STUDY ON EFFECT OF VARIATION OF DIISOCYANATE AND NCO/OH MOLAR RATIO ON MECHANICAL, THERMAL AND ELECTRICAL PROPERTIES OF INTERPENETRATING POLYMER NETWORKS DERIVED FROM BIOMASS

Corresponding Author: K. Rathika1* and S. Begila David 2 1Research scholar, Reg No: 10252 , Scott Christian College, Affliated to MS university, Abishecpatty, Tirunelveli, [2] Assistant professor, Department of chemistry, Scott Christian College (Autonomus), Ngl.

ABSTRACT

Polymers derived from biomass are now a matter of the utmost importance from both commercialand academic points of view.Interpenetrating polymer networks were prepared from Castor oil, toluene 2,4diisocyanate, Acrylonitrile withsuch polymers were investigated by FTIR spectroscopy. All these IPNs films were characterised byresistance to chemical reagents, swelling behavior, mechanical studies such as tensile strength, Young's modulus, elongation at break (%) and soil burial. Thermal stability behavior of the polymer degradationwas studied by thermogravimetric analysis (TGA), and differential thermal analysis (DTA). Dielectric ptrperties such as dielectric constant,dielectric loss and dielectric loss tangent were also estimated.The scanning electron microscopy (SEM) micrographs revealed changes in the surface morphology of thepolymers.

Key words: Castor oil; Acrylonitrile; cross linkedpolyurethanes; interpenetratingpolymer networks; crosslinkerN,N'methylenebis acrylamide;

INTRODUCTION

Interpenetrating polymer networks (IPNs) constitute a rapidlydeveloping branch of polymer blend technology which may intimatelycombine the properties of two crossliniked polymers in a network form1.An IPN structure is obtained when atleast one polymer network issynthesized and/or crosslinked in the immediate presence of the other.Proper combination and interpenetration of polymer networks will enableto enhance certain properties which are otherwise difficult to achieve bychemical variations in the polymer chain. The IPNs synthesized by thecombination of various chemical types of polymer network exhibitvarying degree of phase separation depending on the compatibility ofcomponent polymers2-4.In recent time IPNssynthesized from castor oil have been paid good attention in theindustrial applications5 (Begum and Siddaramaiah, 2004).IPNs have been used as damping materials6-8,biomedical materials9, gas transport membranes10.Polyurethanes (PU) comprise a class of materials which can varywidely from rubbery to glassy thermoplastics and from linear polymer tobeing a thermoset. By varying the processing conditions the properties ofpolyurethanes can be tailor-made to produce desirable molecular structureand physical properties11-13.Castor oil and its derivatives have been usedin the preparation of rigid, semirigidand flexible polyurethane foams 14.Castor oil polyurethanes have been used for the synthesis of semi IPNsand sequential IPNs 15.

MATERIALS AND METHODS

Castor oil, toluene 2,4-diisocyanate (TDI), N,Nmethyleneacrylamide and benzoylperoxide (sigma aldrich) were used.Acrylonitrile (AN) monomer from HPLC chemicals.All other reagents were of analytical grade .

.Preparation of Polyurethane prepolymer (PPU)

A reaction kettle, under dry nitrogen, was charged with TDIand castor oil of varying ratio of NCO/OH was added slowlywith stirring. The reaction was carried out at 45°Cfor 1h.

Synthesis of Interpenetrating Polymer Networks (IPNs)

The PU and AN in different weight to weight ratios wereseparately taken in presence of the initiator and the crosslinker.The mixture was constantly stirred at room temperature for

15min. Thereafter, the temperature was increased to 75°C withstirring for about 1 h which was poured into a glass mould andkept in an oven at 75°Cfor 24 h. The thin film was formed,

cooled and removed from the mould.

Table 1 Data on feed composition of individual IPNs

Sample code	NCO/OH	Content of polyurethane (wt%)	Content of monomer(wt%)
IPN-1CA	1.6	25	75
IPN-2CA	1.6	35	65
IPN-3CA	1.6	45	55
IPN-4CA	1.8	25	75
IPN-5CA	1.8	35	65
IPN-6CA	1.8	45	55
IPN-7CA	2.0	25	75
IPN-8CA	2.0	35	65
IPN-9CA	2.0	45	55

Characterization Methods

Infrared spectra

Infrared spectra of the synthesized IPNs in KBr pellets wereobtained from Shimadzu FTIR 4200 series spectrophotometer.

Mechanical properties

The tensile strength, Young's modulus and elongation at breakwere measured at room temperature using InstronHouns-Fielduniversal testing machine model 4204 as per ASTM D-638mthod.

Resistance to chemical reagents

Acid, alkali and solvent resistance were estimated according to ASTM-D543-67 method. Samples were hung in the reagent for seven days and tested for change in weight and for their film appearance16.

Determination of StablityIn Organic Solvents

The stability of the newly prepared biopolymers in common organic solvents acetone,toluene ,methyl ethyl ketone and dimethyl acetamide (DMA) were carried out according to ASTM C 267. The conditioned samples were kept in 100 ml of the organic solvent for the period of 60 days.The medium was changed once in a week.The weight loss was determined17.

Thermogravimetric analysis

In the present work, TGA/DTA studies were carried out usingSDT Q 600V 8.3 build 101 instrument at the heating rate of10 C/min from ambient to 700 C in nitrogen atmosphere using2-5 mg of the sample 18.

Electrical properties

The IPNs prepared from castor oil and toluene -2,4-diisocyanatereacted with acrylic monomer likemethyl mithacrylate were taken for experiment to determineelectrical properties.Dielectric properties such as dielectricconstant and loss factor were evaluatedby taking thin film of 8 mm diameter (d) and thickness (t) of 0.3 mm,using Hioki-3532-50 LCR Hitester Instrument.

Soil burial test

The replicate pieces of the sample (5 cm x 3 cm) were buried in the garden soil at the depth of 30 cm from the ground surface for 3 months, inoculated with the sewage sludge having ability to adhere and degrade the polymer film. The test specimen was periodically removed from the soil and the specimen was then gently washed to remove attached soil and dust after being dried in vacuum oven19. The extent of degradation was examined by weight loss and surface observation. Scarming Electron Microscope (SEM) was used for assessing surface damages of polymeric sheet subjected to soil burial test.

Scanning electron microscopy

To produce the SEM image, the electron beam is swept across the area being inspected, producing many such signals. These signals are then amplified, analyzed, and translated into images of the topography being inspected. Finally, the image is shown on a CRT20.

The surface morphology of the samples were done by a Joel scanning electronmicroscope of model JSM-6390LV SEM after platinum coating on the surface.

