Charge Trapping in Layered Nanostructured Films

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Structural disorder in amorphous organic thin films can result in localized electronic states that trap and store charges in equilibrium. These trapped charges can dominate the current-voltage (I-V) characteristics of organic devices due to the relatively low charge carrier density in organic solids.

Our recent experiments on organic devices with deliberately-inserted metal or organic traps demonstrated that charge trapping can significantly alter I-V characteristics of an operating device [1]. Predictions of energy band structure indicate that an ITO anode / 50 nm Alq3/ 10 nm trap / 50 nm Alq3 / 50 nm Mg:Ag / 50 nm Ag cathode structure with a trap layer of organic DCM2 or silver metal can be effective at trapping charge. This monopolar device transports only electrons. When a forward bias is applied on the device, electrons begin to fill the trap layer (Figure 1). With increased trap filling, the number of traps decreases, resulting in an increase in the effective charge mobility. Additionally, as the deep metal traps are filled, the effective trap level within the charged metal nanoclusters decreases. With decreasing trap depth, the probability of finding a trapped electron outside the trap boundaries increases, and the trapped carrier density can exceed the intrinsic carrier density in the vicinity of the trap (Figure 2). The trapped charges effectively dope the surrounding organic semiconductor which is manifested as an increased conduction through the device and results in a sharp conductance turn-on in the device I-V characteristics. Applying reverse bias on the device depletes the trap layer of electrons and eventually, switches the device to a low conduction state. The device demonstrates on/off current ratio of fifty for the DCM2 trap and ten million for a silver trap. Metals have higher trap density and deeper trap energy, and therefore, have a larger impact on the on/off current ratio.

We are presently modeling the charge trapping mechanism in these structures in order to generate a generalized description of the process. Space charge limited conduction for a uniform trap density and spatially non-uniform charge traps are both considered in our model.

REFERENCES: