Synthesis and electrical conductance behaviour of terpolymer resin-II derived from p-hydroxybenzaldehyde, urea and ethylene glycol

Amit N. Gupta

Department of Applied Chemistry, JD College of Engineering and Management, Nagpur, India

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Summary Terpolymer resin abbreviated as HBUE-II was synthesized by polycondensation using monomers p-hydroxybenzaldehyde (0.2 M), urea (0.1 M) and ethylene glycol (0.4 M) in the presence of polyphosphoric acid as catalyst at 120 °C. The terpolymer was characterized by elemental analysis, FT-IR, 1H NMR and UV–vis spectra. The resin was found to show semiconducting behaviour in the temperature range 301–448 K. The activation energy by conduction was found to be 1.1163 kJ mol⁻¹.

Introduction

Semiconductors are useful ingredients of modern electronics. More interest developed in semiconducting polymer for studding such as, electro-optics, optoelectronics devices such as PLED’s, photovoltaic, photo detectors, FET’s and displays, optical scanners, remote control devices, wireless LAN, security sensing, automatic lighting controls, gas sensors, colour sensor element for digital camera, photonics, and night vision instruments. Kushwaha et al. (2012) studied polymer resins derived from p-nitrophenol, resorcinol, formaldehyde, electrical conductivity of resin found to be in order 0.0926 × 10⁻⁶ to 0.3294 × 10⁻⁶ S/cm at room temperature and activation energy was 4.089 kJ mol⁻¹. Kapse et al. (2013) reported resin derived from p-hydroxyacetophenone, resorcinol, glycerol and electrical conductivity of terpolymer found in order of 2.5912 × 10⁻⁶ to 6.4955 × 10⁻⁶ S/cm and activation energy was 11.56 kJ mol⁻¹ at room temperature. In this research work, p-hydroxybenzaldehyde, urea, ethylene glycol polymer resin synthesized with catalyst polyphosphoric acid by polycondensation method and over a wide range of temperature, electrical properties of HBUE-II polymer were investigated.

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Experimental

Polymer resin abbreviated as HBUE-II and synthesized by polycondensation of p-hydroxybenzaldehyde (0.2 M), urea (0.1 M) and ethylene glycol (0.4 M) in polyphosphoric acid as a catalyst in oil bath at 120±2 °C temperature for 5 h. After purification, 82% yield found.

Result and discussion

 Elemental analysis has been carried out as follows: Found: C, 67.31; H, 6.01; N, 6.77 Calc. for C_{12}H_{25}O_{5}N_{2}: C, 67.48; H, 6.11; N, 6.85% (Gupta et al., 2012a, 2013a).

IR spectrum of HBUE-II polymer resin is shown in Fig. 1. IR absorption of HBUE-II polymer resin was as follows: ν_{max}/cm^{-1} 3570m for N–H stretching-secondary amide group, 3430b for phenolic hydroxyl group with intermolecular hydrogen bonding, 2744w and 2916m for —C–H–stretching in the aldehyde, doublet due to Fermi resonance, 1685m for C=O amide and amide-I band, 1655s for C=O band and aldehyde, 1598m for aromatic ring, 1561m for N–H bending, 1344m for aldehydic C–H bending, 1298w and 1284m for C–N stretching band in —CONH— group, 1220m, 1095m and 961w for 1,2,3,5-tetra substitution of aromatic ring, 830w for —CH$_2$— wagging (Gupta et al., 2012b, 2013b, 2014).

Inset (a) of Fig. 1 shows ultraviolet visible spectra of HBUE-II polymer. HBUE-II terpolymer sample displayed two characteristic broad bands at 280–320 and 210–265 nm. Observed position for the absorption band indicate the presence of a carbonyl (>C=O) having a carbon–oxygen double bond conjugation with aromatic nucleus. The latter band or more intense band can be accounted by π–π$^*$ transition and former band or less intense band due to n–π$^*$ transitions (Karunakaran et al., 2011; Silverstein and Webster, 1998).

Inset (b) of Fig. 1 shows $^1$H NMR spectrum of HBUE-II polymer. δ in the range 1.3 ppm was of —CH$_2$— in HBUE-II. Signal at 2.48 ppm was due to —CH$_2$—NH in polymer resin. Signal at δ 2.60 ppm was due to DMSO solvent. Signal at δ 3.40 ppm was assigned to secondary amine proton in polymer. Signal at δ 3.80 ppm was attributed to CH–OH moiety. Signal at δ 6.95 ppm was due to aromatic ring protons in HBUE-II. Signal at δ 7.2 ppm was due to C–NH in HBUE-II terpolymer. Weak signal δ 9.4 ppm was due the aldehydic proton (Field et al., 1969).

Electrical conductivity

The DC conductivities of HBUE-II resin were study of temperature range 301—448 K. Value of specific conductance was determined from specific resistance. Powdered sample of HBUE-II was palatalized using hydraulic press at a pressure of 17 lb/in$^2$. Surface of the pallet made to conduct by applying
Semiconducting nature of graphite paste. Solid state conductivity was recorded as a function of temperature by two probe methods. The electrical conductivity varies exponentially with the absolute temperature according to relationship as given in Eq. (1):

$$\sigma = \sigma^0 \exp\left(-\frac{E_a}{kT}\right)$$  \hspace{1cm} (1)

$$\log \sigma = \left(\frac{-E_a}{2.303k}\right) + \log \sigma^0$$  \hspace{1cm} (2)

where $\sigma$ = electrical conductivity at temperature $T$, $\sigma^0$ = electrical conductivity at temperature $T \to \sigma^\infty$, $E_a$ = activation energy of electrical conductance, $k$ = Boltzmann constant, $T$ = absolute temperature. The plot of log $\sigma$ versus $1/T$ was found to linear in the temperature range as shown in Fig. 2 that indicate Wilson's exponential Eq. (2) was satisfied. This indicates the semiconducting nature of the HBUE-II resin. The activation energy by conduction was found that 1.1163 kJ mol$^{-1}$. The electrical conductivity for HBUE-II resin was found in the range of $0.1679 \times 10^{-6}$ to $0.2392 \times 10^{-6}$ S/cm for temperature range 301 – 448 K.

**Conclusion**

Data of elemental analysis, FT-IR spectra, $^1$H NMR spectra and UV–vis spectra support the structure of HBUE-II terpolymeric resin. In presence of the linear nature of plot of log $\sigma$ versus $1/T$ in mentioned temperature range, the Wilson’s exponential law is obeyed. It has been concluded that the resin HBUE-II shows the semiconducting behaviour. The nature of plot further suggests the hopping mechanism of conduction is due to the loosely bound $\pi$ electrons at the unsaturation centres in the polymeric matrix.

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**References**


