Design and Implementation of Nano Ribbon Interconnects

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Abstract

Over the past few years, the development of on-chip interconnects has been considered one of the most challenging areas in VLSI circuit integration. As interconnects are scaled down, the effects of parasitic capacitance become significant. Additionally, the resistivity of Cu-based interconnects increases due to the influence of sidewall surfaces and grain-boundary scattering. Furthermore, the low current bearing capability of interconnects in nano-scale dimension circuits, coupled with increased thermal energy, makes them unreliable for future advanced nano-scale technology.

These issues have made it increasingly difficult to identify the right interconnect materials that can provide the necessary reliability and resistivity. Graphene nanoribbons have emerged as a promising candidate for next-generation interconnects due to their amazing transport and electrical properties. They have the least resistivity in nature with a high current density, long mean free path, and large electron mobility. However, the electrical and transport properties of GNR can be affected by changes in their device structure.

To address this issue, our project aims to discuss the electrical and transport properties of various models of nanoribbon in a detailed manner. We will also incorporate a circuit modelling of the resistive-capacitive distributed network for nanoribbon interconnects and calculate the corresponding interconnect RC delay.

The project will involve calculating the schematic view of the unit cell of different models, binding energy of ZGNR and AGNR, and band structure of ZGNR and AGNR using Quantum ATK. Wide-width nanoribbons are the most suitable candidates for the interconnect model. This project will provide insights into the potential use of graphene nanoribbons as a reliable interconnect material for future advanced nano-scale technology.

KEYWORDS : *Graphene Nanoribbon, band structure, parasitic resistance, electron mobility*

INTRODUCTION:

With the discovery of low dimensional materials (LDM's) i.e. materials whose physical properties must be at least of 1-dimension and which lay in the range somewhere between that of individual atoms and the bulk material had created a huge potential in nanoelectronics and opto-electronic applications. Before 21st century the only known LMD's were buckminsterfullerene and carbon nanotube (CNT) which were considered inside 0-D and 1-D materials. The discovery that C60 forms spontaneously in a cage like fused ring structure(truncated icosahedron) or carbon plasma was announced and it resembles soccer ball structure was hypothesized.

CARBON-NANOTUBES (BUCKY TUBES) are expected to have a wide variety of usage in different fields with different properties that come into play. Capillarity in open nanotubes has already been tested various times ,while their electronic structure and strength of their mechanical structure is yet to be determined. But all this time 2-D materials were the only family members that were missing due to its thermodynamics instability. But the earlier structure and properties of graphene and 2-D materials were theorised by Wallace by using "tight binding" approximation" in which graphite has zero activation energy i.e. minimum number of energy required by molecule to convert it into a feasible product at zero room temperature but are further created at high

temperatures by exciting their valence or conduction band to their highest level and their electrical conductivity is assumed with mean free path.

But it was until 2004-2005 ,when while performing some experiments Konstantin Novoselov accidentally found graphene and atomic 2-D crystals such as Transition metal dichalcogenides (TMDs) which are a layered materials of significant thickness and scalability those are stable at room temperature by the use of mono-crystalline graphitic films which have a measurable amount of thickness and are of high metallic quality, these films are found to be 2-D dimensional metals with perfect amount of overlap found between the both two bands(conduction and valence bands)in which electrons(e-) and holes(+ve) exhibits strong ambipolar electric effect at high concentrations from 1000 to 1013 per square-cm and high room temperature mobility are induced by applying gate voltage at that particular temperature.

In early 2000's he performed various other experiments, the main experiment which is built by using micromechanical cleavage which is developed using micro- crenulations where he found that these atomically thin sheets or plates provide stability under critical conditions, which exhibit high crystalline quality and are continuous at microscopic scale or level. With the help of these research efforts and exploration of 2-D physics it makes easier for scientist for manufacturability of planar 2-D ,which helps in vigorous future research.

In recent years, electronic properties of graphene were basically with the theoretical aspect of graphene, with thickness of one-allotrope of carbon, 2-D Dirac-like electronic excitations which are consistent with both principle were coined. Following with this, the discovery of graphene in 2004 was huge success with experimental effort by enabling strong absorption of light (>70%)in atomically thin MoS2 films(<=4 layers) for either narrowband or wideband incidence like solar radiation.

One of the most significant recognitions in the field of 2D materials occurred in December 2010 when it was compared to the prestigious Nobel Prize, highlighting the potential of these materials in various scientific fields, especially electrochemistry. To fully comprehend the potential of 2D materials, several properties such as their structural, electronic, luminescence, optical, and mechanical strengthening must be analyzed, which requires a diverse range of preparation and characterization techniques.

Additionally, the current understanding of electrochemical behavior and modification of 2D layered materials is an essential aspect of their potential applications. The future perspective of 2D materials includes upcoming technologies such as optoelectronics, photocatalysis, and renewable energy sources, with a primary focus on group six transition metal dichalcogenides and emerging technologies beyond graphene.

These materials have the potential to revolutionize the future generation of technology, including devices for electrochemistry, sensing, and photovoltaics used in solar panels. Furthermore, 2D heterostructures are gaining popularity, offering significant benefits due to their unique characteristics, such as semiconductors' chemical composition changes, leading to a myriad of exciting applications in various fields of science. In summary, 2D materials are vital for the future of science and technology, with a promising future ahead.

