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Biological Activity and Electrical Behavior of Newly Synthesized Nanoporous Terpolymer Resin Derived from Dithiooxamide with Formaldehyde

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Abstract:
The terpolymer (2, 2'-HBDF) synthesized in the presence of acid catalyst by the condensation of 2, 2'-Dihydroxybiphenyl (2, 2'-HB) and Dithiooxamide (D) with Formaldehyde (F) using 1:1:2 molar proportions of the reacting monomers. The copolymer possesses antimicrobial activity for certain bacteria such as Staphylococcus aureus, Escherichia coli, and fungi Aspergillus niger, Candida albicans. Linear graph are found by the plots of log σ vs 10^3/T over a wide range of temperature, which indicate that the Wilson's exponential law $\sigma = \sigma_0 \exp^{(-\Delta E/kT)}$ is obeyed. From the electrical conductivity of these copolymers, activation energies of electrical conduction have been evaluated and values lies in the range 7.1 x 10^{-20} to 4.5 x 10^{-20} J/K. On the basis of above studies, these copolymers can be ranked as semiconductors.
Keywords: Antimicrobial screening Terpolymer, synthesis, electrical conductivity

Introduction:

The use of terpolymers in all spheres of life has been abundantly increases in recent years because of novelty and versatility. They occupy the pivotal position in the field of polymer science. A copolymer involving 2, 4-dichlorophenylmethacrylate and vinyl acetate was reported as a significant inhibitor for the growth of microorganisms (Patel MM et.al 2003). The progress in this field has been extremely rapid, as they are generally useful in packing, adhesives and coating in electrical sensors, ion exchangers, organometallic semiconductors, activators, catalyst and thermally stable materials, high temperature flame resistant fibers (Niley SN. 2018). Terpolymer approach for controlling the crystalline behavior of naphthalene diimide based polymer acceptors and enhancing the performance of all polymer solar cells (Kim Y. et al.2016). Although carbon nano tubes are effective fillers to enhance the mechanical and electrical properties of polymers, they cannot be dispersed easily in a solvent or a polymer matrix due to the Vander Waals forces (Vedejo R. et. Al. 2011, Vaia RA et al. 2004). Pal TK reported electrical conductivity of Salicylic acid-Biuret/ Dithiooxamide/ Dithiobiuret- Trioxane terpolymer resins (Pal TK et al 1989). A variety of conjugated organic molecules are known as semiconductors, the carrier mobility in them is usually low. This is due to the difficulties in, which electrons jumps from one molecule to another and hence, the carrier mobility in the compound of this type increasing molecular size. Kanda S. reported the rubeanato-copper semi conductive polymers and studied their AC and DC conductivity (Kanda S. et al., 1961). The resin HBUE-II shows the semiconducting behavior (Kapse SK and coworkers 2013). Poly (3, 4-ethylene dioxythiophene)s are the conducting polymers (CP) with the biggest prospects in the field of bioelectronics due to their combination of characteristics (Mntione D et al 2017).

Synthesis of 2, 2'-Dihydroxybiphenyl (2, 2'-HB)-Dithiooxamide (D)-Formaldehyde (F) i.e. 2, 2'-HBDF Terpolymer Resins:-

Terpolymer resin (2, 2'-HBDF-I) was prepared by condensing 2, 2'-dihydroxybiphenyl (1.86 gm, 0.1 mol), dithiooxamide (1.20 gm, 0.1 mol.) and formaldehyde (7.5 ml of 37 %, 0.2 mol.) in the presence of 2M HCl (200 ml) as a catalyst at 122 $\pm$ 2^0C in an oil bath for 5 h (Sanjiokumar S. Rahangdale et.al 2019, 2020, 2021, Santosh P. Chakole, 2020). The solid product obtained was immediately removed from the flask as soon as the reaction period was over. It was washed with cold water, dried and powdered. The powder was repeatedly washed with hot water and methyl alcohol to remove unreacted monomers. The air-dried terpolymer resin was extracted with diethyl ether to remove copolymer. It was further purified by dissolving in 8 % NaOH and then was filtered. The terpolymer was then precipitated by drop wise addition of 1:1 (v/v) conc. HCl/water with constant stirring and filtered. The process was repeated twice. The resulting polymer sample was washed with boiling water and dried in a vacuum at room temperature. The purified terpolymer resin was finely ground to pass through a 300 mesh size sieve and kept in a vacuum over silica gel. The yield of the terpolymer resin was found to be 70%.

