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Energy transfer and dynamics studies of photoluminescence of polythiophene derivative in blend thin films

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Thin films of the blend luminescent poly 3-(2-(5-chlorobenzotriazolo)ethyl) thiophene (PCBET) with poly-(p-(methyl)-phenylmethacrylate) (PMPMA), polyvinylcarzole (PVK), and poly (methyl methacrylate) (PMMA) were deposited by spin coating. Systematic studies on optical properties, the concentration effect, and energy transfer of these conjugated polymers within the blend films are discussed. Fluorescence lifetimes of excited state in the blend films were investigated by nanosecond time-resolved spectroscopy, UV-vis, photoluminescence (PL), synchronous PL spectra. These results and analysis suggest that energy transfer, from good matrix material (PMPMA and PVK) with active chromophores to PCBET, leads to the enhancement of PL emission of PCBET in a blend system. © 2012 American Institute of Physics. [doi:10.1063/1.3678453]

I. INTRODUCTION

Blend polymer thin films with nano and micro network structure play an important role and determine the functional performance of materials. These films with perfectly flat surface and maze-like structure have been developed for wide-spread applications.¹ In the electronic industry, a blend polymer film is expected to be an excellent approach for better photo-electronic and electro-optic devices.^{2,3} Their advantages are the low cost, large-size production and easy fabrication for future polymeric light emitting diode (LED), polymer solar cells, etc.⁴ One of the interesting candidate polymers for LEDs,^{4,5} polymer solar cells,² and resist films of nano-lithography⁶ is the polythiophene derivative. Photophysics and photochemistry of these conjugated polymers have been investigated in many research groups because these researches can provide approaches to a deeper understanding of the electroluminescence of conjugated polymers.^{1,7} In this paper, we focus on poly 3-(2-(5-chlorobenzotriazolo) ethyl) thiophene (PCBET) films blended with other polymers; systematic analysis on optical properties, energy transfer between a matrix material and PCBET, and the concentration effect of the blend films are accomplished.

In general, poly (methyl methacrylate) (PMMA), which is an inactive polymer, was thought of as a good matrix material in the blend systems.^{8,9} Because polyvinylcarzole (PVK) has active chromophores, some kinds of blend systems with PVK have also been studied.^{10–12} However, a poly-(p-(methyl)-phenylmethacrylate) (PMPMA), which is synthesized by introducing a phenyl ring component into the PMMA molecule, has a better thermal stability, and its structure is more suitable for PCBET comparing with PMMA.⁹ There are two essential reasons in choosing PMPMA and PVK to combine with PCBET material: (i) PCBET, PMPMA, and PVK have a similar phenyl ring component. They will be mix efficiently. (ii) The matrix molecules with

chromophore-phenyl ring components are selected for suitable energy transfer between two blend polymers under some conditions.

In previous work, the studies of Langmuir–Blodgett (LB) films of PCBET blended with amphibious arachidic acid (AA)¹³ and the studies on energy transfer from PVK to PCBET¹² were reported. Here the spin coating blend films of PCBET/PMPMA plus some PCBET/PVK have been fabricated and investigated; to compare the results, data about blend films of PCBET/PMMA are also provided and discussed. Because there are no reports on the systematic study and detailed data of PCBET and its blend system until now, the UV-vis spectra, photoluminescence (PL, or fluorescence) spectra, synchronous PL measurement, and fluorescence decay spectra on nanosecond time-resolved and the lifetime data of excited state of the blended polymer film were inspected.

II. EXPERIMENTAL MATERIALS

So far, for the conjugated polymers that have been investigated, electron injection has proved to be less feasible than hole injection. To overcome the drawbacks, an incorporation of an electron-transporting (ET)¹⁴ material was introduced. The synthesized PCBET¹⁵ does have an electron-transfer moiety in its side chain.¹⁶ The PMPMA⁹ and PVK were chose as matrixes and an active polymer with function of energy donors phenyl.¹⁶ PMPMA was synthesized by the authors;⁹ PVK and PMMA were purchased from Aldrich.

