA provides considerable satiric hindrance and this makes polymer blend (Epoxy: 2 or 5%NR: 5%PMMA) rigid and relatively strong and so increase in Tg value(Sihama E.salih et.al.,2015;William D.Callister et.al., 2012)**.** On the other hand when the NR ratio increased in the blend from 2% to 5% the Tg value is decreased as shown in Figure (17b and c) andTable (1), this may be attributed due to highly dispersed NR phase acting as plasticizer and it is reducing the stiffness of the polymer blends (D.Hussinaiah et.al.,2014). The (Tg) values of these groups of polymer blends and the reference material are listed in Table (1).

Morphology test

Figure (18) shows the surface morphology of the polymer blends (98%EP: 2%NR),(93%EP: 2%NR: 5%PMMA) and (90%EP:5%NR: 5%PMMA), these images show a homogenous distribution of NR phase which are embedded in to epoxy phase as shown in figure (18a),which appears as continuous and homogenous morphology. The surface morphology of polymer blends after the addition (5%PMMA), are shown in Figure (18b, c)that make the ternary polymer blend (EP: NR:PMMA) behaves as strength material, compared with binary polymer blend (EP: NR), From these Figures it is found there is a difference in the surface morphology of binary polymer blend (Epoxy: NR).Figure (18 (a)) which appears as continuous and homogenous morphology, whereas the ternary polymer blend (93%EP:2%NR:5%PMMA)and(90%EP:5%NR:5%PMMA) show semi-continuous morphology, this is related to the addition of PMMA to the polymer blend (EP-NR), where the dark regions are epoxy phase while the bright regions are PMMA phase which appears as a spherical drops in the matrix material (figure (18 (c)). The SEM micrographs of fracture surfaces for the modified epoxy resins of binary polymer blend (Epoxy: NR) and ternary polymer blend (EP: 2%NR: 5%PMMA) and (EP: 5%NR: 5%PMMA) at different magnification were recorded Figures 19 (a, b), (c, d) and (e, F)) respectively. These blend systems appear to have a co-continuous morphology. The SEM photo showing different morphologies with various constituents of polymers blend. The fracture surface of binary polymer blend (Epoxy: NR) (figure 19a,b showed homogeneous micro structure, this photos shows a much smoother fracture surface, which seems to indicate better interfacial adhesion between EP and NR **(**Rohani Abu Bakar and M.S.Fauzi J.,2012).These results showed that there are no phase separated domains in the binary polymer blend system and confirmed the formation of homogeneous inter cross-linked network structure's (D.Hussinaiah et.al.,2014).Whereas the fracture surface of ternary polymer blend (EP: 2%NR: 5%PMMA) and (EP: 5%NR: 5%PMMA) exhibited a heterogeneous morphology (figure 19 (c and d) and figure 19 (e andf) a co-continuous two phase structure that could

be broken down into an island-like structure, the SEM photos show very few of cavities structure, this indicates a fairly weak interaction between the components of polymer blend (NR, PMMA and the matrix EP). In the end the morphological analysis of the fractured surface of ternary polymer blend (EP: 5%NR: 5%PMMA) showed rubber dispersions in the sub-micrometer size (43.89um) as show in SEM photo (figure 19 (f), It was reported that the present a spherical droplet rubber particles will act as energy dissipating center in the epoxy (D.G. Dikobe and A.S.Luyt, 2010). Therefore from the morphological evolutions of the modified epoxy network which were examined by scanning electron microscope and the toughening mechanism were determined to be due to rubber cavitation, followed by plastic deformation of the matrix resin as reported in (D.G. Dikobe and A.S.Luyt,2010 ; Lee Yip Seng et.al., 2011).

CONCLUSIONS

From the presented experimental results of this research, the following can be the conclusions:-

1-The mechanical properties (fracture strength, young modulus, compressive Strength and hardness for two groups increase with the addition of the PMMA in the blend, and reach highest values at 5% PMMA ratio, whereas the elongation rates decreases with increasing PMMA ratio in the blend.

2- As well as the addition 5% PMMA to polymer blend (epoxy: 2% or 5%NR) gave the best mechanical properties such as the tensile strength, young's modulus, compressive strength and hardness.

3-The test values of mechanical properties for the first group polymer blend are higher than the values of the second group and it can be seen that increasing the weight percentage of PMMA at ratios more than 5% decreased the values of mechanical properties for ternary polymer blends samples.

