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Transient Absorption Decay Characteristics at Visible Wavelength Region for NMe_2-Silole:Fluorene Blend Film

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1. Introduction

Recently, many organic devices have attracted considerable attention for flat panel displays, general lightings, field effect transistors, and photovoltaic cells. In generally, several organic materials have a high absorption coefficient in comparison to silicon and selective absorption at blue, green, and red wavelength regions [1-4]. These special advantages lead us to realize stacked organic image sensors instead of conventional charge coupled devices and complementary metal oxide semiconductor sensors.

For larger organic image sensor with a lower cost, we need to develop solution-processed organic photoconductive devices. However, one of the most serious problems of solution processes is the dissolution of the under layer, and it makes difficult to prepare multilayer structures formed by different polymer layers using a conventional wet process. Since most photo-excited carriers recombine in an organic layer without reaching electrodes as a photocurrent in the case of a single layer device, which has lower photoconductive characteristics than a multilayer device [1,2]. One possible approach to improve photoconductive characteristics is the use of a bulk heterojunction structure, which realizes the dislocation of photo-induced carriers in an organic layer.

Our research group reported an improved photoconductive characteristic by doping several silole derivatives into poly(dioctylfluorenyl-co-benzo-thiadiazole (F8BT) [5,6]. F8BT showed superior photoconductive characteristics owing to its high absorption coefficient only at the blue wavelength region [1] and high carrier mobility [7]. In addition, the carrier dislocation efficiency can be improved by doping another organic material [8].

In this study, we investigated charge carrier dynamics in a silole doped F8BT blend film by measuring transient absorption decay at a visible wavelength region. The transient absorption characteristics are useful to understand carrier dynamics in organic material [9,10], and they were measured by femtosecond pump-probe technique.

2. Experimental

After dissolving F8BT into chloroform at a concentration of 1wt%, 1,1-dimethyl-2,5-bis(*N,N*-dimethylaminophenyl)-3,4-diphenylsilole (NMe_2-silole) was added into the resulting solution. The ratio of NMe_2-silole:F8BT was changed as 0, 12, 33, 60 and 100 mol% to investigate the concentration dependence on the transient absorption characteristics. The organic solution was stirred for over 24 hours at a room temperature until F8BT was completely dissolved. After passing through the filter with 0.45 μm holes, the organic solution was spin-coated on a silica glass substrate. The rotation speed of spin-coating process was 1000 rpm (0%, 12%, 100%), 2000 rpm (33%), and 2500 rpm (60%). Then, the sample was annealed in nitrogen atmosphere at 70 ℃ for 1 hour to remove the organic solvent. Finally, an encapsulating glass cap was covered on the top of organic layer.

Time-resolved absorption decay characteristics were measured using Ti:sapphire femtosecond laser system. The detail of measurement is described the following paper [9,10]. The wavelength of pump light was 480 nm and that of probe light was 600 nm. We show in Fig. 1, the schematic configuration of experimental setup and molecular structures of F8BT and NMe_2-silole.

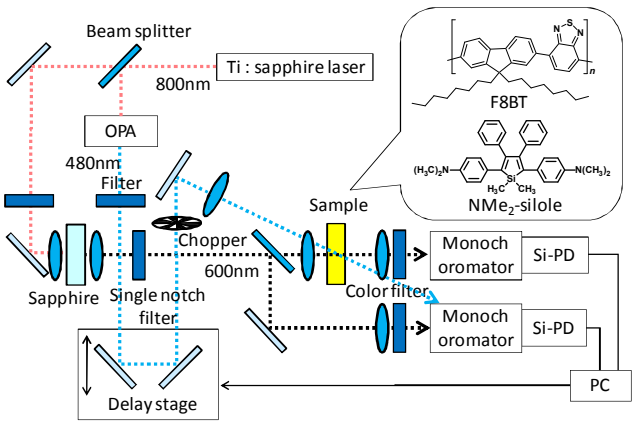

Fig. 1 Experimental setup to measure transient characteristics of NMe_2-silole doped F8BT neat film and molecular structures of F8BT and NMe_2-silole.

3. Results and Discussion

Figure 2 shows the change in optical density (ΔOD) at 600 nm for NMe_2:F8BT blend film. The ΔOD increased with increasing the concentration of NMe_2–silole into F8BT up to 60%. As clearly shown in Fig. 2, the NMe_2-silole neat film showed little changes in the ΔOD when the excited pump laser was irradiated. This result indicates the increased ΔOD showed the large amount of photo-induced carriers in NMe_2:F8BT.

