

## The influence of Different Acid Chloride on The General Characterizations, Electrical and Ultrasonic mechanical of Terpolymers:

### Abstract:

Interfacial condensation polymerization has been used to synthesize new unsaturated terpolyesters based on the combination of three diarylidencyclohexanone from 4-hydroxybenzaldehyde, vanillin and 3-hydroxybenzaldehyde and cyclohexanone in acid media. Monomers and polymers were investigated by FT IR and  $^1\text{H}$  NMR. The molecular weight was determined by the intrinsic viscosity measurements. The thermal stabilities of the prepared Terpolyester were evaluated thermogravimetric analysis (TGA). Differential thermal analysis (DTA) was used for determination of glass temperatures. X-ray analysis shows the degree of crystallinity. The morphological properties of some selected polymers were detected by SEM. The electrical properties especially dielectric constant has also determined. The mechanical properties of selected terpolyesters have been measured using ultrasonic echo pulse technology.

**Keywords:** Unsaturated terpolyester, Characterization, Acid Chloride, Electrical, Ultrasonic mechanical.

### 1. Introduction

Terpolyester is kind of copolyesters in which three different monomers are present in the main chain. The same various types of copolyesters are explained in terpolyesters as alternating, random, block, and graft copolyesters. Several articles have interested on synthetic terpolyesters with especial in the medical properties [1-3].

Unsaturated polyesters are among the most common polymers used in conjunction with glass fiber reinforcing [4, 5] and widely used as thermosetting resins in various industrial areas [6-8]. They are prepared by polycondensation of diacids and diols using titanium or tin alkoxides as catalysis [9]. The reaction temperature is usually up to  $150^\circ\text{C}$  [9, 10]. For this condition many monomers are not suitable for the formation of linear polyesters, due to uncontrollable side reactions and formation of gel [11-13]. Typically linear unsaturated polyesters processed to a relatively low molecular weight then it is dissolved in a monomer such as styrene to form a viscous solution. Crosslinking occurred usually initiated with free radical initiator, as vinyl copolymerization between the polyester and the solvent as vinyl

acetate or methyl methacrylate. Halogenated monomers can use for improving flame-resistance, such as ortho- and para-bromostyrene [14, 15]. The unsaturation has been commercially synthesized by introducing low cost material like maleic anhydride and fumaric acid in the polymer main chain [16]. If only unsaturated acid and glycol are used, the final product is too highly cross-linked and brittle to be useful. For this reason, copolyesters are normally prepared containing both unsaturated acid and a non-cross-linkable acid [16]. Due to the highly extensive uses of unsaturated polyesters, recycling process has been suggested to solve the problems of waste materials. One recent method involves the alcoholises of waste resin with propylene glycol, followed by re-esterification with additional maleic anhydride [17, 18]. More styrene is then added to the reconstituted polymer for cross-linking. Many studies for fabricated polyesters using biocatalysts and green monomers from renewable resources were introduced, attributed to the eco-friendly products. Furthermore, polymers are biodegradable [19, 20]. Nowadays, many studies were focused on the formation of unsaturated polyester composites and their mechanical properties [21-22]. Others studied the unsaturated polyesters as layered silicate nanocomposites [23].

The ratio of the capacitance of a condenser containing the material to the capacitance under vacuum referred to the dielectric constant of material ( $\epsilon$ ). The capacitance of a condenser measures the extent of charges was stored. One approach has focused on studying polymer thin films and their electrical properties with special interest to dielectric behaviour for their important applications as insulation, isolation and microelectronics [24, 25]. Addition of some conducting fillers to improve the magnitude of electrical conductivity of insulating polymers materials have been published in recent articles [26, 27]. The dielectric constant was measured for a variety of materials like cellulosic, [28] protein, and synthetic fibres [29].

Polymers are usually described as viscous liquid and elastic solids. An ideal linear elastic solid obeys Hooke's law; i.e. stress is proportional to the rate of change of strain. An ideal viscous liquid obeys Newton law; i.e. stress is proportional to the rate of change of strain [30]. Ultrasonic method and mechanical spectroscopy are non-destructive testing techniques and can be used for the determination of elastic properties of polymers [31]. Poisson's defined the ratio ( $\nu$ ) between transverse strain and longitudinal strain in the elastic loading direction [32]. For most polymer materials Poisson's ratio tending to 0.5. This can be noticed as a shift from elastic to viscoelastic [33]. Nowadays, many studies were focused on the formation of unsaturated polyester composites and their mechanical properties [34-35].

The presented study outlines the synthesis and characterization of new terpolyesters of

diarylidene cyclohexanone. Our target was to study and demonstrate the effect of alkyl-cycloalkanone moiety on the thermal stability properties of terpolyesters. The crystallinity, solubility, morphologic properties of this new terpolyesters was also examined. The electrical properties have also recorded further, the mechanical properties using new technique by ultrasonic echo pulse of solid polymers.