RESULTS AND DISCUSSION

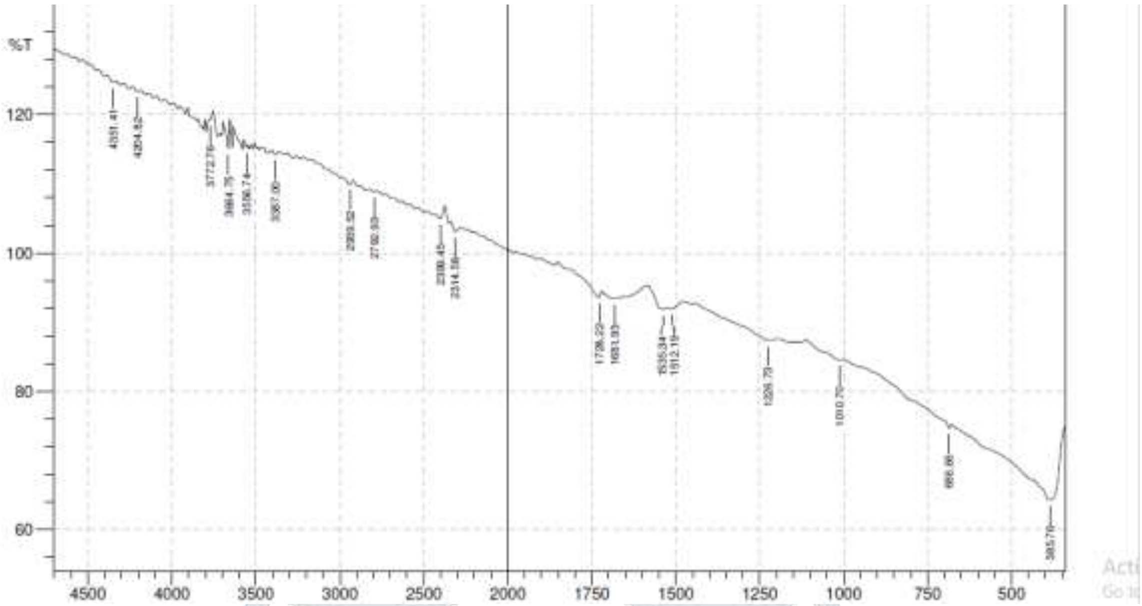
FT-IR Spectral Analysis

FTIR provides a method for identifying the chemical bonds and units present it the chemical structure. This method can be used to identify whether any new bonds or units have been constructed during the curing of the mixtures. In particular, the goal is to identify whetherthere are bonds or units that are not present in the pure networks, as they would indicates thatmore than a simple IPN mix of two networks is obtained.

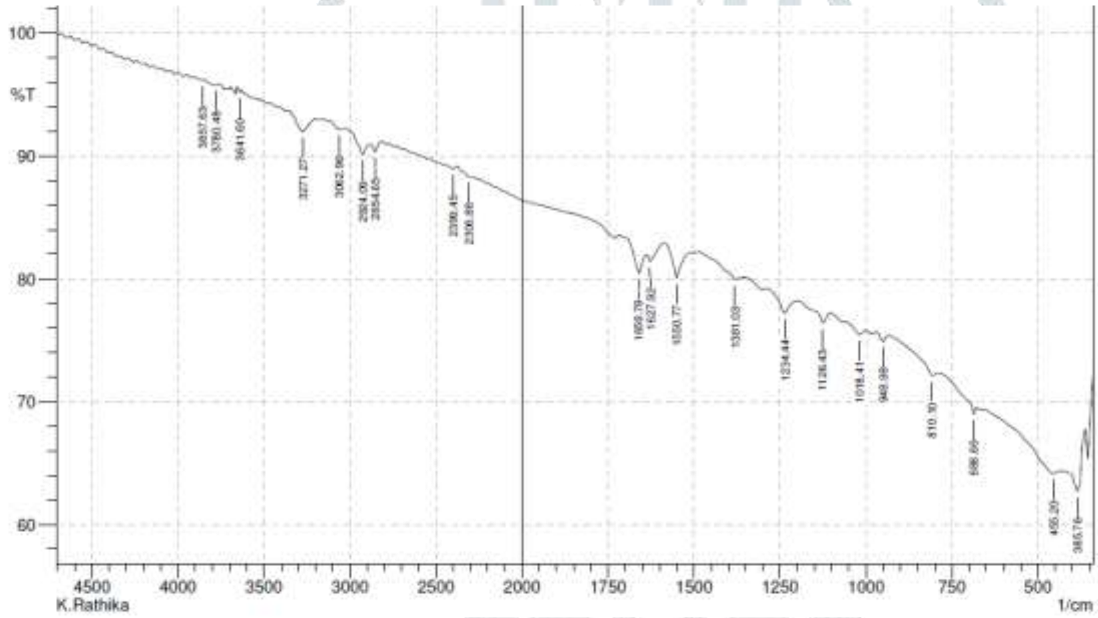
The presence of component materials in the macromolecules was confirmed by the study of FT-IR spectra. The characteristic absorptions of IPN-3CA corresponding to N-H stretching of >NH group at 3387 cm-1, C-H stretchings (ss/as) of >CH2 and -CH3 groups at 2792.97 cm-1 and 2939.52 cm-1, there is no absorption band at 2260 cm-1 due to NCO group of polyurethane, but C=O stretching of urethane linkage at bending at 1226.73 cm-1 was observed(Prashantha et al.,2001) relied on these two confirmation signals during preparation ofGC–PU/PHEMA interpenetrating polymer networks were obtained by transfer moulding21. The interpretations in present study are in accordance with these reported observations.

The characteristic absorptions of IPN-6CA corresponding to N-H stretching of >NH group at 3271.27 cm-1, C-H stretchings (ss/as) of >CH2 and -CH3 groups at 2854.65 cm-1 and 2924.09 cm-1, there is no absorption band at 2260 cm-1 due to NCO group of polyurethane, C=O stretching of urethane linkage at 1658.78cm-1. C-O bending at 1234.44.

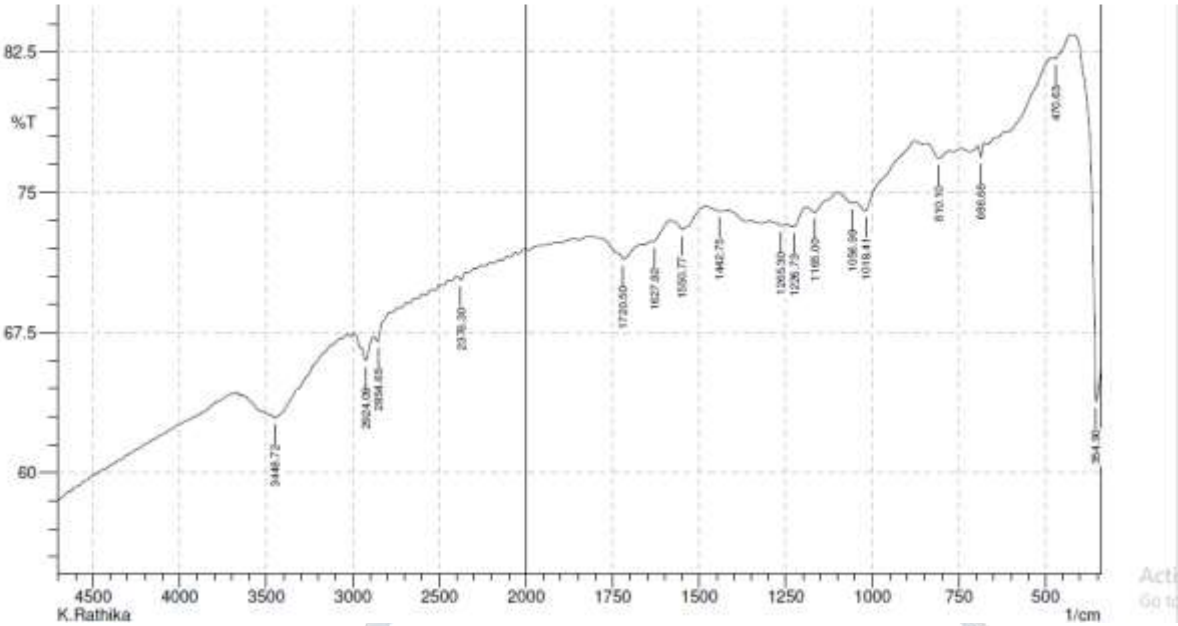
The characteristic absorptions of IPN-9CAM corresponding to >N-H stretching of =NH group at 3448.72 cm-1, C-H stretchings (ss/as) of >CH2 and -CH3 groups at 2854.65 cm-1 and 2924.09 cm-1, there is no absorption band at 2260 cm-1 due to NCO group of polyurethane prepolymer C=O stretching of urethane linkage at 1720.50, C-O bending at 1226.73. These are presented in Figure 1.