A. Film and characterization

A thin polymer film is formed on the quartz and glass substrate by spin coating. The spin coater consists of a flat chuck onto which operators would place the slide flat. A vacuum holds the slide down onto the chuck. Liquid was poured onto it, and the flat chuck spins at constant RPM. The blend polymer films were obtained by 1000 RPM spin by a chloroform solution with a concentration of 4.7 mg/ml. UV-vis

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spectra were measured by using a photodiode array spectrophotometer (Scinco Inc., S-2100 Labpro TM). Photoluminescence spectra were measured by a spectrofluorometer (ISS Inc., PC1). The fluorescence lifetimes were measured by an applied photophysics SP-70 ns spectrofluorimeter (UK). Its flashlamp chamber was filled with high purity nitrogen at 600 mbar, and the pulse repetition rate is 50 KHz. The deconvolution on short lifetime was carried out with the iterative method employing APL software in SP-70 ns spectrofluorimeter. It involves in removing effects of the decay curves (or models), rise time of excitation pulse, and respondent function of the measurement system. SP-70 has an ability to reach 0.2 ns lifetime measurement/analysis resolution using this deconvolution calculation. The goodness of lifetime deconvolution is judged and valued by χ^2 reductions, Durbin–Warson (D.W.), residuals and autocorrelation function.

III. RESULTS AND DISCUSSION

A. UV-vis and PL spectra of the PCBET, PMPMA, and PVK films

We evaluate the UV-vis absorption and PL character of the PCBET, PMPMA, and PVK films. In Fig. 1(a) (top part), curves (1) and (2) show the UV-vis absorption spectra of PMPMA and PCBET, respectively, and curves (3) and (4) show their PL spectra. In Fig. 1(b) (bottom part), curves (5) and (6) are the UV-vis absorption and PL spectra of PVK. To remove the effect of second-degree diffraction in PL spectra, curve (3) was obtained by synchronous PL measurement in an excitation range of 180 nm–280 nm and emission range of 300 nm–400 nm. Curve (4) was excited by 422 nm. From the figure, PCBET has strong UV-vis absorption bands at around 422 nm and 285 nm, which are attributed to the π - π^* transition of the conjugated segments and substituted benzotriazole derivative. Normally, PMPMA has two strong 210 nm and 228 nm absorption bands. The emission of the PCBET and PMPMA is 600 and 370 nm, respectively. It is easy to figure out that all these bands have quite wide full width half maximum (FWHM). The large spectral overlap between donor emission and acceptor absorption in PCBET/PMPMA blend means that energy transfer could be efficient. As to PCBET/PVK system, it has a similar and analogous case.

B. Energy transfer effect of PCBET/PMPMA at 228 nm excitation

We analyze the PL character of the blend film mainly based on following a potential electroluminescence (EL) application. As is known, both photoluminescence and EL originate from the radiate recombination of exciton states. In the PL case, it forms by photoexcitation; and for EL, it is from the combination of oppositely charged polarons (radical ions) generated by injection of electrons and holes. Anyway, results of PL study can be seen as consistent with EL's.¹⁷

It is well known that the luminescence polymers, which diluted by blended with other polymers, show different PL and EL spectra comparing with those of pure polymers.^{11,18} We believe that the blend system of PCBET/PMPMA can be used to prevent exciton transfer and get higher luminescence. According to the discussion in Sec. III A, the strong 228 nm absorption of PMPMA can be chosen as the exciting wavelength to produce wideband light emission (at around 370 nm), which overlaps the absorption band of PCBET. The produced 370 nm emission can continue to excite PCBET in the PCBET/PMPMA system; this process is used to increase the PL intensity of PCBET at around 590 nm wavelength and finally obtaining the energy transfer from PMPMA to PCBET. Figure 2 shows the PL spectra of PCBET blend films with PMPMA at different blend ratios. To prevent any third degree diffraction effect of 210 nm, which is near the emissive around 590 nm of active polymer PCBET, the PL spectra were only monitored and measured at 228 nm exciting wavelength. The 370 nm PL emission of PMPMA (left) and 590 nm emission of PCBET (right) in the PCBET/PMPMA film was excited at 228 nm (PMPMA absorption position) under different weight mixing ratios.

