High-mobility electron-transporting materials for printed transistors

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In this presentation, we report the design of a highly soluble (60 mg/mL) and printable n-channel polymer (poly{[N,N9-bis(2-octyldodecyl)-naphthalene-1,4,5,8-bis(dicarboximide)-2,6-diyl]-alt-5,59-(2,29-bithiophene)}, (P(NDI2OD-T2)) exhibiting unprecedented organic thin-film transistors (OTFT) characteristics under ambient conditions.. Top-gate bottom-contact transistors were fabricated with Au contacts and various polymeric dielectrics, with electron mobilities up to 0.45-0.85 cm^2/Vs and Ion/Ioff ratio of 10^6. Several solution-process methodologies were used to deposit the semiconductor layer including spincoating, gravure, flexographic and inkjet printing, demonstrating great processing versatility. The OTFT performance was monitored in ambient conditions and under different relative humidities, demonstrating remarkable stability.

Furthermore, we will discuss a few important fundamental findings enabled by this P(NDI2OD-T2) polymer. First of all, the structure/property difference between NDI (naphthalene-dicarboximide)-based and PDI (perylene-dicarboximide)-based n-type polymers will be presented. We found that NDI-based polymers are regioregular on the contrary of the PDI-based polymers. As a result, the NDI-polymers exhibit significantly higher molecular weights and 20x higher electron mobility than the PDI-based polymers for OTFTs having the same architecture. Secondly, we demonstrate that P(NDI2OD-T2) OTFT performance are independent of the dielectric constant of the polymeric dielectrics. This result differs substantially from that generally reported for amorphous tri-arylamine-based p-channel polymers, where hole mobility decrease by ~ 20x when k increases from 2.0 to 3.6. Our work has shed some lights on the relationship between polymer dielectric constant and OTFT device performance. Thirdly, due to mostly amorphous nature of P(NDI2OD-T2), its electrical performance is insensitive to the molecular weight and distribution of the polymer. This feature is extremely important for facile polymer large-scale synthesis and batch to batch reproducibility of the TFT characteristics. Finally, the first spin-coated and gravure-printed polymeric semiconductor complementary inverters exhibiting large gains (25–60) and operating in ambient conditions have been realized. We believe that the discovery of this n-channel material has answered several questions about field-effect electron transport capabilities of polymeric semiconductors and that new fundamental studies will be possible. (He Yan, etc, Nature, 2009, 457, 679-686)