Charge carrier density dependence of the hole mobility in PPV

C. Tanase, P. W. M. Blom, D. M. de Leeuw, and E. J. Meijer, phys. stat. sol. (a) 201, 1236 (2004)

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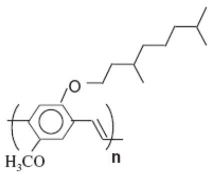
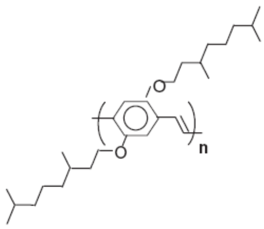
Changhee Lee
School of Electrical Engineering and Computer Science
Seoul National Univ.
chlee7@snu.ac.kr

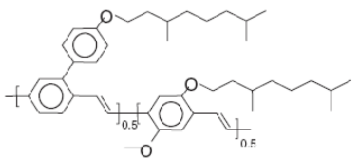
Chemical structures of PPVs



OC_1C_{10}-PPV
poly(2-methoxy-5-(3′,7′-dimethyloctyloxy)-*p*-phenylene vinylene)



$OC_{10}C_{10}$-PPV
poly[2,5-bis(3′,7′-dimethyloctyloxy)-*p*-phenylene vinylene]



NRS-PPV
random copolymer of poly(2-methoxy-5-(3′,7′-dimethyloctyloxy)-*p*-phenylene vinylene) and poly[4′-(3,7-dimethyloctyloxy)-1,1′-biphenylene-2,5-vinylene]

Table 1 Parameters $\mu_{LED}(E = 0)$ (zero-field mobility) at room temperature and σ (the width of the Gaussian density of states) for the PPV-derivatives as determined from hole-only diode.

polymer	$\mu_{LED}(E = 0)$ (m²/Vs)	σ (meV)
$OC_{10}C_{10}$-PPV	9.0×10^{-10}	93
OC_1C_{10}-PPV	5.0×10^{-11}	110
NRS-PPV	1.5×10^{-12}	125

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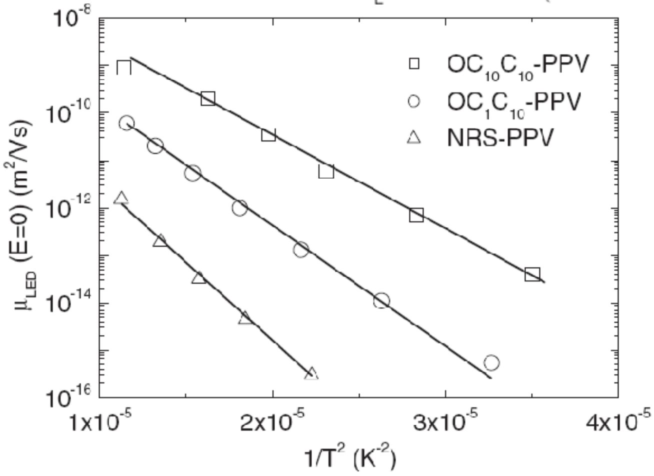
Temperature dependence of the zero-field mobility $\mu_{LED}(E = 0)$

$$DOS_{Gauss} = \frac{N_t}{\sqrt{2\pi}\,\sigma}\exp\left(-\frac{\varepsilon}{2\sigma^2}\right) \qquad \mu_{LED} = \mu_0 \exp\left[-\left(\frac{3\sigma}{5k_BT}\right)^2 + 0.78\left(\left(\frac{\sigma}{k_BT}\right)^{1.5} - \Gamma\right)\sqrt{\frac{eEa}{\sigma}}\right]$$



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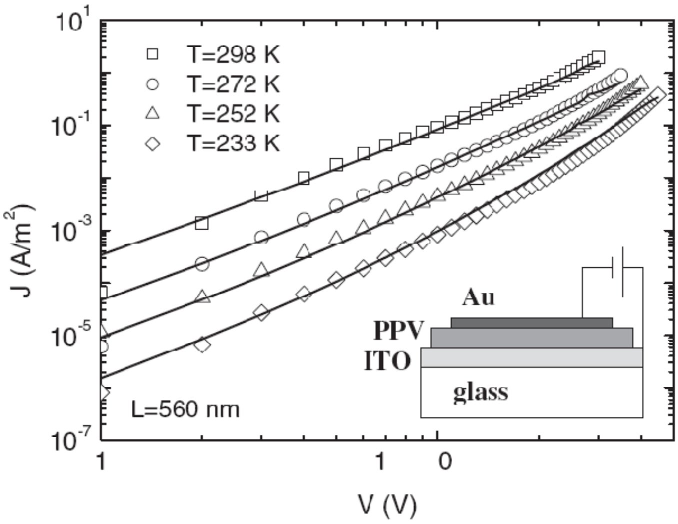
Temperature dependent I-V characteristics of NRS-PPV hole-only diode