As discussed in the preceding text, energy transfer effect leads to the 590 nm peak of PCBET. Under a 228 nm excitation, the emission of pure PCBET film cannot be observed at about 590 nm because PCBET does not directly absorb the 228 nm light. Interestingly, when the blend polymers were excited at 228 nm, the strong emission of PCBET was observed at 590 nm, whereas the intensity of PMPMA emission in the range of 320–410 nm becomes very weak or can not be observed. This phenomenon occurs for the reason that the PL emission band (320–410 nm) of PMPMA overlaps the

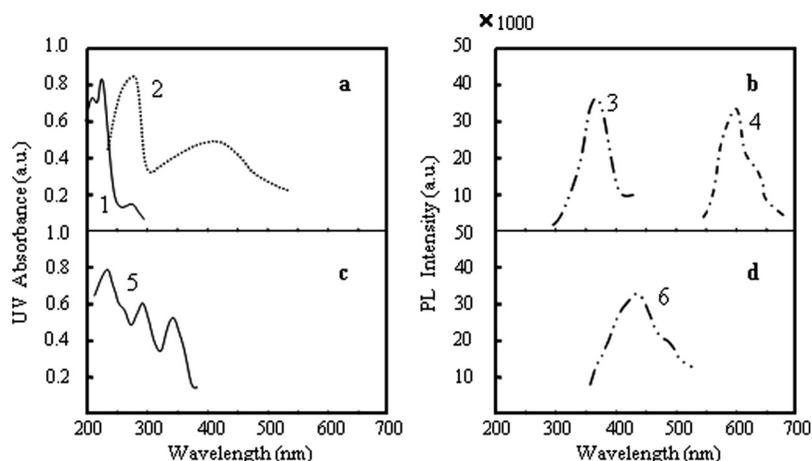


FIG. 1. (a) UV-vis absorption spectra of PMPMA (1) and PCBET (2) films on quartz substrates; (b) photoluminescence (PL) spectra of PMPMA (3) and PCBET (4) films; (c) UV-vis absorption spectra of PVK films (5); (d) photoluminescence (PL) spectra of PVK films (6).

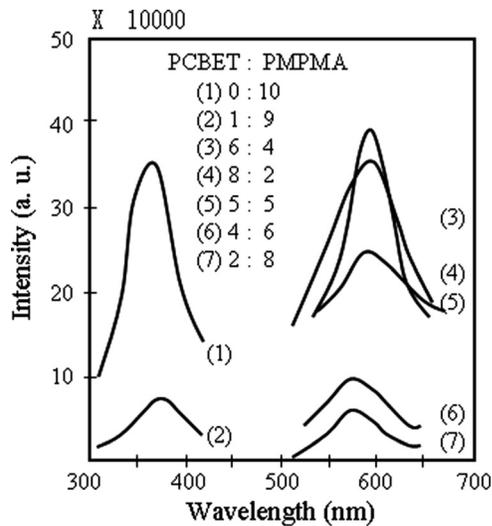


FIG. 2. PL Spectra of blended PCBET/PMPMA films were excited at 228 nm (PMPMA absorption position) in different weight mixing ratios. The ~ 370 nm emission of PMPMA is left spectra and ~ 590 nm emission spectra of PCBET locate at right.

absorption band (350–440 nm) of PCBET in Fig. 1, and PMPMA emission in the region of 320–410 nm has transferred to the PCBET.

From 2:8 to 5:5 blend ratios in the right spectra (at ~ 590 nm) of Fig. 2, the intensity of PCBET increases with decreasing the amount of mixing PMPMA. PCBET intensity of curve (4) with 8:2 ratio of PCBET/PMPMA decreases slightly comparing to that in curve (3) with ratio 6:4. At 6:4 ratios, energy transfer reaches maximum, and this supports that the PCBET obtains more energy from PMPMA.

These results suggest that the energy-transfer process from the photo excited PMPMA to PCBET results in the 590 nm emission. The energy transfer process is probably highly efficient as seen from the left spectra of Fig. 2 in which the fluorescence of PMPMA at 380 nm was not observed in blend films excluding pure PMPMA and 1:9 ratio; and the 590 nm PL emission of PCBET was observed in the blend system from 2:8 to 8:2 ratio. The spectral overlap (310–400 nm) between PMPMA emission and PCBET absorption region is large enough for efficient energy transfer. The

energy migration between donor and acceptor is most suitable in the blend ratio of 6:4 (PCBET:PMPMA).

