Simulation of planar cntfet biology essay

Science, Biology

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Abstract:

Carbon Nanotube Field Effect Transistor (CNTFET)[1] are promising nanoscaled devices for implementing high performance, very dense and low power circuits. There are different types of CNTFET configurations like planar, coaxial, vertical, ambipolar CNTFET. The core of a CNTFET is a carbon nanotube (CNT)[3]. Its conductance property depends on the chirality of nanotube material is used as gate insulator and thickness of gate insulator[1]. In this paper the effect of chirality, different diameters of CNT, different dielectric material used as gate insulator and thickness of gate insulator material for planar type CNTFET is simulated and studied by quantum simulation using the non equilibrium Green function formalism with self consistent born approximation. Plots of Id vs Vd for planar CNTFET of

fifferent dielectric constant, chirality and diameter will be obtained and compare. The CNTFET simulation will be carried out by CNTFET lab tool of nano HUB. org [6] which is an online based java platform engine.

Introduction:

Device scaling is driving force towards technological advancement. Dimension of individual device in integrated circuit follow Moor's Law. Today silicon based Metal Oxide Field Effect Transistor (MOSFET) have technology size less than 45nm is common in electronics world. As the size becomes smaller, scaling of MOSFET becoming harder further scaling faced serious limits to fabrication technology and performance of device these all limits can overcome to some extend by modifying channel material in the traditional MOSFET structure with a single CNT. CNT is use to get high channel mobility devices. Superior performance of CNTFET is if multiple CNTs with highly transparent contact and better spatial control can be utilize to construct CNTFET which include low power dissipation and noise, with high drive current. A CNTFET is a field effect transistor in which CNT used as channel material by replacing traditional bulk silicon material. The unique electronic structure of graphene which roll up and form cylinder of CNT which gives special electrical properties to CNT. In CNTFET semiconducting channel is CNT. A single wall CNT (SWCNT) is only one cylinder of grapheme which is simple to manufacture and hence the CNTFET becomes a very promising alternative to MOSFET. SWCNT have diameter close to 1nm-2nm with tube length may be millions time longer than diameter. The SWCNT is also called as graphene into seamless cylinder. A SWCNT can act as conductor or semiconductor. The chirality vector decides the CNT is metallic if(n= m), semimetalic if n-m= 3i i is an integer else where it is semiconducting. The diameter of CNT can be calculated based on equation(1)Where a= 0. 142nm is the inter atomic distance between each neighboring carbon atom. CNTFET is a three terminal devices two contacts (source and drain), a CNT acting as channel, which controlled by third cotact(gate). Planar CNTFET (fig. 1) constitute majority of devices fabricated due to relative simplicity and moderate compatibility with existing manufacturing technologies. Fig. 1 Structure of planar CNTFET. Our focus is to study variation in output characteristics of planar CNTFET by varying the diameter of CNT, thickness of oxide material and different dielectric material used as gate insulator. Current calculation using Landaur's formula: The output characterstics of CNTFET devices calculate using transmission spectrum. The schematic CNTFET is shown in fig. 2Fig. 3 General structure of CNTFET. The wavelength of travelling electrons is equal to the channel length of the CNTFET, so the electron may get transmitted or reflected. The electron injected from left side will transmit or reflect back. The probability of transmission of electron having energy E is denoted by T(E). then the current density provided by the electrons transmitted from left electrode to right electrode is given in equation(2). Where q is charge of electron, n(k) is number of electron with wave vector k flowing from left to right, v(k) is velocity of electrons with wave vector k travel from left to right, T(k) is transmission probability of electron of wave vector k. Current density also given asEquation(3) gives current density is also refferd to be Landaures formula and is used for yhe calculation of current voltage characteristics of nano scale electronic devices. Simulation current calculation: Non Equlibrium

Green’s function: Density of states function can be calculated for obtaining the current voltage relation of CNTFET is given by equation(4)Where γ is shift and Δ is broadening of energy levels U is channel potential. The number of electrons also related to potential of channel region is given by equation(5)N= γ1 and γ2 represent electron flow rate at left and right electrode respectively. The iterative method used to calculate the number of electrons and potential created by them is shown in fig. 3Fig. 3 Current calculation by iterative method.

Simulation of planar CNTFET:

CNTFET tool use to find the current vs. voltage characteristics of planar and coaxial CNTFET. We have verified the following parameters viz. CNT diameter, gate insulator material and thickness, by keeping all other parameters constant shown in fig. 4(a). Fig. 4 (a) Parameters for CNT (b) Dimension of planar CNTFET.

Simulation and result:

1. For different diameters: The doped CNT used as channel with gate insulator Hafnium Dioxide (Dielectric const.= 16) and oxide is 10nm. thick. Here we change the chirality ‘ n’ value of zigzag CNT for diameters 1nm and 2nm. Fig. 6 Id vs Vd curve for different diameter of zigzag CNT. Larger diameter smaller the band gap of CNT, it will increase the current and give high drain current. the result for diameter 1nm 1nd 2nm shown in fig. 6. the energy band gap realated to diameter using equation(6). Where Eg is energy band gap, d is diameter of CNT. 2. For different dielectric material: We have taken dielectric materials viz. SiO2 (3. 9), HfO2 (16), HfSiO4 (11), Li2O3(30)

and TiO2(80). By keeping all other parameters such as CNT of dia. 1nm and oxide thickness of 9nm. Fig. Id vs. Vd curve for different dielectric material SiO2, ZrO2,, Li2O3 and TiO2 for zigzag CNT. 3. for different thickness of gate insulator: We simulate for thickness values viz. 2. 5nm, 6nm, 8nm, 9nm, and 10nm by keeping all other parameters gate insulator is HfO2 and diameter of CNT is 1nm constant. Fig. 8 Id vs Vd curve for different thickness of gate insulator.

Result and Discussion:

Diameter of CNTIonIoffIon/Ioff1nm8. 7215E-73. 42705E-232. 544E162nm6. 81985E-63. 42705E-231. 990E17Table1: Ion/Ioff ratio for various diameter of CNTIn this analysis Ion/Ioff is increases significantly as the diameter of CNT is increase. We observe that for different dia. The Ioff remain constant but Ion increases. Hence with increase in Ion the Ion/Ioff ratio increases. Dielectric constant of materialIonIoffIon/Ioff3. 95. 57E-074. 46E-071. 246251. 18E-068. 32E-071. 418301. 28E-069. 10E-071. 506801. 67E-069. 90E-071. 686Table2: Ion/Ioff ratio for various gate insulating material with different dielectric constant. The gate insulator with increase in dielectric constant the Ion/Ioff not varies significantly as both Ion and Ioff varies significantly with different material. Oxide ThicknessIonIoffIon/Ioff10nm8. 6E-77. 33E-231. 173E169nm9. 23E-77. 33E-231. 259E168nm9. 52E-77. 33E-231. 299E166nm1. 34E-67. 33E-231. 828E152. 5nm1. 56E-67. 33E-232. 128E15Table3: Ion/Ioff ratio for various thickness of gate insulting material HfO2 layerThe oxide thickness will increase the Ion as thickness decreases i. e inversely related to oxide thickness where as Ioff remain constant.

Conclusion :

The CNTFET is a nanodevice where Carbon Nanotube is used in channel region. The Ioff remain constsnt in different diameter values of CNT and thickness of insulator but it increases with dielectic constant reduces. The Ion increases with increase of diameter, increasing oxide dielectric constant and reducing oxide thickness.