## 2. Experimental

### 2.1. Materials

p - Hydroxybenzaldehyde and m-Hydroxybenzaldehyde were purchased from Aldrich (Germany). 4 - Hydroxy-3-methoxybenzaldehyde (vanillin) from Aldrich (Germany). p-Nitrobenzoic acid from Merck (Germany). Sebacoyl and isophthaloyl chlorides were purchased from Merck (Germany), Cyclohexanone Fluka (Germany). Other chemicals were purchased from Aldrich, Merck, Fluka and purified by standard methods

### 2.2. Instrumentations

The infrared spectra for all solid samples were recorded on IR-470 infrared spectrophotometer, Shimadzu; and Pye Unicam SP3-100 spectrophotometer (Japan) using KBr pellet technique. Nuclear Magnetic Resonance spectra for monomers and models were recorded on a Varian EM-390 (90MHz) spectrometer and GNM-LA (400MHz) (USA) spectrophotometer at room temperature in DMSO or  $\text{CDCl}_3$  using TMS as the internal reference. Nuclear Magnetic Resonance spectra for polymers were recorded on a Bruker AVANCE 500 (USA) spectrometer (500 MHz) at room temperature in  $\text{CF}_3\text{COOD}$ . The ultraviolet visible spectra were scanned on U. V.-Visible spectrophotometer, Labomed, (USA), Spectro Double Beam 8 Auto cell, U. V D 3200, 190-1100nm in conc.  $\text{H}_2\text{SO}_4$  as solvent The solubility of the polymer were examined using 0.02 g of polymer in (3-5 ml) of solvent at room temperature. The inherent viscosities of the polymer solution (0.5%w/v) in conc.  $\text{H}_2\text{SO}_4$  were determined at 30°C using an Ubbelohde suspended level viscometer VWR (Germany). X-ray diffract graphs of the polymer were obtained with Philips X-ray Pw 1710 (Japan) diffractometer, using Ni-filtered  $\text{CuK}\alpha$  radiation. Thermo-gravimetric analysis (TGA), differential thermal analysis they are carried out in air with Shimadzu TGA-50. Perkin Elmer Differential Scanning Calorimeter Pyris 1 was used for the determination of  $T_g$  of solid polymers. The thermogram was recorded at heating and cooling rate of 5 °C/min. X-ray diffraction of polymers was recorded on Bruker AXS D8 Advance diffractometer with Cu

$K\alpha$  characteristic radiation at a voltage of 40 KV and a current of 40 mA. The scanning rate was  $0.4^\circ/\text{min}$ ; the range of  $2\theta$  was from  $20^\circ$  to  $80^\circ$  at room temperature.

The morphology of the polymer were examined by Scanning Electron Microscopy (SEM) using a JSM-5400 LV instrument; images were recorded with a Pentax Z-50P Camera with ILford film at an accelerating voltage of 15KV (USA).

### 2.3. Electrical properties

The dielectric constant ( $\epsilon$ ), parallel resistance ( $R_p$ ) and parallel capacitance ( $C_p$ ) were determined for specimens in the form of discs. They were prepared as discussed lately, the diameter 10mm and thickness about 7mm. The measurements have been carried out at room temperature and frequency rang 100Hz-1MHz using HIOKI 3532-50 LCR Hi TESTER.

### 2.4. Ultrasonic Velocity measurements

Ultrasonic waves travel through any solid material at a specific velocity related to the material characterization and its density. Here we used the pulse technique which is widely used to generate ultrasonic measurements for solid and fluids. A pulse of sinusoidal voltage is applied to a piezoelectric transducer that is directly contacted with the samples under investigation. Then, the electrical pulse converted to acoustical pulse that transmitted into the medium. The pulse propagates down the medium, and reflected to the opposite face. The time intervals between successive echoes can be measured and velocity of the wave is determined. Once time intervals duration is obtained and the thickness of the samples determined the velocity of the ultrasonic wave of the sample can be calculated by equation (1);

$$v = 2d/\Delta t \quad (1)$$

Where  $d$  is the thickness of the sample and  $\Delta t$  is the time intervals (32).

In general, the solids are subjected to three types of stressing condition: uniaxial stress, triaxial stress and pure shear. If a uniaxial stress is applied on a body, then elongation in the same direction will be produced. Young's modulus ( $E$ ): Is defined as the ratio of the linear stress to linear strain as. Shear of rigidity ( $G$ ): Is defined as the ratio of the shear stress to the shear strain. Bulk modulus ( $K$ ): Defined as the ratio of the hydrostatic stress to the volumetric strain. Micro-hardness ( $H$ ): Is a measure of the resistant of material to being penetrated and eroded by another material's shear projection. The four constants held as equations 2-6;

$$L = \rho V_l^2 \quad (2)$$

$$G = \rho V_s^2 \quad (3)$$

$$E = 2(1 + \nu)G \quad (4)$$

$$K = L - (4/3)G \quad (5)$$

$$H = (1 - 2 \nu) E / 6 (1 + \nu) \quad (6)$$

Where  $\rho$  is the density of the material,  $L$  is the longitudinal elastic modulus,  $V_l$  and  $V_s$  are the longitudinal and transverse ultrasonic velocities and  $\nu$  is Poisson's ratio [32,33].