Similarly, the other terpolymer resins, 2, 2'-HBDF-II, 2, 2'-HBDF -III and 2, 2'-HBDF - IV were synthesized by varying the molar proportion of the starting monomers i.e. 2, 2'-dihydroxybiphenyl, biuret and formaldehyde in the ratios 2:1:3, 3:1:4 and 4:1:5 respectively. The samples yield and reaction details are tabulated in Table 1.

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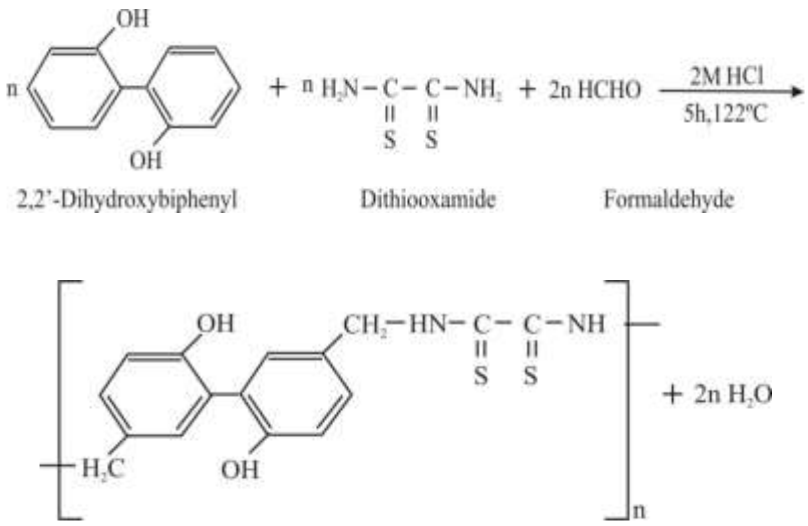

Fig. 1: Proposed reaction for 2, 2'-HBDF-I terpolymer resin

Table 1 Reaction Details of 2, 2'-HBDF Terpolymer Resins.

Resin abbreviation	Reactant			Molar ratio of reactant	Catalyst 2M HCl (ml)	Reflux temp. ±2 K	Yield (%)	Melting point of resin (K)
	2,2'-Dihydroxybiphenyl '2,2'-HB' (mole)	Dithiooxamide 'D' (mole)	Formaldehyde 'F' (mole)					
2,2'-HBDF-I	0.1	0.1	0.2	1:1:2	200	392	70	454
2,2'-HBDF-II	0.2	0.1	0.3	2:1:3	200	392	72	464
2,2'-HBDF-III	0.3	0.1	0.4	3:1:4	200	392	74	477
2,2'-HBDF-IV	0.4	0.1	0.5	4:1:5	200	392	78	488

Experimental

The electrical resistivity was measured over a wide range of temperatures (i.e. from 303 to 423 K). The measurements involved following steps.

(i)Preparation of Pellets for Resistance Measurements

To prepare the pellets, terpolymer resins was thoroughly ground in agate pestle and mortar. The well powdered terpolymer was pelletalized isostatically in a steel die at 10 tones / inch^2 with the help of hydraulic press. The pellet thus obtained was hard and crack free. A thin layer of colloidal graphite in acetone was applied on both sides of the pellets and dried at room temperature for 4-6 hr. The colloidal graphite on either side of pellet functioned as electrode. The surface continuity of the pellet was then tested by means of multimeter. The average diameter of this pellet and its thickness were measured using a Screw Gauze. Actual dimensions were measured as average of the three measurements taken at three places.

