Transparent ambipolar light-emitting field-effect transistors based on multilayer heterostructures

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Organic light-emitting field-effect transistors (OLETs) are a new class of electro-optical devices that offer an alternative architecture to generate electroluminescence from organic thin films and may allow addressing the open questions concerning charge-carrier recombination and light emission in organic materials. In OLETs the exciton quenching at the metal electrodes can be avoided if the recombination region is positioned inside the channel. In addition the exciton-charge quenching can be drastically reduced as a consequence of the improved current balance within the device. The OLET devices have potential applications in optical communication systems, advanced display technology, solid-state lighting. Moreover the possibility of integrating a resonant optical cavity inside the active region makes the OLET device structure suitable for the realization of an electrically pumped organic laser. However, in order to bring about this potential OLETs should be realized that combine in a single device high current density, balanced electron and hole currents, charge recombination separated from the injecting electrodes of at least 2 microns.

Here we report on the approach of engineering the active layer of the OLET as an organic heterojunction formed by different materials each having a specific electrical/optoelectronic function within the device. We realize fully transparent ambipolar OLETs based on a three-component organic heterojunction (n-type semiconductor, p-type semiconductor, host-guest emission matrix) specifically engineered for the optimization of the FET charge transport and the optical emission. By employing α,ω-diperfluorohexyl-4T (DHF4T) as n-type semiconductor, Alq3:DCM as light emitting layer and dihexylquaterthiophene (DH4T) as p-type semiconductor current density values as high as KA/cm^2 can be achieved in correspondence of an electron and hole charge mobility of 10^{-2} cm^2/Vs. The imaging of the recombination area within the channel shows that the maximum of the emission efficiency is obtained when the recombination area is separated from the drain electrode of 3-5 microns. These results demonstrate that the three-layer heterojunction approach may enable the realization of the full potential of the OLET devices.