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Toy Model Of Spinfet Transistor

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Abstract

The study of spin polarized transport in semiconductors is achieved by the transmission of current in semiconductor devices, our study focuses on spintronics or spin electronics in these devices.

We chose the spinFET transistor or the transistor at `spin rotation' as a better implementation because it is a type of HEMT transistor in which we replace the source and drain by ferromagnetic contacts. The source contact acts as a spin polarizer for electrons injected into the conduction channel of the transistor and the drain contact is a spin analyzer to those (spins) have reached the end of the canal. The drain current varies with orientations of the spin of electrons at the end of the canal and the magnetization of the drain contact. However, it is possible to control the current through the grid voltage.

We have presented a simple toy model in the 1D channel formed in $In_{0.53}Ga_{0.47}As$ *a spin FET transistor.*

Keywords: Spin polarized transport, spintronic, spinfet, Semiconducteur

1. Introduction

The electrons are not only characterized by their electrical charge, but also by their spin magnetic moment. Up to the late 90's, the electronics had virtually ignored the electron spin (except pauli's law that two electrons can not be in the same energy state with equal spin orientation ..). Since then, spin electronics, or magneto-electronics Prinz [1], grows increasingly and rapidly.In this section we will see how it is possible to introduce the concepts of magneto-electronic components in a semi-conductor.

2. Spintronic

The spin electronics, or "spintronics" Prinz [2], is a new research theme has been booming since the late 80s. The first structures studied in this area are made of ferromagnetic metal multilayers, separated by insulators or "tunnel" or by non-magnetic metal films. Their operating principles are related to a property of ferromagnetic metals on the spin of electrons: they inject or collect preferentially carriers whose spin is polarized along the direction of their magnetic moment. Such devices are already used industrially as magnetic field sensors for read heads of hard disks, or are expected to be soon in the case of magnetic random access memory. During the past four years, groups working in the field of semiconductor components were also interested in properties related to the spin of the electron Bournel,[3]. Indeed, recent studies have shown that it is possible to act on the spin of charge carriers and use this quantity to modify the electrical and optical structures in semiconductors.

3. Spintronics in semiconductors (spin FET)

In semiconductors, the control of the spin of the carriers, in addition to their charges, may give rise to a new generation of electronic devices Wolf et al [4]. This idea was born of a new concept device that can benefit from the manipulation of spin to create a new feature. Is the case of Datta and Das transistor wich we will briefly describe the principle [5]. This concept was proposed in 1990 and named Spin FET "rotation spin transistor". This device looks at first sight to the classical field effect transistor, as illustrated in Figure (I) and has a current source, a drain and a channel with a conductance controllable via a gate voltage, Vg, however, comparison stops there. The spin transistor is based on spin selective contacts, that is to say capable of injecting or collecting a given spin orientation. The injection and the collection of spin-polarized current is carried by ferromagnetic electrodes (Fe, for example). To modulate the drain current, Datta and Das proposed to control the rotation of the "bundle" of spin in the channelusing the spin-orbit Rashba coupling to be a function of voltage applied to the gate [6], The drain current reaches a maximum value when the spin orientation is parallel to the magnetization of the electrodes and injection manifold.

It reaches a minimum value when they are opposed. This concept also implies a transistor coherent transmission, i.g without loss of spin between the injector (source) and collector (drain). Under this proposal, the channel where the propagation of spin takes place must be a gas of electrons in two dimensions (2 DEG) to take advantage of high mobility allowing a coherent propagation. This 2-DEG channel can be obtained in a transistor structure with modulation doping (MODFET) type InGaAs / InAlAs Das et. al. [7].

4. Model and Results

4.1. Drain current variations

The expression of the drain current in a spin-FET in our model is given by the following equation:

$$I_D = q\frac{E_y}{V_C}\mu\left(E_y\right)E_x\frac{1+P_0\cos\left(E_y L/V_R\right)}{1+P_0} \qquad (1)$$

Where the parameter V_C, equal to $q/(2\varepsilon_0\,\varepsilon_{SC}\,W)$, is uniform to the voltage. It may be noted that the term E_y/V_C in this expression represents the density in the grid controlled by accumulated electrons in the channel. The parameter μ denotes the electron mobility and thus μE_x represents the speed of electrons. The mobility μ varies with the intensity of confinement in the channel, it means with the field E_y the ratio $(1+P_0\cos(E_y L/V_R))/(1+P_0)$ reflects the analysis of spin at the drain. This ratio varies periodically, with period $E_{y0}=2\pi V_R/L$. Its amplitude depends on the spin polarization P_0.We initially consider the mobility constant and we study the derivative g of I_D/μ function of E_y.