IPN-3CA



IPN-6CA



IPN-9CA

Figure 1 IR- Spectrum of IPNs

Mechanical properties

The mechanical properties of the systems were evaluated using tensile testing. This provides information such as initial Young's modulus,elongation at break, ultimate stress and strain.The mechanical propertiesnamely tensile strength, Young's modulus, elongation at the breakingpoint, have been presented in Table-2.

These IPNs exhibit good mechanical properties as compared to their individual component networks I and II22.Component network I is a swollen crosslinked polyurethane which is elastomeric in nature and has been used in liquid phase in this investigation. Interpenetration of this liquid polyurethane with AN monomer results in hard elastomeric films. Increase in polyurethane content in the IPN increases the extent of crosslinking in IPN and dominates the behaviour of the overall IPNs. Incorporation of polyurethane as a separate phase in the poly(AN) matrix of IPNs improved the mechanical properties. Thus it is observed that IPNs obtained from elastomeric PU and AN have quite different properties from their individual monomers. This supports further the observations made by earlier workers 23.

Table2 Mechanical properties of IPNs

Samples	Tensile Strength(Mpa)	Elongation at break(%)	Young's Modulus(Mpa)
IPN-1CA	2.86	148	2.54
IPN-2 CA	3.42	137	2.68
IPN-3CA	3.96	126	3.02
IPN-4CA	7.46	119	3.43

IPN-5CA	6.92	108	4.15
IPN-6CA	8.74	102	4.85
IPN-7CA	9.14	96	5.32
IPN-8CA	10.69	93	6.52
IPN-9CA	11.26	88	7.27

Chemical resistance

Chemical resistance test was carried out according to ASTM-D543-67. Degradation of biopolymers in 25% CH_3COOH,25% H_2SO4,25% HCl,5%HNO_3 and NaOHwasstudied and the weight loss % was estimated. The weight loss % in chemical resistance test was presented in Table 3 The weight losses of all samples were faster at PH greater than 10. It is because the base promotes hydrolysis by providing the strong nucleophilic reagent OH –, the degradation was faster with increase in PH . The degradation of crosslinked biopolymers was very high in sodium hydroxide. Here, the biopolymers with ester linkages can be easily hydrolyzed in the presence of alkalis.

Table 3 Weight loss % in chemical resistance test

Samples	25%CH_3COOH	25%H_2SO_4	25%HCl	5%HNO_3	NaOH
IPN-1CA	3.3204	1.1402	.6901	.5402	.5410
IPN-2CA	3.0253	1.2430	.6651	.6515	.6076
IPN-3CA	3.3140	1.2501	.6764	.5064	.5205
IPN-4CA	3.0205	1.1800	.6430	.5576	.5302
IPN-5CA	3.2431	1.3786	.6322	.4806	.5541
IPN-6CA	3.5424	1.8103	.6618	.4682	.5652
IPN-7CA	3.8060	1.1505	.6734	.6560	.5680
IPN-8CA	3.3240	1.6420	.7910	.6014	.5907
IPN-9CA	3.6215	1.1806	.8034	.6210	.6415

The percentage weight loss of IPNs were determined in CH_3COOH,H_2SO4, HCl, HNO_3, and NaOH etc. the results are furnished in table 3. All the IPNs show excellent acid and alkali resistance .Nayak et al .,199724 all the IPNs show excellent acid and alkali resistance as compared to unmodified castor oil polyurethane/PHEMA IPNs. It is observed that IPNs irrespective of NCO/OH ratio and PU/PHEMA composition, are stable in acids and alkali. Thus the polymers are stable towards acids, and alkali. But in alkaline medium high weight loss % was observed. After the chemical ageing the polymer film become irregular with large number of pits, granular formation and cracks on the surface. The number of granular formation, cracks and pits becomes deeper with increasing time. IPNs likeIPN-1CA,IPN-4CA and IPN-5CA shows very good chemical resistance than the other IPNs.

Stability in organic solvents

The commonly used organic solvents such asacetone, toluene ,methyl ethyl ketone and dimethyl acetamide (DMA) are used in the present study. Weight loss percentages of samples were shown in Table 4 lowest degradation rates were observed. This is due to the hydrophobic nature of this polymer network appeared by the long aliphatic hydrocarbon chain of fatty acid part of the triglyceride reported elsewhere 25. IPNs are swelled in all the solvents like acetone, toluene ,methyl ethyl ketone and dimethyl acetamide (DMA). Some weight loss and dimensional changes was observed in soft segment of polymers.These IPNs are lose their gloss in acetone, toluene and methyl ethyl ketone.Among all the solvents used, the solubility parameter of dimethyl acetamide (δs) was found to be the solubility parameter of polyurethanes, as there was maximum swelling only in this solvent. Due to higher crosslink density the percentage of weight loss was lesser in samples like IPN-1CA andIPN-3CA . Samples like IPN-4CA and IPN-5CA shows higher weight losspercentage.

Table 4 Weight loss percentage in organic solvents

Samples	NCO/OH Molar ratio	PU/PMMA weight ratio	acetone	Toluene	Methyl ethyl ketone	Dimethyl acetamide
IPN-1CA	1.6	25/75	.05	.00	.02	.14
IPN-2CA	1.6	35/65	.04	.02	.04	.12
IPN-3CA	1.6	45/55	.02	.01	.02	.08
IPN-4CA	1.8	25/75	.05	.05	.05	.10
IPN-5CA	1.8	35/65	.03	.05	.07	.12
IPN-6CA	1.8	45/55	.03	.04	.04	.08
IPN-7CA	2	25/75	.04	.03	.03	.08
IPN-8CA	2	35/65	.04	.04	.01	.06
IPN-9CA	2	45/55	.06	.05	.01	.07

THERMAL STUDIES

TGA Studies

The thermal stabilities of IPNs were studied from their thermograms ,which are asshown in Figure 4. For the same purpose we have chosen in the random manner, IPN-3CA, IPN-6CAand IPN-9CA.