4- The morphological analysis of the fractured surface of ternary polymer blend (EP: 5%NR: 5%PMMA) showed rubber dispersions in the sub-micrometer size (43.89um), the present a spherical droplet rubber particles will act as energy dissipating center in the epoxy .
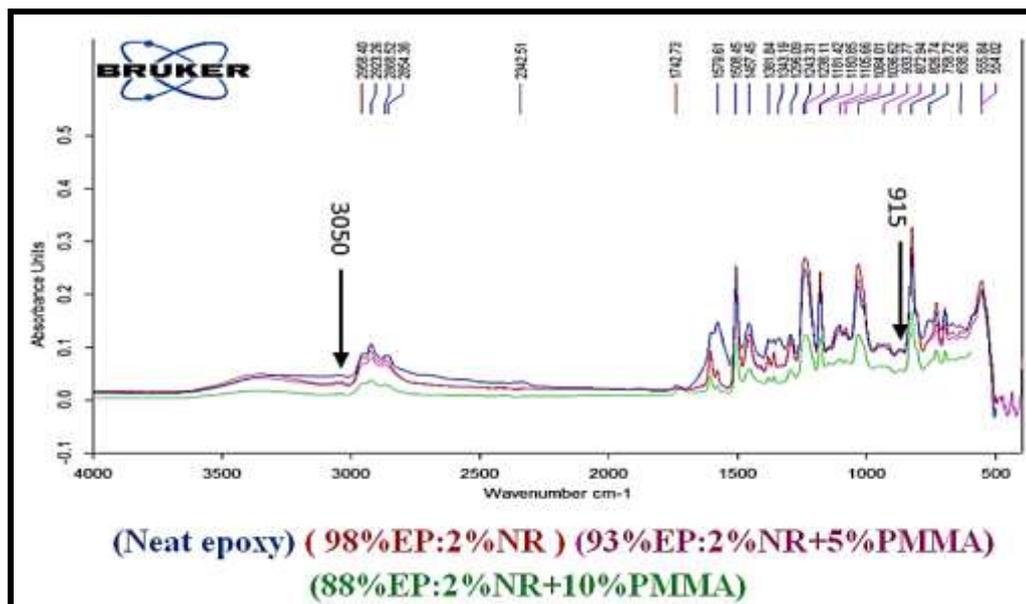

Fig (1) FTIR spectrum of ternary polymer blend (Epoxy-NR - PMMA) as a function of PMMA content in the blend
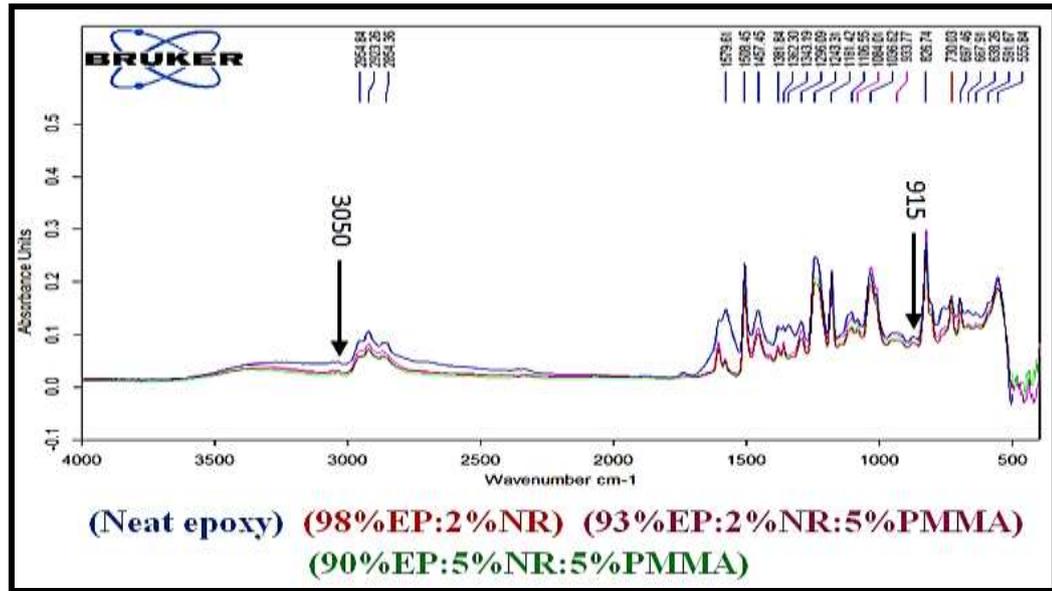
Fig (2) FTIR spectrum of binary polymer blend (98%EP: 2%NR) and ternary blend (Epoxy: X%NR: 5%PMMA), as a function of NR content in the blend
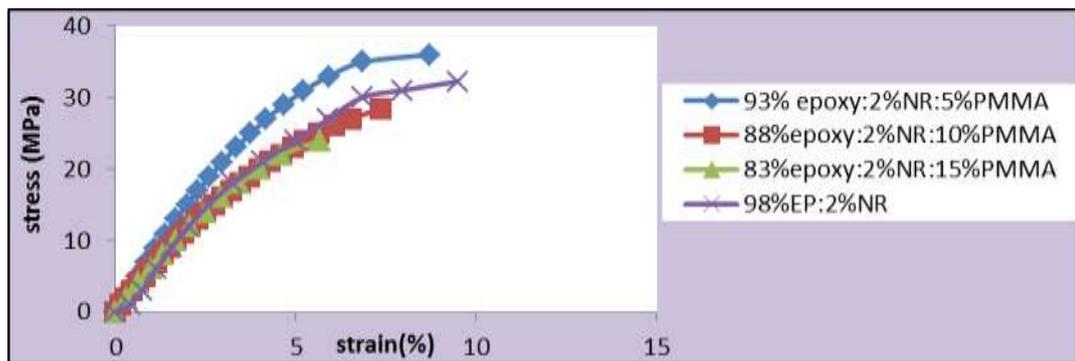(93%EP: 2%NR: 5%PMMA) and (90%EP: 5%NR: 5%PMMA)