SCLC

$$J_{SCLC} = \frac{9}{8}\varepsilon_o\varepsilon_r\mu\frac{V^2}{d^3}$$

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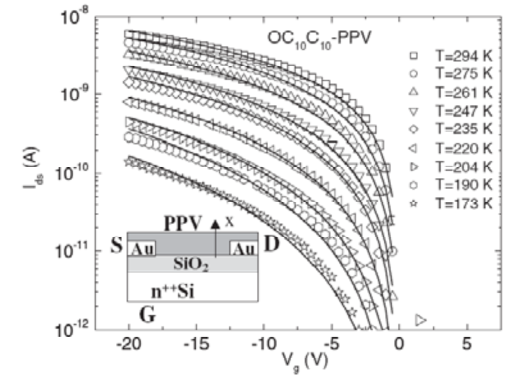
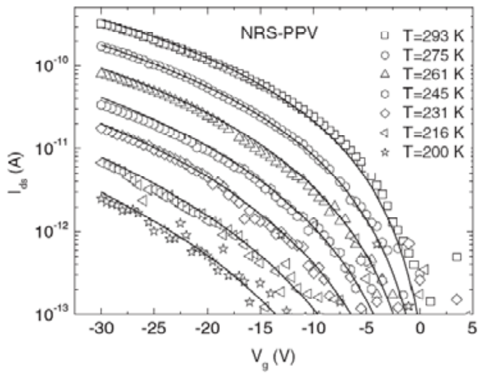
Transfer characteristics of PPV field-effect transistor





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Mobility of PPV field-effect transistor

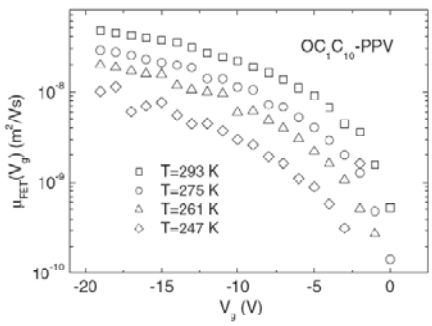

Fig. 6 Temperature dependence of the OC_1C_{10}-PPV filed-effect mobility as a function of gate voltage as determined from Eq. (3) (symbols).

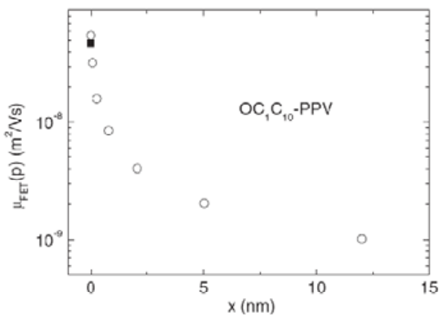

Fig. 7 Distribution of local mobility in the accumulation channel as a function of the distance from the semiconductor/insulator interface of an undoped semiconductor for $V_g = -19$ V.

$$\mu_{\mathrm{FET}}(V_g) = \frac{\partial I_{ds}}{\partial V_g}\frac{L}{WC_iV_d} \qquad C_i = 17\ \mathrm{nF/cm^2}$$

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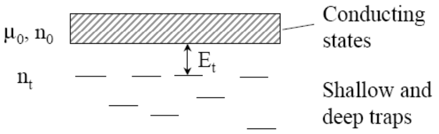
Multiple trapping transport



$$n_t / n_0 = (N_t / N_c) \cdot \exp(E_t / kT)$$

$$\mu = \mu_0 \cdot (1 + (N_t / N_c) \cdot \exp(E_t / kT))^{-1}$$

$$\approx \mu_0 \cdot (N_c / N_t) \cdot \exp(-E_t / kT)$$

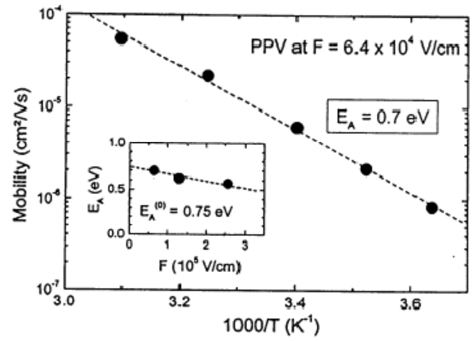


FIG. 2. Temperature dependence of the drift mobility in PPV at $F = 6.4 \times 10^4$ V/cm in an Arrhenius representation. The inset shows the field dependent activation energy of the drift mobility with an extrapolation to zero field.

