Terahertz electromodulation spectroscopy on organic semiconductors

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Organic field-effect transistors promise applications in a variety of fields, ranging from display technology to electrochemical sensing and bioelectronics. The charge transport in thin-films of molecular semiconductors or polymeric semiconductors, however, is far from understood. New insights are gained by THz electromodulation spectroscopy (THz-EMS), which probes the fundamental intrinsic transport processes. With this contribution, we present the properties of THz-EMS, its limitations, and examples that highlight the properties of band transport, the dominant scattering processes, and trap formation in organic semiconductors.

Terahertz electromodulation spectroscopy probes the AC conductance of mobile charge carriers [1]. Figure 1 illustrates the technique. Charge carriers are electronically injected into the semiconductor layer of the devices where they reduce the transmission of THz radiation. The investigated materials are the molecular semiconductors dinaphtho[2,3-b:2',3'-f]thieno[3,2-b]thiophene (DNTT), benzothieno[3,2-b][1]benzothiophene (C_8-BTBT-C_8), and the polymer semiconductor poly-diketopyrrolopyrrole-terthiophene (PDPP3T). All devices are fabricated on sapphire substrates or on 125 μm thick foils of polyethylene naphthalate (PEN). The molecular semiconductors are deposited by physical vapor deposition [2] and the polymers by blade coating [3].

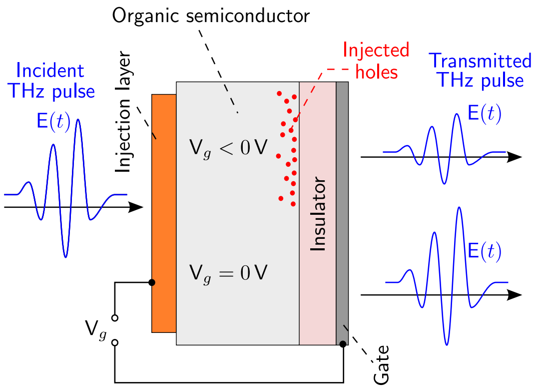

Fig. 1. Schematic of a device and the measurement of the relative differential transmission.

Figure 2 shows results obtained on C_8-BTBT-C_8 by transmitting THz pulses with a bandwidth of 2.5 THz through the device. A negative bias leads to the injection of holes and their Drude response reduces the THz transmission. As soon as the threshold voltage $V_{th} \approx -15\,V$ is reached, the THz signal decreases linearly with the density of injected holes. The carriers' mobility μ can be obtained from the observed relative differential transmission $\Delta S/S$ using $\mu = \frac{-\Delta S}{S} \cdot \frac{2\sqrt{\epsilon_b}}{e\, n_{2D}\, Z_0}$ where ϵ_b is the relative background permittivity, Z_0 is the impedance of free space, and n_{2D} stands for the carrier sheet density. Mobilities in molecular semiconductors, as well as in polymeric semiconductors, reach $\mu \approx 10\,\mathrm{cm}^2$/Vs.

A more detailed analysis of measured mobilities and the associated mean free paths of the carriers reveals substantial inconsistencies with the picture of band transport [2, 3]. We will show that the contradictions can be only resolved by assuming inhomogeneous semiconductors. In this model, only a small fraction of the charge carriers participates in band transport. These carriers have a mobility that by far exceeds the measured average value of $\mu \approx 10\,\mathrm{cm}^2$/Vs.

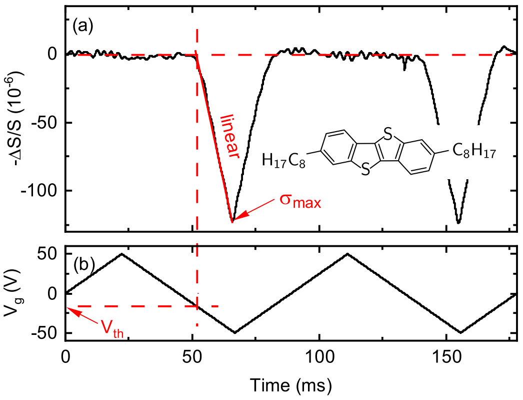

Fig. 2. (a) Dependence of the relative differential transmission $\Delta S/S$ on the applied voltage V_g (b).

References

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