(ii)Sample Holder

A simple spring loaded sample holder was fabricated using brass electrodes. The prepared pellet was mounted between the two brass electrodes, one of which was spring loaded while other electrode rested on the brass platform.

(iii)Furnace for Heating the Samples

For resistivity measurements at different temperatures a small furnace was used. The current to the furnace was recorded by means of A. C. ammeter and controlled by a rheostat. To ensure a uniform temperature inside the furnace, a thin metal cylinder was inserted into it. The temperature of the furnace was recorded by means of chromel-alumel thermocouple connected with digital multimeter in which millivolts were measured. The connection wires of two electrodes which were insulated with porcelium beads were taken out for connections.

(iv)Measurement of Resistivity:-

The resistance of the pellet was measured on Auto Comput LCR-Q meter 4910. Connection wires from the furnace were connected to the terminals of the instrument. In this way corresponding resistance of the pellet was measured by keeping the pellet in sample holder. Resistivity (σ) was then calculated using the relation.

$$\sigma = R \times A/l$$

where, R = Resistance of the pellet
A = Surface area of the pellet
l = Thickness of the pellet
σ = Resistivity.

The conductivity measurements were made over a wide range of temperatures. The electrical conductivity (σ) varies exponentially with the absolute temperature according to well known relationship,

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$\sigma = \sigma_0 \exp^{(-Ea/ kT)}$

where, σ = Electrical conductivity at temperature T.

σ_0 = Electrical conductivity at temperature $T \to \infty$

Ea = Activation energy of electrical conduction.

K = Boltzmann Constant (0.8625 x 10^{-4} evdeg^{-1}or 1.3817 x 10^{-23} J molecule^{-1}K^{-1}).

T = Absolute temperature.

This relation has been modified as,

$\log \sigma = \log \sigma_0 + (-Ea/ 2.303\ k\ T)$

According to this relation, a plot of log σ Vs 1/T would be linear with negative slope. Such plots were made on the basis of each set of data. From the slopes of the plots, the activation energy (Ea) of electrical conduction was calculated.

Antimicrobial Screening

Biological assay depends upon a comparison of the inhibition of growth of microorganism by measuring the concentration of the sample to be examined with the known concentration of standard antibiotic. For the antimicrobial analysis the in vitro disc diffusion method has been employed. In this study the ligand and their chelates were tested for their effect on certain human pathogenic bacteria such as Gram-positive (*Aspergillus niger and Candida albicans*).

The nutrient agar medium was boiled and sterilized by autoclaving at 7 kg pressure (120 ^{0}C) for 20 min for the study of antibacterial activity. 20 mL media was poured into the sterilized Petri plates and kept at room temperature for a few minutes, and allowed to solidify in plates. It was then incubated for 12 h and inoculated with microorganism using sterile swabs. All of these manipulations were carried out with utmost care under aseptic conditions. The test solution prepared by dissolving the compound in DMSO was filled with the media using a micropipette and incubated at 35 ^{0}C for 48 h. The same procedure was adopted for the antifungal studies in which potato dextrose agar was the medium.

During the course of time, the test solution diffuses and the growth of the inoculated microorganisms such as Staphylococcus aureus, Escherichia coli, Aspergillus niger, and Candida albicans were found to be affected. The activity developed on the plate was measured by measuring the diameter of the inhibited zone in millimetres. The drug ciprofloxacin was used as the standard for bacteria and nystatin for fungi.

