DEVICE MODELLING OF ARCHIMEDEAN SPIRAL GRAPHENE NANOSCROLL FIELD-EFFECT-TRANSISTOR

MUHAMMAD AFIQ NURUDIN BIN HAMZAH

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To my family, near and far

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ABSTRACT

For the past decades, researchers indicate that persistent scaling of conventional silicon Metal-Oxide-Semiconductor Field Effect Transistor (MOSFET) reaching its physical limit at 10nm, resulted in its performance degradation as the search continues for a low-power and high speed, density and reliability devices. The frailty due to the Short Channel Effects (SCE) has limited the device scaling. In addition, the emergence of Carbon Nanotube (CNT) in the past two decades has been a remarkable breakthrough in solving for transistor SCE; but there has also been a problem in controlling its band gap energy. Graphene Nanoscroll (GNS) is one of the carbon-based materials that inherit most likely similar electrical properties as CNT. But GNS possesses an advantage to modulate its properties by varying its carbon layer overlapping region owing to the open edge spiral, resulting in band gap variations. This study is to investigate the GNS carrier statistic against its geometry variation and its performance as a MOSFET. The carrier statistic such as the energy band gap, density of states, carrier density and intrinsic velocity were modeled and the results show strong relation to the overlapping region of GNS. The energy band gap exhibits an inverse relation to the overlapping region and metallic properties was restored when the overlap has reached certain limit. The carrier density also increases with the overlapping region as a sign of gap narrowing. Moreover, the intrinsic velocity increases with overlap region and remains constant as it reaches graphene Fermi velocity, signifying ballistic transport near Fermi point. The charge distribution in GNSFET was characterized based on the Landauer Buttiker's formalism. The output current shows good agreement with the experimental results at constant conductance and GNS structural parameters. Furthermore, the GNSFET demonstrated comparable performance to the CNTFET within ballistic limit. The GNSFET was also benchmarked with the latest 22nm MOSFET technology, which indicates faster switching capability due to enhancement in Subthreshold Swing (SS) and Drain Induced Barrier Lowering (DIBL).

ABSTRAK

Sejak beberapa dekad yang lalu, para pengkaji menyatakan pengecilan skala bagi peranti Logam-Oksida-Semikonduktor Transistor Medan Elektrik (MOSFET) secara berterusan hingga kepada had keupayaan fizikal panjang pengalir 10nm akan menyebabkan kebolehupayaannya merosot akibat daripada Kesan Pengalir Pendek (SCE). Kelangsungan kajian bagi menghasilkan peranti dengan penggunaan kuasa yang rendah dan berkelajuan tinggi dilaksanakan. Kemunculan *Carbon Nanotube* (CNT) dua dekad lalu didapati berupaya bagi menangani permasalahan ini; akan tetapi, ia mempunyai kesukaran dalam mengawal lebar jalur tenaganya. *Graphene Nanoscroll* (GNS) merupakan salah satu bahan berasaskan karbon yang mempunyai ciri-ciri elektrik yang hampir sama seperti CNT dengan kebolehan untuk mengawal jurang tenaganya melalui lapisan karbon yang bertindih, disebabkan oleh hujungnya yang terbuka pada bahagian sebelah tepi. Tujuan kajian ini dijalankan adalah untuk menyelidik statistik-pembawa GNS terhadap perubahan geometrinya dan kebolehupayaan sebagai MOSFET. Model matematik diterbitkan bagi ciri-ciri statistik cas pembawa seperti jurang tenaga, kadar ketumpatan keadaan kuantum, ketumpatan cas pembawa dan halaju intrinsik cas pembawa yang dipengaruhi oleh kawasan lapisan karbon yang bertindih. Kajian mendapati jurang tenaga berkadar songsang dengan lapisan bertindih karbon dalam GNS dan bersifat konduktor apabila penambahan lapisan bertindih mencapai had tertentu. Selain itu, halaju intrinsik meningkat dengan lapisan bertindih dan menjadi tepu pada halaju Fermi *Graphene*, menandakan pengangkutan balistik berhampiran titik Fermi. Pengagihan cas dalam GNS dihitung berdasarkan *Landauer Buttiker's Formalism*. Arus keluaran yang dikira menunjukkan perbandingan yang baik dengan hasil eksperimen dan prestasinya mampu menyaingi CNTFET dalam had balistik. Silikon MOSFET 22nm digunakan sebagai penanda aras, di mana GNSFET mempunyai daya penukaran suis lebih pantas serta meningkatkan Kecerunan Bawah-Ambang (SS) dan bagi Halangan-Merendah Longkang-Teraruh (DIBL).