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Research Paper

IMPACT OF WORK FUNCTION OF CONTACT METAL ON N-TYPE CARBON NANOTUBE FIELD EFFECT TRANSISTOR

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Carbon nanotubes is excellent for nanoelectronic devices due to their unique structural and electrical properties. The effect of work function of metal and carbon nanotube on junction of contact electrode in Carbon Nanotube Field Effect Transistors (CNTFETs) play an important role. In CNTFETs, the schottky barrier height at the drain and source terminal depend on work functions of contact electrode. The contact electrode nature on the drain current for coaxial CNTFET has been studied in this work. The single walled carbon nanotubes zig-zag type, are considered as channel and SiO_2 as gate insulator in CNTFET. The current-voltage curves for coaxial CNTFETs with variations of gate voltage, the conductance of Single Walled Carbon Nanotube Field Effect Transistors (SW-CNTFETs) has been mofidied by using Al as the metal considered for electrodes against Ag metal contact electrode. It is found that Al- CNT contact CNTFET shows better ohmic current voltage curves than Ag-CNT contact CNTFET for ballistic transport.

Keywords: Carbon nanotube, Work function, Schottky barrier, Metal electrodes, Gate insulator SiO_2

INTRODUCTION

Carbon nanotube may be composed of single wall or multiwall nanotubes. Their nature may be metallic or semiconducting depending on their folding angle and diameter. Both are used in fabrication of FETs. Carbon Nanotube Field Effect Transistor (CNTFET) are promising nano devices utilizing the unique electrical and mechanical properties of CNT and are used for implementing high performance, very dense and low power circuits. The zigzag type carbon nanotube (13,0) work function is 4.80 eV have both metallic and semiconducting property is used as channel where the metals as contact electrode in source, drain and gate electrode. Ag has work function 4.26 eV and Al has work function 4.08 eV. The gate insulator SiO_2 has dielectric constant K is 3.9. The current-voltage characteristics of CNTFET have been reported for about two decades with fabricated process as well as simulation using software. Martel *et al*. fabricated field effect transistors with single and multiwall

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carbon nanotube and found that using the gate electrode the conductance of SWCNT could be modulated more than five orders of magnitude. By analyzing transfer characteristics of FETs the concluded that nanotubes have higher carrier density than graphite and hole mobility comparable to haveily p doped silicon (Martel, 1998). Wind *et al*. fabricated single wall CNT field effect transistor in conventional metal oxide semiconductor field effect transisotor structure using top gate electrode and observed that these devics exhibited excellent electrical characteristics (Wind, 2002). Carbon nanotube transistor one of the most alternative for bulk silicon MOSFET as results of simulated cylindrical CNTFET both output and transfer characterstics curves are analysed along with the effect of different dielectric material used as gate insulator (Rasmita, 2009). The saturation current increases with k but decreases rate is the effect of using high dielectric material at gate insulator. The current voltage chraceristics and contact metal electrode and carbon nanotube contacts for five different materials have been studied by calculations with a finding that Ti leads the lowest contact resistance and Au with a maximum (Yuki, 2007). Nosho and Ohno *et al*. fabricared different metals according their work functions and investigate Ti and Pd contact electrodes showed p-type conduction behavior, devices with Mg contact electrodes showed ambipolar characteristics and most of the devices with Ca contact electrodes showed n type conduction behavior. The schottky barrier height agaist the electron is small for n type so drain current easily flow because these devices is less effected by contact resistance (Nosho, 2006). In p type the barrier height against the hole is high so p type conduction is only made possible when the barrier is reduced by the application of a negative gate voltage (Yang, 2005). Ying Wu *et al*. combining the Chemical Vapor Deposition (CVD) method to synthesize ultra long SWCNT on SiO_2 surfaces with FIB techniques, the electrical components based on SWCNT with controllable positions were obtained. The SWCNT can be aligned on the surface with the length of several millimeters and individual SWCNT can be selected to form the desired device. The resistance of nano devices formed in this way were ranging tens K-ohm or M-ohm. In this characterization with SEM pictures, show that the nanotube with metallic electrodes may be widely used in both basic research and applications (Ying, 2007). Diameter dependent contact phenomena are observed for metallic and semiconducting nanotubes related to schottky and tunnel barriers (Kim, 2005). Ohmic to very small nanotubes are currently a new challenge. Ali Javey *et al.* fabricated the p type electrode Pd have large work function and n type electrode Al at the source and drain region respectively, by patterned Chemical Vapor Deposition (CVD) of SWCNTs on SiO_2 substrate. In this complenetry CNTFET important issues regarging nanotubes FETs including hysteresis, OFF state leak currents and nanotube diameter (Ali, 2003). The work function of contact metal plays an important role for controlling the flow of carriers through the carbon nanotube channel and reduce the threshold voltage (Aurangzeb, 2007). Elecrical contact to the CNT is substantially improved using a graphitic interfacial layer catalyzed by Ni layer.The p type semiconducting CNT with graphitic contacts exhibits high ON state conductance at room temperature. This work is an alternative approach to form good electrical contact (Chai, 2012). Junho Cheon *et al*. Fabricated a stable n type CNTFET device based on tunneling through energy band engineering layer. This method can be especially useful for carbon nanotube device with metallic CNT because it eliminates the ohmic contacts between metallic CNT and p type electrode (Junho, 2013). Simulate the random networks of carbon nano tubes with to various geometry factors and compared with experimental results (Min, 2013) and show transfer curves depending on density of carbon nano tubes.