$$g(u)=\frac{qE_X}{V_C}\,\frac{1+P_0(\cos(u)-u\sin(u))}{1+P_0} \qquad (2)$$

Where u is a dimensionless parameter equal to $E_y\,L/V_R$, except in V_C, the function $g(u)$ does not depend on parameters characterizing the quantum wire transistor. The variations of g give the information on the transconductance of the spin-FET

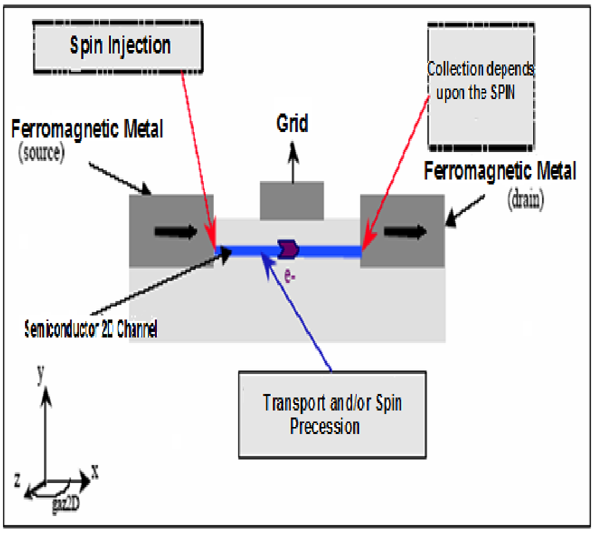

Figure I-Schematic diagram of the transistor with spin precession *(spin- FET)*

In Figure 2 we have represented the variations of the transconductance with the dimensionless parameter $E_y\,L/V_R$ for P_0 = 80, the spin precession leads to relatively large important electrical effects.

We observe both an important effect of negative transconductance for $E_y\,L/V_R$ ranging: 400° to 520° the transconductance becomes negative in this area for P_0 equal to 100% in the other hand the transconductance becomes back positive for $E_y\,L/V_R$ ranging between 540% and 720%. These nonlinear variations of transconductance is related to strong current oscillations.

For values of P_0 = 10%, these effects are never observed in the considered interval for $E_y\,L/V_R$: the transconductance remains positive. In this case, the amplitude of current oscillations due to modulation of the spin polarization in the perpendicular field is very low.

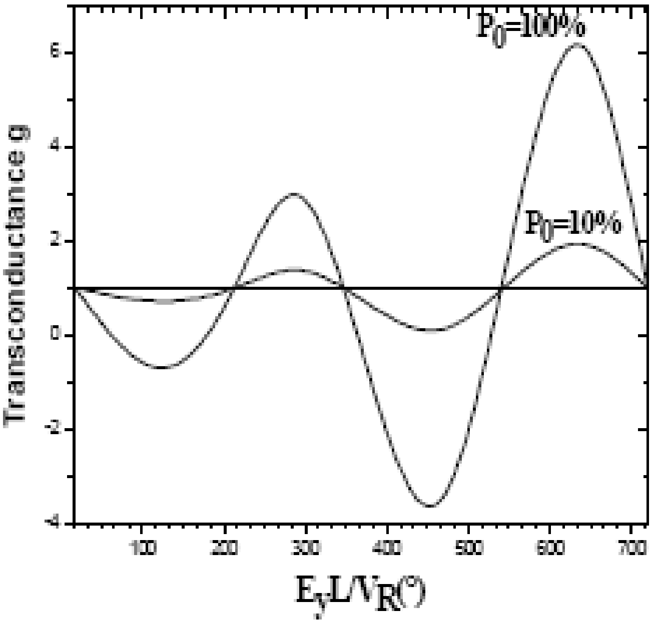

Figure 2 Transconductance g function of dimensionless parameter $E_y\,L/V_R$ in a spin-FET quantum wire $In_{0.53}Ga_{0.47}$ As . For P_0 = 100% and 10%.

5. Conclusion:

In this work we have established a relation giving the expression of the current source-drain as a function of the parameters of the used semiconductor, the potential across the control grid and the polarization of injected spins, then we have calculated the associated transconductance. This model is based on semiclassical consédérations with carriers of spin injected and collected that have ballistic trajectories inside the conduction channel. We have presented here the dependence of the transconductance as a function of spin polarization for a qualitative assessment of the model. we note that the spin-FET offers an interest as a component if the spin polarization P_0 imposed by the ferromagnetic contacts is equal to 100%.

6. References

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