Fig (3) Stress-strain curves for ternary polymer blends (epoxy: 2%NR: X% PMMA)
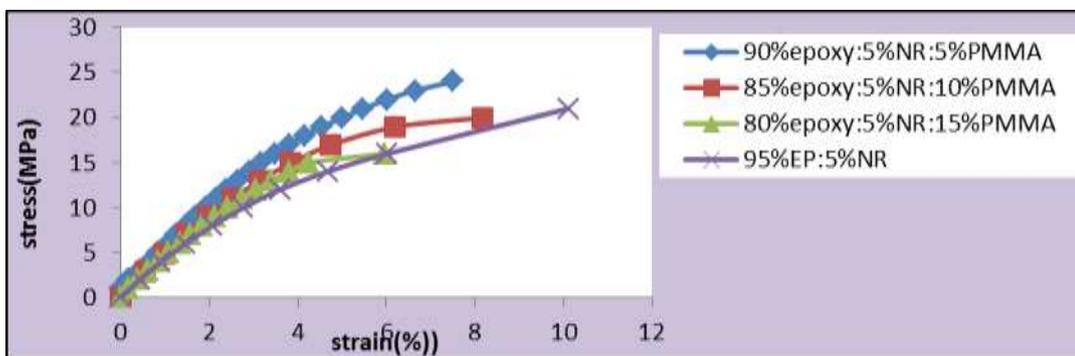as a function of PMMA content in the blend

Fig (4) Stress-strain curves for ternary polymer blends (epoxy: 5%NR: X% PMMA)
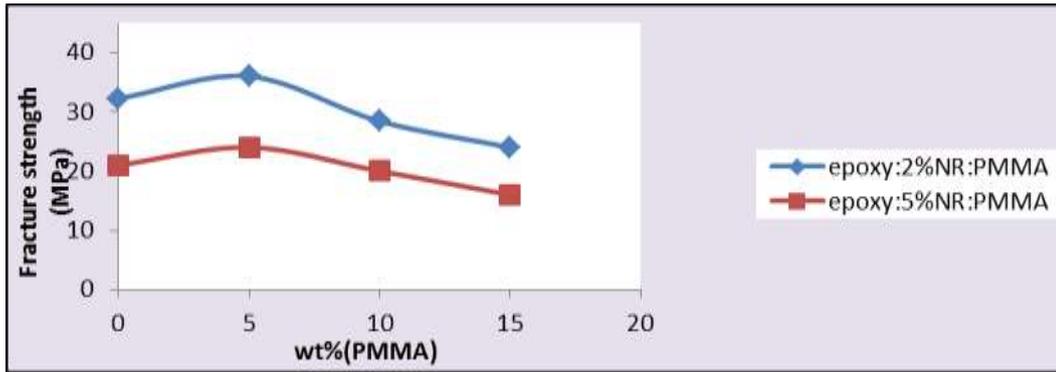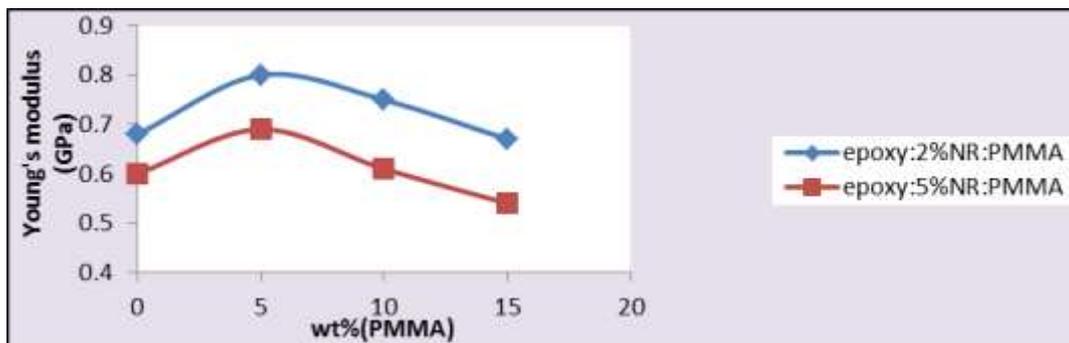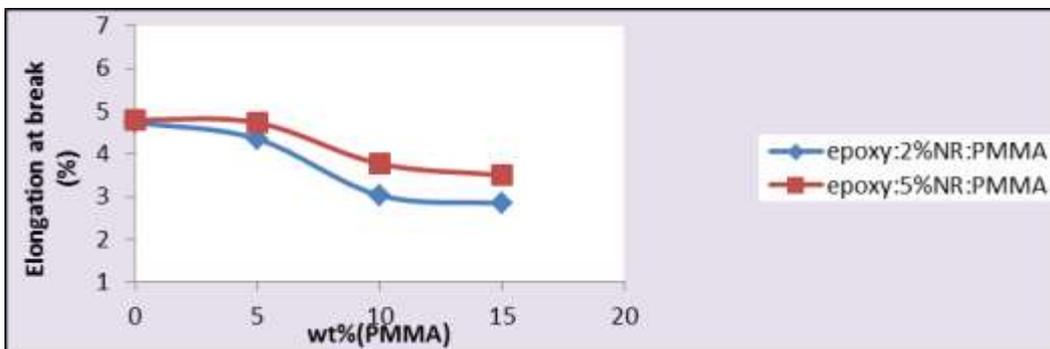as a function of PMMA content in the blend

Fig (5) Fracture strength for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
as a function of PMMA content in the blend .

