# ORGANIC TRANSISTORS FIELD EFFECT PERFORMANCES

**Ouiza Boughias[1,*], Mohamed-Said Belkaid[1], Farida Nemmar[1] & Djedjiga Hatem[1]**
[1] Laboratory of Advanced Technologies of Genie Electrics. Electronics Department.
[1]The University of Mouloud Mammeri B.P.N°17 R.P 15000, Tizi-Ouzou, Algeria

**ABSTRACT**
In the late 70 the researchers have shown the existence of electrically conductive polymers. For this the polymer must be conjugate which have give birth to organic electronics. This field of research motivates seriously some industrial. The conductor polymers are used like active layer in the devices like as organics transistors, solar cells and electroluminescent leds. Organic transistors field effects are particulary interesting because their manufacturing processes are much low complex and low cost than their equivalents made from inorganic materials. Among the parameters characterizing the organic transistors we find the switching speed which is the fraction of the mobility of charge carriers through the conduction channel length. The organic transistors must submit an acceptable life during because the organic semiconductor materials are sensitive to oxygen and humidity.
The advantages of organic transistors to classical transistors are light weight, flexibility and low cost of manufacturing process at large surface.
In this paper, we study the electrical proprieties of organic transistor and compare it to classical transistors.

**Keywords:** O*rganic field effect transistor,* O*rganic MOSFET transistor,Pentacene, High-k.*

## 1. INTRODUCTION
Integrate circuits are constituted of many transistors, thus, the improvement of individual transistor performances involves the development of integrated circuits. Among the different ways of this improvement, we find the use of organic materials as an active layer. It consists on the replacement of silicon by conjugated polymers or small molecules. These organic materials are called polymers. They are insulating because they do not lead an electrical current, but after modification they become conducting of electricity if they are conjugated. Conjugated polymers in their undoped state are used like active layer in organic electronic devices. To satisfy the specification sheets, we should have a compromise between the material mobility and the transistor geometry. So, we should choose high mobility materials for the active layer transistor or reduce transistor geometry.

## 2. STRUCTURE OF CLASSICAL FIELD EFFECT TRANSISTORS
The MOSFET transistor consist of four electrodes source (S), drain (D), gate (G) and bulk (B). The source and the drain are separated by the semiconductor which is mono-silicon
The gate, which is poly-silicon with high doped, is separated from the semiconductor with an insulator, which is silicon oxide ($SiO_2$) as shown in “Fig.1”.

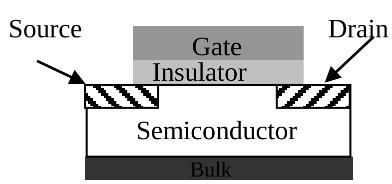


*Figure 1.Classical field effect transistor.*

The voltage applied to the gate determines the current which flows between source and drain, this voltage may be superior to same value called threshold voltage ($V_{th}$). For negative gate voltage, the holes are attired at the interface of silicon / silicon oxide. If we increase the gate voltage under the electrical field effect, the holes are pushed to the surface until these latter comport only negative fixes charge. If the gate voltage is greater than threshold voltage ($V_G > V_{th}$), the electrons will be attracted to the drain under the longitudinal electrical field effect created by $V_{DS}$ positive voltage.

## 3. STRUCTURES OF ORGANIC FIELD EFFECT TRANSISTORS
Organic field effect transistors are based on MIS (Metal-Insulator-Semiconductor) type structure in its fabrication. This structure in organics field effect transistors is used to get two kinds of transistors: top contact transistor (“Fig. 2.a”) and bottom contact transistor (“Fig. 2. b”).

In the first one, the source and the drain regions are deposited above the active semiconducting layer. In the second, the active semiconducting layer is deposited above source and drain regions as shown in "Fig. 2".

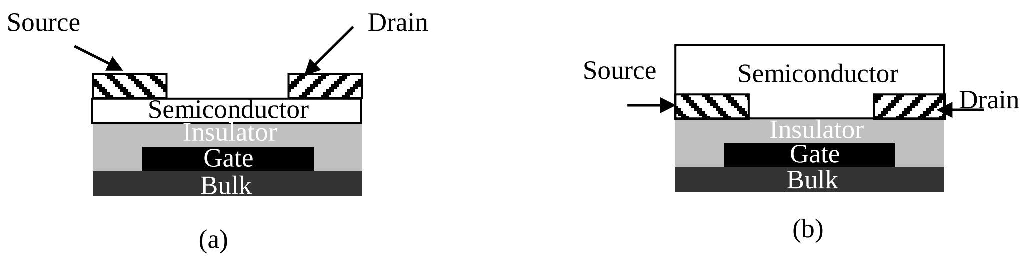


*Figure 2.Organic field effect transistor with*
*(a) top contact transistor,*
*(b) bottom contact transistor.*

## 4. COMPARISON BETWEEN CLASSICAL AND ORGANIC TRANSISTORS

In organic field effect transistor, the circulation of the current between the drain and the source is obtained by an applied gate voltage which actives the semiconductor. In the absence of gate voltage, the transistor is on "off" state. Thus, no current circulate between the drain and the source. With applied gate voltage, there is a current which flows between the source and the drain. This current result from the apparition of channel charges in the semiconductor.

The channel formed can be n or p type. The charge carriers are the electrons in n-channel and holes in the p-channel. The channel type depends on the nature of the semiconductor and the gate voltage. In the inorganic field effect transistors, the conduction channel is formed by inversion layer of minority carriers. However, in the organic field effect transistors the channel is formed by majority carriers. If we compare the carrier mobility of the organic and inorganic devices we find that the mobility of inorganic semiconductor is lower than that of organic semiconductor. For example, the mobility of mono-silicon is about two hundred times higher than that of pentacene as it can be seen on table 1 [1].