## 2.5. Synthesis of Monomers i, ii, iii and Their Models ia, iia, iiia

The monomers I and III and their models were synthesized as described in our previous work [34, 35]. A new monomer II and its model were prepared by the same procedure by condensation of m-hydroxy benzaldehyde with cyclohexanone for 3 hrs. as brown needles from ethanol, yield 91%, m. p 215°C.

Model IIa was obtained by the reaction of 2, 6- bis (3-hydroxybenzylidene) cyclohexanone and benzoyl chloride as yellow plates from benzene yield, 93%, m. p 216°C.

$^1\text{H}$  NMR (90 MHz, DMSO- $d_6$ ,  $\delta$ ): = 9.75 ppm (s, 2H, 2OH group), at 7.65 ppm (s, 2H of 2CH=C); at 6.8 - 7.35 ppm (m, 8H of Ar -H), at 2.85 ppm (m, 4H of 2CH<sub>2</sub>) and at 1.85 (pentet, 2H of CH<sub>2</sub> of cyclohexanone).

IR (KBr) (II monomer):  $\nu$  = IR spectra recorded from KBr pellets showed characteristic bands for C=O cyclohexanone at 1690-1700  $\text{cm}^{-1}$ ; C=C stretching at 1590-1600  $\text{cm}^{-1}$ ; phenylene rings at 1590-1510  $\text{cm}^{-1}$ .

$^1\text{H}$  NMR (90 MHz, CDCl<sub>3</sub>,  $\delta$ ): 8.25- 8.60 ppm (m, 4H 30, 34, 35, 39 Ar-H), 7.50 – 8.10 ppm (m, 12H 14-19, 31-33, 36-38 Ar-H), 7.15 –7.25 ppm (s, 2H, 8, 9- CH=C), 2.60-2.90 ppm (t, 4H, 2, 4- 2CH<sub>2</sub>), 1.25 – 1.85 ppm (pent., 2H 3-CH<sub>2</sub>) of cyclohexanone.

IR (KBr) (IIa model):  $\nu$  = 1735 (s) (C=O of ester group), 1670 (s) (C=O of cyclohexanone), 1600 (s) (C=C).

## 2.6. Synthesis of 4, 4-Azodibenzoyldichloride

This has been done in two steps the first is the formation of azobenzene 4, 4-dicarboxylic acid followed by conversion to acid chloride azobenzene 4, 4-dicarboxylchloride as described previously [34, 35].

## 2.7. Synthesis of Terpolymers

In a three necked, round – bottomed flask (500 cm<sup>3</sup> volume) equipped with a mechanical stirrer (2000 rpm/min), dry nitrogen inlet and out let, and dropper, a mixture of three different monomers (mol/mol) of diarylidene cyclohexanone, and a suitable quantity of sodium hydroxide; that is stoichiometric quantity (0.02mol) of 100% excess (0.04 mol) dissolved in 100 ml of water was introduced. After mixing (0.02 mol.) of acid chloride dissolved in 40 ml methylene chloride

was added over a period 2-3 min. at 25°C and vigorously stirring. After complete addition of acid chloride, the stirring was continued for 60 min., during which yellow solid product separated out. The solid polymer was filtered off, washed by water, hot ethanol, hot acetone, and dried under reduced pressure (1 mmHg) at 100°C for two days. Three terpolyesters were separated and casted from methylene chloride.

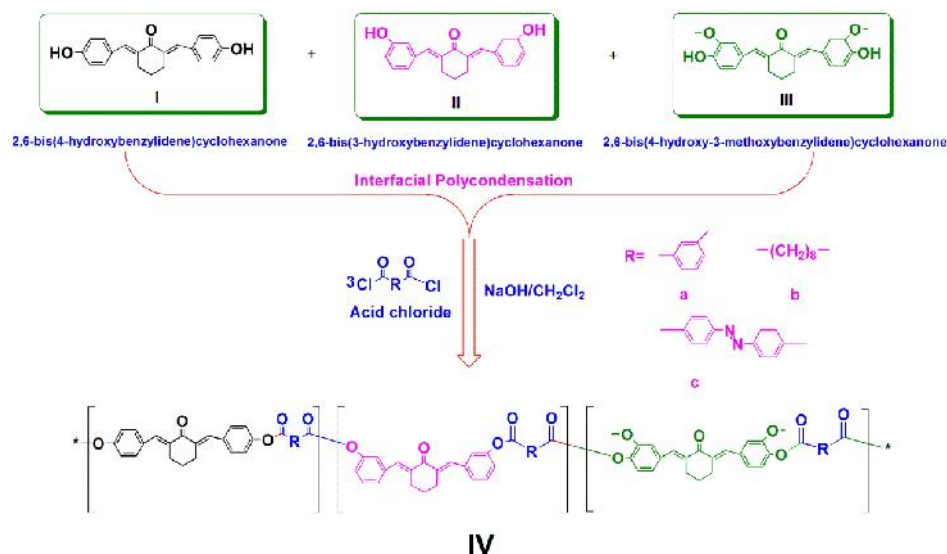
**Table 1.** Mole ratios of monomers, acid chlorides, physical states, yield%, viscosity average molecular weight and glass temperature of synthetic terpolyesters I, II and III.

