High Performance *n*-Channel Organic Field-Effect Transistor of Conjugated Polymers with Fluorine-Substituted Phenylene Unit

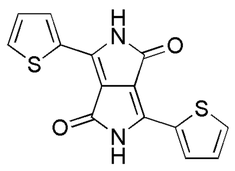
Eui Hyuk Jung, Jung Ha Park, Jae Woong Jung and Won Ho Jo*

Department of Materials Science and Engineering, Seoul National University, Seoul 151-744

GRL Global Research Laboratory 서울대 + Univ. of Massachusetts Nanomaterials for Environmentally Friendly Energy Conversion

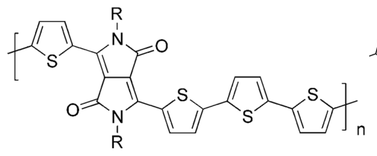
Introduction

❖ High hole mobility diketopyrrolopyrrole (DPP)-based polymers



DPP

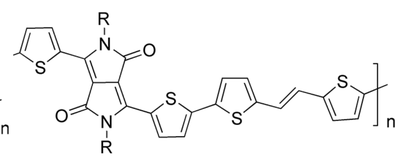
- Strong electron-deficient moiety
- Planar conjugated structure
- Strong π–π interaction



PDPPQT

μ_h= 1.04 $cm^2V^{-1}s^{-1}$

J. Am. Chem. Soc. **2011**, *133*, 10364



PDVT-10

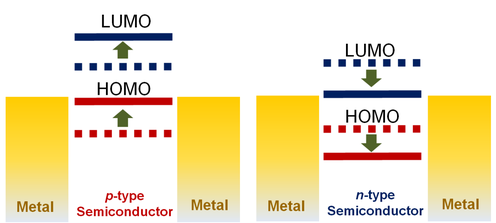
μ_h= 4.0–8.2 $cm^2V^{-1}s^{-1}$

Adv. Mater. **2012**, *24*, 4618

- Until now, many superb *p*-type conjugated polymers based on DPP have been reported. However, there aren't almost represented *n*-type substance.

❖ Effects of molecular energy level upon OFETs

✓ **Transport behavior in organic materials**



Energy level↑ → *p*-type behavior

Energy level↓ → *n*-type behavior

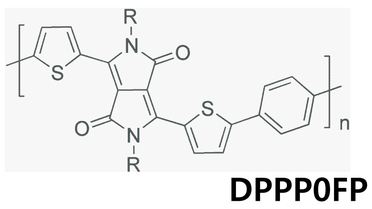
✓ **Natural properties of fluorine atom**

- Highest electronegativity

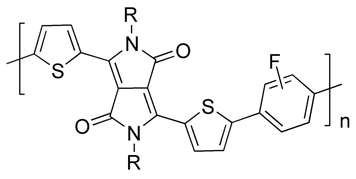
H	C	N	F
2.55	3.04	3.44	3.98

- Smallest electron-withdrawing group → less steric hindrance

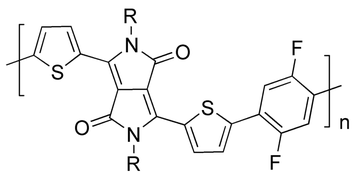
❖ Molecular designs for *n*-type organic materials



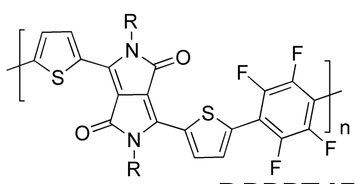
DPPP0FP



DPPPT1FP



DPPPT2FP



DPPPT4FP

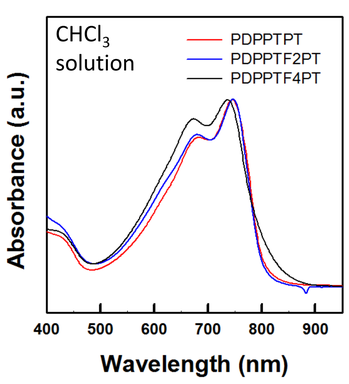
Objectives

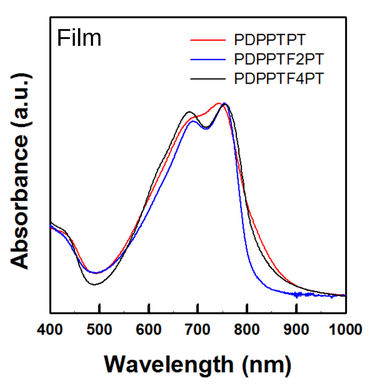
- To lower the energy level of the polymer by introducing electron-withdrawing fluorine atoms to phenyl unit that is copolymerized with diketopyrrolo[3,4-*c*]pyrrole (DPP)
- To investigate the effect of fluorine substitution on organic field-effect transistor properties of solution-processable polymers