Moreover, it should be pointed out that the energy migration does not efficiently occur in the blend ratio of 1:9 (PCBET/PMPMA). This is probably because the amount of PCBET is too little because only the intensity of 1:9 ratio (PCBET/PMPMA) at 380 nm was observed, and relevant PCBET emission intensity at 600 nm was not observed.

C. Energy transfer effect of PCBET/PVK at 235 nm excitation

PCBET/PVK has a similar regularity comparing with PCBET/PMPMA system. According to the Sec. III A, the PL spectra of PCBET/PVK were measured after exciting at 235 nm for the purpose of gaining the energy transfer effect. Figure 3 shows the PL spectra of PCBET blend films with PVK at different blend ratios. The ~ 400 nm PL emission of PVK (left) and ~ 600 nm emission of PCBET (right) in PCBET/PVK films were excited at 235 nm (PVK absorption position) at different weight mixing ratios. In Fig. 3(a), the peak of PCBET at ~ 600 nm is attributed to the result of energy transfer from PVK under 235 nm excitation; the emission of pure PCBET film was not observed at ~ 600 nm because PCBET does not directly absorb the 235 nm light. Interestingly, when the blend polymers are excited at 235 nm, the strong emission of PCBET can be observed at ~ 600 nm, whereas the intensity of PVK emission in the region of 390–460 nm becomes very weak. Because the PL emission band (390–460 nm) of PVK overlaps the absorption band (350–440 nm) of PCBET, the strong emission at ~ 600 nm occurs after an excitation of 235 nm.

The trend of PL intensity in blend PCBET films for detail can be clearly found in Fig. 3, especially in that Fig. 3(b) gives an easily understood picture to the spectra in Fig. 3(a). In the simplified figure of spectra (Fig. 3(a), left), the top and bottom curves show the PL intensity of PCBET peaks at ~ 600 nm and PVK at ~ 400 nm with variety of blend ratios, respectively. From 3:7 to 5:5 ratios, the intensity of PVK increases at ~ 400 nm emission as the intensity of PCBET rising at ~ 600 nm. The intensity of PVK becomes stronger while the content of PVK amount decreases. The PVK partially transfers its energy to PCBET. From 5:5 to

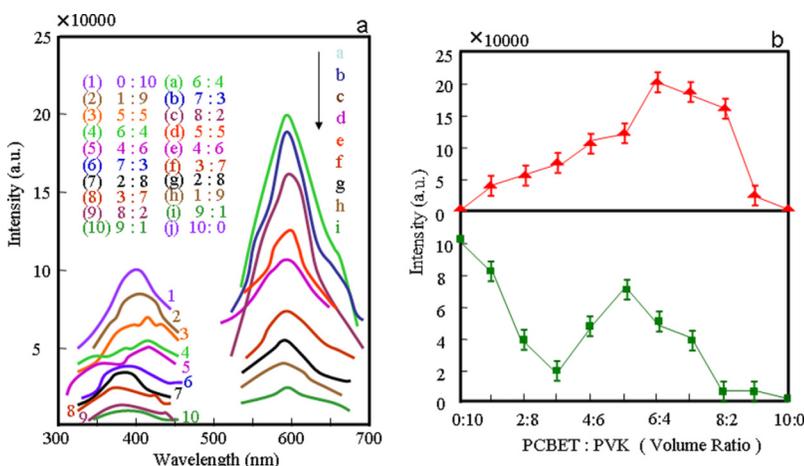


FIG. 3. (Color online) PL spectra of blended PCBET/PVK films were excited at PVK absorption 235 nm (PVK absorption position) in different weight mixing ratios. (a) The ~ 400 nm emission of PVK (left) and ~ 600 nm emission of PCBET (right) at different weight mixing ratios; (b) The simplified figures of spectra (left), Top: intensity of PL of PCBET at ~ 600 nm emission, Bottom: intensity of PL of PVK at ~ 400 nm emission.