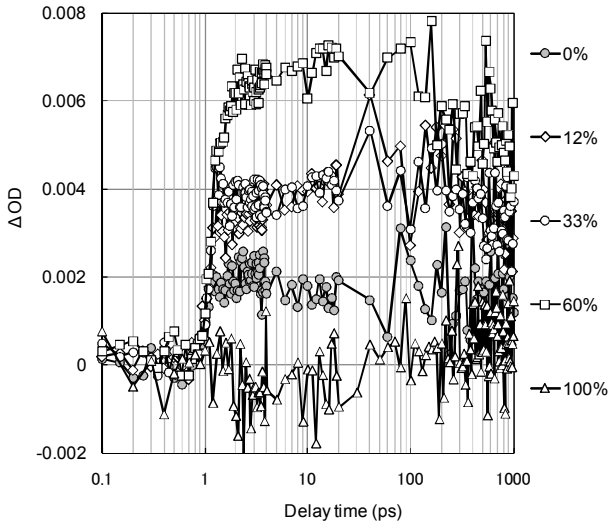

Fig. 2 ΔOptical density decay at 600 nm of NMe_2-silole doped F8BT neat film. The concentration of NMe_2-silole doped F8BT was changed as 0, 12, 33, 60 and 100%.

Figure 3 shows external quantum efficiency (EQE) of an organic photoconductive device when the electric field of 20 MV/m was applied. The device structure is indium tin oxide (150 nm) / NMe_2-silole:F8BT / LiF (1 nm)/ Al (150 nm). The EQE increased with increasing the concentration of NMe_2-silole up to 43 mol%, and then it decreased above 50 mol%. The highest EQE of 8.9 % was achieved when NMe_2-silole was doped into F8BT.

The improved EQE can be explained by the carrier dislocation efficiency in an organic layer. The ΔOD shown in Fig. 2 was corresponding to the photo-excited carrier density; therefore, the carrier dislocation efficiency was improved by doping NMe_2-silole into F8BT. This fact indicates the increased EQE was caused by the higher carrier dislocation efficiency in the organic layer with increasing the concentration of NMe_2-silole. The separated electrons/holes move to electrodes with low recombination probability, resulting in the high EQE, as shown in Fig. 3.

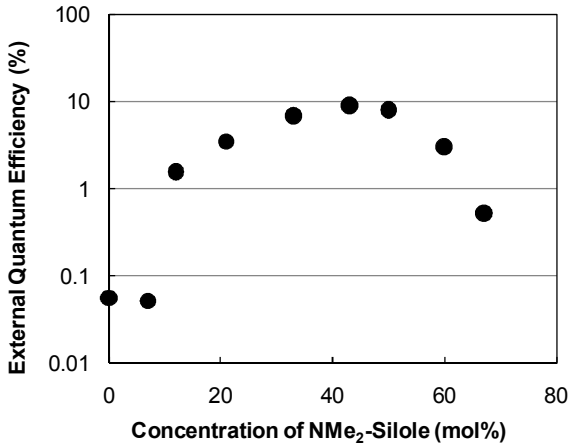

Fig. 3 EQE of photoconductive device (ITO/NMe_2-silole:F8BT/ LiF/Al) at an electric field of 20 MV/m.

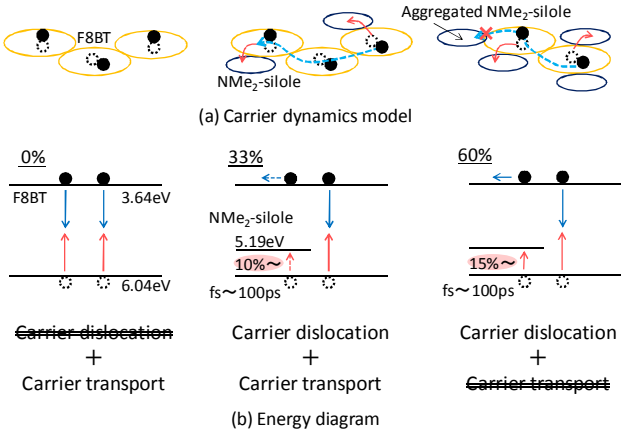

Fig. 4 Estimated carrier dynamics in NMe_2-silole: F8BT blend film.

Figure 4 summarizes the suggested carrier dynamics in NMe_2-silole:F8BT. NMe_2-silole is easily aggregated when the concentration was over 50 mol%. The fact indicates the aggregated NMe_2-silole prevents the efficient carrier transport in the organic layer. Therefore, the EQE was decreased when the excess NMe_2-silole was doped into F8BT, as shown in Fig. 3.

4. Conclusion

In conclusion, we investigated transient absorption characteristics at a visible wavelength region (600nm) of NMe_2-silole doped F8BT neat film. The photo-induced carrier density efficiency was increased with increasing the concentration of NMe_2-silole. We found that efficient carrier dislocation can be realized by doping NMe_2-silole.

Acknowledgements

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