

Photophysical Properties of Hydroxylated Amphiphilic Poly(*p*-phenylene)s

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A homologous series of polyhydroxylated poly(*p*-phenylene)s with different alkoxy groups (C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH) were synthesized with use of the Suzuki polycondensation reaction. Comparative studies of the structure correlation between their photophysical properties and film morphology is described. The absorption and emission spectra of polymers in solution and thin films showed similar features indicating that the electronic properties in solution were retained in the film state. Compared to the polymer with the short alkoxy chains (C₆PPPOH), the polymers with long alkoxy groups (C₁₂PPPOH and C₁₈PPPOH) showed improved film forming properties with continuous and smooth film morphology. The absorption properties of the C₁₂PPPOH showed an enhanced effective conjugation length and high quantum yield implying planarization of the backbone through alkoxy chain packing (C₁₂H₂₅O–) and potential hydrogen bonds. No overlap in the absorption and emission spectra was observed, which indicated minimized excimer formation or excitation energy transfer in the films. Time-resolved fluorescence measurements showed that the decay times increased from 43 ps (C₆PPPOH) to 78 ps (C₁₂PPPOH) and 99 ps (C₁₈PPPOH). Electrochemical studies were performed for all polymers and the observed oxidation potential for C₆PPPOH was higher than that of C₁₂PPPOH and C₁₈PPPOH. In addition, the C₁₂PPPOH has the lowest band gap of $\Delta E = 2.59$ eV when compared to the 3.1 (C₆PPPOH) and 2.61 eV (C₁₈PPPOH) gaps. The optical band gaps estimated from the absorption onset of the polymers are significantly higher than those obtained from electrochemical data. C₁₂PPPOH was chosen for investigating the charge carrier mobility by the time-of-flight (TOF) technique. The observed results also showed negative field dependent values of the drift mobility for the polymer C₁₂PPPOH.

Introduction

Conjugated polymers are of considerable academic and industrial interest as active materials in devices such as waveguides,¹ fluorescent chemical sensors,² photoconductors,³ organic light-emitting diodes (OLEDs),⁴ and the most promising new applications such as flexible displays. Compared to their inorganic counterparts, their processability, film forming properties, highly efficient radiative processes, and tunability of their band gap using chemical modifications make conjugated polymers promising candidates for various applications.^{5,6} The basic characteristics required for conjugated materials in OLED application are semiconducting properties and high quantum yield of the photoluminescence.^{7,8} Even if these requirements are achieved, it is necessary to optimize the quality of the emitting layer by an appropriate deposition technique to control the film morphology, charge carrier mobility, and emission yield of the device. The present study deals with investigating photophysical properties of a new class of amphiphilic poly(*p*-phenylene)s, (C_nPPPOH), and their thin film properties. The effect of side chains on the polymer backbone and the

morphology of spin-coated films are of interest owing to the strong correlation between the photophysical properties in solution or in solid state with the structure of these polymers. The electronic structure of conjugated polymers in the film state is of current interest because of easy and potential applications for such materials in optoelectronic devices. At present, active layers in light emitting devices (LEDs) are made mostly via spin coating technique. Incorporating appropriate functional groups on the backbone has a significant influence on the film forming nature as well as on the electronic properties of the polymers in the film state.⁹

Among the conjugated polymers, polythiophenes, polycarbazoles, poly(phenylene vinylene)s, and poly(*p*-phenylene)s have attracted particular interest as blue electroluminescent polymers due to their high quantum yield and good charge transport properties.^{10,11} In earlier studies, the low solubility of the poly(*p*-phenylene)s limited the processability for device fabrications. Introduction of substituents on the PPP backbone is an alternative method to improve solubility; however, the repulsion of the side group forces the phenyl rings to a nonplanar conformation. The tilt angle and the effective conjugation length strongly influence the band gap, which increases with substitution as compared to the unsubstituted PPPs. To circumvent such limitations, the planarization of the PPP backbone has been achieved through various methods such as covalent bond modification¹² or incorporation of weak interactions such as

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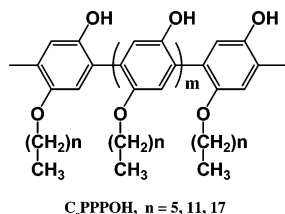


Figure 1. Chemical structure of the polymers.

hydrogen bonds on the polymer backbone.¹³ The planarization of the PPP backbone minimizes the torsional angle between the neighboring phenyl rings and the band gap is expected to shift to a smaller value. Here, photophysical and optoelectronic properties of three multifunctional amphiphilic poly(*p*-phenylene)s ($C_n\text{PPPOH}$) with free hydroxyl groups and alkoxy groups on the polymer backbone are discussed in detail. The design strategy relies on the use of hydroxyl groups incorporated on the polymer backbone as a potential hydrogen-bonding functionality to planarize the PPP backbone (Figure 1).