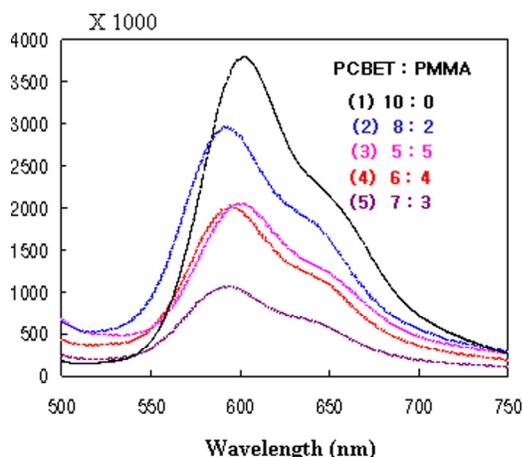


FIG. 4. (Color online) PL spectra of PCBET films blended with PMMA at different mixing ratios.

6:4, the intensity of PVK decreases at 400 nm while that of PCBET at ~ 600 nm increases. At 6:4 ratios, the energy transfer reaches maximum. These facts support that PCBET obtains more energy from PVK. From 6:4 to 10:0 ratios, the intensity of PVK continues to decrease at ~ 400 nm while that of PCBET at ~ 600 nm begins to decrease (following the decreasing tendency of PVK). It means that the energy transfer from PVK to PCBET can be maximized at appropriated mixing ratio.

To further illustrate the relation between transfer rate and concentration, we introduce transfer rate $\beta = 1 - \{\tau_d / \tau_d^0\}$ to obtain the relation, where τ_d means lifetime of donor when there is acceptor, and τ_d^0 means lifetime of donor when there is no acceptor. As a result, For PCBET/PVK mixing system, transfer rate 0.132, 0.270, 0.411, 0.515, 0.636, and 0.738, corresponds to mixing ratio 1:9, 2:8, 3:7, 4:6, 5:5, and 6:4, respectively.

D. PL spectra of PCBET/PMMA and microstructure of blended PCBET films

In two cases of PCBET blended with PMPMA and PVK in the preceding text, we observe the enhancement of fluorescence at the optimum mixing ratios. However, this optimum enhancement was not observed in the blend system of PCBET/PMMA. Because PMMA molecule has no chromophores, there is no energy transfer appearing from PMMA to PCBET in PCBET/PMMA system. Figure 4 shows the PL spectra of PCBET blend films with PMMA at different blend ratios. In this figure, the strongest intensity of ~ 600 nm emission is pure PCBET (10:0 ratios) film. Blend ratios 10:0, 8:2, and 5:5 of PCBET/PMMA respond to curves 1-3, respectively. The PL intensity of curves 2 and 3 decrease much with the increasing of the amount of PMMA compared to that of curve 1. This comes from the concentration effect of composition dilution. For 5:5, 6:4, and 7:3 blend ratios of PCBET/PMMA, the PL intensity of curve 4 decreases slightly and curve 5 decreases rapidly with the increase of the amount of PCBET compared to that of curve 3. These phenomena are probably deduced: (i) a better network structure suitable for a good PL at 5:5 or 6:4 blend ratios is formed compared with 7:3 ratios; (ii) active chromophores in

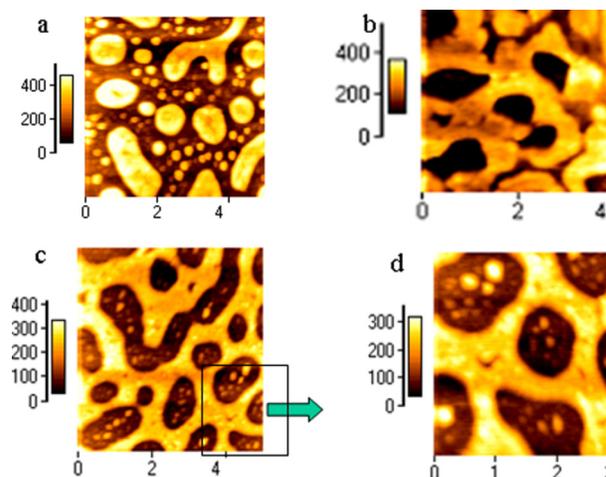


FIG. 5. (Color online) AFM images of blended PCBET films with PMMA at a different blend ratios, unit of plane scale is μm , and highness is angstrom. (a) PCBET:PMMA is 8:2; (b) 6:4; (c) 5:5; (d) zoom in for image (a).

PCBET are of quasi mono-dispersed structures among the long chains and thiophenes.

