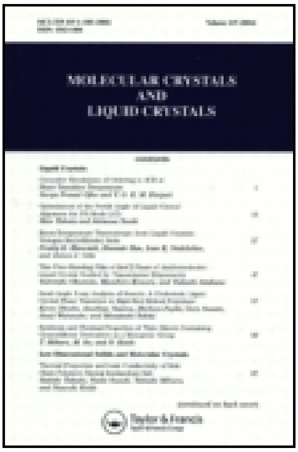

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Influence of UV Irradiation on Characteristics of Ambipolar Organic Field-Effect Transistors Utilizing Poly(alkylfluorene)

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The influence of ultraviolet (UV) irradiation on carrier conduction and emission characteristic of the top-gate-type ambipolar organic field-effect transistors (OFETs) utilizing crystallized poly(9,9-dioctylfluorene) (F8) films were investigated. For a device with irradiated UV light, only p-type conduction was exhibited and the hole field-effect mobility was almost the same as that without UV irradiation. As a result, the EL emission was not observed owing to the decrease of n-type conduction after UV irradiation. It is suggested that the quenching center which is generated in F8 film by UV irradiation is greatly related to the electron trap site of OFETs.

Keywords Organic field-effect transistors; light-emitting; cytop; fluorene; UV

1. Introduction

Organic field-effect transistors (OFETs) have been extensively studied because of their applications to low-cost, large-area, and flexible electronics. The top-gate-type OFETs utilizing polyfluorene derivatives exhibited the ambipolar and light-emitting characteristics. Moreover, poly(methyl methacrylate) (PMMA) which does not contain electron-trapping groups have been used as a gate insulator for ambipolar OFETs [1]. We aimed to fabricate the gate electrode by solution process, and made an attempt to use the amorphous fluoropolymer Cytop (Asahi Glass Co., Ltd.) which has high stability as a gate insulator. However, because the Cytop film has a very low surface tension, it is difficult to form the gate electrode on the film by solution process. It is known that the surface energy of insulator such as Cytop can be expected to be modified by UV irradiation. Therefore, it is important to study the influence of UV irradiation on the organic films. The influence on organic light-emitting diodes using amorphous poly(9,9-dioctylfluorene) (F8) films has been reported [2]. In this study, we investigated the influence of UV irradiation on the characteristics of ambipolar OFETs utilizing crystallized F8 films as an active layer.

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2. Experimental

Top-gate and bottom-contact type OFETs were fabricated on a commercially available polished indium tin oxide (ITO) precoated glass substrate. The ITO was used for the source and drain electrodes of OFETs. We used crystallized F8 film annealed at 290 ºC (about 60 nm) as an active layer and both PMMA film (about 200 nm) and Cytop film (about 300 nm) as gate insulators formed by spin-coating, respectively. The detailed fabricating and measuring methods of the OFETs are already reported [1]. Then, vacuum UV light of wavelength 172 nm was irradiated on the films in the mixture atmosphere of nitrogen (98%) and oxygen (2%). The influence of UV irradiation on each layer of OFETs was measured by Fourier transform infrared (FT-IR) and photoluminescence (PL) spectroscopies. After