In this paper, we proposed Zigzag SWCNT is used in the CNTFET between the source and drain region. Firstly, as shown in Figure 1 in source, drain and gate region of CNTFET Ag as contact electrode. The gate insulator is SiO_2 have k=3.9. Using nanoHUB.org we simulates the current-voltage curves for Ag contacted coaxial CNTFET. Secondly, as shown in Figure 2 we consider Al as contact electrode at source, darin and gate terminal of coaxial CNTFET. The gate insulator is also SiO_2 have k=3.9. Using the nanoHUB.org we simulates the current-voltage curves for Al contacted coaxial CNTFET. Finallly, we compare the results of Ag contacted CNTFET and Al contacted CNTFET.

Figure 1: Schematic of Proposed Ag Contacted N Type CNTFET Using SiO_2 as Gate Insulator

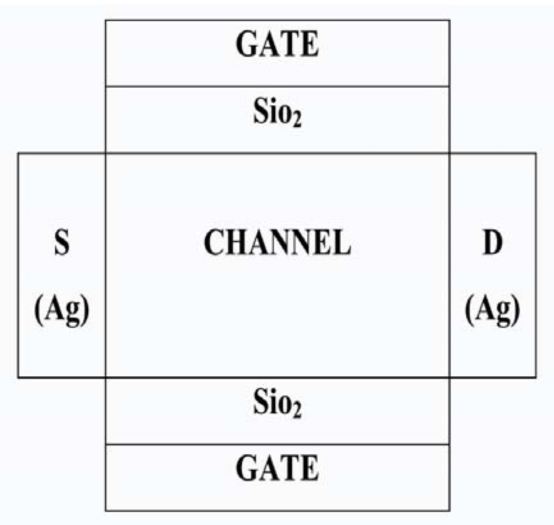
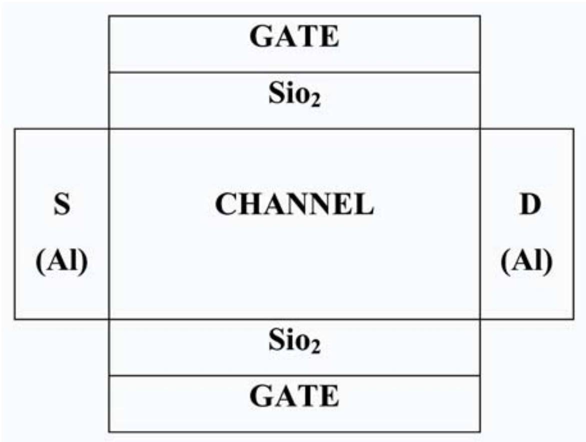
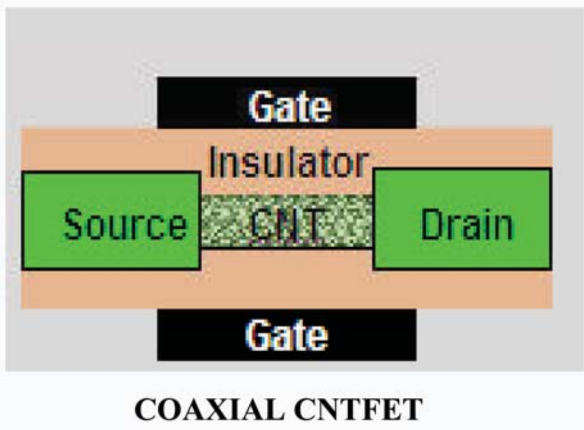