Experimental Section

Synthesis of Polymers. Amphiphilic poly(*p*-phenylene)s $C_6\text{PPPOH}$, $C_{12}\text{PPPOH}$, and $C_{18}\text{PPPOH}$ were synthesized by using the Pd(0) catalyzed Suzuki polycondensation as reported earlier and characterized.^{13e,14} The molecular weights of the precursor polymers were measured with GPC: $M_n = 10450$, $M_w = 23524$ and PDI = 2.2 for $C_6\text{PPPOH}$, $M_n = 3083$, $M_w = 4139$, and PDI = 1.34 for $C_{12}\text{PPPOH}$, and $M_n = 6851$, $M_w = 8937$, and PDI = 1.3 for $C_{18}\text{PPPOH}$. The UV-vis spectra were measured on a Shimadzu 3101 PC spectrophotometer and fluorescence measurements were carried out on a RF-5301PC Shimadzu spectrofluorophotometer. The thermal properties of the polymers were investigated by thermogravimetric analysis (TGA), using a SDT 2960 TA instrument at a heating rate of 10 deg/min under nitrogen. Powder X-ray patterns were obtained with a D5005 Siemens X-ray diffractometer with Cu K α (1.5 Å) radiation (40 kV, 40 mA). The polymer samples were mounted on a sample holder and scanned between $2\theta = 1.5^\circ$ and 50° . The electrochemical behavior of the polymers was investigated with cyclic voltammetry (CV).²³ The cyclic voltammograms were recorded with a computer controlled μ -Autolab type II potentiostat/galvanostat controlled by the Autolab GPES software version 4.7 at a constant scan rate of 50 mV/s. Measurements were performed in an electrolyte solution of 0.1 M tetrabutylammoniumperchlorate (Bu_4NClO_4) dissolved in acetonitrile. An undivided three electrode configuration cell was used with a glassy carbon working electrode, platinum wire as the counter electrode, and Ag/AgCl as the reference electrode. The polymer dissolved in chloroform was drop casted onto the glassy carbon electrode to form a thin film and was dried in a vacuum oven before being inserted into the cell. The AFM imaging of the films was done in air, using a Nanoacope III AFM (Digital Instruments Inc), in the tapping mode with silicon cantilevers.

The relative PL quantum yields of the polymers in toluene solution were determined by using quinine sulfate in 0.1 M sulfuric acid as the reference.¹⁵ The absolute PL quantum yields of the polymer films were determined by using an integrating sphere (Lab. Sphere Com) with He-Cd laser (325 nm; 11 mW) as an excitation source.^{16,17} To obtain a correct value for absorption, a bare quartz substrate was used when measuring on an empty sphere before measuring the polymer samples. Errors due to fluctuation of excitation light and differences in position of the sample inside the sphere were minimized by repeating the measurement several times, using polymer film

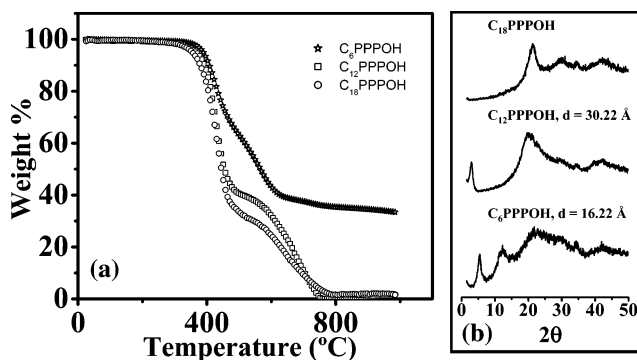


Figure 2. TGA traces (a) and powder X-ray diffraction pattern (b) of the polymer samples $C_6\text{PPPOH}$, $C_{12}\text{PPPOH}$, and $C_{18}\text{PPPOH}$. The calculated d -spacing values (in Å) are shown in the figure.