Results and Discussion:

Electrical Conductivity of 2, 2'-HBDF Terpolymers:

The DC resistivity of the 2, 2'-HBDF terpolymers were measured in the temperature range of 303 to 423 K. The electrical conductivity of the terpolymer samples at room temperature vary from 1.4x10^{-13} to 2.3x10^{-12} Siemen(Gurnule WB, 2001). The temperature dependence of the electrical conductivity (Fig. 2) is found to be linear in the temperature range under study showing thereby that Wilson's exponential law is obeyed. Examination of the plots also revealed that the electrical conductivity of the terpolymers increases with the increase in temperature. Hence these terpolymers can be termed as semiconductors. The activation energy calculated from the slopes of the plots is found to be in the range of 7.1 x 10^{-20} to 4.5 x 10^{-20} J/K. The low magnitude of the activation energy may be due to the large number of π electrons. The activation energy was found to decrease in the order of 2, 2'-HBDF-I > 2, 2'-HBDF-II > 2, 2'-HBDF-III > 2, 2'-HBDF-IV. The above decreasing order of activation energy may be ascribed to the introduction of more and more aromatic skeleton in the repeat unit structure of the terpolymers.

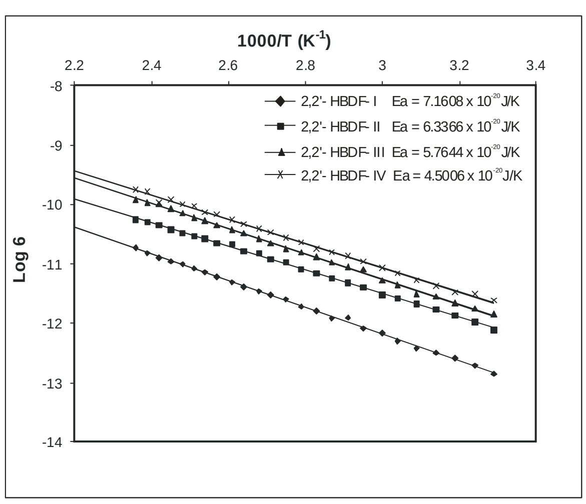

Fig. 2. Electrical Conductivity Plots of 2, 2'-HBDF Terpolymers. (Temperature dependence of log σ)

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Table 2 Evaluation of Activation Energy of Conduction of 2, 2'-HBDF-I
Diameter of pellet (r) = 1.502cm.
Surface area of the pellet (A) = 1.771 cm.^{2}
Thickness of the pellet (l) = 0.192 cm. A/l = 9.228cm