In follow-up of past decade, researchers and scientists are being ardent focusing on improving and innovating these 2-D technologies using nanotech's. Some of the applications have achieved a great amount of success towards a large-scale production , while some still requires deep research and putting a great amount of efforts to prove their potential in order to find success as well as make the use of their project and implement it with full pragmatism.

LITERATURE SURVEY

[1] In this paper, it presents a study on the oxygen functionalized armchair GeNRs (AGeNR) and zigzag GeNRs (ZGeNR). The investigation involves using density functional theory (DFT) to study the potential configurations of

O- and H-edge functionalized GeNRs. This is followed by a nonequilibrium Green's function (NEGF)-based transport study of these configurations. In other words, the paper discusses the use of DFT to analyze the possible configurations of AGeNR and ZGeNR with O- and H-edge functionalization. They then use NEGF to study the transport properties of these configurations.

[1]The paper includes the calculation of important small signal current parameters, such as RQ, Lk, and CQ, which demonstrate the potential applicability of oxygen functionalized GeNRs for interconnect applications.To put it differently, the authors of the paper have computed critical small signal current parameters, including RQ, Lk, and CQ, which showcase the suitability of oxygen functionalized GeNRs for use in interconnect applications.

[2] The authors of this paper, Jaiswal et al., investigated the electronic and structural properties of armchair graphene nanoribbons (AGNRs) with edge termination/doping of Fe atoms. The researchers also studied the effects of edge termination/doping of Pd and Ru atoms in AGNRs and observed that the electronic properties of AGNRs are significantly influenced by these transition metal (TM) atoms. Based on the existing literature, the study found that edges are the most accessible means of modifying the properties of AGNRs. In summary, Jaiswal et al. observed that Fe atom edge termination/doping improves the electronic and structural properties of AGNRs, while the electronic properties of AGNRs are significantly affected by Pd and Ru atom edge termination/doping.
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[2]:In this paper, The edges are passivated with the help of photo galvanic effect by using various transition metals (TM)which are ductile and malleable provides a capable result for the future superior electronic structure (zigzag , armchair), mechanical, transport & optical properties of nanoribbons.

[3]: In this paper, Srivastava and Banerjee et.al discuss in full depth and provide the solutions about the problems and consequences faced by interconnects (connecting more circuit elements) and beyond value of 90nm entering within the nanotechnology. Earlier It was presumed that this phenomenon was related to the internal and external outline(boundary) of the conductor, which in future become of more prominence as was founded that its area of cross-section within that dimension approaches for the electrons free mean path.

[4]: Behnam et al. and his colleagues produced graphene nanoribbons of varying widths using the standard CVD technique. The GNRs were positioned on a N-Si substrate between two Au/Ti contact electrodes and protected by an AlOx layer. AFM images were taken to visualize the width and thickness of the GNRs. Raman spectroscopy was used to characterize the CVD-grown bulk graphene and GNRs with different aspect ratios. The CVD graphene displayed a narrow 2D peak and an absence of the defect-induced D0 peak. However, the D band intensity increased due to the higher proportion of edge carbons. The presence of edges in graphene nanoribbons of different aspect ratios resulted in significant disorder in the D and D0 bands.

[5]: Wallace et al. conducted theoretical predictions on the electronic structure and properties of graphene, which is the first and most well-known member of the two-dimensional (2D) material family. Graphene consists of a single layer of carbon atoms arranged in a hexagonal lattice. In contrast, Boehm described carbon foils composed of a single layer of carbon atoms before the discovery of graphene. Therefore, Boehm's work can be seen as a precursor to the discovery of graphene and the subsequent exploration of the properties and potential applications of 2D materials.

CONCLUSION

In conclusion, the design & implementation of nano –ribbon interconnects is an adamant and of high prioritised area of research in the field of nanoscale electronics. By using materials such as graphene and germanene,

researchers have been able to create nanoribbons with unique electrical properties that are well-suited for use as interconnects in nanoscale devices. By edge-passivating or edge-oxidizing these nanoribbons, researchers have been able to further improve their performance and suitability for use in a variety of applications. Overall, the development of nano ribbon interconnects has the potential to revolutionize the way that we build and connect nanoscale devices, paving the way for the creation of faster, more efficient, and more powerful electronics.

In the realm of nanoscale electronics, the creation and implementation of nano-ribbon interconnects is an essential and high-priority area of research. Researchers have utilized materials like graphene and germanene to design nanoribbons with exceptional electrical properties that are ideal for interconnect use in nanoscale devices. Through edge-passivation or edge-oxidation of these nanoribbons, researchers have been able to further enhance their performance and utility for use in various applications. Ultimately, the development of nano-ribbon interconnects has the potential to revolutionize the way we construct and connect nanoscale devices, enabling the creation of faster, more efficient, and more powerful electronics.
The negative value suggests structural feasibility for all passivated or terminated unit cells and it can be observed that both edged F-passivated nanoribbon shows the best stability and hence they are the best GNR interconnect. The IV characteristics graph shows that the graphene material that we are using is of highly metallic character.
Small signal dynamic performance parameters are obtained for interconnect modelling using two probe model. By edge-passivating or edge-oxidizing these nanoribbons, researchers have been able to further improve their performance and suitability for use in a variety of applications. Overall, the development of nano ribbon interconnects has the potential to revolutionize the way that we build and connect nanoscale devices, paving the way for the creation of faster, more efficient, and more powerful electronics.

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