samples of different dimension and different UV absorbance. The time-resolved photoluminescence measurements were carried out by exciting the spin-coated polymer films on quartz substrates, using a femtosecond laser, and measured with an FS streak camera. The solution quantum yields of the polymers were calculated with use of quinine sulfate as the reference and the solid-state quantum yields were measured by using an integrating sphere. The charge carrier mobility measurements were done by using a conventional time-of-flight (TOF) photoconductivity measurement on indium-tin oxide (ITO)/polymer/aluminum sandwich structures. Test devices were prepared by spin coating the polymer solution in toluene (30 mg/mL, 500 rpm) on a transparent ITO (sheet resistance of 20 Ω /square) patterned glass substrate. These films were annealed at a temperature of 60 $^\circ\text{C}$ for 3 h in a nitrogen atmosphere to remove residual solvent. A 60 nm thick aluminum (Al) electrode was evaporated onto the polymer film by an Edwards thermal evaporator (Auto 306) at 10^{-7} Torr of pressure. The active area of the device was 4 mm². The thickness of the films was measured with a surface profilometer.

Results and Discussion

A homologous series of amphiphilic $C_n\text{PPPOH}$ ($C_6\text{PPPOH}$, $C_{12}\text{PPPOH}$, and $C_{18}\text{PPPOH}$) have been synthesized via Suzuki polycondensation of the respective monomers and were carefully purified to remove all impurities and catalyst residues.^{13a} The incorporation of a long alkoxy chain on one side and hydroxyl groups on the other side of the polymer backbone (Figure 1) improved the solubility in common organic solvents. The TGA analysis and X-ray diffraction studies were performed to investigate the role of alkoxy chain on the thermal stability and solid-state structural characteristics of the polymer. The thermogravimetric analysis of the three polymers showed that they are stable up to 325 $^\circ\text{C}$ under nitrogen atmosphere with the mass loss of less than 2% (Figure 2a). The powder X-ray diffraction patterns of the polymers are shown in Figure 2b. spin-coated films of the polymers did not diffract X-ray. The measured 2θ values revealed a d -spacing of 16.2 ($2\theta = 5.44^\circ$) and 30.2 Å ($2\theta = 2.92^\circ$) respectively for $C_6\text{PPPOH}$ and $C_{12}\text{PPPOH}$. However, in the case of $C_{18}\text{PPPOH}$ there were no peaks observed at the low angle region. However, it is expected to show a peak below 1.5° , which we were not able to measure using our instrument. The observed increase in the d -spacing with the increase in alkoxy chain length is common for many ordered polymers.^{18,19} This shows that the side chains $C_6\text{H}_5\text{O}-$, $C_{12}\text{H}_{25}\text{O}-$, and $C_{18}\text{H}_{25}\text{O}-$ organize well inside the polymer lattice.

The morphology of the polymer films prepared by spin coating toluene solutions of $C_6\text{PPPOH}$, $C_{12}\text{PPPOH}$, and C_{18} -