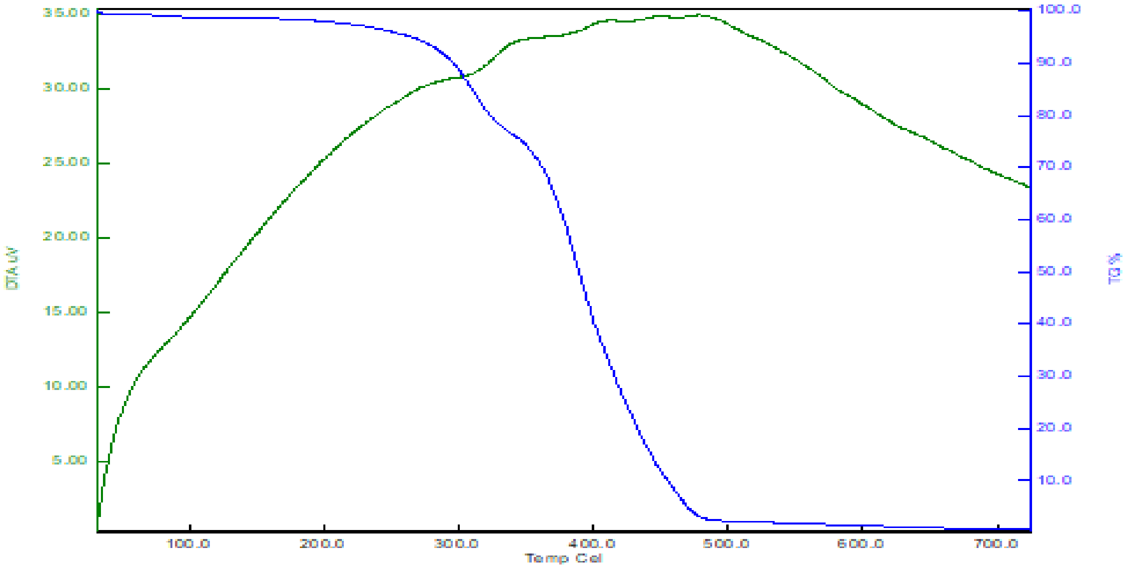
The data showing the percentage weight loss at various temperatures are furnished in table. The thermogravimetric analysis reveals that the IPNs are thermallystable up to 250 C with minor weight losses. These weightlosses are due to loss of moisture and elimination of solventmolecules embedded in the samples. Thesignificant weight losses of these three IPNs are observed in the temperature range of 300 C-500 C, which can be attributed to the decomposition of benzene ring and decomposition of crosslinking with N-N methylene bisaerylamide between PU and MMA monomer units. The minor weight losses between 500C- 700C are due to complete decomposition of cross linking’s with N-N methylene bis acrylamide between PU and AN monomers units.Mohanty et al. 2012, which also supports the above discussed results26.

Table 5 TGA data of IPNs

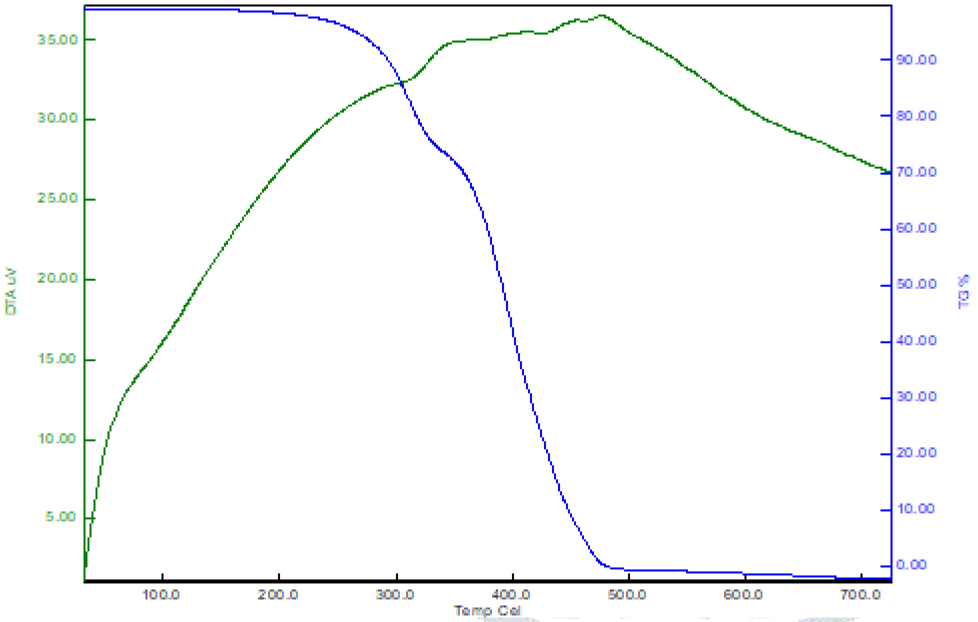
Sample code	200	300	400	500	600	700
IPN-3CA	0	20	60	35	95	99
IPN-6CA	5	30	65	30	98	-
IPN-9CA	5	20	60	31	90	99

Differential Thermal Analysis

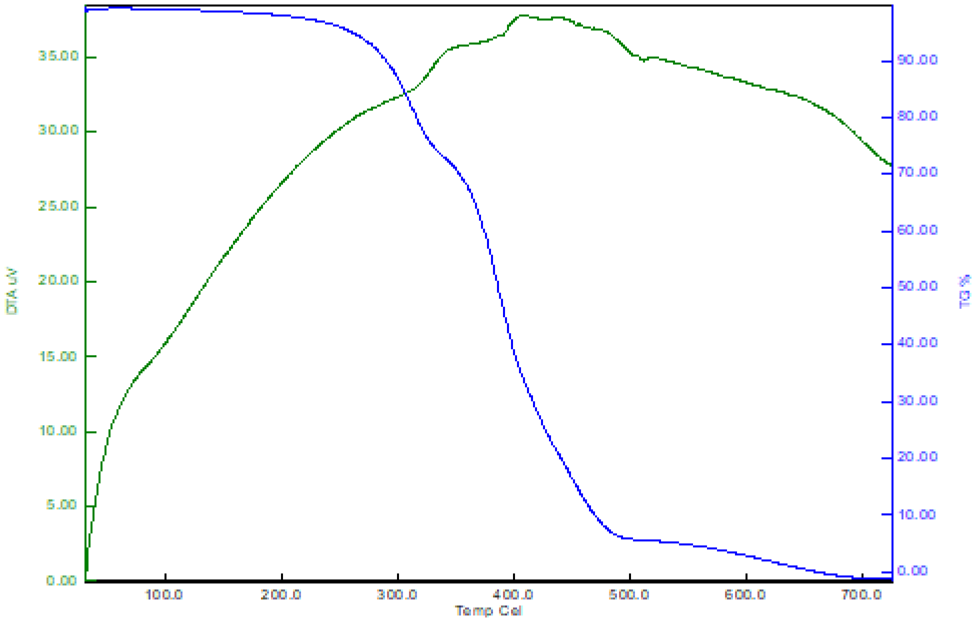
The Differential themal analysis (DTA) of IPN samples and castoroil polyurethane are presented in Fig. 2. DTA curvesshow a series of degradation processes occurring in a particulartemperature range. The DTA curves of IPN do not show any endothermic peak for softening. But two or three exotherms areinvariably seen in the cured samples. The Differential thermal analysisdata is presented in Table 5.8. In case of IPNs with NCO/OH ratio 1.6 thefirst exotherm is observed in the range of 330°- 360°C; second exothermappeared nearly 420-440°C and third exotherm appeared betweennearly 480-490°C. IPNs with NCO/OH ratio 1.8 show the first exothermbetween 340° -360°C; second exotherm between 440° - 460°C and thirdexotherm is around 495°C. In the case of IPNs with NCO/OH ratio 2 the first exotherm is observed between 350° - 360°C; secondexotherm appeared between 440°- 460°C and third exotherm appearedaround 510°C. It has been reported27,28 that the exotherm around350° C is relatively weak and is due to the cleavage of meta substituted long alkenyl side chain of the phenyl ring. The second exotherm around440° to 480° C, which may be due to the breaking up of -CO-NH bond.The exotherm around 520° to 580° C is due to disintegration ofpolyurethane moiety. IPN-3CA with NCO/OH ratio 1.6 contains 45 % castoroil polyurethane shows three exotherms at 337°C, 420°C and 485°Crespectively. IPN-6CA with NCO/OH ratio 1.8 contains 45 % castor oilpolyurethane shows three exotherms at 359°C, 445°C and 495°Crespectively. IPN-9CA with NCO/OH ratio 2.0 having 45 % castor oilpolyurethane shows three exotherms at 360°C, 450°C and 510°Crespectively. The thermal stability of IPNs increases with the increase ofpolyurethane content. Similar trend is observed in all the other IPNs.