| Code | Acid chloride (0.06mol) in 100ml dry<br>CH <sub>2</sub> Cl <sub>2</sub> | Yield<br>[%] | Mv 10 <sup>3</sup><br>g/mol | T <sub>g</sub><br>[°C] |
|------|-------------------------------------------------------------------------|--------------|-----------------------------|------------------------|
| IV a | 6.10 g                                                                  | 80           | 8500                        | 345                    |
| IV b | 7.00 g                                                                  | 86           | 10300                       | 105                    |
| IV c | 9.20 g                                                                  | 89           | 9600                        | 325                    |

### 3. Results and Discussion

Here, in this study we used new monomers based on 3-hydroxybenzaldehyde for the formation of 2, 6-bis (3-hydroxybenzylidene) cyclohexanone II by the reaction condition as described in Scheme 1. Further, the model compound was also synthesized and both were characterized by IR and <sup>1</sup>HNMR.

The new terpolyesters containing diarylidenecyclo-hexanone moiety in the main chain were synthesized by interfacial condensation polymerization technique for one mole of both monomers and three moles of acid chloride as described in scheme 1. The same technique was used to synthesize a series of polyesters and copolyesters of diarylidenecyclopentanone [34].



**Scheme 1.** Synthesis of 2, 6-bis (3-hydroxybenzylidene cyclohexanone) II, its model compound and terpolyesters of IV a, IV b and IV c.

### 3.1. Polymer Characterizations

**3.1.1. IR spectra:** IR spectra recorded from KBr pellets was mixed with respective polymer showed characteristic bands for C=O ester at 1730-1745  $\text{cm}^{-1}$ ; C=O cyclohexanone at 1690-1700  $\text{cm}^{-1}$ ; C=C stretching at 1590-1600  $\text{cm}^{-1}$ ; phenylene rings at 1590-1510  $\text{cm}^{-1}$ ; and C-O-C bonds (ether linkage) at 1250-1260  $\text{cm}^{-1}$ .

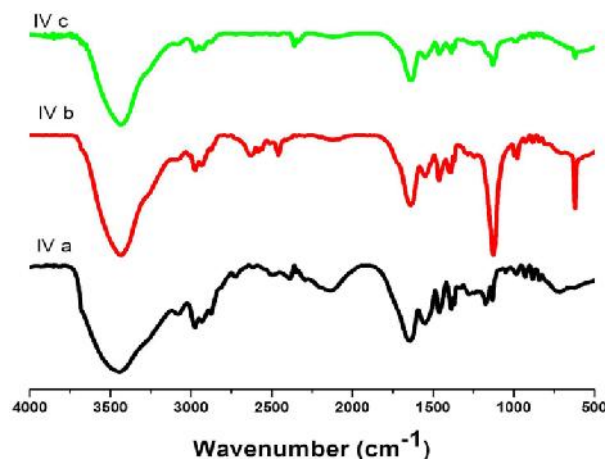


**Figure 1:** FT IR of terpolyesters

### 3.1.2. $^1\text{H}$ NMR Spectra

$^1\text{H}$ -NMR spectra were recorded using a BRUKER DRX-500 spectrometer.  $^1\text{H}$ -NMR spectra were measured at 25°C in  $\text{CF}_3\text{COOD}$  as an internal reference. The chemical shifts (in ppm) are referenced to tetramethylsilane Figure 1, shows the  $^1\text{H}$ NMR for terpolymers (IV a,

IV b, IV c) all spectra recorded the presence of: 0.90-1.05, 1.30-1.65, and 3.00-3.50 ppm (m-CH<sub>2</sub>-cyclohexanone), 4.00-4.30 ppm (m-OCH<sub>3</sub>), and 7.00-8.90 (m-Ar-H). Moreover, polymer II with sebacate main chain showed at 2.5-2.90 ppm (m-CH<sub>2</sub>).