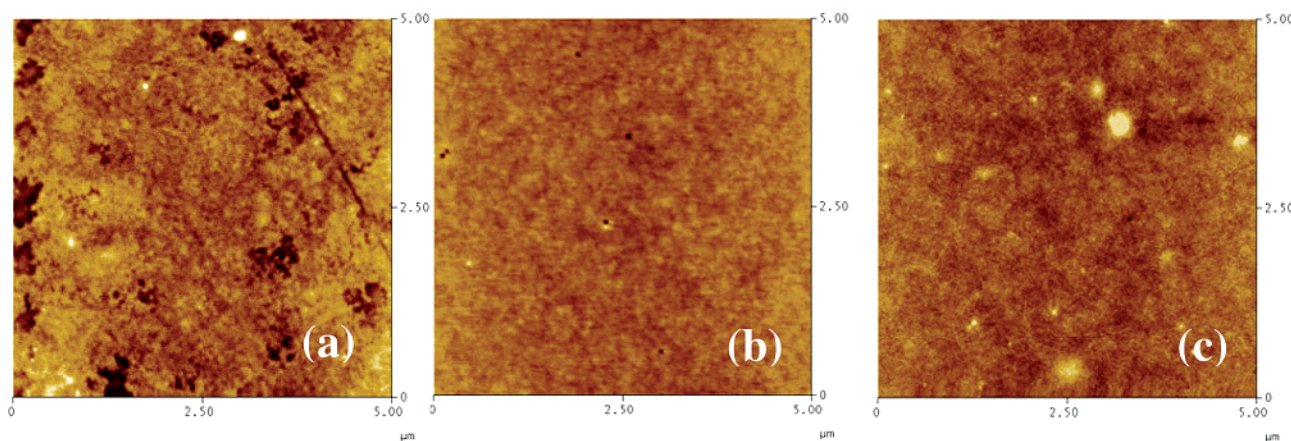


Figure 3. AFM image of a spin-coated film of C₆PPPOH (a), C₁₂PPPOH (b), and C₁₈PPPOH (c), spin coated from toluene solution on an ITO coated glass substrate. The observed film roughness (rms) was 0.77 (a), 0.59 (b), and 0.71 nm (c).

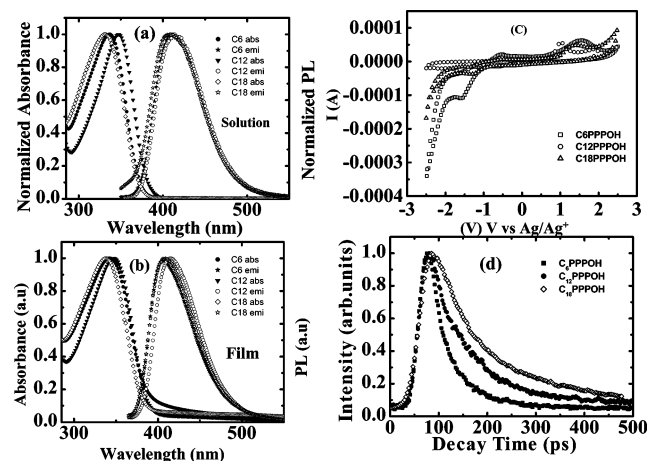


Figure 4. Absorption and emission spectra of polymers C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH in toluene (a) and in film (b), cyclic voltammograms of the polymer films coated on glassy carbon electrode (c), and decay times of the films of C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH cast from toluene solution (d).

PPPOH on an ITO coated glass substrate was studied by using AFM in the tapping mode. The AFM height images are shown in Figure 3 with rms roughness ($5 \mu\text{m} \times 5 \mu\text{m}$) of 0.77, 0.59, and 0.71 nm for C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH, respectively. By using the same concentration and spinning speed, the morphologies of the spin-coated films were seem to be affected by the variation in the length of the alkyl chain on the polymer backbone. The solubility and aggregation of the polymer in a solvent is a critical factor toward the film roughness. Here, the medium size alkoxy chain polymer C₁₂PPPOH gave smooth films compared to C₆PPPOH and C₁₈PPPOH. This may be due to the low solubility of C₆PPPOH, which resulted in films with inhomogeneous surface characteristics and considerable roughness, while a longer alkoxy chain (C₁₈PPPOH) induce more aggregation in toluene and led to the formation of a rough film.

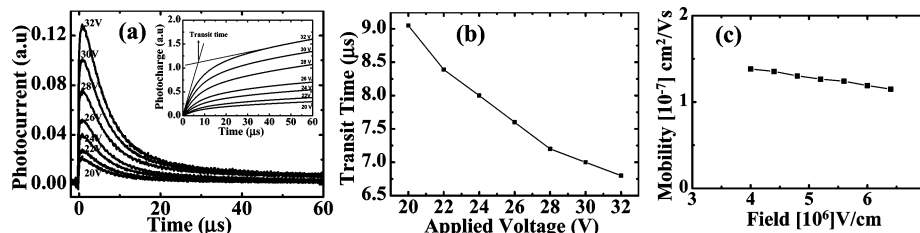
The absorption and photoluminescence (PL) spectra of the polymers in toluene and solid film are given in Figure 4. The solid-state spectra of the polymers were recorded from transparent and uniform films prepared by spin coating from their toluene solutions on a quartz substrate. The absorption maxima (λ_{max}) in solution are 336 (C₆PPPOH), 347 (C₁₂PPPOH), and 331 nm (C₁₈PPPOH), whereas the observed λ_{max} of the corresponding films are 340 (C₆PPPOH), 348 (C₁₂PPPOH), and 338 nm (C₁₈PPPOH). The absorption maxima were red-shifted in solution and in thin film for the polymer C₁₂PPPOH as