TGA/DTA curve of IPN-3CA



TGA/DTA curve of IPN-6CA



TGA/DTA curve of IPN-9CA

Figure 2 TG/ DTA of IPNs

Table 6 DTA data of IPN polymer samples

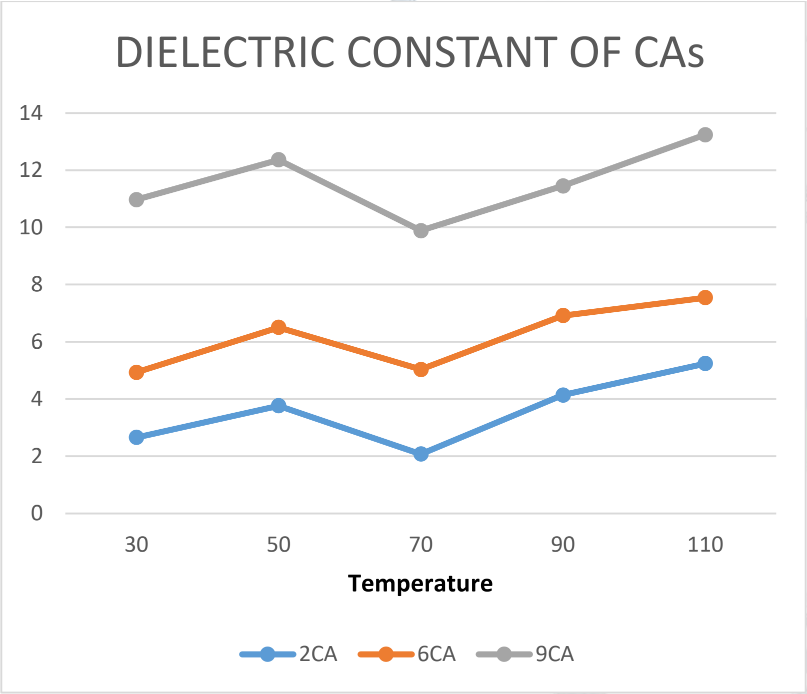
Sample code	Composition	NCO/OH molar ratio	PU/PMMA wt. ratio	Temp.C	DTA Peak/C Exo
IPN-3CA	PU+AN	1.6	45:55	300-400 400-500	337 420 485
IPN-6CA	PU+AN	1.8	45:55	300-400 400-500	359 440 495
IPN-9CA	PU+AN	2.0	45:55	300-400 400-500	360 450 510

Electrical properties

Updated survey of the literature reveals that there are relativelyfew reports available regarding the dielectric behaviour ofIPNs.The dielectric properties (ε’,ε”, and tan δ)versus temperatureat 10 KHZ frequency for 1PN-3CA, IPN-6CAand IPN-9CA are shownin Figure-3.The fact that dielectric loss (ε”) does notchange with temperature implies that IPN does not undergo attenuationwhen placed in dielectric field.Dielectric constant is the ability of a dielectric material to storeelectric potential energy under the influence of an electric field.Dielectric constant (ε’) is a propertyof insulation, which determines the electrostatic energy storedwithin the solid material. For all the IPNs, at a given test frequency,dielectric constant increases wiith increase in temperature due to softeningof IPNs. At a high temperature, dielectric constant reachesa plateau and then gradually decreases (dip) at some temperature rangearound 70°C and later on, it increases. The gradual decrease comes from a decrease in the orientation of the dipoles as the kinetic motionof the molecules opposes the orienting effect of the dielectric field,and from the decrease in density. Loss tangent (tan §) would alsoexhibit similar behaviour as it is related to dielectric constant,

$$\varepsilon'' = \varepsilon' \text{ x } \tan\delta$$

From these dielectrical properties, it may be concluded thatthe IPNs prepared behave like semiconductor and havebordering properties of insulators29.