Fig (6) Young's modulus for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
as a function of PMMA content in the blend .

Fig (7) Elongation at break for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
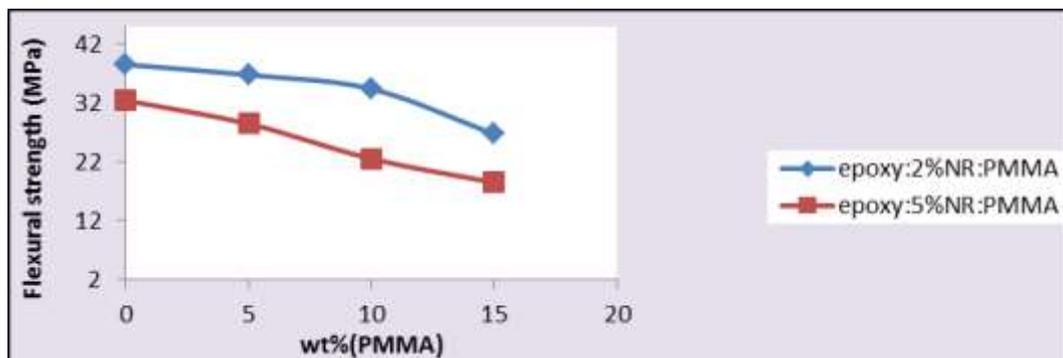content in as a function of PMMA the blend

Fig (8) flexural strength for ternary polymer blend (Epoxy: 2 or 5%NR: X% PMMA)
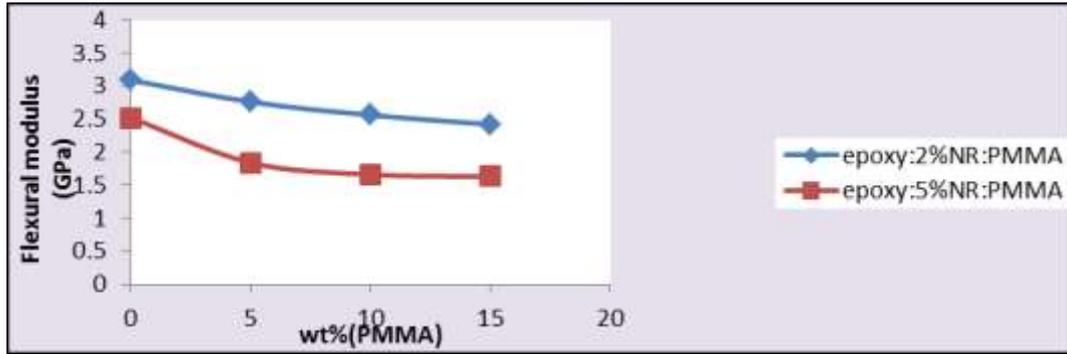as a function of PMMA content in the blend.

Fig (9) Flexural modulus for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
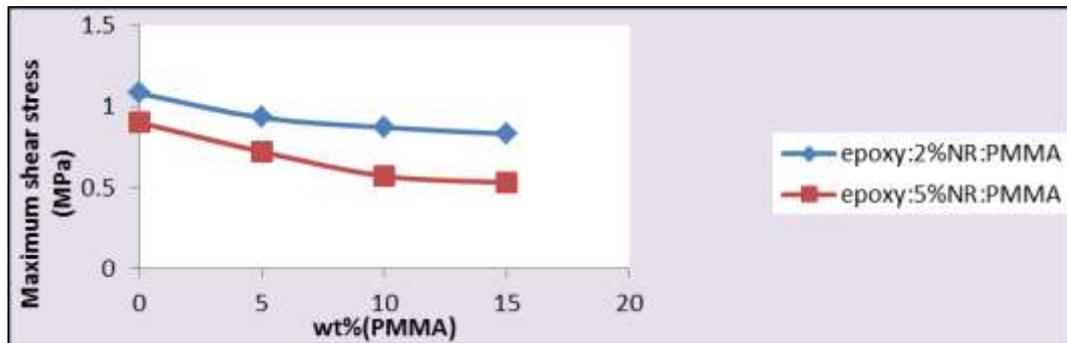as a function of PMMA content in the blend .

