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Electrical Characterization of Organic Electronic Materials

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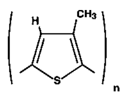
In the last decades, there has been a revival of interest in organic materials. Since the discovery of metallic and semiconducting properties of some organics, the road opened up for cheap electronics. Moreover, the organics have an advantage over their inorganic counterparts in that the possible number of organic materials is virtually unlimited; they can be tailor-made to suit any application. Two mainstream electronic products can be highlighted; on the one hand there is a large research effort on light-emitting diodes (LEDs), and on the other hand there are field-effect transistors (FETs). Final envisioned products are the flexible displays and other flexible electronics and electronic bar-codes. Whereas for the latter especially the cost will be a determining factor to compete with conventional materials, for the former there is the unique situation that they can only be made from plastic materials and as such a new market will be created. One could imagine things like wearable (not just portable) electronics, although probably only the future will tell what applications will make it into commercial products.

For traditional inorganic materials (viz. silicon), theories have been developed to describe their electronic behavior. Many good textbooks now exist that explain the devices based on these materials very well, see for example the classic "Physics of Semiconductor Devices" of S.M. Sze. These works are perfect to describe the classic devices of the junction diode, the Schottky diode, the bipolar junction transistor and the field effect transistor, to name but a few - everything up to, say, the 1980's. After that time, some good works were done to describe new devices such as the thin-film field-effect transistor, see the works of Powell, Shur, and Street. The question now is: to what extent can these theories, developed for inorganic materials, be applied to novel materials?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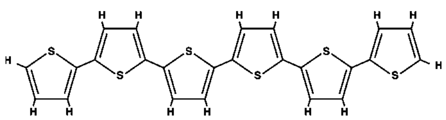
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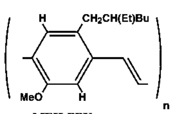
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Some examples of organic electronic materials. The common factor is that in each a path of alternating single and double bonds can be recognized.

In the presentation, we will show where and how the theories fail. We will present alternative models when necessary or stay with the old ones when they are adequate (using Occam's Razor to justify the choice).

Questions that will be addressed include the validity of the semiconductor band model, the donor and acceptor theory, the chemist's point of view versus the (solid-state) physicist's point of view, the influence of traps, the importance of the interface, the low mobility of the charge carriers, etc. The measurement techniques that will be discussed cover admittance spectroscopy, deep-level transient spectroscopy (DLTS), IV curves, CV plots, transfer curves, current transients, thermally stimulated and scanned currents and capacitance. It will be shown that in all these cases care had to be taken when trying standard, commercial, equipment since they distort the measurements up to the point of the conclusions being invalid. The techniques were used for two terminal devices (pn junctions and Schottky barriers) and three terminal devices (thin-film FETs).

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