

New Optimization Nanotechnology Structures CNTFET

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Abstract - The high frequency properties of CNTs (Nano Tube Carbon) are very interesting because of their extraordinary structure, electrical and mechanical. They offer good electrical properties such as high conductivity. The conductivity value of single-walled NTC conductors is 70 times higher than that of copper. For semiconductors, load mobility values greater than $10^5 \text{ cm}^2/\text{Vs}$ compared to $1500 \text{ cm}^2/\text{Vs}$ for amorphous silicon used in the electronics industry. The current density greater than 10^9 . As a result, the impedance of an NTC structure can be considered as a function of the diameter and length of the nanotube and the internal physical parameters. Such structures in electronics don't use the basic components such as resistors, capacitors and coils but active elements such as NTC transistors. In this article, we will present new structures based on nanotube-carbon transistors CNTFET that offer low energy consumption, and we compare them with classical active structures.

Keywords - Nanotechnology ; Nanotube carbon; CNTFET ; C-CNTFE ; Inductance active.

I. INTRODUCTION

The studies of high frequency resistances and inductances are motivated by the high demand of the telecommunication applications such as the filtering of L.T.I (linear time invariant) continuous or discrete systems, the controlled oscillators and the decoupling [1, 2]. This basic element of analogical electronics is therefore very essential for modeling structures.

The modeling of the impedance of high frequency CNTFET structures requires a preliminary study of the behavior of the basic elements that make up the transistor, such as resistances and self-inductances. These basic elements are generally the access resistances and parasitic capacities of the gate, the drain and the source of the non-linear component CNTFET, since they depend on the physical properties and are a function of the frequency of use. Their influences lead to coupling effects, which constitute an additional difficulty in designing models equivalent to CNTFET such as resistances and inductances [3]. This difficulty has led the designers of very large scale integrated circuits to find solutions for the reproduction of discrete elements such as: resistances, capacities and coils in nanotechnological

structures. This renewal is mainly due to the performances and the improvements of the techniques of realization of the CNTFET transistors in nanotechnology.

We remind that these achievements are presented in GaAs technology and that they can be used for other technology.

We will present two new systems with nanotechnology impedance structures CNTFET GaAs consumption a low energy operating around gigahertz.

II. MODELING CARBON NANOTUBES

The carbon nanotubes mono layer, are modeled by resistance R and inductance L according model Goldfarb (Fig.1), formula (1), impedance of nanotube carbon Z_{cnt} is modelling by (1), depends and it is function of parameters intrinsic of the CNT [4].

$$Z_{cnt} = R_{cnt} + jL_k \omega = \frac{\pi \hbar v}{4e^2 v_f} + j \frac{\pi \hbar}{4e^2 v_f} \omega \quad (1)$$

Where : $v = 3 \cdot 10^8 \text{ m/s}$: Relaxation frequency;

$v_f = 9.7 \cdot 10^5 \text{ m/s}$: Fermi speed;

$\hbar = \frac{h}{2\pi}$: Planck constant reduced.

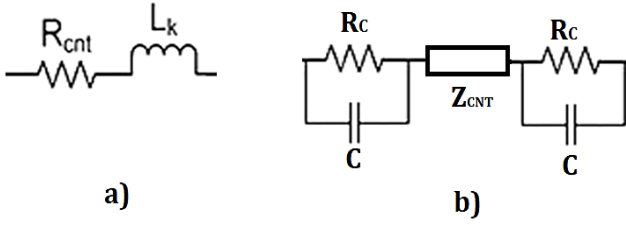


Fig.1. Equivalent circuit electrical model for CNT : (a) Impedance of Z_{CNT} , (b) Z_{CNT} with contact impedance Z_c of CNT.

The influence of the geometrical parameters of the metallic carbon nanotube are function on value of the inductance L . This inductance decreases with the increase of the length CNT and decreases with the decrease of the diameter of CNT (2). The inductance L is given:

$$L = \frac{\mu_0}{2\pi} \left[h \cdot \ln \left(\frac{h + \sqrt{r^2 + h^2}}{r} \right) + \frac{3}{2} (r - \sqrt{r^2 + h^2}) \right] \quad (2)$$

Where : r : radius of the carbon nanotube;
 h : length of the carbon nanotube;
 μ_0 : permeability of vacuum of CNT.

The inductance variation L as a function of the length h of the metal nanotube are decrease with the length of the carbon nanotube [2].