Fig (10) Maximum shear stress for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
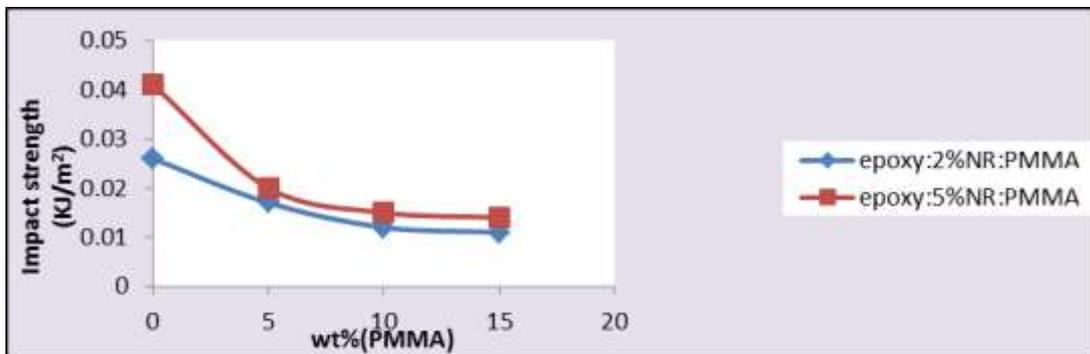as a function of PMMA content in the blend.

Fig (11) Impact strength for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
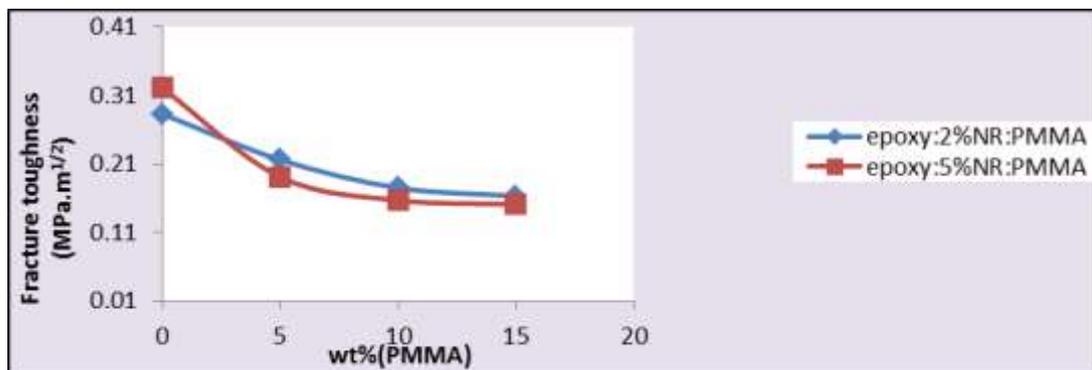as a function of PMMA content in the blend

Fig (12) fracture toughness for ternary Polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
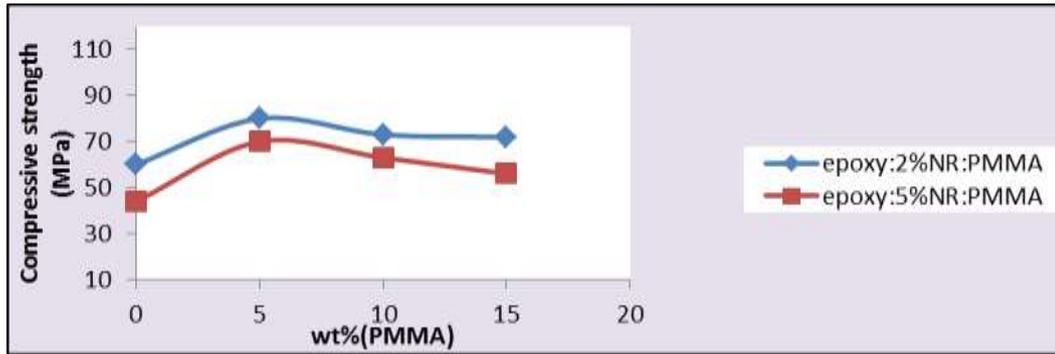as a function of PMMA content in the blend

Fig (13) Compressive strength for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
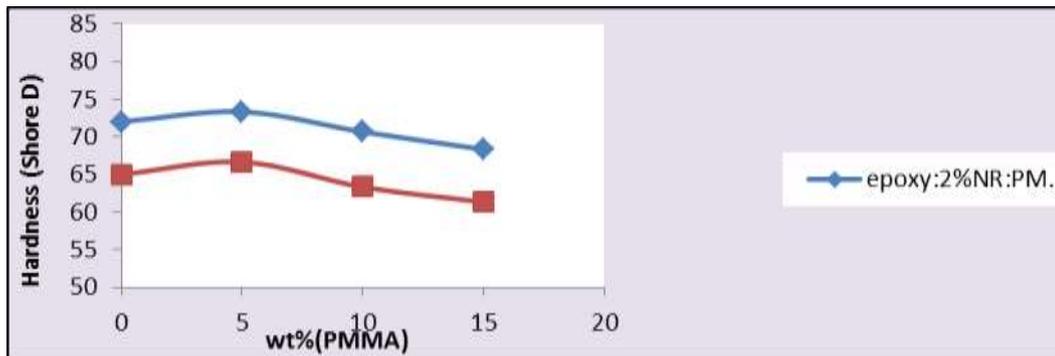as a function of PMMA content in the blen

