Suppression of exciton quenching in organic semiconductor devices

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区　　分　：　甲

論　文　内　容　の　要　旨

In Chapter 1, the background and motivation of this thesis are introduced. In organic light-emitting diodes (OLED), a rapid decrease in external quantum efficiency (η_{EQE}) has been observed as current (J) increases, namely efficiency roll-off. Efficiency roll-off at high current density is one of the crucial problems for high-brightness OLEDs such as passive matrix displays in terms of power consumption and device lifetime. Therefore, the suppression is a critical issue for the further development of OLEDs. In addition, the suppression of efficiency roll-off is required to reduce the threshold current density to an achievable level for the realization of organic semiconductor laser diodes (OSLDs). The purpose of this study is to suppress efficiency roll-off observed in OLEDs through an understanding of efficiency roll-off mechanisms with the aim of realizing high-brightness OLEDs and OSLDs in future.

In Chapter 2, efficiency roll-off in OLEDs with the thermally activated delayed fluorescence emitters 1,2-bis(carbazol-9-yl)-4,5-dicyanobenzene (2CzPN) and 3-(9,9-dimethylacridin-10(9H)-yl)-9H-xanthen-9-one (ACRXTN) was investigated by considering intramolecular exciton relaxation processes. Efficiency roll-off at high current density was dramatically suppressed using ACRXTN as an emitter instead of 2CzPN because of the suppressed singlet-triplet annihilation (STA) and triplet-triplet annihilation. The rate constant of reverse intersystem crossing from a lowest triplet excited state (T_1) to a lowest singlet excited state (S_1) for ACRXTN was about 300 times higher than that of 2CzPN due to the quite small difference between S_1 and T_1 of ACRXTN, leading to a decrease of triplet exciton density and the suppression exciton annihilation processes under optical and electrical excitations.

In Chapter 3, in order to suppress STA, the efficient incorporation of oxygen as a triplet quencher into solid-state organic films was demonstrated by applying a high oxygen pressure of 200 MPa to the films by using a modified cold isostatic pressing technique. The oxygen-incorporated film showed strong suppression of STA because triplet excitons were quenched by oxygen incorporated inside the films. It was confirmed that oxygen molecules were uniformly distributed in the film and that oxygen molecules were tightly settled in the film to some extent even when the film was in a vacuum. The concentration of oxygen inside the film was calculated to be a high value of 4.4×10^{20} cm^{-3}.

In Chapter 4, a ter(9,9’-spirobifluorene) (TSBF) doped emissive layer has been demonstrated to show the most suppressed efficiency roll-off at high current densities, comparing to the other emissive layers doped with 4,4’-bis[(*N*-carbazole)styryl]biphenyl (BSB-Cz), 4,4’-bis[4-(diphenylamino)styryl]biphenyl (BDAVBi),

2,3,6,7-tetrahydro-1,1,7,7,-tetramethyl-1H,5H,11H-10-(2-benzothiazolyl)quinolizino[9,9a,1gh]coumarin (C545T), DCM, 4-(dicyanomethylene)-2-methyl-6-julolidyl-9-enyl-4H-pyran (DCM2), and 4-(di-cyanomethylene)-2-tert-butyl-6-(1,1,7,7- tetramethyljulolidin-4-yl-vinyl)-4H-pyran (DCJTB). The suppression of the efficiency roll-off can be ascribed to the suppressed STA in the TSBF-doped emissive layer due to the small absorption coefficient of the triplet excitons of TSBF. In addition, singlet-polaron annihilation, singlet-heat quenching, and electric field-induced quenching were also suppressed due to the small trap carrier density on a recombination zone, which is caused by small trap depth of TSBF in the emissive layer, and its large radiative rate constant.

In Chapter 5, the summary of this thesis and future prospects are introduced.