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Enhanced electrical conductivity in P3HT/F4-TCNQ nanowires grown with a porous alumina template

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Purpose Poly(3-hexylthiophene) (P3HT) has been widely applied to organic transistors and photovoltaic cells, and an urgent task is to improve its conductivity. Chemical dopants, like tetracyanoquinodimethane (TCNQ) and 2,3,5,6-tetrafluoro-7,7,8,8-tetracyanoquinodimethane (F4-TCNQ), were used to improve the performance of P3HT-based devices. But the doping level was strongly confined, thus the improvement of conductivity got to a bottleneck. In this study, we report on fabrication process of F4-TCNQ highly doped P3HT nanowires. We found that the conductivity of P3HT/F4-TCNQ nanowires prepared in porous alumina template was improved because of F4-TCNQ concentration increased by capillary force in nano-pores.

Method F4-TCNQ doped P3HT nanowires were grown using an anodized aluminum oxide (AAO) template. In this process, F4-TCNQ was doped in different ratios, 0.1 wt%, 1 wt% and 10 wt%. Four-probe scanning tunneling microscope (STM), integrated with a scanning electron microscope (SEM), was employed to measure the resistivity in individual nanowires precisely. The four-probe STM technique has significant benefits in providing stable contacts, suppressing the contact resistance effect, accessing individual measurement nano-objects, and especially in allowing multiple measurements on the same nanowires. Fig. 1a is schematic of the STM measurement procedure. The outer pair of probes is fixed on both sides of the wire to provide electrical current. The inner pair monitors the voltage drop at each interval via moving one of them.

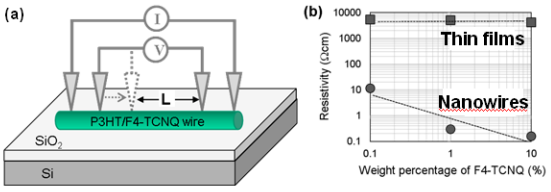

Fig. 1 (a) Schematic of the STM measurement procedure. (b) F4-TCNQ concentration dependence of resistivities for composite nanowires (circles) and thin films (squares).

Result Fig. 1b shows the resistivities of F4-TCNQ doped P3HT nanowires. The resistivities were tuned in the range of 0.1-10 Ωcm by changing the F4-TCNQ concentration from 10 to 0.1 wt. %. Note that, these are 2-4 orders of magnitude smaller than those of the corresponding P3HT/F4-TNCQ thin film composites. In contrast, the resistivities of F4-TCNQ doped P3HT films were around 4-5 × 10^3 Ωcm, almost independent of the F4-TCNQ concentration. The differences can be attributed to two major effects introduced by the AAO template. First, the nanoscaled channels of an AAO template promote polymer chain alignment. Second, F4-TCNQ was able to be highly doped into P3HT nanowires because of capillary force, thus more F4-TCNQ molecules participated into increasing the hole density owing to the high electron affinity of cyano groups and fluorine atoms. In contrast, F4-TCNQ molecules were segregated by phase separation in films when the doping level increased.