Results

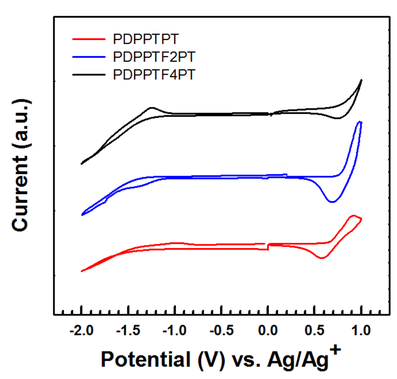
❖ Optical and electrochemical characteristics of the polymers

✓ **Absorption spectra**





✓ **Cyclic voltammograms**

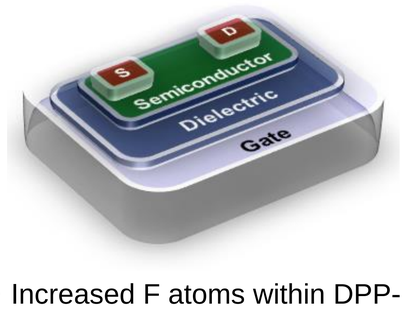


Polymer	M_n (kg mol^{-1})	PDI	λ_{max}^{sol} (nm)	λ_{max}^{film} (nm)	E_g^{opt} (eV)	HOMO (eV)	LUMO (eV)	E_g^{ec} (eV)
PDPP0FP	17.4	2.01	745, 683	744, 700	1.38	–5.36	–3.56	1.8
PDPP2FP	18.8	1.73	747, 680	754, 690	1.45	–5.57	–3.56	2.0
PDPP4FP	16.3	1.79	743, 674	756, 683	1.33	–5.65	–3.64	2.0

- Substituted number of fluorine atoms↑ → energy levels↓

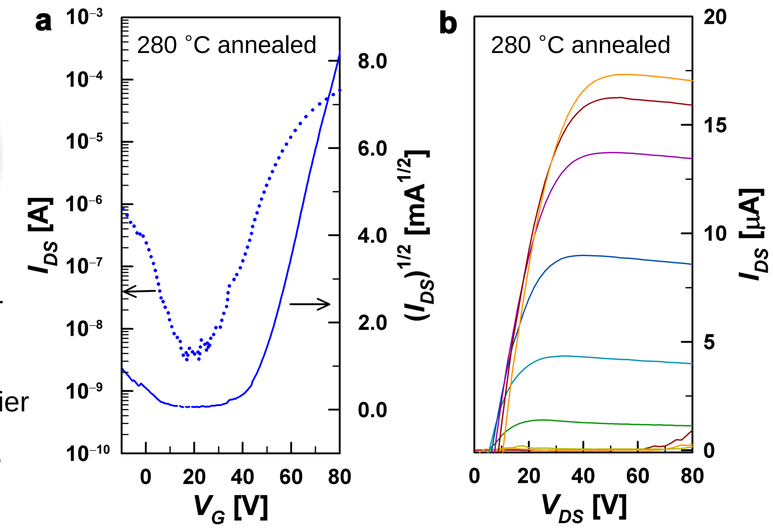
❖ Organic field-effect transistor

✓ **Device structure**



- Increased F atoms within DPP-based on conjugated polymer change the type of charge carrier transport from *p*-type to *n*-type.