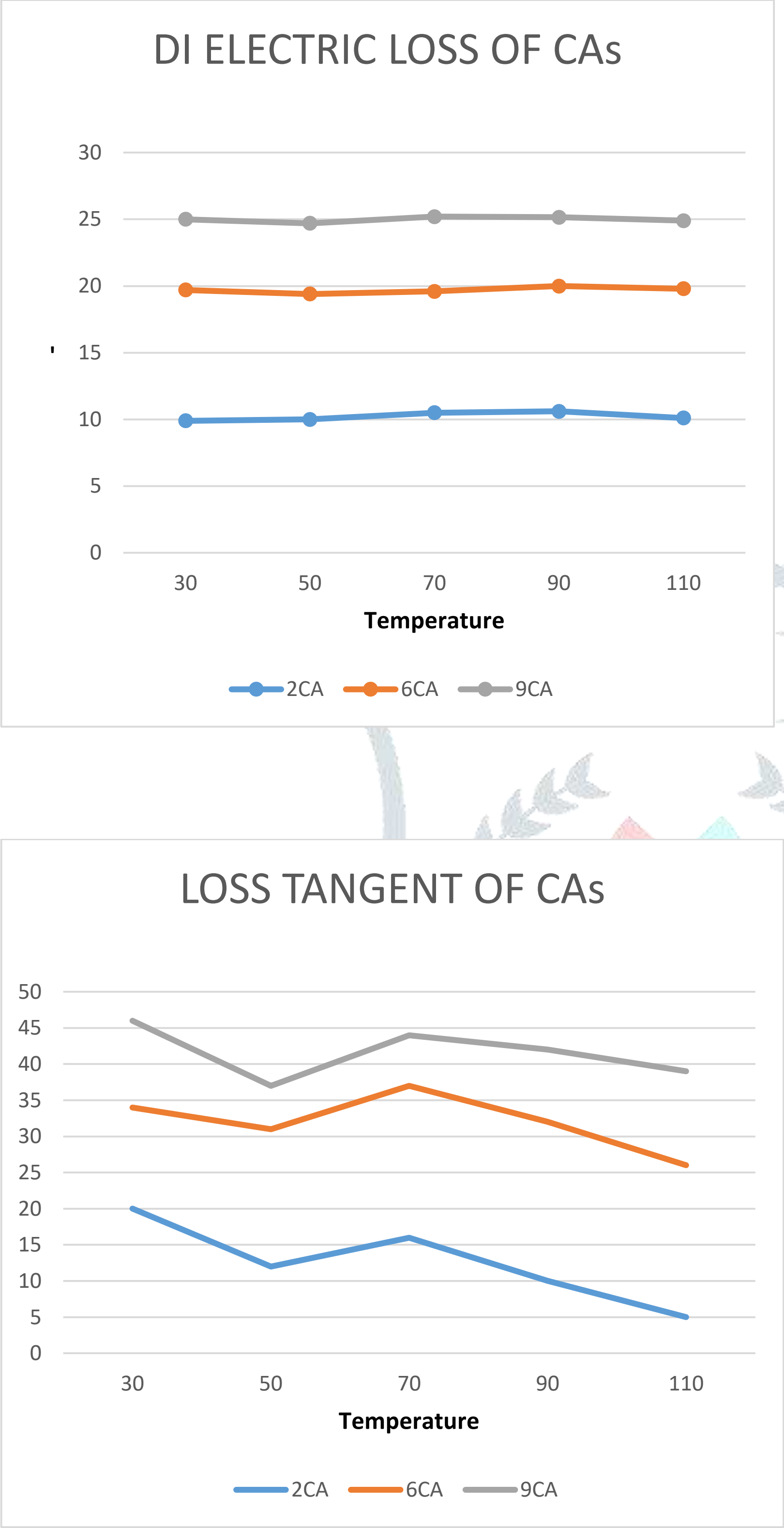


Figure 3 a) Dielectric constant of CAs b) Dielectric loss of CAs c) Loss tangent of CAs

Bio-degradation of polymers

Soil burial test

One of the serious problems, mankind is facing now, is theproduction and enormous use of the various types of man madepolymers, which is a growing threat for the environment due tounabated dumping. Since the polymeric materials do notdecomposed easily, that is why the environmental pollution andxenobiotic nature of these polymers is a worldwide problem30. Polyurethane is widely used invarious fields, such as manufacture of plastic foam, cushions,rubber goods, synthetic leathers, adhesive, paints, fibers etc.

The present study deals with the isolation of polyurethanedegrading microorganisms from the soil, analysis ofbiodegradation and optimization of various factors (temperature,pH and by using different co-metabolites). PU films were buriedin soil for a period of 3 months and then used for the isolation ofPU degrading microorganisms.Polyurethanes are considered to be comparativelysusceptible to microbial degradation 31. In our study, bacterial stainshaving the ability to utilizePU as a sole carbon source, were isolated after soil burialthrough enrichment in liquid medium. Kay et al. (1991) isolated 15 kinds of bacteria frompolyester PU pieces following their burial in soil for 28 days32.Shah et al (2008) also isolated 12 bacterial strains, 5 throughenrichment technique and 7 from buried PU films after sixmonths33. Soil organic carbon content and pH influence thestructure of soil microorganisms34.Attachment of microorganisms to buried PU is mediated bynonspecific hydrophobic interaction35and localenvironmental conditions also influence the surfacehydrophobicity of fungi and bacterial 36.Therefore, the differences in the physiochemical properties ofthe soil may influence microorganisms which successfullycolonize the surface of polyurethane.Biological degradation of polymers is generally influenced by anumber of factors. Besides the nature of the polymer substances,the kind of organism involved in biodegradation andenvironmental condition (e.g. nutrient supply, temperature andpH) are known to drastically influence the degradation rate37.

Weight loss in soil burial degradation test is given in Table 5.7. The calculation of biodegradation rate from weight loss of polymer films in soil burial test constitutes a practical problem, since the soil sticks on to the filmsurface, and weight measurement are not accurate. Kimura et al. in their study of degradation of plastics in the soil emphasized that the degradation of plastics were mainly caused by bacteria and fungi and that different soil conditions affected the rate of degradation of plastics 38.

Table 7 Weight loss in soil burial degradation test

Weight loss in grams			
Samples	Initial	after 30 days	after 60 days
IPN-1CA	2.062	2.057	1.956
IPN-2CA	2.820	2.078	2.002
IPN-3CA	2.048	2.044	1.862
IPN-4CA	2.048	2.046	1.844
IPN-5CA	2.069	2.065	1.976
IPN-6CA	2.052	2.052	1.974
IPN-7CA	2.060	2.058	1.930
IPN-8CA	2.117	2.115	2.017
IPN-9CA	2.058	2.058	1.953

The loss of tensile strength, discoloration and crackingobserved for soil buried in polyester polyurethane is a typical ofthe effects of degradation of polyester polyurethane as a result ofsoil burial39. In our study, on thesurface of the polyurethane film, there were discoloration, spotsand cracking. Different patterns of degradation observed byfungi with different samples of polyurethane, were attributed tothe many properties of polyurethanes such as topology andchemical composition40. In addition,synthetic polymers generally have short repeating units. Theregularity in synthetic polymers allows the polymer chains topack easily, resulting in the formation of crystalline regions.This limits the accessibility of the polymer chains to enzymes.Huang and Roby (1986)41 observed polyurethane degradation proceeding in a selective manner, with the amorphous regionsbeing degraded prior to the crystalline regions. It was alsoobserved that polyurethanes with long repeating units andhydrophilic groups would be less likely to pack into highcrystalline regions as normal polyurethanes and these polymerswere more accessible to biodegradation.In soil degradation studies initially no weight loss was found within 20 days. After 40 days nearly 20% weight loss was occurred in all the samples. Soil degradation reached nearly 60 days weight loss of all the samples were increased to 40 %. Mittal et al.,42which also supports the above discussed results.

Sem morphology

Semmorphology playsa major role in affecting IPN properties, it has been extensively studied by electron microscopy and glass transition behaviour. The morphology of the IPNs depends on the method of synthesis, compatibility of polymer systems employed and on the relative rates of formation of eachnetwork.Sperling and coworkers43 have reported thatthe morphology ofsimultaneous interpenetrating networks (SINs) is found to IPN the mold. Comprising the electronmicrograph of IPN where the NCO/OH ratio was increased from 1.6 to 2.0 and the prepolymer-monomer ratio varies from 25:75 to 45:65,it was observed that when the monomer concentration becomes more,the AN phase becomes a continuous phase. It can be stated that the continuous dispersed phase morphology occurs only when the AN content exceeds or equal to 65%. when the PU content is less than 45%, the IPN morphology becomes complicated since both phases assume local or total continuity.

