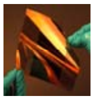
Time of Flight Mobility Measurement on Conducting Polymers

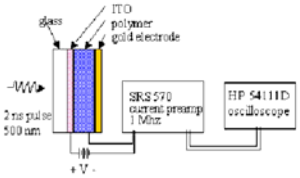
Eli Visbal, Carnegie Mellon University
Dr. John Ferguson, AFRL/MLBP

Introduction



Although plastics are traditionally thought of as insulators, it has been discovered that polymers can make very good conductors. In a process called doping, small amounts of certain chemicals are combined with the polymer transforming it into a very good conductor. Without doping, the intrinsic form of these polymers can be used as semiconductors. It is important to measure the electric mobility of these un-doped polymers because this characteristic limits the conductivity, the response time in electronics and exciton (electron/hole pair) diffusion as well as charge transport in photovoltaics. Testing mobilities assists in finding polymers that are well suited for applications like photocells.

Apparatus Diagram



Experimental Setup

- The conducting polymer is placed between Indium Tin Oxide (ITO) and gold contacts and a Voltage is put across them producing a large electric field through the thin layer of polymer.
- 2 nanosecond pulses of 500 nanometer wavelength light strike the polymer creating excitons, electron/hole pairs, which easily dissociate and move in opposite directions due to the electric field
- The current is measured as a function of time

Scher-Montroll Dispersive Transport

In crystalline semiconductors there is a well defined packet of charge that moves across the sample in this type of experiment. The center of the packet moves with a constant velocity giving an initially constant current that tapers off near the end due to the spread of the packet. In an amorphous material such as the polymers being tested the transport is entirely different. According to the Scher-Montroll model, the displacement of the mean position of charge is described by:

(1) $x(t) \sim t^{\eta}$, where $0<\eta<1$.

We then have:

(2) $I \sim dx/dt$, which gives (3) $I \sim t^{\eta-1}$.

This expression does not take into account carriers reaching the opposite electrode and disappearing. When that effect is taken into account the following expressions are obtained:

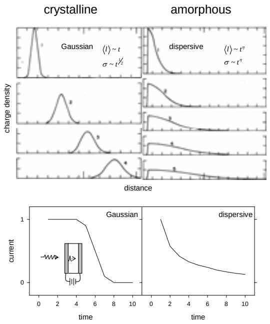
(4) $I \sim t^{-(1-\eta)}$, for $t < t_{transit}$, and (5) $I \sim t^{-(1+\eta)}$, for $t > t_{transit}$

These expressions give the current long before and long after the mean position of charge has reached the contact respectively. From these expressions we expect that on a log/log graph of current as a function of time there will be two lines, a less steep followed by a steeper line, with the sum of their slopes being –2. The intersection of these lines is $t_{transit}$. We can then determine a mobility from the following equation:

(6) $\mu E = L/t_{transit}$,

where μ is mobility, E electric field and L thickness of polymer.

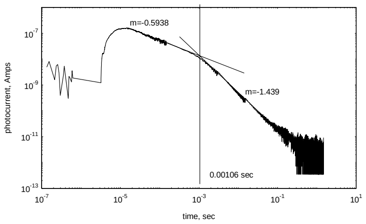
Charge Transport



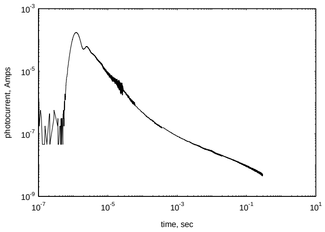
Results and Analysis

To verify that instrumentation was working properly a time of flight mobility test was performed on a poly(9-vinylcarbazole) or PVK sample. The log/log plot of the current vs. time has two linear regions and the sum of their slopes is -2.03. This is very close to the value of -2 predicted by equations (4) and (5). The intersection of these lines gives us $t_{transit}$ = .00106 sec. The thickness of the sample was measured twice giving an average value of 2.22 μm. During the test the sample was subjected to a voltage of 74.6 V with the polarity indicated in the apparatus sketch. Using equation (6) we find that the mobility, μ, equals 6.23 x 10^{-11} $m^2/(Vs)$ for this particular voltage and thickness. Given that the electric field was pointing towards the gold contact this is the hole mobility of the sample. All electrons were immediately pulled into the ITO. The value of this mobility measurement is comparable to previous results of PVK.

PVK Mobility

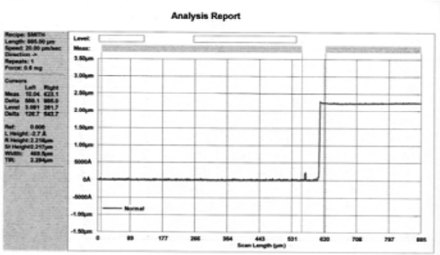


PTV Mobility



Our goal has been to measure the mobility of poly(thienylene vinylene) or PTV, however none of the measurements made so far are in agreement with the Scher-Montrol model. They have all been similar to the graph shown to the left, which does not exhibit the characteristic linear regions. Profilometry (thickness testing) revealed that the thickness of this particular sample is highly irregular. This may prevent the resolution of Scher-Montrol type transport. The next PTV sample tested had similar poor results. It is suspected that heat damage caused while making the sample may have reduced the mobility such that the current was not strong enough to make accurate measurements.

PVK Thickness Measurement



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