Fig (14) Hardness for ternary polymer blend (Epoxy: 2 or 5%NR: X% PMMA)
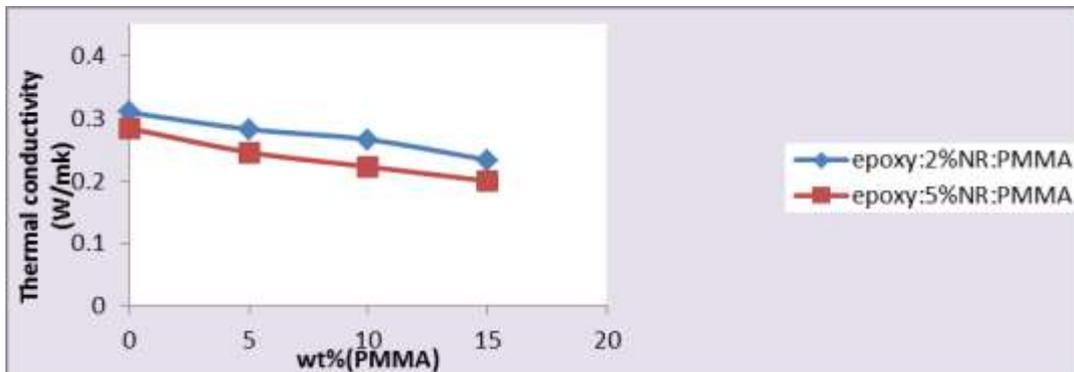as a function of PMMA content in the blend

Fig (15) Thermal conductivity for ternary polymer blends (Epoxy: 2 or 5 %NR: X% PMMA) as a function
of PMMA content in the blend.
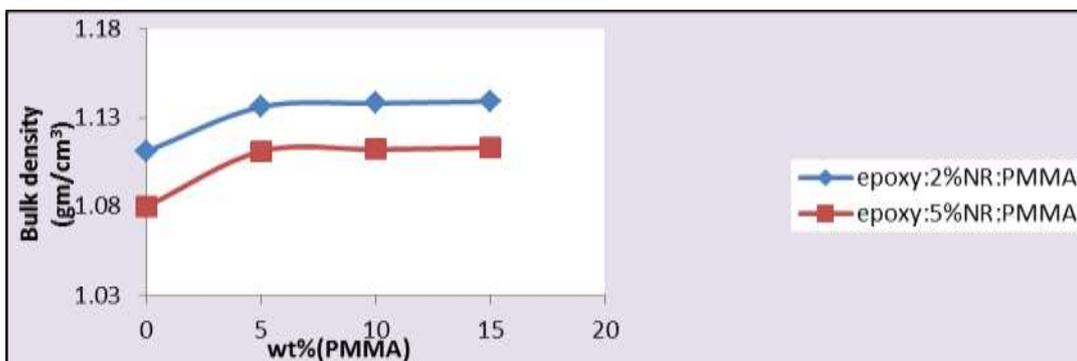
Fig (16) Bulk density for ternary polymer blend (Epoxy: 2 or 5 %NR: X% PMMA)
as a function of PMMA content in the blend.

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a-Neat Epoxy

b- (98%Epoxy:2%NR)

c- (95%Epoxy: 5%NR)

d-(93%EP:2%NR: 5%PMMA)

e-(90%EP:5%NR: 5%PMMA)

Fig (17) DSC images illustrating of (T_g) values for
(a) neat epoxy, binary polymer blend   (b) (EP-2%NR),
(c) (EP-5%NR), ternary polymer blend   (d) (EP: 2%NR: 5%PMMA) and
(e) (EP: 5%NR: 5%PMMA)

