

Velocity-Field Characteristics of Pentacene OTFTs

Brian Cobb, Lawrence Dunn, Liang Wang, and Ananth Dodabalapur

The University of Texas at Austin

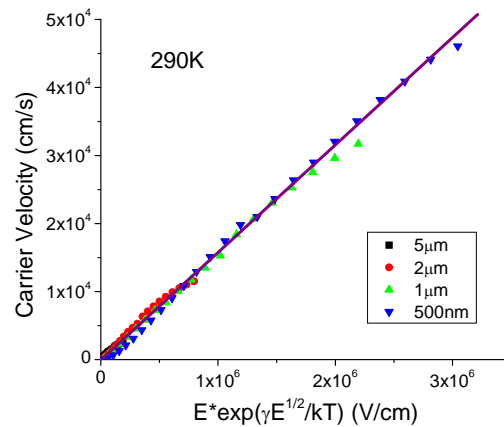
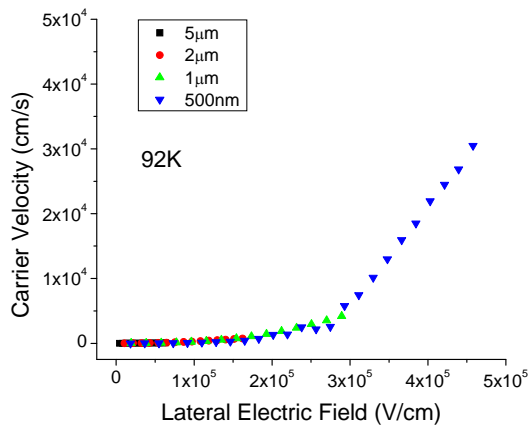
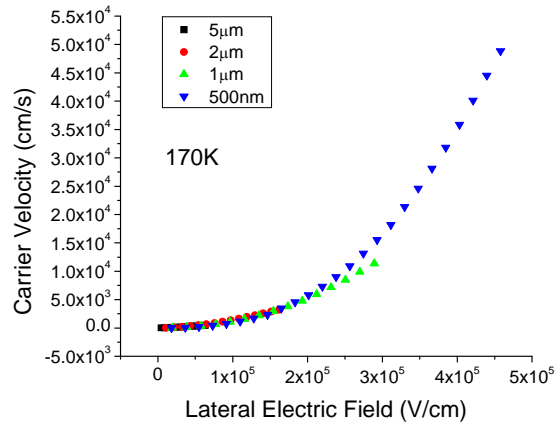
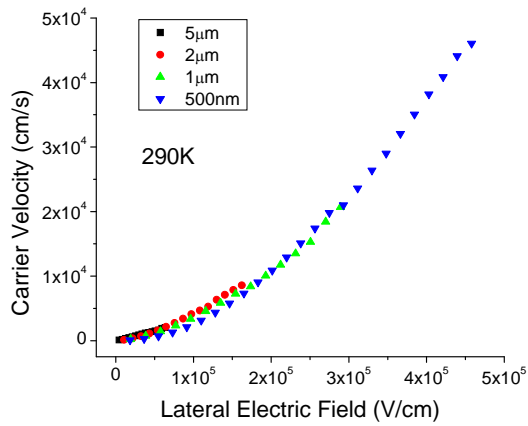
The way in which carrier velocity is related to electric field within organic semiconductors has been explored previously for both disordered and crystalline materials. However, typical organic field effect transistors employ polycrystalline semiconductors, with grain boundaries and alignment of crystal structure play important roles in charge carrier transport.

In this report, we have obtained the carrier velocity as a function of the lateral electric field within an organic field effect transistor. Velocities of $\sim 6 \times 10^4$ cm/s are observed at room temperature at moderate electric fields ($< 5 \times 10^5$ V/cm) in a polycrystalline pentacene device. The relationship agrees quite well with the Frenkel-Poole relationship describing the mobility-field characteristics of charge carriers in disordered semiconductors. The Frenkel-Poole relationship describes the mobility varying with electric field as $\ln(\mu) \propto E^{1/2}$. As the mobility is defined to be a factor governing the relationship between velocity and field ($v = \mu E$), this can be expanded to imply that the velocity varies with electric field as $E \cdot \exp(\gamma E^{1/2}/kT)$, where γ and k are constants. This is confirmed to be the case in the polycrystalline pentacene devices we have investigated.