compared to C₆PPPOH. Even though the molecular weight of C₁₂PPPOH is lower compared to C₆PPPOH and C₁₈PPPOH, the aforementioned absorption properties support that the effective conjugation length is higher for C₁₂PPPOH. This is due to optimum organization provided by the alkoxy chain (C₁₂H₂₅O-) toward the planarization of the polymer backbone. Similar results were observed in the case of the emission maxima (λ_{emi}) of C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH in solution (412, 414, and 407 nm) and in thin film (407, 417, and 411 nm). The Stokes' shift was found to be 76 (in solution) and 67 nm (in the film) for C₆PPPOH, 67 (in solution) and 69 nm (as film) for C₁₂PPPOH, and 76 (in solution) and 73 nm (in the film state) for C₁₈PPPOH. The quantum yields of the polymers were $(79 \pm 2)\%$ (solution) and $(55 \pm 5)\%$ (solid state) for C₆PPPOH, $(57 \pm 2)\%$ (solution) and $(50 \pm 5)\%$ (solid state) for C₁₂PPPOH, and $(69 \pm 2)\%$ (solution) and $(53 \pm 5)\%$ (solid state) for C₁₈PPPOH. The observed quantum yields in solution are higher compared to the film indicating that intramolecular quenching by internal conversion and intersystem crossing is low in solution as compared to the film state. Similar results were observed in the case of ladder type PPPs, which also showed quantum yields in solution much higher than in the film state.²⁰ Two types of quenching could be explained in the film state: static quenching by the formation of aggregates in the ground state and collisional quenching due to interaction in the excited state. However, there are no differences in the absorption spectrum of the polymers C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH in solution compared to the film indicating that no major aggregation occurs that would cause static quenching in the ground state. Thus, the decrease in the film quantum yield may be mainly from collisional quenching. However, compared to the reported ladder type PPPs, the observed quantum efficiencies of C_nPPPOH in thin films are relatively high. In addition, the Stokes' shift values of 67 (C₆PPPOH), 69 (C₁₂PPPOH), and 73 nm (C₁₈PPPOH) in the film state indicate less overlap between the fluorescence and absorption spectrum minimizing the self-absorption and excitation energy transfer, which are known to reduce the luminescence efficiencies. The observed high quantum yields compared to other substituted PPPs may be due to the planarization of the PPP backbone imparted by the incorporation of alkoxy and hydroxyl side chains.

Cyclic voltammetric measurements were carried out for the polymers. All three polymers exhibited similar electrochemical behavior (Figure 4c). The polymer C₆PPPOH showed an oxidation peak with an onset potential around 0.9–2 V (peak maximum at 1.54 V) and reduction onset around –1.2 and –1.8 V (peak maximum at –1.57 V). In the case of C₁₂PPPOH, an

TABLE 1: Summary of the Electrochemical and Photophysical Properties.

polymer	abs λ_{\max} (nm)		PL λ_{\max} (nm)		optical band gap/eV (film)	HOMO (eV)	LUMO (eV)	electrochemical band gap (eV)	ϕ_{PL} (%)	
	toluene	film	toluene	film					toluene	film
C ₆ PPPOH	336	340	412	407	3.19	−5.93	−2.83	3.1	79 ± 2%	55 ± 5%
C ₁₂ PPPOH	347	348	414	417	3.17	−5.43	−2.84	2.59	57 ± 2%	50 ± 5%
C ₁₈ PPPOH	331	338	407	411	3.21	−5.74	−3.13	2.61	69 ± 2%	53 ± 5%

**Figure 5.** Linear plot of TOF hole transient for different applied voltages (from 20 to 32 V) (a). Variation of transit time with applied voltage (b). Variation of mobility with applied electric field (c).