We consider model in our choice the single-walled metal nanotube model. In high-frequency properties of the NTCs due to their structures, electrical and mechanical, and their wide range of applications the NTCs offer good electrical properties like high conductivity and current density greater than 10^9 A/cm² [5].

III. MODELING CNTFET GAAS TRANSISTOR

The physical compact (Fig. 2), and the electrical modeling of the barrier height modulation carbon nanotube transistor are also called CNTFET or C-CNTFET (modulation barrier CNTFET) or also CNTFET MOS type [3- 6].

This model is described by equation of current I_{ds} :

$$I_{ds} = \frac{4eK_B T}{h} \sum_{p=1}^{p=nsb} \left\{ \ln \left(1 + \exp \frac{-\Delta_p + e \cdot V_{cnt}}{K_B T} \right) - \ln \left(1 + \exp \frac{-\Delta_p + e(V_{cnt} - V_{ds})}{K_B T} \right) \right\} \quad (3)$$

With :

Δ_p : bottom p under-band energy;
 V_{cnt} : threshold voltage carbon nanotube;
 nsb : number of under-band;
 K_B : Boltzmann constant;
 T : Kelvin temperature.

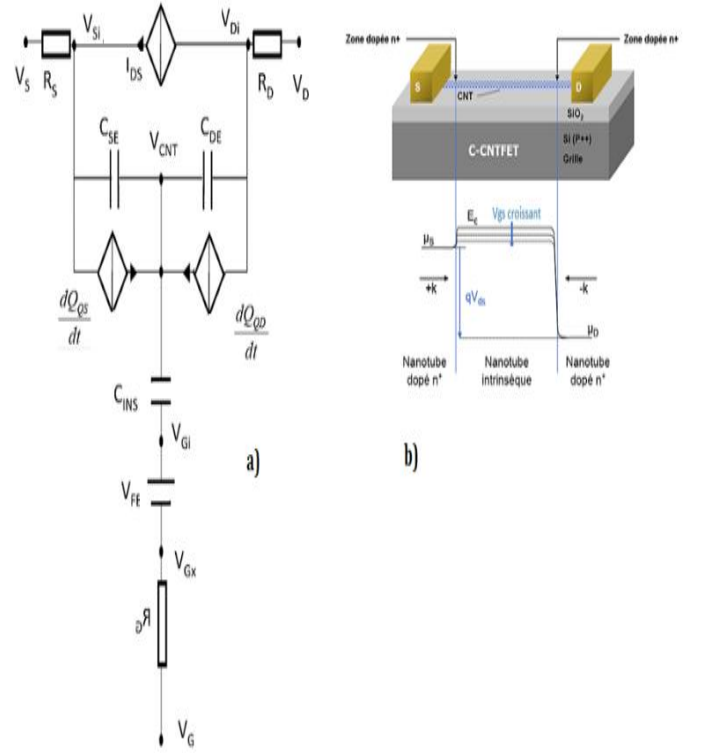


Fig. 2. Compact model electrical and physical CNTFET, a) Compact model of transistor CNTFET; b) model and diagram of conduction band of transistor CNTFET or C-CNTFET.

The model compact shown in Fig. 3, is obtained from the current equation, I_{DS} defined previously by equation (3), and the currents resulting from the charges coming from the source Q_{QS} and the drain Q_{QD} .

This model is depending also the elements [7]: Gate access resistance R_G , access resistances source and drain R_S and R_D respectively (which take potential difference between the electrode source or the drain and the doped nanotube of the contact), capacity of the gate oxide C_{INS} dependent on the geometry and the dielectric constant of the insulator, electrostatic capacities C_{SE} and C_{DE} which represent the charge variation at the intrinsic doped nanotubes/nanotube interfaces, V_{FB} flat strip tension which takes into account the difference between the work of extraction of the metal and the electronic affinity of the nanotube.