Table (1): Tg values of (epoxy-NR) polymer blend as a function of PMMA

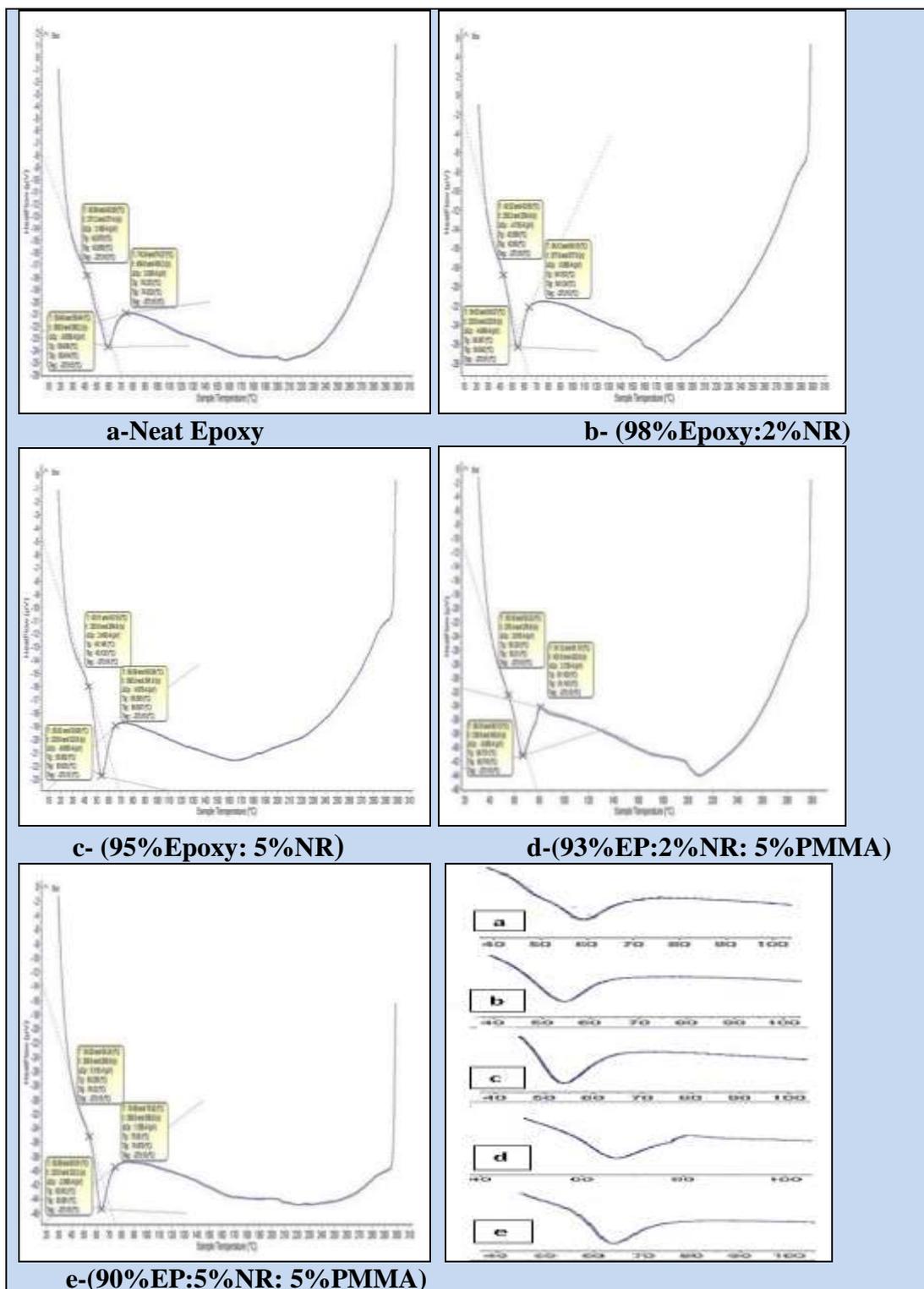| Samples	Tg ^{o}C
neat epoxy	59.41 ^{o}C
(98%:2%NR)	54.63 ^{o}C
(95%EP:5%NR)	53.99 ^{o}C
(98%EP:2%NR:5%PMMA)	66.69 ^{o}C
(95%EP:5%NR:5%PMMA)	63.87 ^{o}C

a- (98%EP:2%NR)

b-(93%EP:2%NR:5%PMMA)
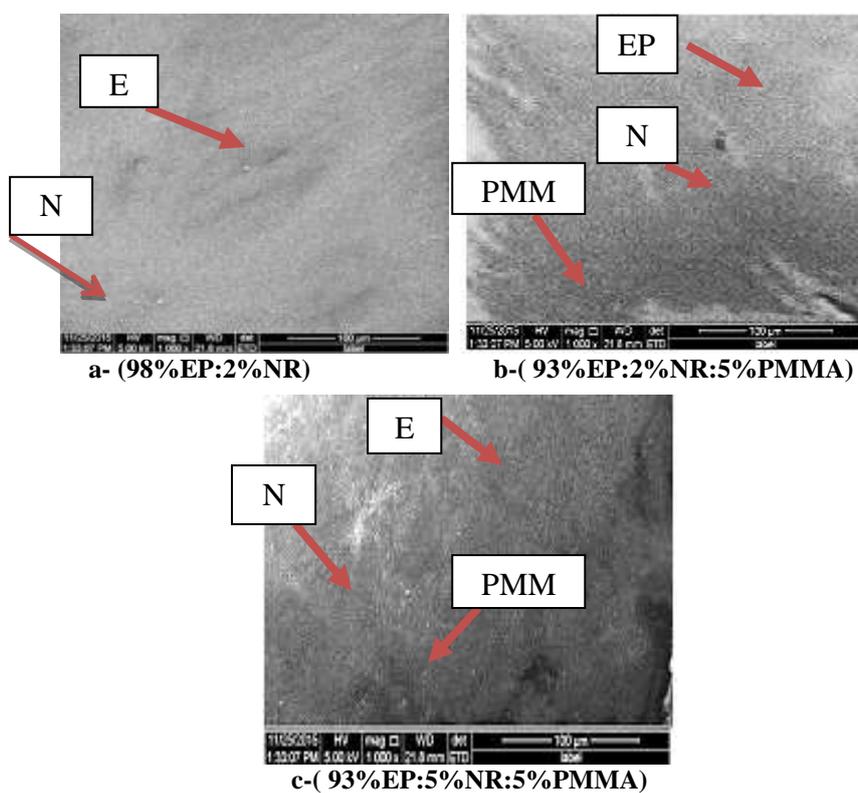
c-(93%EP:5%NR:5%PMMA)