oxidation wave with an onset around 0.7–1.4 V (peak maximum at 1.03 V) and reversible reduction onset around −1.2 to −1.9 V (peak maximum at −1.56 V) was observed. The polymer C₁₈PPPOH also showed similar oxidation and reduction waves at 0.95–1.8 V (peak maximum at 1.34 V) and −1 to −1.6 V (peak maximum at −1.27 V), respectively. The calculated HOMO and LUMO levels and the energy gaps are summarized in the Table 1. HOMO and LUMO levels are calculated according to the empirical formula $E_{\text{HOMO}} = -(E_{\text{ox}} + 4.4)$ eV and $E_{\text{LUMO}} = -(E_{\text{red}} + 4.4)$ eV²¹ and given in Table 1. The oxidation peaks for all three polymers are assigned to the oxidation of the phenylene groups. A similar oxidation potential of 1 V vs Ag⁺/Ag electrode has been reported for poly(*p*-phenylene).^{22,23} The strong interaction between the polar groups and the perchlorate dopant from the supporting electrolyte may be the reason for the observed irreversibility.²³ The oxidation potential of C₆PPPOH is higher than that of C₁₂PPPOH and C₁₈PPPOH, which indicated that the incorporation of the long alkoxy chain facilitates oxidation. The calculated energy gap of C₁₂PPPOH (2.59 eV) is lower as compared to the value of C₆PPPOH (3.1 eV) and C₁₈PPPOH (2.61 eV). The optical band gaps estimated from absorption onset of the polymers were also listed in Table 1, which were significantly higher than those obtained from the electrochemical data.

To further understand the luminescence properties of the C_{*n*}-PPPOH, photoluminescence (PL) in the film was investigated by using time-resolved fluorescence spectroscopy. The signal-to-noise ratio was good. The obtained decay curves were fitted to single-exponential function. The observed decay times are summarized in Figure 4d. The PL decay curves were well fitted to the single-exponential function and the fitting parameter values (R^2) were 0.995, 0.996, and 0.997 respectively for C₆-PPPOH, C₁₂PPPOH, and C₁₈PPPOH polymers.

The relaxation time was increased with an increase in alkoxy chain lengths (43 ± 0.29, 78 ± 0.48, and 99 ± 0.48 ps for C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH, respectively). Radiative and nonradiative lifetimes were also calculated from the decay time and quantum yield by using the famous equations²⁴

$$1/\tau = 1/\tau_{\text{rad}} + 1/\tau_{\text{nrad}} \quad (1)$$

$$\Phi = \tau/\tau_{\text{rad}} \quad (2)$$

where τ_{rad} , τ_{nrad} , τ , and Φ are the radiative lifetime, nonradiative lifetime, measured lifetime, and the quantum yield, respectively. The calculated radiative lifetimes are 53, 136, and 143 ps and

the corresponding nonradiative lifetimes are 200, 183, and 321 ps for C₆PPPOH, C₁₂PPPOH, and C₁₈PPPOH, respectively. Previous studies with PPV polymers showed that the increase in the conjugation decreases the quantum efficiency and decay time values.²⁵ However, with thiophene oligomers an opposite tendency of quantum efficiency and decay time values was observed.²⁶ Such phenomena could be explained considering the decay of the luminescence arising from competing nonradiative decay channels in each system. Identical QE's are observed for all polymers in the film state (Table 1); however, the decay time increased with increase in alkoxy chain length.

The charge carrier transport properties of C₁₂PPPOH were investigated, which is important in order to optimize device structures. The charge carrier mobility (μ) was obtained by time-of-flight (TOF) measurements, using a 50 nm thin film of C₁₂-PPPOH prepared by spin casting. The observed mobility of the holes in C₁₂PPPOH from the photocurrent transients is shown in Figure 5. The shape of the curves is typical for a dispersive transport in organic polymers. The transit times were extracted from the integrated curve of TOF transients and mobilities were calculated. The transit time is related to the mobility as $t_t = L/\mu E = L^2/\mu V$, where L is the thickness, μ is the mobility, E is the electric field, and V is the voltage. The resistivities of most organic solids are sufficiently high that prior to charge injection, the field in the sample may be assumed to be uniform and given as V/L . The mobility has been calculated for different applied voltages. The hole mobility was found to be 1.4×10^{-7} to 1.1×10^{-7} cm²/V for a field ranging from 4×10^6 to 6.5×10^6 V/cm. The variation of the mobility with the applied electric field is shown in Figure 4c. It was found that the charge mobility showed small negative field dependence and this can be explained by using the Gaussian disorder model proposed by Bässler.²⁷ According to this model, the presence of positional and energetic disorder in the system is responsible for the electric field dependence of the mobility with the negative slope. If the positional disorder is more pronounced than the energetic disorders, the carriers hope to lower the barrier site, which may not be in the field direction, resulting in the negative field dependence of mobility. The observed results showed negative field dependent values of the drift mobility for C₁₂PPPOH by TOF measurements.

