Abstract:
We have measured the local potential and capacitance in disordered organic semiconductors by high sensitivity electric force microscopy, directly observing charge injection, transport and trapping.

Summary:
We have followed the electric field and interfacial charge density microscopically as the organic semiconductor (a molecularly doped polymer: triarylamine dispersed in polystyrene) undergoes a transition from ohmic to space-charge limited conduction (SCLC). Electric field and charge density at the metal-organic interface are inferred from the potential and current. The charge density at this interface increases with electric field much faster than is predicted by the standard diffusion-limited thermionic emission theories [1].

We have also observed a surprisingly large variation in the surface potential, which consistently appears under a variety of chemical and physical conditions. The variation arises from the presence of ionized acceptor states. Coplanar, interdigitated metallic electrodes are patterned by photolithography on a quartz wafer. The organic semiconductor is solution cast onto the device substrate.

We directly observe and image long-lived trapped charge in a pentacene thin film transistor as a function of gate voltage. We find that charge traps are distributed inhomogeneously throughout the pentacene film, but, unexpectedly, are not confined solely to grain boundaries [2].

Device substrates are fabricated beginning with a heavily p-doped silicon wafer. A 325 nm thick thermal oxide is grown as a gate dielectric. Source and drain electrodes are defined using optical photolithography. Prior to evaporating 5 nm of chromium and 70 nm of gold as the source and drain electrodes, shallow trenches (60 nm) are etched in the oxide to recess the electrodes. The pentacene film is thermally evaporated onto the device substrate.

References:
Microscopic View of Charge Injection, Transport and Trapping in Organic Semiconductors

**Figure 1, top right:** Topography (top) and force gradient image (bottom) of a 100 nm organic semiconductor film on coplanar gold electrodes. The variation of the force gradient is due to a large variation of the surface potential (100 mV). This source of energetic disorder arises from the presence of ionized organic molecules.

**Figure 2, below left:** Current-voltage characteristics of an organic semiconductor device. The insets show linescans of normalized potential, V(x), and electric field, E(x), across coplanar gold electrodes, demonstrating the transition from ohmic to space-charge limited conduction (SCLC) and the microscopic observation of charge injection into an organic semiconductor.

**Figure 3, below right:** Thin film transistor substrates were fabricated with interdigitated electrodes recessed into the oxide having channel lengths from 2 to 20 microns. The figure shows an electric force microscopy image of trapped charge in a pentacene thin-film transistor after being charged with a gate voltage of -30 V for 30 seconds. The measured charge trapping spatial distribution of the pentacene transistor is very inhomogeneous and contradicts a long-held assumption that the trap density should be correlated with the topography.

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