Figure 2: Schematic of Proposed Al Contacted N Type CNTFET Using SiO2 as Gate Insulator



GEMOTRY OF COAXIAL CNTFET AND BALLISTIC TRANSPORT APPROACH

In coaxial CNTFET, a zigzag carbon nanotube is used as the channel which is surrounded by an oxide layer which is finally surrounded by a metal contact. This metal contact serves as the gate terminal, the source and drain terminal are also metal electrode which make metal-CNT contact at junction.



COAXIAL CNTFET

The Zigzag type CNT is (13.0). Where the diameter of CNT is 1 nm and channel length is

10 nm. The carbon-carbon distance is 0.144 nm. In coaxial CNTFET, the gate length is 8 nm, gate thickness is 2 nm. The gate oxide layer is SiO_2 which dielectric constant K is 3.9.

The ballistic transport approach for the performance of scaled CNTFETs, we use symmetric metal on both source and drain terminals of CNTFET having small work function. The smaller work function near source and drain terminals makes small schottky barriers height against the electrons. The electronic behavior of metallic carbon nanotubes under the influence of externally applied electric fields is investigated using the Non-Equilibrium Green's function method self consistently coupled with three-dimensional (3D) electrostatics (Neophytos, 2007). Thus the electron transport from source to drain is transport like bullet so it makes a ballistic transport approach. The carbon naotubes zigzag type CNT is mostly preferable for both metallic and semiconducting property. The ballistic transport approach in CNTFET were simulated by solving the schrodinger assumed by an atomistic description of the nanotube using a tight binding Hamiltonian with an atomistic (Pz-orbital) basis was used (Jing, 2004).

RESULTS AND SIMULATIONS

In coaxial carbon nanotube field effect transior, Firstly Ag-CNT contact at source and drain terminal.Ag has work function 4.26 eV and CNT has work function 4.80 ev. So we considered the difference of work function of Ag-CNT at source, drain and gate of coaxial CNTFET. Secondly, Al-CNT contact at source and drain terminal. Al has work function 4.08 eV and CNT has work function 4.80 ev. So, we considered the difference of work function of Ag-CNT at source, drain and gate of coaxial CNTFET. We varied coaxial gate voltages for Ag-contact coaxial CNTFET and Al-contact coaxial CNTFET. Where gate insulator length is 4 nm. Thus at ambient temperature 300 K, we simulate the current voltage characteristics for coaxial carbon nanotube field effect transistor. The I-V plot#1 and I-V plot#2 for gate voltage 0.4 V and 0.3 V, respectively for Ag-contact coaxial CNTFET and I-V#4 and I-V#3 for gate voltage 0.4 V and 0.3 V, respectively Al-contact coaxial

Figure 3: I_d – V_d Curves for Ag Contact Coaxial for Varying Gate Voltages 0.3 V and 0.4 V