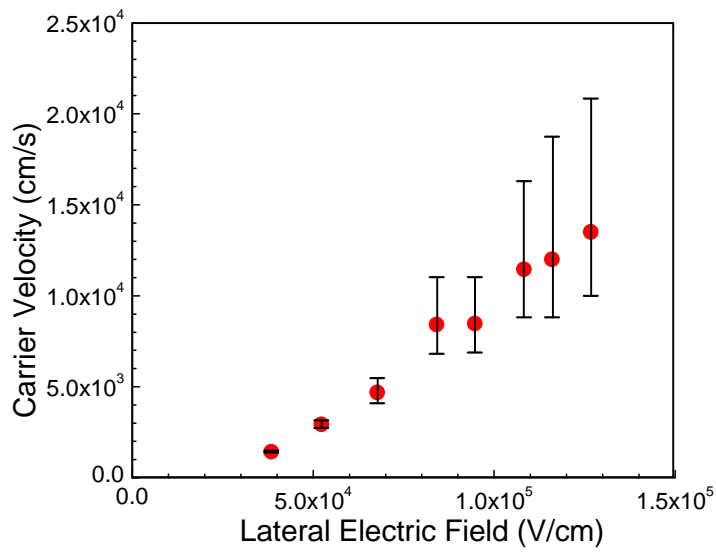
Two separate techniques were employed to calculate the carrier velocity. The first technique involved the steady state current-voltage relationship within the device. At a constant carrier concentration, the lateral electric field was varied through both altering the drain voltage, and changing the device length (devices were measured down to 500nm). Temperature dependence is seen in these results, displaying reduced dependence at higher electric fields. This relationship implies thermally activated hopping dominates charge transport at lower fields, while at higher fields, the field induced barrier lowering begins to become dominant.

The second method employed involved the transient response of the device to an incident voltage step. A direct measurement of the time it takes carriers to traverse the channel can lead to a carrier velocity that agrees with the steady state results when accounting for differences in carrier density.

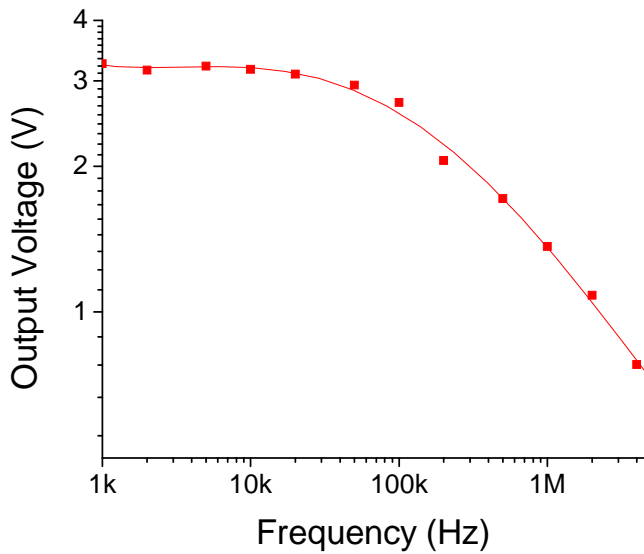
The velocity-field relationship in OFETs is important to understand, primarily when attempting to design circuitry based on these devices. The inherently low mobilities of carriers in these materials means that circuits will often be limited not by the inherent capacitance and resistance at individual nodes, but by the transit time of carriers through the devices themselves. The frequency response of an OFET employed as a half-wave rectifier will also be discussed, including the effect that carrier velocity has on the results, including the speed of operation and efficiency.



Velocity-field curves for a pentacene OFET at a variety of channel lengths down to 500nm, at various temperatures. The bottom right plot displays the agreement between the data and the Frenkel-Poole relationship.



Velocity-field plot for a pentacene OFET obtained through the transient response of the OFET to an applied voltage step.



Frequency response of a diode-connected pentacene OFET used as a half-wave rectifier. The reduced efficiency at higher frequencies is due to the finite velocity of carriers within the channel.