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Enhanced charge-transporting behavior for solution-processable organic transistor through microwave impetus

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[Introduction]

The morphology and molecular packing structure of conjugated polymer affect their charge transporting behavior in the intrachain and interchain, which determine the carrier mobility, an index parameter for transistor device. The good electron transfer in the polymer is due to the regular arrangement of the crystal regions, so that π-orbital overlap leads to good transfer between the chains (increase interchain transfer). However, if the electrons are localized or trapped in the amorphous regions, the transporting properties will be quenched (1). Therefore, the post-processing called thermal annealing is generally required to induce more crystallization in a standard fabrication process for OFET. Thermal annealing is conventionally implemented through thermal conduction methods such as the use of hot plates, however, the energy loss, low efficiency of energy usage and time-consuming question still needs to be modified.

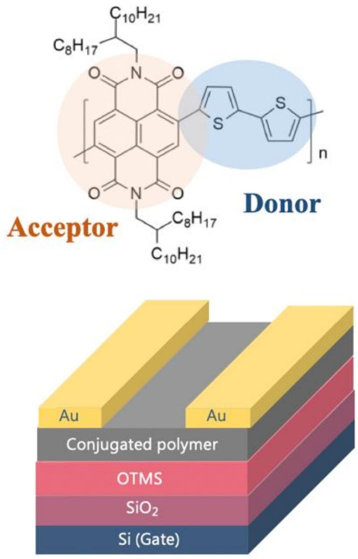

Figure 1. N-type polymer structure and the top contact bottom gate type device structure

Herein we improve the solubility of semiconducting polymer in the solvent by microwave (2) instead of thermal annealing process. Dissolving materials by microwave inherent a fast and efficient advantages via direct energy transfer, while conventional heating methods rely on conduction and convection. The electromagnetic field is used to rotate the polar molecules so we are based on this property to let the polymer swell well in the polar solvent. As the degree of microwaves absorption depends on the rotation of the dipoles of a material, microwave heating, which can be used to heat material selectively, is a potential approach toward enhancing the efficiency of energy usage.

[Experimental]

High molecular weight P(NDI2OD-T2) was purchased from Ossila Corporation ("N2200") (3). Charge transport was probed in organic field-effect transistors (4) in a bottom gate, top contact geometry in nitrogen atmosphere. Interdigitated gold source and drain electrodes of 70 nm thickness with a 50 nm thick semi-conductive layer were evaporated on SiO2 substrates defining transistor channels with a channel length (L) of 1000μm and channel width (W) of 50μm.

[Result and Discussion]

The FETs mobility has achieved 0.291cm2/(V·s) by the microwave method. It's higher than thermal annealing (Fig.2). The microwave method can achieve the same effect within shorter time of annealing preparation. In addition, X-ray diffraction (XRD) and atomic force microscope (AFM) analyses were used to investigate the morphology of PNDI2OD-T2. The domain size decrease and fiber-like increase in AFM spectra. The result of the GIXRD spectra is that the device by microwave treatment is stronger signal than thermal annealing. Therefore, it can be inferred that it is a better crystallization.

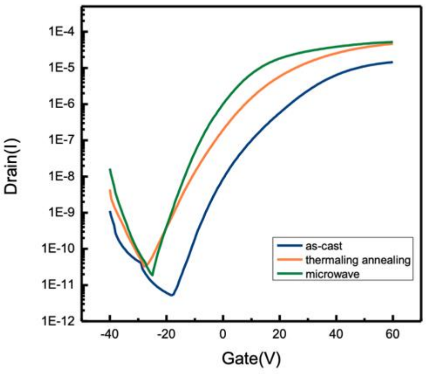

Figure 2. Transfer characteristics of NDI2ODT2 TFTs annealed by microwave (green) and by hotplate(orange).

Detailed steady-state UV-vis and PL measurements on solutions of P(NDI2OD-T2)(Fig.3). The measurement immediately after the microwave it will be seen that the blue shift of the CT peak and decreased intensity. Indicates that the aggregation of the polymer decreasing. There is solid experimental evidence that the distinct optical property of P(NDI2ODT2) by microwave-treatment is primarily caused by polymer swelling [5].

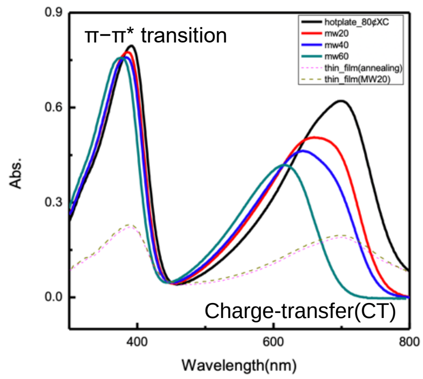

Figure3. Absorption spectra of P(NDI2OD-T2) by various heat-treatment at concentration of 0.05mg/mL

A strategy was developed to improve the charge carrier transport of conjugated polymers. It involved the polymer swelling better in the solution by doing the microwave and induce more regular aggregation. The crystallinity increased and showed a greatly enhanced field-effect mobility. It achieves high efficiency and high carrier mobility. In the future, if microwave combine with printing, the production line of transistors will greatly reduce the cost and simplify.

[References]

(1) Son, S. Y., Kim, Y., Lee, J., Lee, G. Y., Park, W. T., Noh, Y. Y., Park, C. E., Park, T., J. Am. Chem. Soc. 2016, 138, 8096.

(2) Jun,T., Song,K., Jeong,Y., Woo,K., Kim,D., Bae,C., Moon,J., J.Mater.Chem. 2011, 21, 1102

(3) Kurosawa,T., Chiu,Y.C., Zhou,Y., Gu,X.D., Chen,W.C., Bao,Z., Adv.Funct.Mater. 2016, 26,1261.

(4) Jingjing Chang, Zhenhua Lin, Chunfu Zhang and Yue Hao (June 7th 2017). Organic Field-Effect Transistor: Device Physics, Materials, and Process

(5) R. Steyrleuthner, et al. J. Am. Chem. Soc., 134 (2012), p. 18303