

## Editor's Choice

Anomalous charge relaxation in channels of pentacene-based organic field-effect transistors: a charge transient spectroscopy study

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## Abstract

Two types of Si/SiO<sub>2</sub>/pentacene organic field-effect transistors (OFET) with bottom Au-source (S) and - drain (D) electrodes were examined by charge transient spectroscopy (QTS), applying pulsed bias  $\Delta U_{DS}$  to the channel of an OFET with floating gate electrode. The transient charge  $Q(t)$ , flowing through the channel after the removal of the bias pulse, was processed at a constant temperature by a three-channel correlator yielding the signal  $\Delta Q = Q(t_1) - 3/2Q(2t_1) + 1/2Q(4t_1)$ , the scanned delay  $t_1$  being related to the trailing edge of the bias pulse. Most of the QTS spectra were characterized by peaks of  $\Delta Q(t_1)$  with FWHM corresponding to discrete time constants  $\tau_m \approx t_{1m}$ , while scanning  $t_1$  from 2  $\mu$ s to 0.1 s. The common feature of the QTS spectra was a *linear* dependence of the peak height  $\Delta Q_m$  on  $\Delta U_{DS}$  for both polarities of the latter, thereby resembling what is expected for dielectric relaxation (polarization). Some devices showed anomalous (reversed) sign of the signal with respect to the polarity of  $\Delta U_{DS}$ , or even features like transitions from the correct sign to the reversed one. In order to customize the anomalies, a model is presented which ignores injection of excess charge carriers and takes into account two contributions to the total transient charge: a/space charge of intrinsic charge carriers piled up at the blocking Au-electrodes during the pulse, relaxing with the dielectric relaxation time  $\tau_D = \epsilon_0 \epsilon_r / \sigma$  ( $\sigma$  being conductivity of the organics); b/orientation of molecular dipoles ( $\tau_{dip}$ ) in the relaxing electric field of the space charge. It is the dipolar component that is responsible for the anomalous charge flow direction manifested by the signal reversal. The origin of the permanent dipole moment of the otherwise non-polar pentacene molecules may be either attached excess or missing atoms (vacancies) of the defect molecules [J. E. Northrup and M. L. Chabiny, Phys. Rev. B **68**, 041202 (2003)]. In cases of non-blocking contacts the dipolar relaxation would lead to QTS peaks of correct sign, to be distinguished from possibly non-negligible contribution of the dielectric relaxation in the semiconductor. (© 2006 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim)

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