The morphology of the IPNs was studied from their SEM micrographs, which are as shown in Figure . For the same purpose we have chosen in the random manner, IPN-3CA, IPN-6CA and IPN -9CA.Scanning electron micrographs of the IPNs show that there are two distinct phase domainsdue to phase separation of the two component networks44of IPNs.The PU network is formed first and interpenetrated by the polymethylmethacrylate component during IPN synthesis. PU is a continuous phase in which the second component is entangled.The IPNs system is phase separated, and there is dual phase continuity in the midrange composition. But due to their interlocking phase configuration, the extent of phase separation in IPNs may be restricted and the two components are intimately interpenetrating.The glass transition temperatures also confirm the IPN formation. Sperling et al.,1983which also supports the above discussed results.

Its sem results gave us the clear picture of cracked and biodegraded PU film. The small hole, erosion, loss of tensile strength and the roughness of the surface were clearly observed access the chemical changes such as bond formation or cleavage. Sehroon Khan et al45 reported the same results on their work.

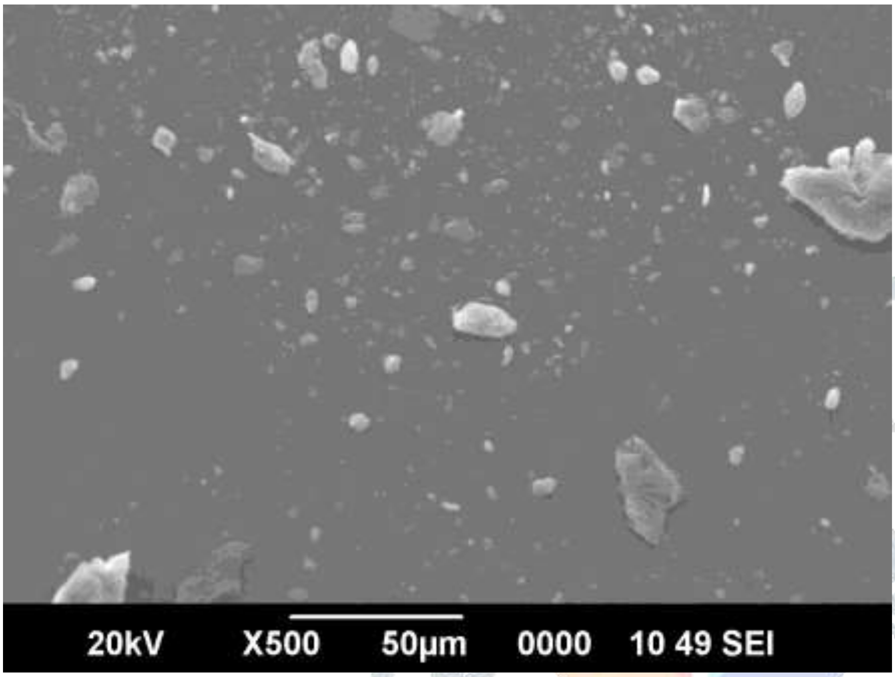