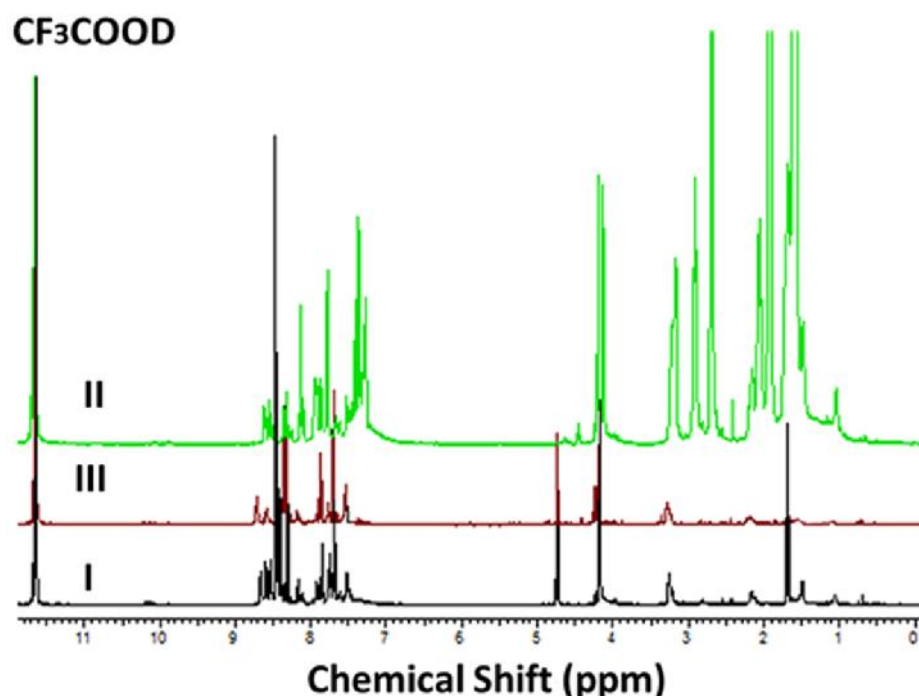


**Figure 2.** <sup>1</sup>H NMR (CF<sub>3</sub>COOD) of copolyester.

### 3.1.3. Solubility

The solubility of the polymers were tested in various solvents including N-methyl-2-pyrrolidone (NMP), dimethyl formamide (DMF), m-cresol, dimethylsulphoxide (DMSO), CHCl<sub>3</sub>-acetone mixture, dichloroacetic acid (DCA), and concentrated H<sub>2</sub>SO<sub>4</sub>. It was found from Table 2, that the majority of the polymers were completely insoluble in NMP, m-cresol, CHCl<sub>3</sub>-acetone mixture. In strong protic solvents as (DCA) (Cl<sub>2</sub>CHCOOH) or (TFA) (F<sub>3</sub>CCOOH) the polymers are completely soluble at room temperature. In case of (conc. H<sub>2</sub>SO<sub>4</sub>) all polymers are completely soluble at room temperature. The slightly higher solubility of polymers based on the aliphatic chain in DMSO and DMF in comparison with polymers have aromatic attributed to higher flexibility of aliphatic and more rigidity of aromatic chains. Introduction of azo group in the terpolyesters main chain increase the polarity and hence increase the solubility.

**Table 2.** Solubility characteristics of copolyesters series I, II and III.

| Polymer Code | A | B | C | D | E | F | G | H |
|--------------|---|---|---|---|---|---|---|---|
| <b>IV a</b>  | - | - | - | - | - | + | + | + |
| <b>IV b</b>  | ± | ± | - | - | - | + | + | + |
| <b>IV c</b>  | ± | ± | - | - | - | + | + | + |

A (DMF), B (DMSO), C (NMP), D (m-cresol), E (Chloroform: acetone 1: 1), F (DCA), G (TFA), H (Conc. H<sub>2</sub>SO<sub>4</sub>). (+) Soluble at room temperature (RT); (±) partially soluble at RT; (-) insoluble at RT.

### 3.1.4. The Viscosity Average Molecular Weight ( $M_v$ )

Polymers under measurement and standards were dissolved in trifluoroacetic acid as solvent. The viscosity average molecular weights of polymers were determined according to *Mark-Hounwink* equation [36-37] as shown in **Table 1**.

### 3.1.5. Thermal Analysis

The thermal stabilities of selected examples of copolyesters were evaluated by Differential thermal analysis (DTA) in air at a heating rate of 10°C min<sup>-1</sup>.

### 3.1.6. Differential thermal analysis (DTA)

Terpolyesters were examined by DTA measurements as shown in Figure 3. The values of  $T_g$  were summarized in Table 1. From the DTA curves it is easy to determine the glass transition temperature  $T_g$  of these terpolyesters. It should be noted that polymers with rigid chains would be expected to have  $T_g$  higher than those with flexible molecules. This is because, on melting, polymers with stiff backbones have lower conformational entropy changes than those with flexible backbones. The chain flexibility is enhanced by the presence of - (COO) - and by increasing the length of - (CH<sub>2</sub>) - units in the main. The chain rigidity is enhanced by the presence of aromatic groups in the main chains [38].

The  $T_g$  for terpolyester with azo groups have higher values than terpolyesters others. The interpretation, attributed to the presence of azo groups in the terpolyester main chain, causes high hindrances to internal rotation about primary valance bonds, and hence raises  $T_g$  [39].

