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QUANTUM EFFECTS OF NANOWIRE FET

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Abstract - *In the course of recent years, nanostructures have evoked a lot of intrigue on account of their particular qualities that influence physical, electrical, compound, natural, and pick electrical properties. The crucial part of Nano science and nanotechnology is nanostructured material. Nanostructures are structures somewhere in the range of 1 and 100nm in size that are comprised of carbon, composite, metal, metal oxide, natural, or inorganic material. As the channel lengths of regular planar metal oxide semiconductor field effect transistors (MOSFETs) Shrink into the nanometer system, execution of the gadgets becomes debased for the most part in view of short channel effects that emerge because of debilitated entryway control. In this work the electrical properties of Nanowire FET's are dissected utilizing the 1 dimensional Schrodinger condition and mimicking the electronic properties utilizing the open source programming instruments like Nano-Hub.org and TCAD Sentaurus test system.*

Key Words: **Nanowire FET**, **Gate all around (GAA) Nanowire**, **Quantum effects**, **Nano-Hub.org**, **TCAD**

1. INTRODUCTION TO NANOWIRE FET

As the channel lengths of ordinary planar Metal-Oxide-Semiconductor Field Effect Transistor (MOSFETs) shrivel into the nanometre system, execution of the device becomes debased for the most part in light of short channel effects that emerge because of debilitated entryway control. The Silicon Nanowire Field Effect Transistor (SNWFETS) with various entryways around the silicon channel that can significantly improve the door control are consequently viewed as promising possibility for the cutting edge transistors and have drawn impressive consideration as of late [1]. In the SNWFETS in the nanometre system, quantum effect, for example, the burrowing and confinement effects ought to be considered cautiously to evaluate their device execution precisely, and the ballistic transport can be viewed as making a predominant commitment to the all-out current. Specifically, as the channel lengths of the SNWFETS contract, the source-to-deplete direct burrowing flow is relied upon to be expanded significantly until it turns into the principle hotspot for the short divert effects in the SNWFETS Nanowires are like ordinary electrical wires separated from the way that they are extremely little. They are defined as having a proportion of length to width bigger than 1000nm. On the other hand, they can be defined whereby their width and thickness is Nano scale however their length is unconstrained. Nanowires are known as 1D materials because of the enormous difference between their breadth and length. This prompts nanowires having uncommon properties, for example, quantum mechanical effects [2-4]. There are an assortment of nanowires, for example, metallic, protecting, superconducting, and semiconducting. What's more, the door encompassing or Gate All around (GAA) structure that can be framed in the nanowire FET permits amazing electrostatic entryway power over the nanowire channel. In addition, the GAA nanowire transistors empower extreme CMOS device scaling with the most ideal short-channel control considering the quantum confinement effects and the dissipating at nuclear measurements. The GAA level nanowire FET engineering displays high similitudes to the FinFET, which is the transcendent innovation in the present 10 nm or even 7 nm process hub. Subsequently, GAA FETs are extremely encouraging competitors in the sub-7 nm hubs to expand the adaptability past the cut off points forced by the FinFET innovation with considerably less multifaceted nature contrasted with the elective scaling approaches [5].

1.1 Quantum effects

In the event that the diameter of a wire is adequately little, electrons will encounter quantum restriction the transverse way. The significance of the quantization is conversely corresponding to the width of the nanowire for a given material. From material to material, it is reliant on the electronic properties particularly on the viable mass of the electrons. Truly, this implies it will rely upon how conduction electrons interface with the particles inside a given material.

1. Tunneling impacts: The quantum mechanical wonder now and then showed by moving particles that prevail with regards to going from one side of a potential boundary to the next in spite of the fact that of inadequate vitality to disregard the top. Since semiconductor epitaxial procedures, for example, sub-atomic bar epitaxy (MBE), metal natural fume stage epitaxy (MOVPE) and metalorgan'ıc MBE (MOMBE) have arrived at a propelled condition of flawlessness, to such an extent that III—V and Si/SiGe numerous hetero structures can be manufactured with vertical layer measurements on the 0.1-10 nanometer scale and an interface sharpness of 1 to 3 nuclear layers, burrowing of transporters through such structures has pulled in much intrigue both for crucial research and for application reasons.

2. Ballistic vehicle: In infinitesimal material science, ballistic conduction (ballistic vehicle) is the vehicle of charge bearers (typically electrons) in a medium, having insignificant

electrical resistivity brought about by dispersing. Without dispersing, electrons essentially comply with Newton's second law of movement at nonrelativistic speeds. By and large, the resistivity of a material exists on the grounds that an electron, while moving inside a medium, is dispersed by pollutions, deserts, warm variances of particles in a crystalline strong, or, for the most part, by any uninhibitedly moving iota/atom forming a gas or fluid. For a given molecule, a mean freeway can be depicted just like the normal length that the electron can travel unreservedly, i.e., before an impact, which could change its energy. The mean freeway can be expanded by diminishing the quantity of polluting influences in a precious stone or by bringing down its temperature.