Temp (K)	1000/T (K^{-1})	Resistance (Ohm) 'R'	Resistance ρ= R. A/l	Conductivity σ = 1/ ρ	Log σ
303	3.30	$7.6929x10^{11}$	$7.0990x10^{12}$	$1.4086x10^{-13}$	-12.8512
308	3.24	$5.5871x10^{11}$	$5.1558 x10^{12}$	$1.9395x10^{-13}$	-12.7123
313	3.19	$4.2412x10^{11}$	$3.9138 x10^{12}$	$2.5550x10^{-13}$	-12.5926
318	3.14	$3.5147x10^{11}$	$3.2433 x10^{12}$	$3.0831x10^{-13}$	-12.5101
323	3.09	$2.8886x10^{11}$	$2.6656 x10^{12}$	$3.7514x10^{-13}$	-12.4258
328	3.04	$2.1998x10^{11}$	$2.0300 x10^{12}$	$4.9260x10^{-13}$	-12.3075
333	3.00	$1.5815x10^{11}$	$1.4594 x10^{12}$	$6.8517x10^{-13}$	-12.1642
338	2.95	$1.3526x10^{11}$	$1.2482 x10^{12}$	$8.0112x10^{-13}$	-12.0963
343	2.91	$8.7819x10^{10}$	$8.1040 x10^{11}$	$1.2339x10^{-12}$	-11.9087
348	2.87	$9.1199x10^{10}$	$8.4158 x10^{11}$	$1.1882x10^{-12}$	-11.9251
353	2.83	$6.8500x10^{10}$	$6.3212 x10^{11}$	$1.5819x10^{-12}$	-11.8008
358	2.79	$5.7081x10^{10}$	$5.2674 x10^{11}$	$1.8984x10^{-12}$	-11.7216
363	2.75	$4.3560x10^{10}$	$4.0197 x10^{11}$	$2.4877x10^{-12}$	-11.6042
368	2.71	$3.6795x10^{10}$	$3.3954 x10^{11}$	$2.9450x10^{-12}$	-11.5309
373	2.68	$3.2187x10^{10}$	$2.9702 x10^{11}$	$3.3666x10^{-12}$	-11.4728
378	2.64	$2.6871x10^{10}$	$2.4797 x10^{11}$	$4.0327x10^{-12}$	-11.3944
383	2.61	$2.2003x10^{10}$	$2.0304 x10^{11}$	$4.9249x10^{-12}$	-11.3076
388	2.57	$1.8339x10^{10}$	$1.6923 x10^{11}$	$5.9088x10^{-12}$	-11.2285
393	2.54	$1.5360x10^{10}$	$1.4174 x10^{11}$	$7.0550x10^{-12}$	-11.1515
398	2.51	$1.2953x10^{10}$	$1.1950 x10^{11}$	$8.3656x10^{-12}$	-11.0775
403	2.48	$1.0836x10^{10}$	$1.0000 x10^{11}$	$1.0000x10^{-11}$	-11.0000
408	2.45	$9.7632x10^{9}$	$9.0094 x10^{10}$	$1.1099x10^{-11}$	-10.9547
413	2.42	$8.5820x10^{9}$	$7.9195 x10^{10}$	$1.2626x10^{-11}$	-10.8987
418	2.39	$7.1993x10^{9}$	$6.6435 x10^{10}$	$1.5052x10^{-11}$	-10.8224
423	2.36	$5.9114x10^{9}$	$5.4550 x10^{10}$	$1.8331x10^{-11}$	-10.7368

Table 3 Evaluation of Activation Energy of Conduction of 2, 2'-HBDF-II
Diameter of pellet (r) = 1.523cm.
Surface area of the pellet (A) = 1.821cm.^{2}
Thickness of the pellet (l) = 0.198 cm. A/l = 9.201cm