The charges of the source, Q_{QS} and of the drain, Q_{QD} are evaluated with equivalent diagram for applications and using the Kirchhoff laws and also the potential function V_{CNT} who are depending flat voltage V_{FB} . The tension V_{FB} is modelling with effective interface Schottky Barrier Φ_{SB}^{eff} by (4) :

$$\Phi_{SB}^{eff} = \left[(\Phi_{SB} - (\Delta_p - eV_{cnt} + eVS, D).exp-dTunnel\lambda Schottky + \Delta_p - eV_{cnt} + eVS, D + V_{cnt} - \Delta_p factor_{SB} eff \Phi_{SB} factor_{SB} eff \Phi_{SB} 1 - 1 + eV_{cnt} - \Delta_p KBT \right] \quad (4)$$

Where:

$factor_{SB}^{eff}(\Phi_{SB})$: correction factor is modelling by (5) :

$$factor_{SB}^{eff}(\Phi_{SB}) = \{ 1.37867 + 1.55024.exp-\Phi_{SB} 0.15228 m_1^*(19) m_1^*(n) 13 \} \quad (5)$$

m_1^* : effective mass of electron with bottom of 1th under-band.

IV. STRUCTURES PROPOSED OF CNTFET GAAS NANOTECHNOLOGY TRANSISTOR

We propose in this paper, two structures one with 3 transistors (Fig. 4) and the other with 4 transistors (Fig. 3), the choice of one or the other depends on the simulated characteristics and each one with these advantages is these disadvantages.

A) First new structure proposed

The first structure Fig. 3, that we propose includes four N-type CNTFET GaAs transistors : J1, J2, J3 and J4 and three connections realized in nanotechnology CNT : C1 C2 and C3.

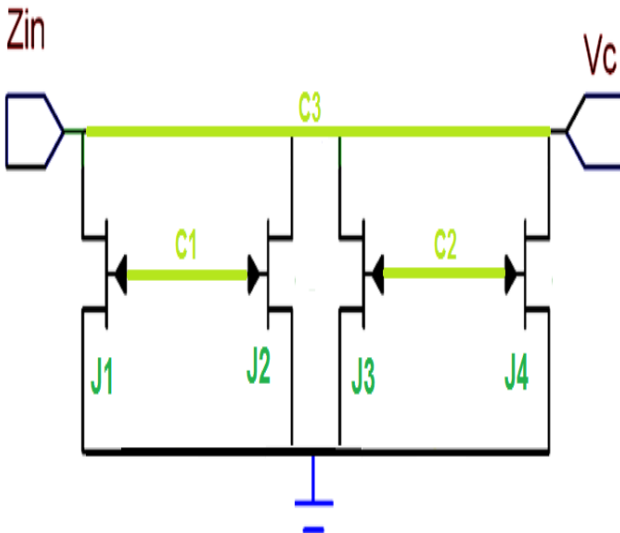


Fig. 3. First proposed electric structure CNTFET GaAs.

The resistance obtained of circuit equivalent is proportional to the parameters of the CNTFET (Fig. 2). This dependence explains the adjustable nature of the resistances series through the bias polarization current and indeed, the intrinsic parameters of the model such as C_{INS} , C_{SE} , C_{DE} , R_S , R_D and R_G .

The variation of the resistances series is proportional with increases of frequency. It is linear with variation frequency between : 1 GHz to 10 GHz.

B) Second new structure proposed

The second structure suggested is represented in Fig. 4. This circuit adopts a configuration with three CNTFET GaAs : J1, J2 and J3 transistors of the type N and three connections CNT : C1, C2 and C3.

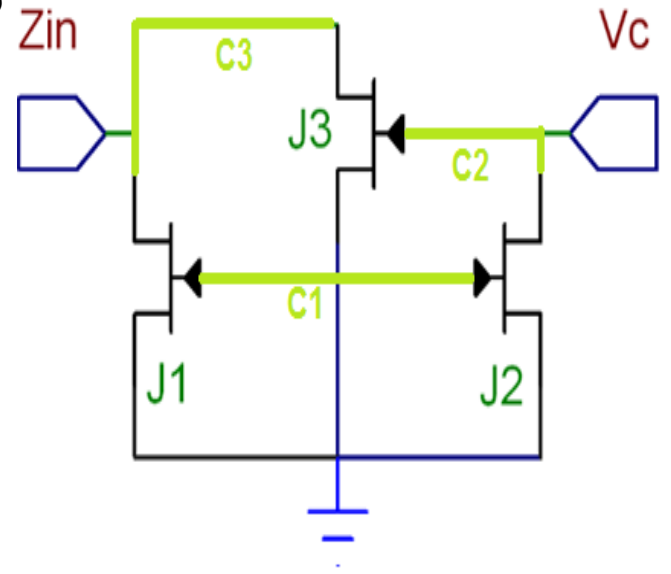


Fig. 4. Second proposed structure CNTFET GaAs.