2. MATHEMATICAL MODELLING

- The 1D Schrodinger equation is written as,

  $-h^2d^2\oint_0(x)/2_{mx}d_x{}^2+(-q)\oint(x)\oint_0(x)=E_0\oint_0(x)$

- Inversion charge density is given by

  $Q_{inv}=C_{TOTAL}(-2C_{TOTAL}V_{th}{}^2/Q_0+\surd(2C_{TOTAL}V_{th}{}^2/Q_0)^2+4Vth^2\ln^2(1+\exp(V_{GS}-V_T+\Delta V_T-V/2V_{th})))$

- The drain current in SG MOSFET is obtained with the assumption that the mobility is independent of the position in the channel.

  $I_{DS}=\mu 2\pi R/L\int Q_{inv}(V)\,dV$

3. RESULTS & DISCUSSIONS

Silicon nanowire transistors are promising device structures for future integrated circuits. A silicon nanowire transistor has a genuinely 3D distribution of electron density and electrostatic potential.

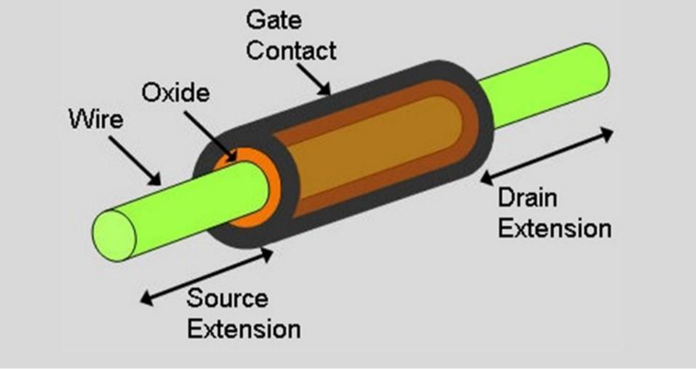

Fig -1: Structure of Nanowire

3.1 Simulation using Nano-HUB.org:

- I_d-V_d Characteristics of Nanowire

The Chart – 1 shows the plot for different drain voltages V_d=0.05V to 1V using a MUGFET tool in Nano-Hub.org.

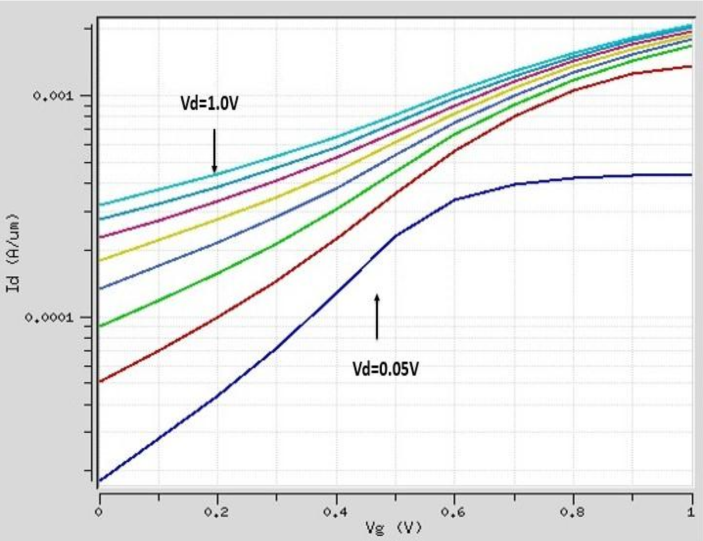

Chart -1: I_d-V_d Characteristics of Nanowire

3.1 Simulation using TCAD simulator:

- 2D Device structure of Nanowire FET

  Fig -2 shows the 2D device structure obtained in TCAD Silvaco simulator.