Temp (K)	1000/T (K^{-1})	Resistance (Ohm) 'R'	Resistance ρ= R. A/l	Conductivity σ = 1/ ρ	Log σ
303	3.30	$1.4494x10^{11}$	$1.3335x10^{12}$	$7.4989x10^{-13}$	-12.1250
308	3.24	$1.0440x10^{10}$	$9.6050x10^{11}$	$1.0411x10^{-12}$	-11.9825
313	3.19	$8.0893x10^{10}$	$7.4421x10^{11}$	$1.3436x10^{-12}$	-11.8717
318	3.14	$7.2625x10^{10}$	$5.9552x10^{11}$	$1.6791x10^{-12}$	-11.7749
323	3.09	$5.1216x10^{10}$	$4.7119x10^{11}$	$2.1222x10^{-12}$	-11.6732
328	3.04	$4.1726x10^{10}$	$3.8388x10^{11}$	$2.6049x10^{-12}$	-11.5842
333	3.00	$3.7154x10^{10}$	$3.4182x10^{11}$	$2.9254x10^{-12}$	-11.5338
338	2.95	$3.3745x10^{10}$	$3.1045x10^{11}$	$3.2210x10^{-12}$	-11.4092
343	2.91	$2.3211x10^{10}$	$2.1355x10^{11}$	$4.6827x10^{-12}$	-11.3295
348	2.87	$1.9579x10^{10}$	$1.8013x10^{11}$	$5.5513x10^{-12}$	-11.2556
353	2.83	$1.5754x10^{10}$	$1.4494x10^{11}$	$6.8992x10^{-12}$	-11.1612
358	2.79	$1.3624x10^{10}$	$1.2534x10^{11}$	$7.9781x10^{-12}$	-11.0981
363	2.75	$1.0273x10^{9}$	$9.4514x10^{10}$	$1.0580x10^{-11}$	-10.9755
368	2.71	$9.1730x10^{9}$	$8.4391x10^{10}$	$1.1848x10^{-11}$	-10.9263
373	2.68	$7.1847x10^{9}$	$6.6099x10^{10}$	$1.5128x10^{-11}$	-10.8202
378	2.64	$6.7067x10^{9}$	$6.1702x10^{10}$	$1.6206x10^{-11}$	-10.7903
383	2.61	$5.1500x10^{9}$	$4.7380x10^{10}$	$2.1105x10^{-11}$	-10.6756
388	2.57	$5.0120x10^{9}$	$4.6110x10^{10}$	$2.1687x10^{-11}$	-10.6638
393	2.54	$4.1305x10^{9}$	$3.8001x10^{10}$	$2.6314x10^{-11}$	-10.5798
398	2.51	$3.7671x10^{9}$	$3.4657x10^{10}$	$2.8853x10^{-11}$	-10.5398
403	2.48	$3.3198x10^{9}$	$3.0542x10^{10}$	$3.2741x10^{-11}$	-10.4849
408	2.45	$2.8741x10^{9}$	$2.6442x10^{10}$	$3.7818x10^{-11}$	-10.4223
413	2.42	$2.4695x10^{9}$	$2.2719x10^{10}$	$4.4014x10^{-11}$	-10.2564
418	2.39	$2.2341x10^{9}$	$2.0554x10^{10}$	$4.8651x10^{-11}$	-10.3129
423	2.36	$1.9797x10^{9}$	$1.8213x10^{10}$	$5.4903x10^{-11}$	-10.2604

Table 4 Evaluation of Activation Energy of Conduction of 2, 2'-HBDF-III
Diameter of pellet (r) = 1.470cm.
Surface area of the pellet (A) = 1.698cm.^{2}
Thickness of the pellet (l) = 0.199 cm. A/l = 8.535cm

Temp (K)	1000/T (K^{-1})	Resistance (Ohm) 'R'	Resistance ρ= R. A/l	Conductivity σ = 1/ ρ	Log σ
303	3.30	$8.3518x10^{10}$	$7.0990x10^{11}$	$1.4086x10^{-12}$	-11.8512
308	3.24	$6.7714x10^{10}$	$5.7557x10^{11}$	$1.7374x10^{-12}$	-11.7601
313	3.19	$5.3577x10^{10}$	$4.5540x10^{11}$	$2.1958x10^{-12}$	-11.6584
318	3.14	$4.2774x10^{10}$	$3.6358x10^{11}$	$2.7504x10^{-12}$	-11.5606
323	3.09	$3.7590x10^{10}$	$3.1952x10^{11}$	$3.1296x10^{-12}$	-11.5045
328	3.04	$2.6679x10^{10}$	$2.2677x10^{11}$	$4.4096x10^{-12}$	-11.3556
333	3.00	$2.2324x10^{10}$	$1.8975x10^{11}$	$5.2698x10^{-12}$	-11.2782
338	2.95	$1.4685x10^{10}$	$1.2480x10^{11}$	$8.0112x10^{-12}$	-11.0963
343	2.91	$1.3154x10^{10}$	$1.1181x10^{11}$	$8.9433x10^{-12}$	-11.0485
348	2.87	$1.1300x10^{9}$	$9.6050x10^{10}$	$1.0411x10^{-11}$	-10.9825
353	2.83	$9.0715x10^{9}$	$7.7108x10^{10}$	$1.2968x10^{-11}$	-10.8871
358	2.79	$7.6540x10^{9}$	$6.4980x10^{10}$	$1.5388x10^{-11}$	-10.8128
363	2.75	$6.6239x10^{9}$	$5.6728x10^{10}$	$1.7627x10^{-11}$	-10.7538
368	2.71	$5.3110x10^{9}$	$4.5143x10^{10}$	$2.2151x10^{-11}$	-10.6546
373	2.68	$4.4882x10^{9}$	$3.8150x10^{10}$	$2.6211x10^{-11}$	-10.5815
378	2.64	$3.6650x10^{9}$	$3.1153x10^{10}$	$3.2099x10^{-11}$	-10.4935
383	2.61	$3.1137x10^{9}$	$2.6466x10^{10}$	$3.7783x10^{-11}$	-10.4227
388	2.57	$2.6672x10^{9}$	$2.2161x10^{10}$	$4.5123x10^{-11}$	-10.3456
393	2.54	$2.2079x10^{9}$	$1.8767x10^{10}$	$5.3284x10^{-11}$	-10.2734
398	2.51	$1.9736x10^{9}$	$1.6776x10^{10}$	$5.9607x10^{-11}$	-10.2247
403	2.48	$1.6431x10^{9}$	$1.3966x10^{10}$	$7.1597x10^{-11}$	-10.1451
408	2.45	$1.3860x10^{9}$	$1.1781x10^{10}$	$8.4878x10^{-11}$	-10.0712
413	2.42	$1.1955x10^{9}$	$1.0162x10^{10}$	$9.8401x10^{-11}$	-10.0070
418	2.39	$1.0806x10^{8}$	$9.1854x10^{9}$	$1.0886x10^{-10}$	-9.9631
423	2.36	$9.7651x10^{8}$	$8.3004x10^{9}$	$1.2047x10^{-10}$	-9.9191