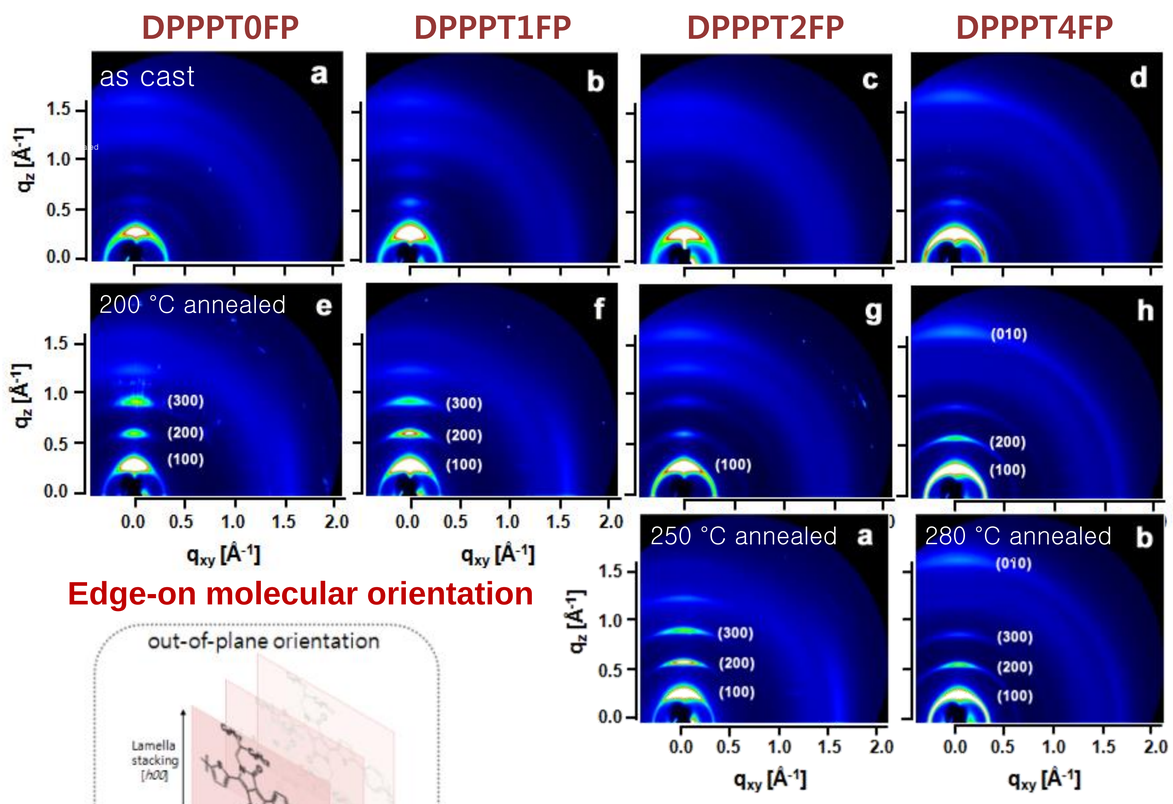
✓ **PDPP4FP OFETs properties**



Polymer	Annealing temperature	$\mu_{h,avg}$ ($\mu_{h,max}$) (cm^2 V^{-1} s^{-1})	$\mu_{e,avg}$ ($\mu_{e,max}$) (cm^2 V^{-1} s^{-1})
DPPP0FP	100 °C	0.06 (0.07)	–
	200 °C	0.34 (0.37)	0.23 (0.24)
	250 °C	0.26 (0.40)	0.08 (0.08)
DPPP1FP	100 °C	0.07 (0.08)	–
	200 °C	0.21 (0.30)	0.21 (0.26)
	250 °C	0.22 (0.23)	–
DPPP2FP	100 °C	0.03 (0.03)	0.08 (0.09)
	200 °C	0.02 (0.02)	0.09 (0.12)
	250 °C	0.03 (0.03)	0.06 (0.08)
DPPP4FP	100 °C	0.03 (0.04)	0.69 (0.80)
	200 °C	0.15 (0.16)	0.90 (0.99)
	250 °C	0.17 (0.19)	1.25 (1.35)
	280 °C	**0.23 (0.25)**	**2.00 (2.36)**

❖ Molecular Orientation

✓ **GIXD patterns**



Edge-on molecular orientation

Face-on molecular orientation

Conclusions

- Polymers substituted with fluorine atoms, DPPPT4F, the best *n*-type charge transporting behavior with an μ_e of 2.36 $cm^2V^{-1}s^{-1}$.
- Fluorination on the polymer backbone effectively controls the HOMO and LUMO energy levels and the transfer behavior of the conjugated polymers.