For the first deduction in the preceding text, a microstructure study of blended PCBET/PMMA films can prove it further. We have observed surfaces of the films blended from ratio 1:9 to 9:1. Figure 5 shows AFM images of blended PCBET films at 8:2, 6:4, and 5:5 PCBET/PMMA ratios. At 5:5 PCBET/PMMA ratios, a network structure is well formed. In other various mixing ratios, the phase separation without network structure occupies most of the surface of blend films beside 6:4 ratio. PCBET/PMPMA and PCBET/PVK systems have similar cases. Figure 6 shows AFM image of network structures of them at 6:4 ratio. Because PMPMA and PMMA have similar base component part, the same network structure was observed in the AFM photographs.

As to deduction (ii) in the preceding text, it means that there is no “concentration quench” effect of fluorescence spectra theory^{19,20} in the PCBET/PMMA blend system, especially for 10:0 and 8:2 blend ratios. For 5:5, 6:4, and 7:3 blend ratios, the PL intensity of curve 3 or 4 becomes stronger than curve 5 with the increase of the amount of PCBET. This observation means that it is the reason for keen competition between deductions (i) and (ii). At 7:3 blend ratio, deduction (i) overwhelms deduction (ii) because the network structure of 7:3 blend ratio is worse than that of 5:5 and 6:4 ratio while their values of blend ratios are neighbor.

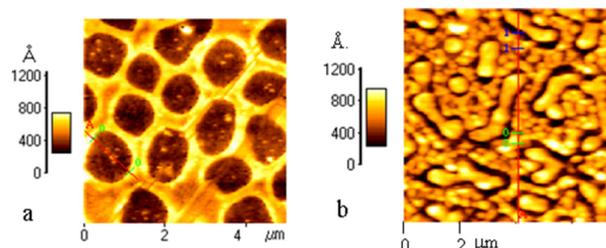


FIG. 6. (Color online) AFM images of blended PCBET films at 6:4 blend ratios with other polymers. (a) PCBET/PMPMA, (b) PCBET/PVK.

E. Fluorescence lifetime study of PCBET blend film

The dynamics of energy transfer in blend system was investigated. All fluorescence (or PL) lifetime values of PCBET, PCBET/PMPMA, PCBET/PVK, and PCBET/PMMA films are shown in Table I, and some relevant fluorescence decay profiles of blended films are shown in Fig. 7. The fluorescence decay profile was fitted with a single exponential component, and lifetime values can be obtained from it in the end.

The fluorescence decays of the PCBET/PMPMA films were recorded in condition of 337 nm wavelength excitation and 600 nm wavelength emission. The fluorescence lifetime of PCBET film is 1.31 ns. The fluorescence lifetime of PCBET/PMPMA increases from 2.35 ns to 2.76 ns with the increase of the amount of PMPMA in blend ratio from 9:1 to 5:5 except the sample of 6:4 ratio. The slightly shortened lifetime (1.92 ns) of the 6:4 blend film demonstrates that the fluorescence quenching of PMPMA happens in the case of strongest PL spectra-curve 3 of Fig. 2. The 1.31 ns lifetime of PCBET is the shortest and probably due to aggregated species in the film of pure luminescent polymer. Because the thiophene rings of PCBET are quasi-planar, the strong attractive interactions between the rings are conducive to their aggregation, rendering them liable to assume stacked face-face packing. The blended PMPMA may reduce the attractive interactions between these rings and decrease aggregation tendency.

TABLE I. The fluorescence lifetime values of the blended films deposited by spin coating (the wavelength of excitation light is 337 nm).