Table 5 Evaluation of Activation Energy of Conduction of 2, 2'-HBDF-IV
Diameter of pellet (r) = 1.477cm.
Surface area of the pellet (A) = 1.714cm.^{2}
Thickness of the pellet (l) = 0.208 cm. A/l = 8.243cm

Temp (K)	1000/T (K^{-1})	Resistance (Ohm) 'R'	Resistance ρ= R. A/l	Conductivity σ = 1/ ρ	Log σ
303	3.30	$501367x10^{10}$	$4.2121x10^{11}$	$2.3741x10^{-12}$	-11.6245
308	3.24	$3.9508x10^{10}$	$3.2396x10^{11}$	$3.0867x10^{-12}$	-11.5105
313	3.19	$3.6592x10^{10}$	$3.0005x10^{11}$	$3.3327x10^{-12}$	-11.4772
318	3.14	$2.8792x10^{10}$	$2.3610x10^{11}$	$4.2354x10^{-12}$	-11.3731
323	3.09	$2.2976x10^{10}$	$1.8840x10^{11}$	$5.3076x10^{-12}$	-11.2751
328	3.04	$1.7938x10^{10}$	$1.4709x10^{11}$	$6.7982x10^{-12}$	-11.1676
333	3.00	$1.4167x10^{10}$	$1.1617x10^{11}$	$8.6079x10^{-12}$	-11.0651
338	2.95	$1.1357x10^{9}$	$9.3132x10^{10}$	$1.0737x10^{-11}$	-10.9691
343	2.91	$9.1156x10^{9}$	$7.4748x10^{10}$	$1.3378x10^{-11}$	-10.8736
348	2.87	$7.8829x10^{9}$	$6.4639x10^{10}$	$1.5470x10^{-11}$	-10.8105
353	2.83	$6.8247x10^{9}$	$5.5962x10^{10}$	$1.7868x10^{-11}$	-10.7479
358	2.79	$5.2648x10^{9}$	$4.3171x10^{10}$	$2.3163x10^{-11}$	-10.6352
363	2.75	$4.4206x10^{9}$	$3.6249x10^{10}$	$2.7586x10^{-11}$	-10.5593
368	2.71	$3.6600x10^{9}$	$3.0012x10^{10}$	$3.3319x10^{-11}$	-10.4773
373	2.68	$3.1636x10^{9}$	$2.5941x10^{10}$	$3.8547x10^{-11}$	-10.4140
378	2.64	$2.6193x10^{9}$	$2.1478x10^{10}$	$4.6558x10^{-11}$	-10.3302
383	2.61	$2.2432x10^{9}$	$1.8395x10^{10}$	$5.4362x10^{-11}$	-10.2647
388	2.57	$1.7938x10^{9}$	$1.4709x10^{10}$	$6.7982x10^{-11}$	-10.1676
393	2.54	$1.6760x10^{9}$	$1.3743x10^{10}$	$7.2761x10^{-11}$	-10.1381
398	2.51	$1.2983x10^{9}$	$1.0646x10^{10}$	$9.3929x10^{-11}$	-10.0272
403	2.48	$1.2155x10^{8}$	$9.9678x10^{9}$	$1.0032x10^{-10}$	-9.9986
408	2.45	$1.0242x10^{8}$	$8.3984x10^{9}$	$1.1906x10^{-10}$	-9.9242
413	2.42	$1.1227x10^{8}$	$9.2066x10^{9}$	$1.0861x10^{-10}$	-9.9641
418	2.39	$7.4590x10^{8}$	$6.1164x10^{9}$	$1.6349x10^{-10}$	-9.7865
423	2.36	$6.8452x10^{8}$	$5.6130x10^{9}$	$1.7815x10^{-10}$	-9.7492