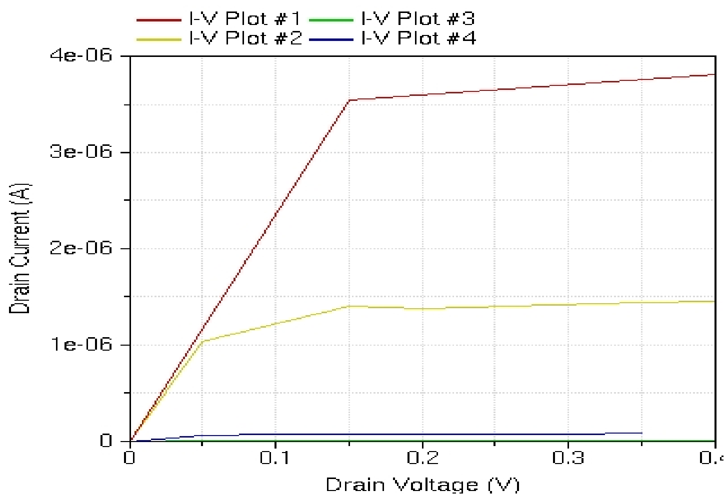
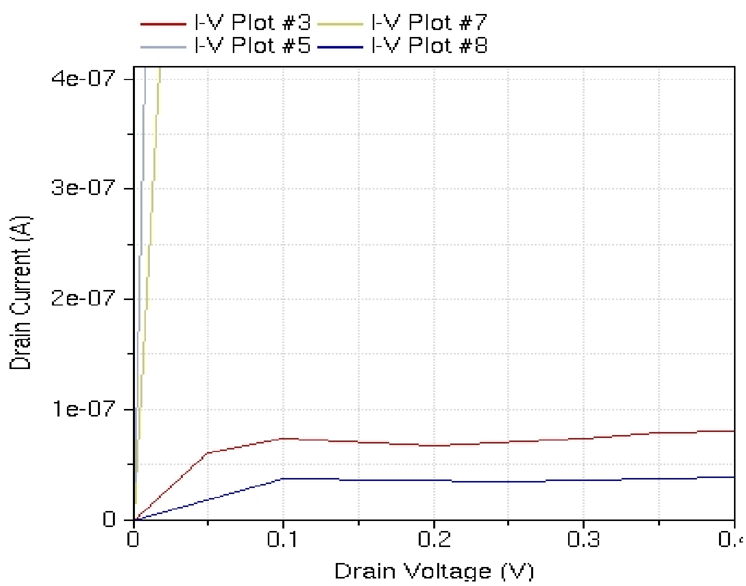


Figure 4: I_d – V_d Curves for Ag Contact Coaxial for Varing Gate Insulator Thickness 3 nm - 4 nm



CNTFET. This current voltage curves shows that Al contact CNTFET shows better ohmic curves or low threshold voltage than Ag contact CNTFET.

Secondly, the current voltage curves for varying gate insulator thickness for fixed gate voltages 0.4 V. The I-V#7 and I-V#5 for gate insulator thickness 4 nm and 3 nm, respectively and I-V#3 and I-V#8 for gate insulator thickness 4 nm and 3 nm, respectively for for Ag-contact coaxial CNTFET. This current voltage curves shows Al contact CNTFET can work better than Ag contacted CNTFET even reducing the gate insulator thickness.

CONCLUSION

In this paper for coaxial carbon nanotube field effect transistor first we analyze that Ag contact coaxial CNTFET current-voltage curves are near ohmic but Al contacted coaxial CNTFET is better ohmic than Ag- CNTFET. Current-voltage curves are nearly similar and CNTFET switching occurs by threshold voltage of the device is reduced giving high switching speed for the proposed device Al-CNTFET have low threshold voltage than Ag-CNTFET. The gate insulator is SiO_2. Varying the gate insulator thickness the Ag contacted carbon nanotube field effect transistor shows the current voltage characteristics in distorted nature while the Al contacted carbon nanotube field effect transistor shows better ohmic characteristics. Using nanHUB.org online simulator we analyze that Al as contact electrodes behave better ohmic than Ag as contact electrode in coaxial CNTFET.

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