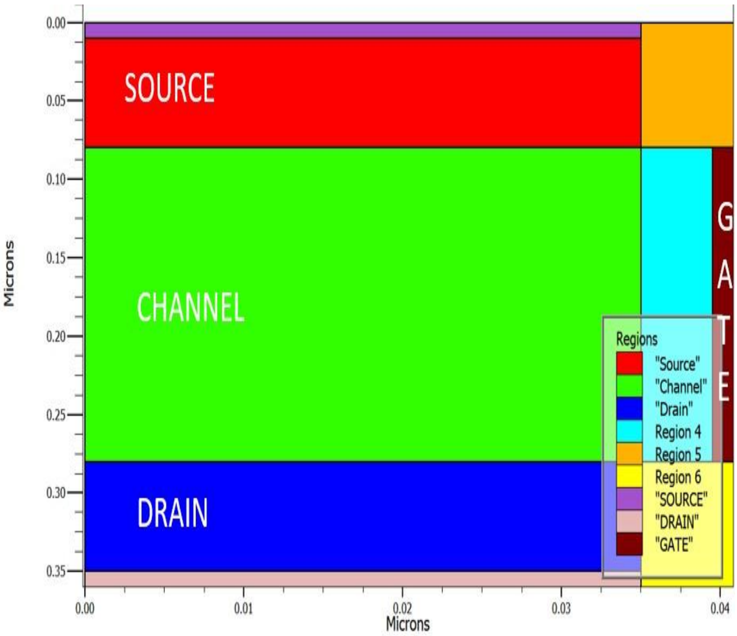

Fig -2: 2D Device structure

- I_d-V_g characteristics

  The fig - 3 shows variation in I_d-V_g for a device specification, drain voltages V_d =0.05 and 1.2Volts, gate voltage V_g=0.0 to 0.15Volts.

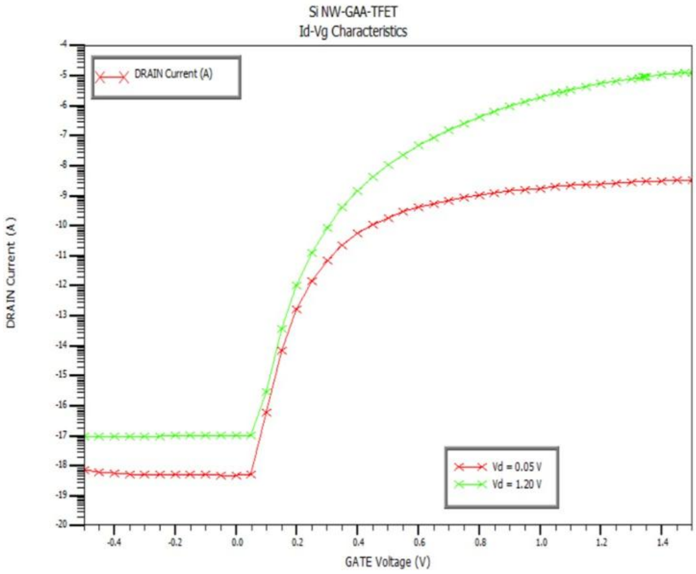

Fig -2: I_d-V_g characteristics

The fig – 4 is the Current density of silicon Nanowire FET is simulated using ATLAS Silvaco tool, 3D plot.

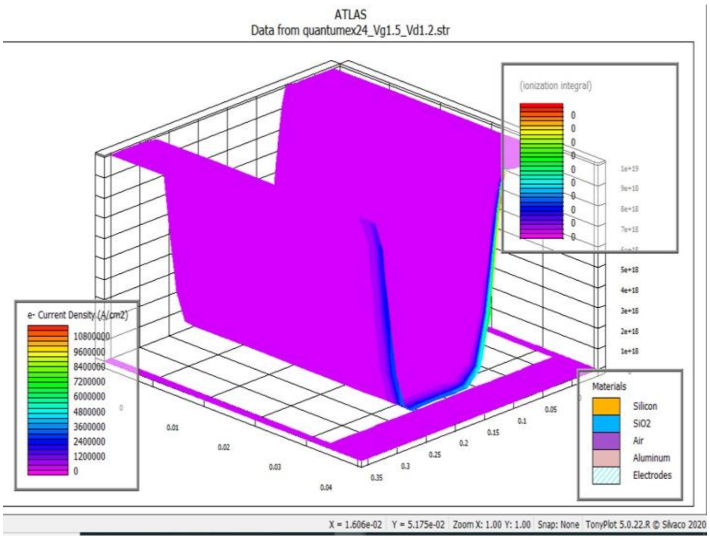

Fig -2: Current Density

4. CONCLUSIONS

The electrical properties of Nanowire FET using direct quantum modelling is being analyzed using the 1D Schrodinger equation and Green function to calculate the current and charge densities in an non equilibrium condition by splitting the wave function into two sum of two functions and then integrating the equation. It is also observed that solving wave equation using Green function is easy by solving only the 'G' function instead of solving the whole wave equation many a times using the Schrodinger equation.

Nanowire FET exhibited improved current characteristics and a controlled short channel effects when compared with MOSFET and FINFET devices.

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