Films	Lifetime τ (ns)	χ^2	D.W.
PCBET	1.31 (Emi: 600 nm)	2.7	1.0
PCBET/PMPMA (9:1 wt.)	2.35 (Emi: 600 nm)	1.5	2.1
PCBET/PMPMA (8:2 wt.)	2.42 (Emi: 600 nm)	1.6	2.0
PCBET/PMPMA (7:3 wt.)	2.57 (Emi: 600 nm)	1.3	1.8
PCBET/PMPMA (6:4 wt.)	1.92 (Emi: 600 nm)	2.9	1.3
PCBET/PMPMA (5:5 wt.)	2.76 (Emi: 600 nm)	1.7	1.9
PVK	44.01 (Emi: 430nm)	1.8	0.9
PCBET/PVK(1:9 wt.)	38.21 (Emi: 430nm)	1.4	2.1
PCBET/PVK(2:8 wt.)	32.15 (Emi: 430nm)	1.6	1.9
PCBET/PVK(3:7 wt.)	25.91 (Emi: 430nm)	1.5	1.7
PCBET/PVK(4:6 wt.)	21.33 (Emi: 430nm)	1.4	2.1
PCBET/PVK(5:5 wt.)	16.02 (Emi: 430nm)	1.9	1.5
PCBET/PVK(6:4 wt.)	11.54 (Emi: 430nm)	1.7	1.4
PCBET/PVK(9:1 wt.)	1.44 (Emi: 600 nm)	1.4	2.1
PCBET/PVK(8:2 wt.)	1.61 (Emi: 600 nm)	1.3	1.7
PCBET/PVK(7:3 wt.)	1.60 (Emi: 600 nm)	1.5	1.8
PCBET/PVK(6:4 wt.)	1.58 (Emi: 600 nm)	1.8	1.9
PCBET/PVK(5:5 wt.)	1.73 (Emi: 600 nm)	2.9	1.5
PCBET/PVK(4:6 wt.)	1.89 (Emi: 600 nm)	1.9	1.7
PCBET/PVK(3:7 wt.)	2.01 (Emi: 600 nm)	1.4	1.6
PCBET/PVK(2:8 wt.)	2.11 (Emi: 600 nm)	2.8	1.1
PCBET/PMMA (9:1 wt.)	1.31 (Emi: 600 nm)	1.4	2.2
PCBET/PMMA (8:2 wt.)	1.29 (Emi: 600 nm)	1.2	1.7
PCBET/PMMA (7:3 wt.)	1.28 (Emi: 600 nm)	2.3	1.2
PCBET/PMMA (6:4 wt.)	1.23 (Emi: 600 nm)	1.8	2.0
PCBET/PMMA (5:5 wt.)	1.20 (Emi: 600 nm)	1.5	1.8
PCBET/PMMA (4:6 wt.)	1.27 (Emi: 600 nm)	1.9	1.6

Notes. Emi: emission.

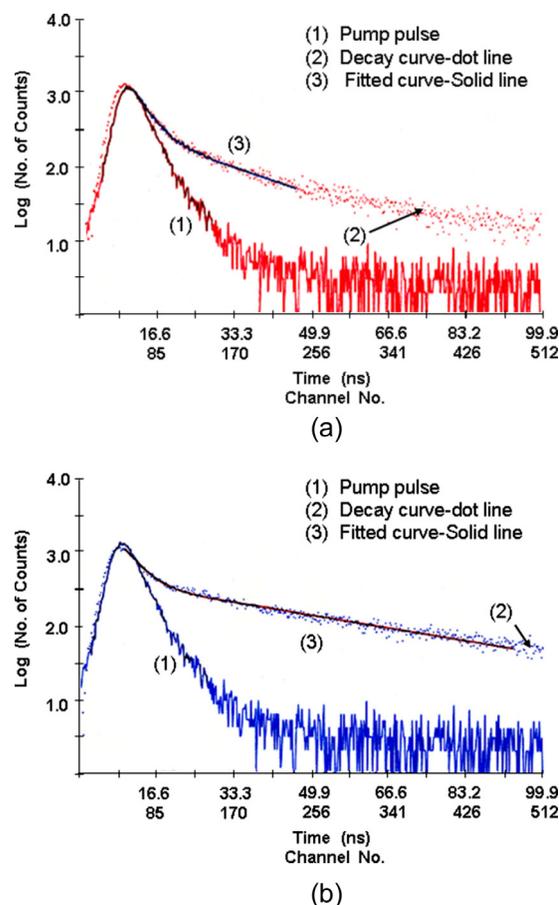


FIG. 7. (Color online) (a) The fluorescence decay profile of sample PCBET/PVK that was fitted with single exponential component. The wavelength of excitation light is 337 nm, the emission light is 430 nm for PVK. (a) The lifetime is 21.33 ns at 4:6 ratio of PCBET/PVK. (b) The lifetime is 38.21 ns at 1:9 ratio of PCBET/PVK.