The variation of the resistances series of the circuit equivalent is not proportional with increases of frequency. It is explained the complicate nature of this configuration [8-9].

V. SIMULATION RESULTS OF THE INDUCTANCES OF PROPOSED MODELS.

On the other hand, if we consider that the connections between the CNTFET transistors are carbon nanotubes Fig. 3, and formula (2), that we can model them by an inductance L_C , then according to the principle of Ohm's laws. The total inductance L Fig. 5, is the sum of inductances : L_{TR} (inductance of CNTFET) and l_C (inductance of carbon nanotube).

The results of the simulations of the inductance L of the circuit in the Fig. 3 are shows in the Fig. 5.

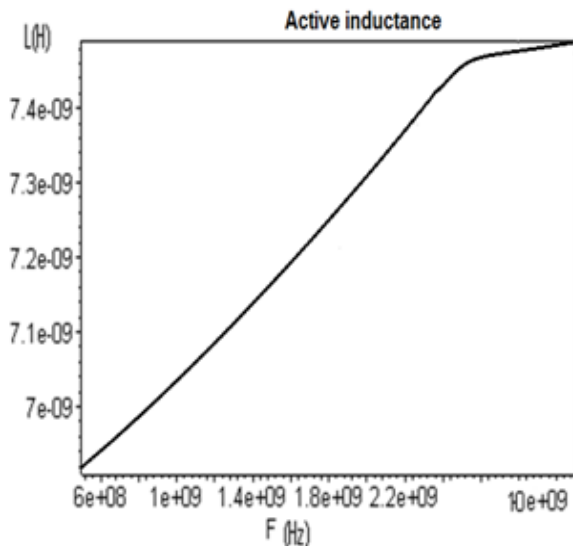


Fig. 5. Simulation inductance L of circuit 1 proposed in Fig. 3.

The results of the simulations for the inductance L of the circuit given in Fig. 4, are shown in the Fig. 6.

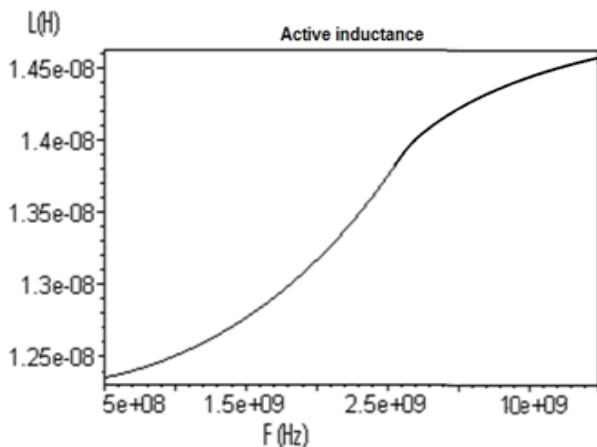


Fig. 6. Simulation inductance L of circuit 2 proposed in Fig. 4.

VI. ENERGY OF THE STRUCTURES PROPOSED IN TECHNOLOGY CNTFET GAAS

Table 1 illustrates an evolution of the inductance L and the resistance R with frequency, between the topologies of structure 1 and 2.

Table 1. Comparison of the values for the two presented structures.

	L (nH)	R (Ω)	P (mW)
<i>First proposed structure</i>	5	7	0.095
<i>Second proposed structure</i>	100	2	0.055

The circuit of Fig. 4, is the one that has the best characteristics and a minimum power consumption P

= 0.095 kW. This proposed circuit in Fig. 4, given a value of the higher inductance $L = 100$ nH and low resistance $R = 2$ Ω , and given a better power consumption $P = 0.055$ mW.

VII. CONCLUSION

We see that the variations of the frequencies are proportional to the variations of the inductances and resistances, circuits proposed it reach the saturation starting from the frequency 10 GHz, this is due to the saturation of the current in the two transistors CNTFET.

The circuit of the proposed structure (Fig. 4) (Second structure proposed), has higher inductances than the circuits transistors with non-conventional links FET GaAs and circuit of Fig. 3.

The best features. It also offers a higher inductance value and lower consumption. This value of the inductance and associated resistance series is suitable for very high frequency applications in amplification, filtering and oscillator at frequencies above 10 GHz.

VIII. REFERENCES

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