*Table 1. Mobility of organic and inorganicsemiconductor.*

| Organic and inorganic semiconductor | Mobility ($cm^2$/V.s) |
|---|---|
| Organic polymer (polythiophene) | 0.1.. 0.6 |
| Organic molecule (pentacene) | ~ 6 |
| Organic mono-crystal (rubrene) | 10.. 20 |
| Si mono-crystal | ~ 1000 |
| Si amorphous hydrogenated | 0.1.. 1 |

Other parameters to compare organic and inorganic semiconductors are toughness and flexibility. In fact, the organic semiconductors are very tough and flexible than the inorganic semiconductors.

## 5. ORIGIN OF POLYMERS CONDUCTIVITY

The large majority of conjugated polymers are constituted by alternance of simple liaison (σ type) and double liaison (σ + π) carbonated. These liaisons can ensure different functions: the σ liaison allows maintain the coherence of the structure, the π liaison allows the relocation of electrons on macromolecular. To improve the conduction of conjugated polymers it should be doped with electrons by reduction or holes by oxidation.

The supplementary electrons or holes allow charge transport along of molecule, which thus become conductive of electricity. We find two types of organic materials:

a) Polymers.
b) Small molecules.

The polymers are deposed by spin coating, example P3HT [6]. The small molecules are deposed by vacuum deposition. The small molecules and the pentacene are the most used materials to realize organic transistor. The small molecules have high mobility of holes than that of polymers.

The polymer can be conductor if the main chain presents an alternance of simple liaison (σ type) and double liaison (σ+π type) carbonated. The simple liaison is longer (0,154 nm) than the double liaison (0,134 nm).
Electronic configuration of carbon atom is $1s^2 2s^2 2p^2$. The atomic orbital 2p has three orbitals, two of them contain two electrons, and the third is non-occupied. These atomic orbitals can combine with other atoms to realize covalent liaisons. These new orbitals are called hybrid orbitals. Electrons wave function gives three types of hybridations: $sp^3$, $sp^2$, and sp.
The $sp^3$ hybridation means that the 2s orbital hybrids with the 2p orbital to form four orbital. This hybridation involves three dimensional structures.
The atomic orbital sp2 is oriented to the neighbor atom, by covering with its last atomic orbital to form a covalent liaison. The electronic doublet is common to two atoms. These liaisons represent the plan skeleton of the molecule.
The atomic orbital 2pz is oriented parallel to neighbor orbital. It covers laterally to give bonding molecular orbital π and anti-bonding molecular orbital π*. These two bonding create the π liaison. The double liaison is thus constituted by σ and π liaisons.
The Fig. 3 shows polymers electrical structure.

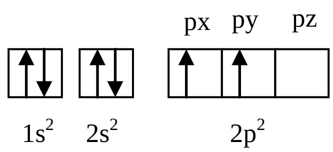


*Figure 3. Polymers electrical structure*

## 6. GATE INSULATORS

Gate insulators play an important role for the good functioning of organic field effect transistor. This insulator must have high resistivity to prevent the leakage current between the gate metal and the semiconductor channel and high dielectric constant to have enough capacitance for channel current flow [3]. There are organic and inorganic dielectric materials which fulfil this role. For OTFT, silicon oxide is used like gate insulator where the functioning voltages observed with $SiO_2$ are the highest [4].
For this, we are oriented to other insulators which have a high dielectric constant. These materials called high-k. Among the most used high-k materials we find tantalum oxide ($Ta_2O_5$), hafnium dioxide ($HfO_2$), titanium dioxide ($TiO_2$), and polymethylmethacrylate (PMMA) as an organic insulator.
These insulators in the organic transistor must satisfy other parameters. It should combine low functioning voltage and high stability. Lower functioning voltage has been observed with tantalum oxide $Ta_2O_5$ like a gate insulator in inorganic transistor but lack stability. Whereas with poly (methylmethacrylate) (PMMA) like a gate insulator we have high functioning voltage and highest stability [4] as it can see in table 2. The main problem of OTFT is the difficulty to combine stability with low functioning voltage.

*Table 2. Comparison between $Ta_2O_5$ and PMMA.*

| Gate oxide | Type | Stability | Work voltage (V) | Mobility ($cm^2$/V.s) | Dielectric constant (F/cm) |
|---|---|---|---|---|---|
| $Ta_2O_5$ | Inorganic | Lack | Low voltage 1.. 2 | Good 0.15 | High 26 |
| PMMA | Organic | highest | High voltage | high | Lower 2.. 3 |

## 7. CONCLUSION

There has been tremendous progress in Organic Thin Film Transistor (OTFT) performance during the last decade. At present, we can consider that the results of the research in this field reached the point at which an initial product application can be seriously considered.

## 8. REFERENCES

[1]. C.S.Liyeon Lee, S.w Ree, Organic thin film transistors: Materials, process and devices, Koren J Chen Eng, 267-285 (2004).
[2]. A-J.Attias, Conjugated polymers and electron conducting polymers, vol. 1, n°E1862, pp. E1862.1-E1862.20, (2002).
[3]. S.Allard, M.Foster , B.Souhare, H.Thiem, and U.Scherf , Organic semiconductors for solution-processable field effect transistors (OFETS), Organic Electronics reviews, (2008).
[4]. A.Attias, Engineering technical, conjugated polymers and electrical conduction polymers, E 1 862-p 8.
[5]. A.L.Denam, M.Erouel, J.Tandy, Organic field effect transistors, article electronic organic.
[6]. Th.Birendra Singh and N.S.Sariciftci, Progress in plastic electronics deviceAR REVIEWS IN ADVANCE 10.1146/annurev.matsci.36.022805.094757, Austria.