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Improving Ambipolar Charge Injection in Polymer FETs with Carbon Nanotubes

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Efficient charge injection is a key issue for organic field-effect transistors (FET). Various methods can be used to optimize injection of either holes or electrons, for example, by modifying the workfunction of metallic electrodes with self-assembled monolayers. For ambipolar FETs this is much more difficult because injection of both charge carriers has to be improved at the same time. Here we demonstrate a simple process to significantly improve ambipolar charge injection in bottom contact/top gate polymer field-effect transistors by adding single-walled carbon nanotubes (SWNT) to the semiconducting polymer at concentrations well below the percolation limit. Such polymer/carbon nanotube hybrid systems are easily produced by ultrasonication and dispersion of SWNT in a conjugated polymer solution. Even at very low nanotube concentrations the charge injection of both holes and electrons, for example, into poly(9,9-dioctylfluorene-co-benzothiadiazole) (F8BT) and poly(9,9-dioctylfluorene) (PFO) is significantly enhanced leading to lower contact resistances and threshold voltages than in FETs with pristine polymer films. This method can be extended to other semiconductors like n-type naphthalene-bis(dicarboximide)-based polymers (e.g. P(NDI2OD-T2)) for which hole injection was greatly enhanced. The proposed mechanism for this effect of carbon nanotubes on injection is independent of the polarity of the charge carriers. It can be maximized by patterning layers of pure carbon nanotubes onto the injecting electrodes before spincoating the pristine polymers leading to almost ohmic contacts for polymers, which usually show only strongly Schottky-barrier-limited injection. This improved injection of holes and electrons allows for a wider range of accessible polymers for ambipolar and thus also light-emitting transistors.