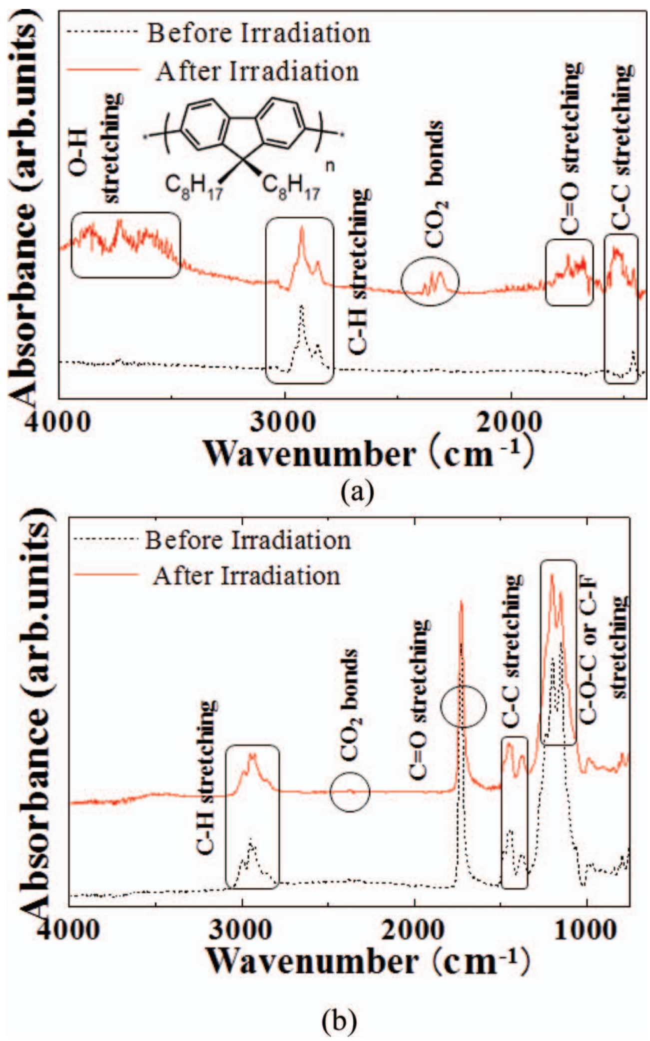

Figure 1. FT-IR spectra of (a) F8 film and (b) F8/PMMA (200 nm)/Cytop (300 nm) multilayer film before and after UV irradiation for 30 seconds. The inset of Figure 1 (a) shows the molecular structure of F8.

the UV irradiation, an Ag gate electrode with a 80 nm thickness was vacuum evaporated at a background pressure of about 10^{-4} Pa onto the gate insulator. The channel length and width of OFETs were 0.1 and 2 mm, respectively.

3. Result and Discussion

The influences of UV irradiation on F8, PMMA, and Cytop films were investigated. Figure 1 (a) shows the FT-IR spectra of F8 film before and after UV irradiation for 30 seconds. The C—C and O—H stretching vibrations appear at 1500 and 2800 cm^{-1}, and the CO_2 peaks appear at 2300 cm^{-1}. Moreover, the broadband peaks around 1700 and 3700 cm^{-1} show C=O and O—H stretching vibrations. The oxygen-related defects such as O—H and C=O stretching vibrations were created on F8 chains after UV irradiation. Figure 1 (b) shows the FT-IR spectra of F8/ PMMA/Cytop multilayer film before and after UV irradiation. The broadband peaks around 1200 cm^{-1} show C—O—C or C—F stretching vibrations related with PMMA or Cytop film. The difference of the spectra before and after UV irradiation was hardly observed. This is considered that PMMA film can absorb the vacuum UV light [3], therefore it prevented the damage of F8 film by UV irradiation.

Figure 2 shows the PL spectra of F8 single layer film and F8/PMMA, F8/Cytop, and F8/PMMA/Cytop multilayer films before and after UV irradiation. The spectra on each layer before UV irradiation were almost the same, however after UV irradiation the difference of each film was clearly observed. The PL intensities of both F8 single layer and F8/Cytop multilayer were markedly decreased. It is clarified that the quenching center that originated in oxygen on the alkyl chain of F8 film was generated by UV irradiation. Therefore, the luminescence of F8 which affected by the photo-oxidation was thermally extinguished by the quenching center [4]. On the other hand, the PL intensities of F8/PMMA and F8/PMMA/Cytop multilayer films were hardly decreased. This is because that the PMMA film prevented F8 layer from degrading under UV irradiation. From only this result, how the quenching center generated by UV irradiation influences on the electron and hole

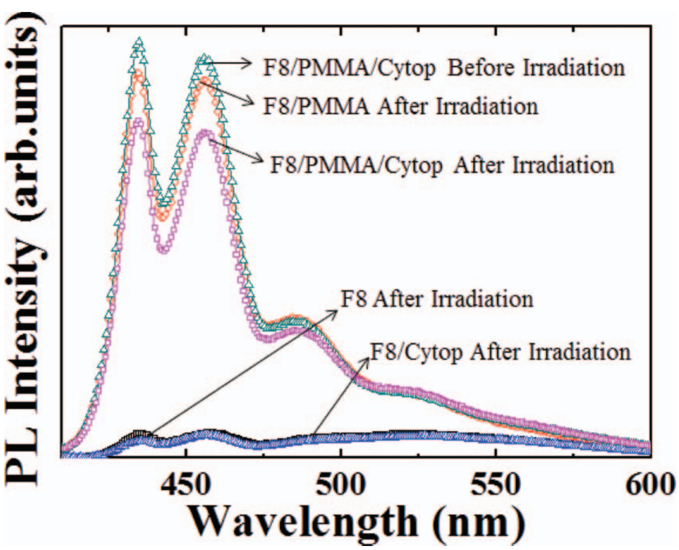

Figure 2. PL spectra of F8 film and F8/PMMA (500 nm), F8/Cytop (500 nm) and F8/ PMMA (200 nm)/Cytop (300 nm) multilayer films before and after UV irradiation for 30 seconds.

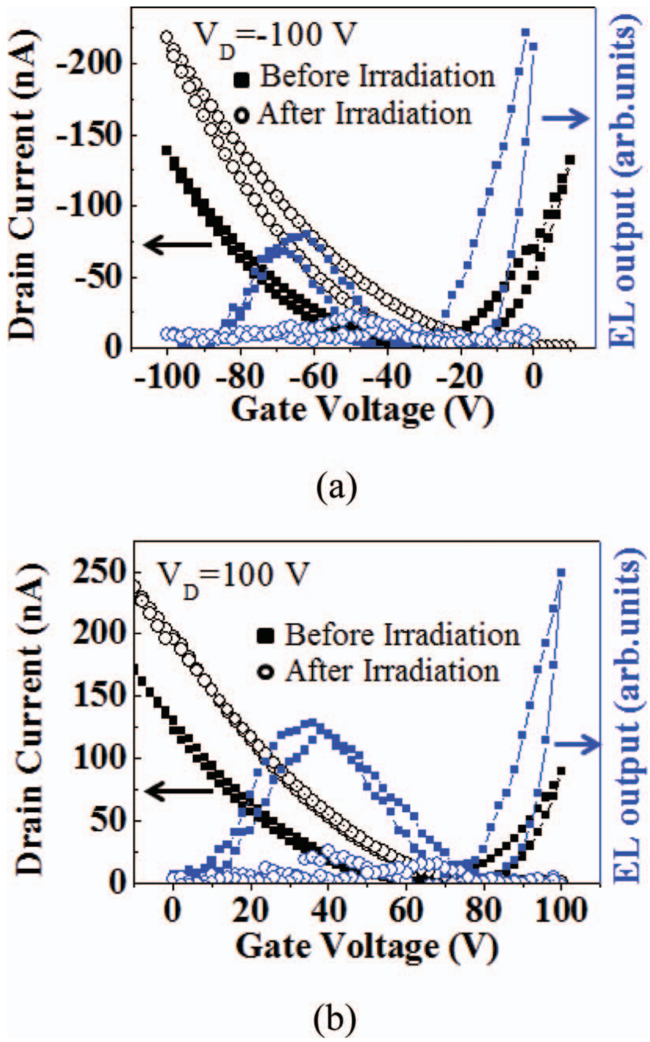

Figure 3. Transfer characteristics and corresponding light output of the F8 OFETs for different drain voltages of (a) 100 and (b) −100 V before and after UV irradiation for 30 seconds.

conduction of a device can not be specified. Therefore, we investigated the influence of UV irradiation in ambipolar F8 OFETs.

Figure 3 shows the transfer and light-emitting characteristics of OFETs for different drain voltages of (a) 100 and (b) −100 V before and after UV irradiation. The OFET without UV irradiation showed the ambipolar and light-emitting characteristics. The field-effect mobility and the threshold voltage with p-type carrier transport were 0.65×10^{-3} cm^2/Vs and −26 V, and with n-type carrier transport were 1.5×10^{-3} cm^2/Vs and 65 V. This is because the value of the work function of the ITO electrode is located approximately in the middle between the HOMO and LUMO levels of fluorene derivatives [1]. On the other hand, for the device with irradiated UV light, only p-type conduction was exhibited, and the hole field-effect mobility was almost the same as that without UV irradiation. As a result, the EL emission was not observed owing to the decrease of n-type conduction after UV irradiation. It is suggested that the quenching center which is generated in F8 film by UV irradiation is greatly related to the electron trap site of OFETs and the effect of quenching center influences in n-type carrier transport of OFETs strongly, compared with PL intensity.

4. Conclusion

The quenching center was generated and light degradation occurred in F8 film by UV irradiation for 30 seconds. The PMMA insulator, which can absorb the vacuum UV light, prevents F8 film from degrading under vacuum UV irradiation. However, for a F8 device with irradiated UV light, only p-type conduction was exhibited, and the hole field-effect mobility was almost the same as that without UV irradiation. It is suggested that the quenching center which is generated in F8 layer by UV irradiation strongly acts as the electron trap site of OFETs.

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