Figure 3 Sem micrograph IPN-2CA before soil burial

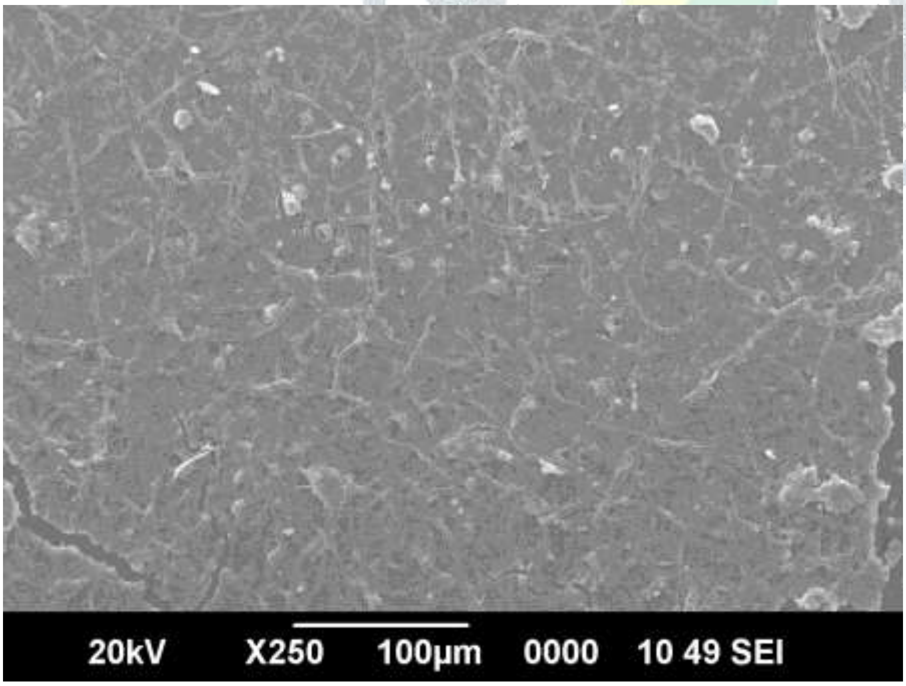


Figure 4 Sem micrograph of IPN-2CA after soil burial

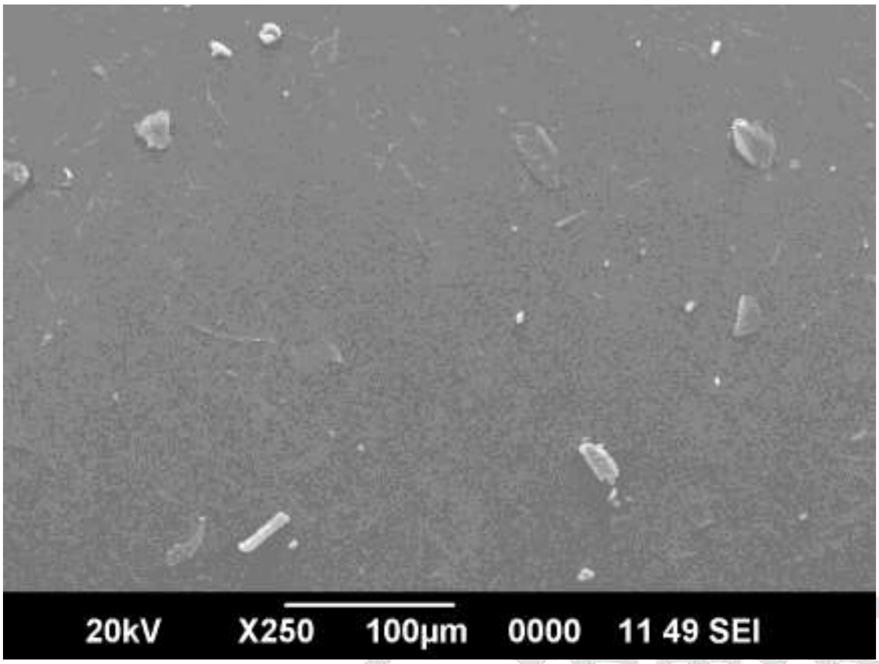


Figure 5 Sem micrograph IPN-6CA before soil burial

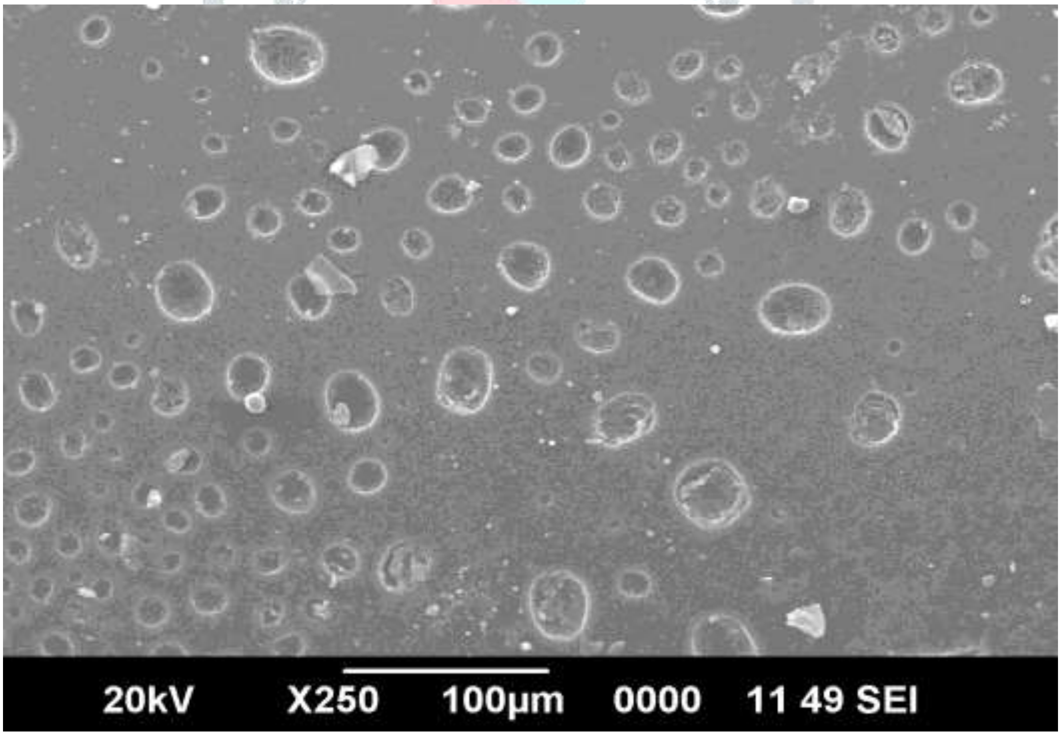


Figure 6 Sem micrograph IPN-6CAafter soil burial

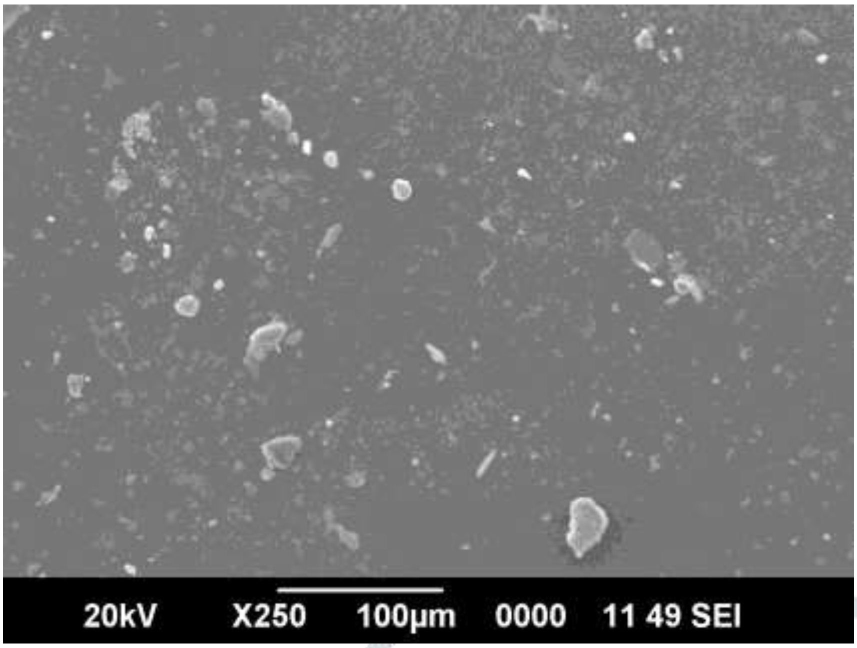


Figure 7 Sem micrograph IPN-9CAB

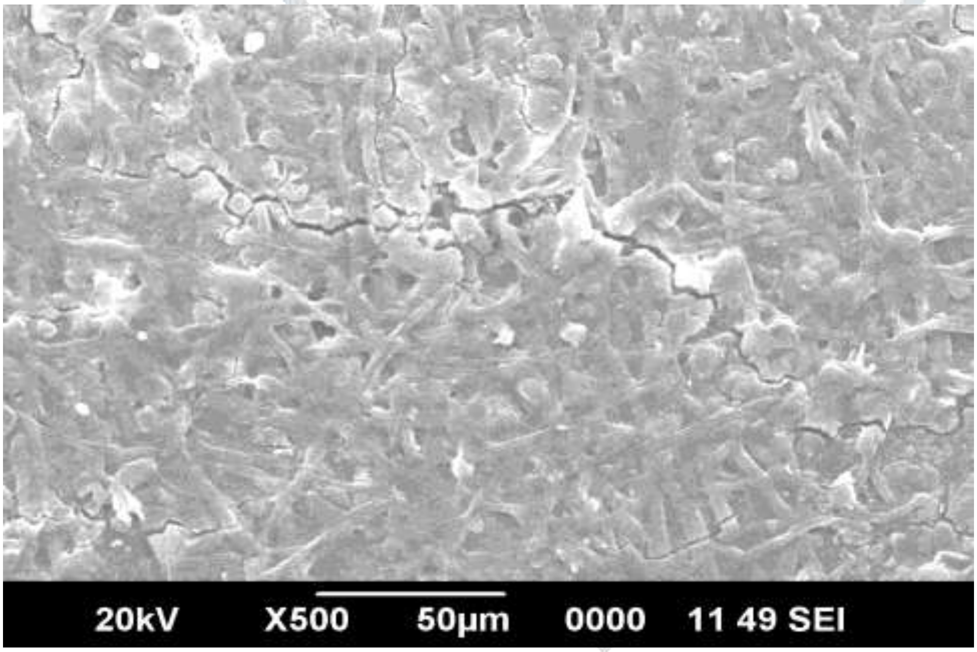


Figure 8 Sem micrograph IPN-9CAafter soil burial

CONCLUSION

These polymers have many advantages compared withpolymers prepared from petroleum based monomers and inmany cases are cheaper than petroleum polymers.Interpenetrating polymer networks showed excellent chemicalresistance, elongation, tensile design the mostdesirable material for a specific end use requirement of theinterpenetrating polymer networks.The major conclusion of this work isthe choice of diisocynate has a profound effect on the thermalstability of the polymer blend.Creation of IPN materials fromfully polymerized immiscible polymers through a bondinterchange copolymerization process, followed bycrosslinking is a concept applicable to many other systems andopens the possibility of creating novel IPN compositions andmicrostructures.

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