# Polarons in organic transistors



*Organic field effect transistors (OFETs) are providing exciting prospects for potential applications in electronics. The active elements of these devices use "plastic" semiconductors, based on carbon and hydrogen. Among the advantages compared to classical silicon transistors, this new generation of components should combine flexibility, low weight, transparency and low cost.*

However, before they can be used in commercial applications, much work needs to be done to improve the performance of these devices. In this respect, enormous progress has been made through optimising the synthesis processes, drastically reducing the concentration of impurities present. At this point, a more fundamental understanding of the microscopic mechanisms governing electron transport in the organic materials becomes necessary.

Systematic studies of transport properties in organic transistors based on rubrene have been done by A. F. Morpugno's team at the Institute of Nanosciences of Delft Technical University (Netherlands). In order to increase the capacitance, that is the maximum density of charge carriers, they use semiconductors having higher and higher dielectric constants for the grid material (Figure 1a).

We have noticed that the electronic conduction, instead of increasing proportionally to the number of charge carriers, has a tendency to saturate, and even to decrease. Measurements as a function of temperature showed that this phenomenon is associated with a regime where the carrier mobility becomes thermally activated : to travel from one electrode to the other, the electrons must jump from molecule to molecule, crossing a finite energy barrier at each jump. The microscopic origin of this phenomenon is to be found in the interaction of the charge carriers with the ions constituting the dielectric material of the grid. The combined effects of this "electron-phonon" interaction and the small bandwidths observed for molecular crystals (of order 0.5 eV) lead to the formation of new quasi-particles : the polarons (see Figs 1b and 1c). Polaron formation traps the carriers' wave functions on individual molecules, and their motion is then by jumps, which explains the experimentally measured energy barriers.

Further studies are being done to analyse the effects of the Coulomb interactions between the electrons. These interactions could be the origin of mysterious behaviour observed for very high grid voltages.

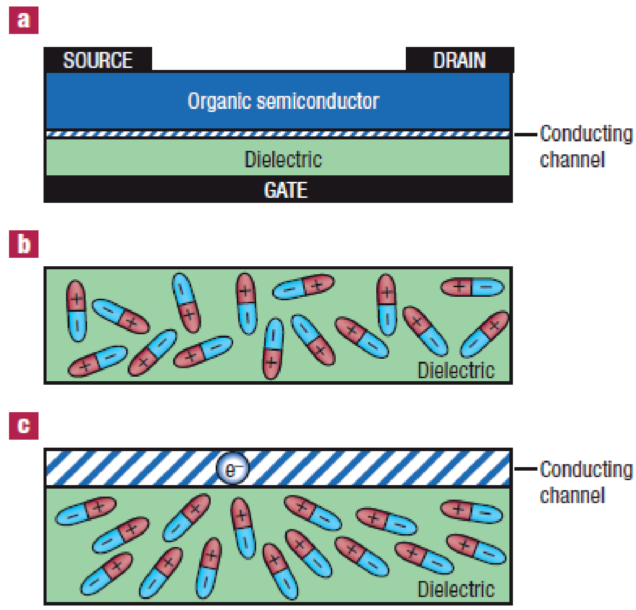


*Fig. 1 (a) Field effect transistor; (b) In equilibrium, the ions of the grid semiconductor are in a disordered configuration; (c) The ions polarise and trap the electrons, giving rise to polarons. (Figure is from the second reference below).*

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## Further reading :

• "Tunable Fröhlich Polarons in Organic Single-Crystal Transistors" I. N. Hulea, S. Fratini, H. Xie, C.L. Mulder, N.N. Iossad, G. Rastelli, S. Ciuchi, and A. F. Morpurgo, Nature Materials 5, 982 (2006)
• "Organic transistors: a polarized response", V. Coropceanu, J.-L. Brédas, « News and Views », Nature Materials 5, 929 (2006).