The lifetime of PCBET in the blend PCBET/PMPMA is noticeably larger in comparison with that of the pure PCBET. The small increase of the lifetime component of PCBET can be explained that due to dilution effect of PMPMA addition after putting PMPMA into PCBET, the dilution produces the decrease of the fluorescence quenching effect or formation of an even dispersion structure of the polymer that decreases the non-radiative process.²¹

The fluorescence decays of the PCBET/PVK films were recorded in condition of 337 nm wavelength excitation, 430 nm and 600 nm wavelength emission. The fluorescence lifetime of PVK film is 44.01 ns. At 430 nm (PVK emission position), the fluorescence lifetime of PVK in PCBET/PVK system at blend ratio of 4:6, 5:5, and 6:4 is 21.33 ns, 16.02 ns, and 11.54 ns, respectively. At 600 nm (PCBET emission position), the fluorescence lifetime of PCBET in PCBET/PVK at ratio of 4:6, 5:5, and 6:4 is 1.89 ns, 1.84 ns, and 1.80 ns, respectively. All these lifetimes are among the lifetime-span of PCBET film (1.31 ns) and PVK film (44.01 ns).

It can be seen that with the increasing of PVK addition, the lifetime of PVK fluorescence increases in the blend PCBET/PVK in comparison with that of the pure PVK at 430 nm. The short lifetime component of PVK of less than 44.01 ns is probably due to dilution effect after putting more PCBET into the PCBET/PVK system and energy transfer

effect (migration of donor) from PVK emission to PCBET (PVK has a strong UV-vis absorption band at ~ 337 nm in Fig. 1(b)). In fact, for the system of PCBET/PVK, the PVK can also be seen as being mixed (or diluted) by contra-part of blend PCBET (The two polymers dilute each other). With increasing of PVK, the lifetime of PCBET fluorescence increases in blend systems. The fluorescence lifetime of PCBET in the blend PCBET/PVK is noticeably larger in comparison with that of PCBET. The explanations are similar as PCBET/PMPMA system in the preceding text.

As to the blended PCBET/PMMA system, it can be seen that with the increase of PMMA, the lifetime of PCBET fluorescence shows a tiny decline. The fluorescence lifetime of PCBET in the blend PCBET/PMMA is noticeably shortened in comparison with that of PCBET. From the short lifetime component, it can be deduced that (i) the PCBET aggregation does not improve after putting PMMA into PCBET, and (ii) there is serious phase separation between PCBET and PMMA because PMMA has no similar phenyl ring like PCBET and PMPMA does.

IV. CONCLUSION

In summary, the absorption spectra, PL spectra, synchronous PL measurement, and the time response of PL intensity for the PCBET films blended with PMPMA, PVK, and PMMA were investigated. Systematic studies of optical properties of the dilution effect of the blend films and energy transfer of these conjugated polymers are important for different applications. The spectral overlap of PMPMA (or PVK) emission and PCBET absorption region is large enough for the efficient energy transfer. This energy-transfer results in the 600 nm photo-exciting emission of the PCBET at PMPMA excitation of 228 nm and at PVK excitation of 235 nm. As a result, the enhancement regularity of fluorescence at the optimum mixing ratios of was obtained. These results and the PL analysis suggest that excitons produced by photo-excitation in PMPMA and PVK can be transferred to PCBET in the blend film. The PL emissive intensity of PCBET at blend ratio of 6:4 is much stronger than that of pure PCBET film and other mixing ratios.

The energy transfer mechanisms and fluorescence lifetimes of excited state in the blend films were discussed. The dynamics of energy transfer in donor-acceptor blends and concentration effect of luminescent polymer are crucial to the blend system. The fluorescence lifetime of PCBET film

is 1.31 ns. The fluorescence lifetime of PCBET in PCBET/PMPMA system increases from 2.35 ns to 2.76 ns with the increase of PMPMA. The fluorescence lifetime of PVK film is 44.01 ns. Obviously, the fluorescence lifetime of PVK in the PCBET/PVK system becomes shorter while the fluorescence lifetime of PCBET in PCBET/PVK becomes longer. The results of PL of all blended films and excited state lifetime of PCBET/PVK suggest that the energy transfer from PMPMA (or PVK) to PCBET leads to PL emission enhancement of PCBET.

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