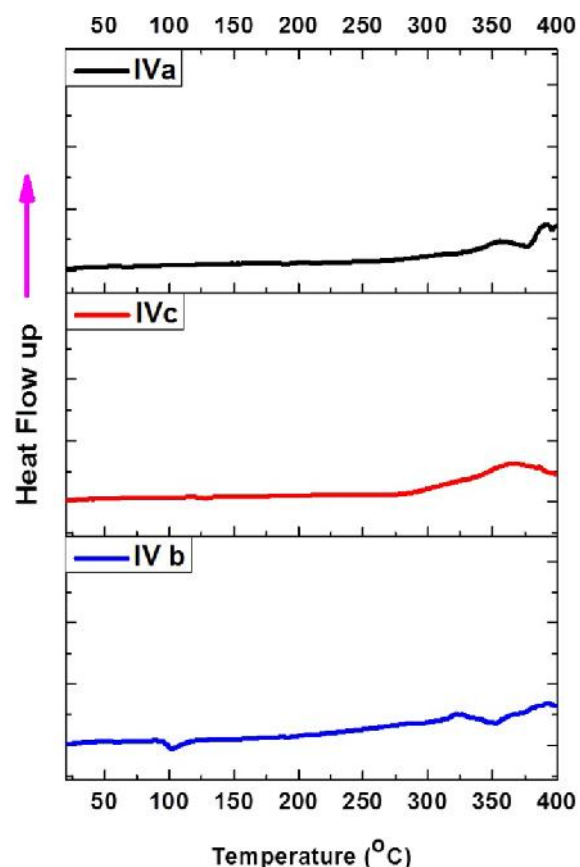


**Figure 3.** DTA of terpolyesters

### 3.1.7. X-Ray Analysis

X-ray diffractograms of terpolyesters showed an amorphous patterns in the region  $2\theta = 5-30^\circ$ , after this region showed a few reflections of sharpness peaks with an amorphous back ground in the region  $2\theta = 30-60^\circ$ , this indicate some degree of polycrystallinity of terpolyesters. It was noted from the Figure 4 that the presence of cyclohexyl ring in the polymer chain beside the presence of methylene groups, eight, increase the polymer chain flexibility, that urge the approach and mutual attraction of the adjacent chains might be induced some extent of crystallinity. Moreover, it should be noted that the presence of methoxy groups as substituent in the phenyl ring caused some hindering between the repeating units and enforced the unsymmetrical orientation in the polymer chains and reduced the close packed structure and hence these copolyesters exhibit only a low degree of crystallinity [40]. Moreover, in terpolyesters with azo group as a polar group in addition to  $C=C$ - bonds induces some order between two adjacent chains in the terpolyester towards some extent of crystallinity [41-43] as shown in **Figure4**.

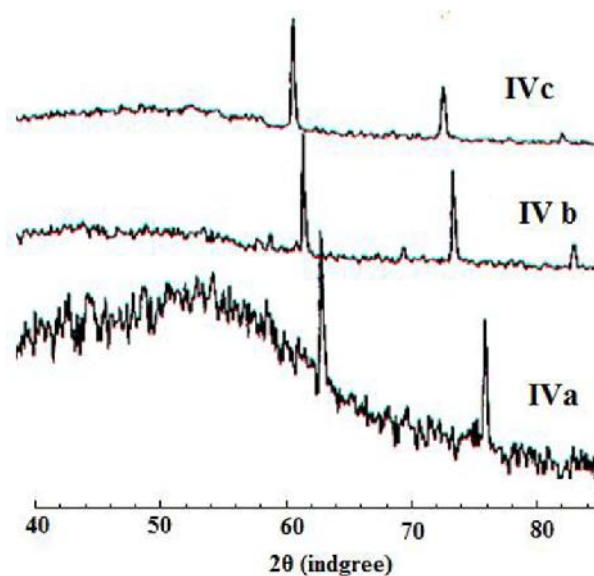
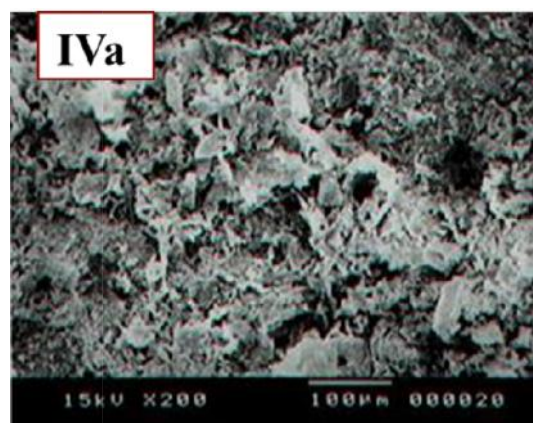


**Figure 4.** X-ray diffraction patterns of terpolyesters I, II, III

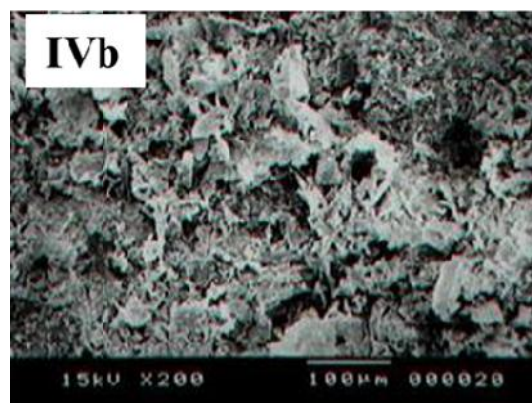
### 3.1.8. Morphological Features

The morphology of the synthesised terpolyesters were examined by scanning electron microscopy (SEM). The samples were prepared by the same manner as described in instrumentations part.