Lebedev et. al, Appl. Phys. Lett., 71 (18) 2686 (1997)

Field-effect mobility

$$\mathrm{DOS}_{\mathrm{expon}} = \frac{N_t}{k_B T_0} \exp\left(\frac{\varepsilon}{k_B T_0}\right) \qquad \mu_{\mathrm{FET}}(p) = \frac{\sigma_0}{e}\left[\frac{\left(\frac{T_0}{T}\right)^4 \sin\left(\pi \frac{T}{T_0}\right)}{(2\alpha)^3 B_c}\right]^{T_0/T} p^{\frac{T_0}{T}-1}$$

Table 2 Parameters T_0 (the width of the exponential density of states), σ_0 (the conductivity prefactor), α^{-1} (the effective overlap parameter), $\mu_{\mathrm{FET}}(V_g)$ (the field-effect mobility determined from Eq. (3) at $V_g = -19$ V and room temperature).

polymer	T_0 (K)	σ_0 (10^6 S/m)	α^{-1} (Å)	$\mu_{\mathrm{FET}}(V_g)$ (m^2/Vs)
$OC_{10}C_{10}$-PPV	340	0.13	2.6	8.7×10^{-8}
OC_1C_{10}-PPV	540	31	1.4	4.7×10^{-8}
NRS-PPV	560	3.5	1.36	4.0×10^{-9}

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Comparison of field-effect mobility and diode mobility

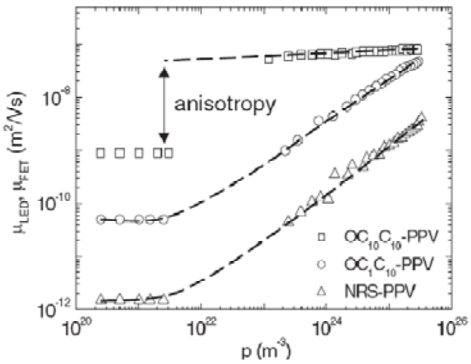
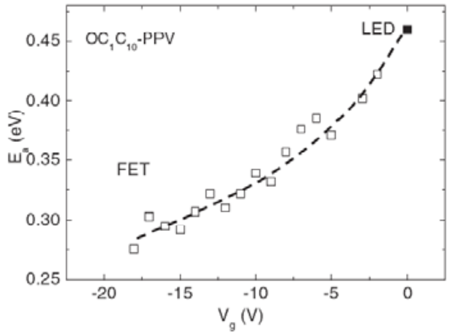


Fig. 8 Hole mobility as a function of charge carrier density in diode and field-effect transistor for NRS-PPV, OC_1C_{10}-PPVand $OC_{10}C_{10}$-PPV. The dashed line is a guide for the eye.



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Gaussian density of states (DOS)

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2009. 1st Semester

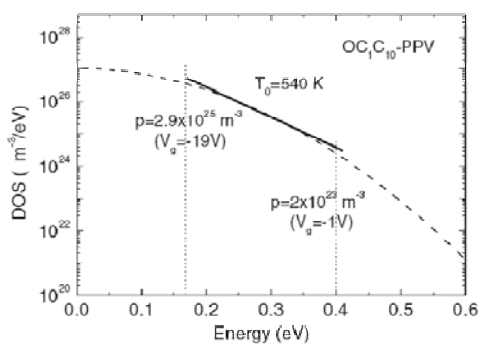

Fig. 10 Gaussian density of states (DOS) (dashed line) and the exponential DOS (solid line) as a function of energy for OC_1C_{10}-PPV.

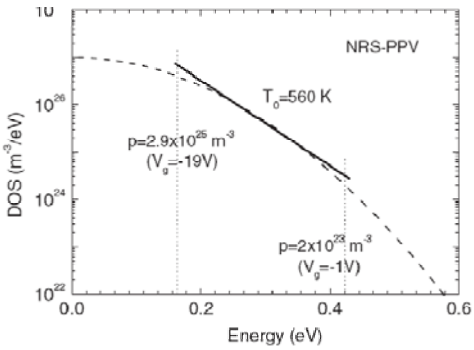

Fig. 11 Gaussian density of states (DOS) (dashed line) and the exponential DOS (solid line) as a function of energy for NRS-PPV.

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