Fig (18 a, b, c and d) SEM Images Showing the effect of addition (5%PMMA) on the Surface Morphology of polymer blend (98%EP: 2%NR) at Magnification (X=1000)

Comparative Study between Specifications of Two groups of
the ternary Polymer blend Used in structural applications

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Wafaa M. Salih
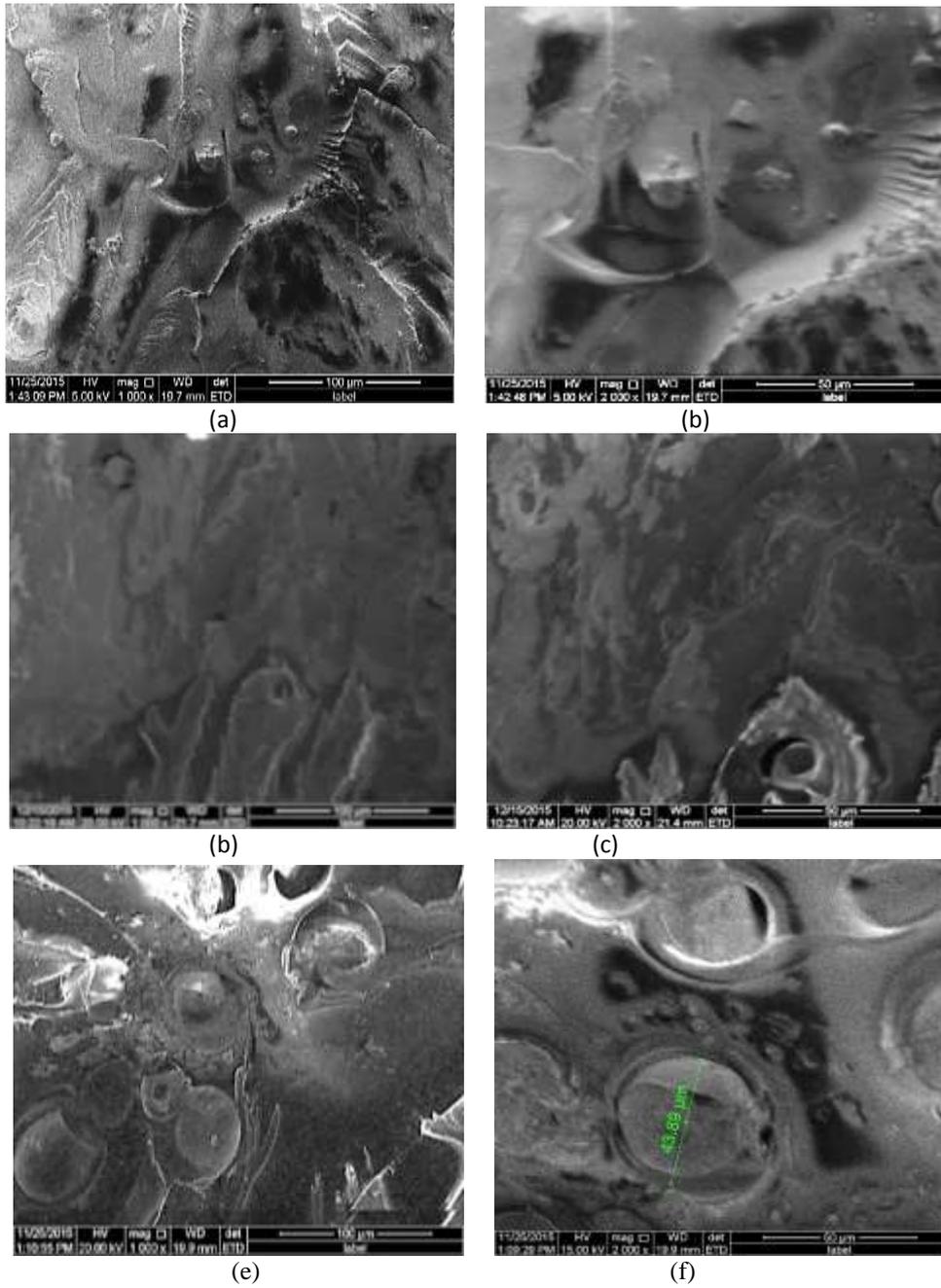**Masarra A. Abdul hameed**

Fig (19) : SEM photos of the fracture surfaces Morphology of (a and b) binary
polymer blend (EP: 2%NR) , (c and d) of ternary polymer blend
(EP: 2%NR: 5%PMMA) and (e and f) of ternary polymer blend
(EP: 5%NR: 5%PMMA) . At different Magnification
[(a) (c) and (e) (1000× magnification)] ; [(b), (d) and (f) (2000× magnification)] .

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