In general, the photoelectric properties of a conjugated polymer depend on the nature of the polymer backbone and the way in which they self-organize in the lattice. Recently, Casalbore-Miceli et al. investigated the alkyl/alkoxy chain

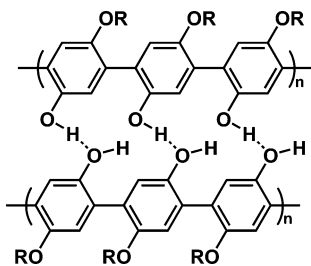


Figure 6. Illustration of the potential interchain hydrogen bonding in the polymers C_n PPPOH.

dependence on the photophysical properties of poly(terthiophenes).²⁸ The nature of the substituents and their regiochemical distribution were the most important factors affecting the intrachain conformation and the interchain organization of the material. In fact, alkoxy groups are better electron donors and sterically less demanding than alkyl groups. On the other hand, if the alkyl group is long, it negatively affects the intrachain planarity but positively affects the interchain self-organization by improving the order and planarity. Hence there is an optimum side chain length that will result in a high electroluminescence and quantum efficiencies.^{19,29} Another interesting study about the role of different substituents on photophysical properties of polythiophene backbone showed that increasing the bulkiness of the substituent increases the quantum yield in solution. However, with spin-coated films, an increased ordering can either increase or decrease the quantum yield, depending on the separation of the conjugated backbones.³⁰ Comparative studies of the structure–property relationship on photophysical properties and the morphology of the film of a new series of C_n PPPOH were carried out and identified that the polymer bearing a medium alkoxy chain length C_{12} PPPOH showed better film forming and optoelectronic properties. Interestingly, there is no difference in the absorption and emission spectra of the polymer in the solid state as compared to the solution. The absorption and PL properties of the polymer indicated that the effective conjugation length is higher for C_{12} PPPOH, which may be due to the planarization of the backbone through potential O–H–O hydrogen bonds and alkyl chain crystallization. In addition, the absence of the overlap in the absorption and emission spectra with approximate Stokes' shift of 70 nm showed the minimized excimer formation and excitation energy transfer in films. The PL quantum yields of C_n PPPOH in the film state were high compared to those of other substituted nonplanarized PPPs,³¹ which may be due to the planarization of the PPP backbone due to the incorporation of the alkoxy and hydroxyl groups. The electrochemical studies revealed that the oxidation potential of C_6 PPPOH was higher than that of C_{12} PPPOH and C_{18} PPPOH. The band gap of the polymer was calculated and C_{12} PPPOH has a low band gap with an energy gap of 2.59 eV as compared to those of C_6 PPPOH and C_{18} PPPOH (3.1 and 2.61 eV). The optical band gaps estimated from absorption onset of the polymers are significantly higher than those obtained from electrochemical data. The time-resolved fluorescence measurement showed that the decay time increased from C_6 PPPOH to C_{12} PPPOH and C_{18} PPPOH. The charge carrier mobility was measured for the polymer C_{12} PPPOH, which has good film forming properties and improved optical properties compared to C_6 PPPOH and C_{18} PPPOH. Observed results showed negative field dependent values of the drift mobility and dispersion parameters for the polymer C_{12} PPPOH.

Conclusions

The structure property relationship, photophysical properties, and morphology of the film of a homologous series of alkoxy and hydroxyl group-substituted poly(*p*-phenylene)s, C_n PPPOH, were described. The optical properties of the polymers in solution and thin film were comparable, which indicates that the electronic property of the polymer in solution is retained in the film state. The polymer C_{12} PPPOH has improved film forming properties with continuous and minimum roughness as compared to C_6 PPPOH and C_{18} PPPOH. High quantum yields in the film state were observed compared to those of other substituted PPPs, and the time-resolved fluorescence measurement showed that the decay time increased with the length of alkyl chains. The band gap was calculated from the electrochemical studies and was significantly lower than optical band gaps estimated from absorption onset of the polymers. The charge carrier mobility by the time-of-flight (TOF) technique showed negative field dependent values of the drift mobility and dispersive transport character for the polymer C_{12} PPPOH, which is typical for organic polymers.

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