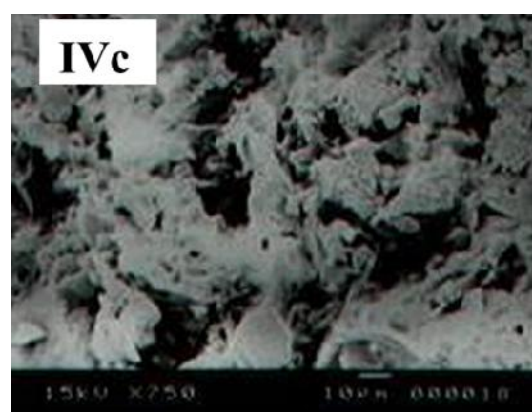
The study terpolyesters showed that the surface of terpolyester IV Figure 5, magnification of  $X=200$  likes fibrous aggregates; terpolyesters IV b in Figure 6, magnification of  $X=200$  appeared as fibrous aggregates; terpolyesters IV c with azo group in the main chain with magnification of  $X=750$  in Figure 7 showed waxy-looking masses.



**Figures 5.** SEM images of terpolyesters I surface at 200nm magnifications.



**Figures 6.** SEM images of terpolyester II, surface at 200nm magnifications.



**Figures 7:** SEM images of terpolyesters III, surface at 750 nm magnifications.

### 3.2. Electrical Properties of Terpolyesters

The dielectric constant ( $\epsilon$ ) and the electrical resistance  $R_p$  of terpolyesters including aliphatic, aromatic and azo group in the main chain have been studied carefully at room temperature and have been calculated according to equation 1 [43].

$$\epsilon(\omega) = [C_p(\omega) / \epsilon_0] (d/A),$$

where  $\epsilon_0$  is the absolute permittivity (dielectric constant) of free space, which in SI unit the value  $8.855 \times 10^{-2} \text{ C}^{-2} \text{ N}^{-1} \text{ m}^{-2}$  (= farad  $\text{m}^{-1}$ ),  $C_p$  parallel capacitance,  $\omega$  angular frequency,  $A$  and  $d$  are the effective cross-sectional area and thickness of the sample respectively.

It is clear from Figure, that the terpolyesters are good insulator. Polymer III which contain azo group in main chain show inversely proportional with frequency due to the presence of ( $-\text{N}=\text{N}-$ ) group with lone pair of electrons on nitrogen atom and  $\pi-\pi^*$ ,  $n-\pi^*$  transition which increase polarization for the samples and decrease with frequency. Also the values of the electrical resistance  $R_p$  of the two groups are about  $10^7$  ohms. So we

conclude that these copolyesters can be used as a dielectric medium and as insulator in different applications. The values of the dielectric constants have been determined and the measured values of  $R_p$  are reported in **Table 3**.

**Table 3:** The values of relative dielectric constant ( $\epsilon$ ), parallel resistance ( $R_p$ ) and parallel capacitance( $C_p$ ) for selected copolyesters and terpolyesters.

| Polymer | $d(m)$<br>$10^{-3}$ | $\epsilon^a$ | $R_p^b (\Omega) 10^7$ | $C_p^c 10^{-11}$ |
|---------|---------------------|--------------|-----------------------|------------------|
| IVa     | 3.20                | 80-85        | 7-9                   | 1.55             |
| IVb     | 5.18                | 100-110      | 6-8                   | 1.20             |
| IVc     | 1.50                | 70-73        | 4-6                   | 1.30             |