Antimicrobial Screening

The microbial screening results of 2, 2'-HBDF copolymer ligand show (Table 6) higher activity is due to the donor atoms of the ligand and the π-electrons delocalization. This effect increases the lipophilic character, which favours the permeation through the lipoid layer of the bacterial and fungal membranes (Patel M. 2003). The higher activity may also be due to the presence of - OH and the aromatic ring(Singh N et.al 2000). It is perceived that the factors such as solubility, conductivity, dipole moment and cell permeability mechanism may be alternative reasons for the increased activity of the metal complexes (Bagihalli G. B., Patil S. A., Badami P. S. (2009). The ligand has good inhibition against the growth of Gram-negative bacteria which induces tumour. Hence the copolymer ligand may possess antitumor activity. The Gram-positive bacteria are both pathogenic and invasive. The copolymer has good inhibition characteristics against the growth of this pathogen. *Aspergillus niger* cause aspergillosis, the growth of the fungus is controlled by the copolymer chelates to some extent. The *Candida albicans* can penetrate into the intestinal walls and cause diseases. From the findings, the growth of *Candida albicans* is inhibited by the addition of 2, 2'-HBDF copolymer resin.

Table 6. Antimicrobial activities of 2, 2'-HBDF copolymer resin.

Copolymer	**Diameter of zone of inhibition (mm)**			
	S. Aureus	***E. Coli***	***A. Niger***	***C. Albicans***
2, 2'-HBDF-II	15	16	17	15
Solvent (DMSO)	--	--	--	--

Conclusions

The plots of log σ Vs 1000/T were found to be linear in the temperature range under study, which indicate that the Wilson's exponential law $\sigma = \sigma_0 \exp^{(-\Delta E/kT)}$ is obeyed. These terpolymers may be ranked as semiconductors. The electrical conductivity of TMF copolymers at room temperature lies in the range of $1.4x10^{-13}$ to $2.3x10^{-12}$ Siemen. The energy of activation is found to decrease in the order: 2,2'-HBDF-I > 2,2'-HBDF -II > 2,2'-HBDF -III > 2,2'-HBDF -IV and electrical conductivity is found to increase in the order: 2,2'-HBDF -I < 2,2'-HBDF -II < 2,2'-HBDF -III < 2,2'-HBDF - IV. The energy of activation (Ea) of electrical conduction calculated from the slopes of the plots is found to be in the range of 7.1×10^{-20} to 4.5×10^{-20} J/K.

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