<sup>a</sup> dielectric constant

<sup>b</sup> parallel resistance

<sup>c</sup> parallel capacitance

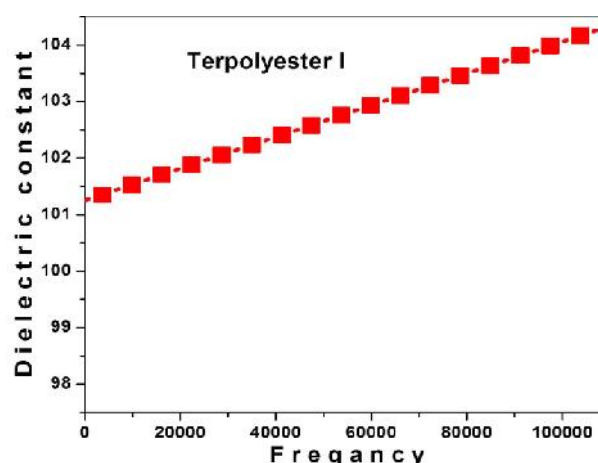


**Figure 8.** Relation between dielectric constant and frequency for terpolyester IV a.

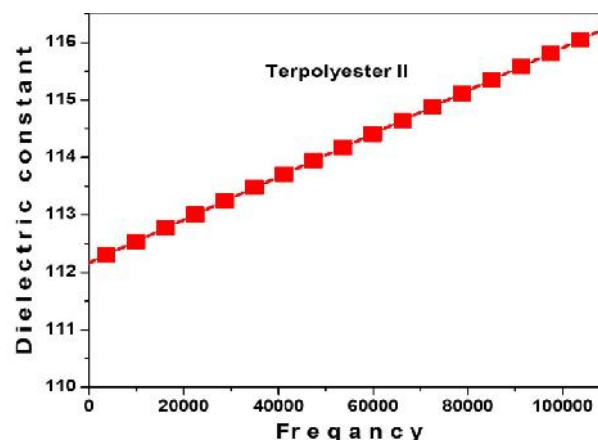
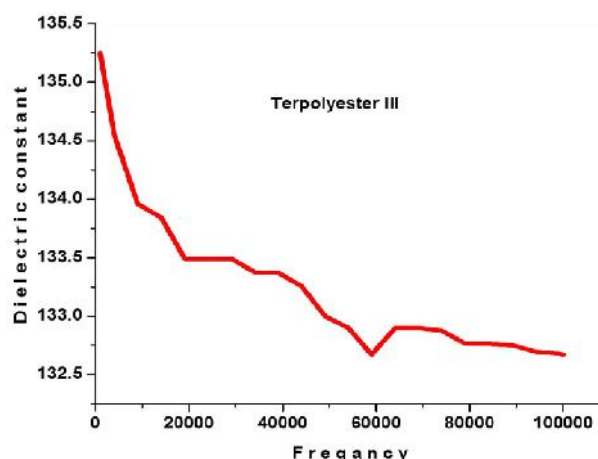


**Figure 9.** Relation between dielectric constant and frequency for terpolyester IV b.

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300 **Figure 10.** Relation between dielectric constant and frequency for terpolyester IV c.

### 301 3.3. Mechanical Properties

302 Values of longitudinal, transverse ultrasonic velocities and elastic moduli constants for  
 303 different copolyesters and terpolyesters based on arylidene cyclohexanone are tabulated in  
 304 Table 1. The ultrasonic changes may be explained on the basis of physical properties of  
 305 terpolyesters as shown in **Table 4,5** are heterogeneous and have higher long chain. In polymer  
 306 (Iva-c) terpolyesters, they have higher long chain than copolyesters, elasticity will increase  
 307 due to the effect of the neighbouring group, polymer (IVb) is more elastic than (Iva) as  
 308 discussed later [44]. Polymer with azo groups in the main chain showed average elasticity  
 309 between those with aromatic and aliphatic groups, this can be attributed to the mobility of azo  
 310 group in presence of aromatic chain groups [44].

311 **Table 4 :** Densities, ultrasonic velocities (longitudinal, transverse) and Poisson's ratio for  
 312 copolyesters and terpolyesters.

| Polymer | $\rho^a$ ( Kg/m <sup>3</sup> ) 10 <sup>3</sup> | $V_L^b$ ( m/s) | $V_s^c$ (m/s) | $\nu^d$ |
|---------|------------------------------------------------|----------------|---------------|---------|
| IVa     | 1.41                                           | 6015           | 3234          | 0.29    |
| IVb     | 1.30                                           | 6527           | 3221          | 0.34    |
| IVc     | 1.43                                           | 6345           | 3245          | 0.32    |

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<sup>a</sup> density

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<sup>b</sup> longitudinal velocity

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<sup>c</sup> transverse velocity

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<sup>d</sup> Poisson's ratio

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**Table 5:** Elastic moduli for selected copolyesters and terpolyesters

| Polymer | (L) <sup>a</sup> GPa | (G) <sup>b</sup> GPa | (E) <sup>c</sup> GPa | (K) <sup>d</sup> GPa | (H) <sup>e</sup> GPa |
|---------|----------------------|----------------------|----------------------|----------------------|----------------------|
| IVa     | 51.01                | 14.75                | 38.05                | 31.43                | 2.10                 |
| IVb     | 55.38                | 13.49                | 36.15                | 37.39                | 1.44                 |
| IVc     | 48.23                | 13.27                | 34.77                | 30.53                | 1.68                 |

<sup>a</sup> Longitudinal Modulus

<sup>b</sup> Shear Modulus

<sup>c</sup> Young's Modulus

<sup>d</sup> Bulk Modulus

<sup>e</sup> Micro- Hardness

#### 4. Conclusion

In the present study new aliphatic and aromatic terpolyesters have been synthesized by interfacial condensation polymerization technique. The solubility of polymers was very poor in organic and inorganic solvent except in very strong acids such as sulphuric and trifluoroacetic acids. XRD results showed amorphous case with respect to some semi-crystalline with aromatic and azo terpolyesters. TGA analyses indicate one and two steps of decompositions. The glass transition temperature was examined by DSC showed increasing with aromatic and azo copolyesters. The heterogeneous surface with the formation of layers has shown by SEM images. The dielectric constant of copolyesters and terpolyesters with aliphatic or aromatic chains demonstrated the insulator characters. However, others with azo groups in the main chain demonstrated some electrical properties due to highly polarizability. The mechanical properties of copolyesters and terpolyesters were investigated using ultrasonic waves and kinds of elastic moduli have been calculated. The terpolyesters with aliphatic main chain have more elasticity than others with aromatic chains.

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