Eurasian J. Sci. Eng., 2023, 9(2), 12-24
https://doi.org/10.23918/eajse.v9i2p2

Published by Tishk International University
Available at: https://eajse.tiu.edu.iq/

RESEARCH ARTICLE Open Access

REVIEW OF COMPOUND SEMICONDUCTORS RELIEVING BOTTLENECKS OF INCESSANT MOSFET SCALING: HEROISM OR A RACE IN THE DARK

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Article History
Received: 14.12.2022
Revised: 20.05.2023
Accepted: 08.06.2023
Communicated by: Dr. Orhan Tug
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Abstract: In last five decades, the exponential demand in the field of electronic applications is powered by a drastic escalation in the compactness of silicon based complementary metal oxide semiconductor (CMOS) field effect transistor (FETs) and qugumentation in logical performance. But silicon based transistor scaling is now heading to its restraints, intimidating to cease the micro-electronics revolution. Another family of semiconductor materials thus have been under surveil- lance that can be rightly placed to handle this problem: Compound Semiconductors. The spectacular electron transport features of such materials might be point of focus that can lead to development of FETs based on such materials in nano-scale regime. This article provides a speculation in the future of compound semiconductor material-based devices with emphasis on effects of incessant scaling. Whilst aggressive scaling, requirements and constraints that include power dissipation, operating frequency, gain, leakage current must be kept balanced with predictive technologies nodes and also with the fabricating aspects of devices. The scaling restraints requisite a transformation from planar architectures to three-dimensional device structures to cater future performance requirements of CMOS nodes beyond 10 nm. Compound semiconductor materials are progressively waged in various electronic, opto-electronic, and photonic applications due to the prospects of adjusting the properties over a broad parameter domain conveniently by tuning the alloy composition. Ironically, the material properties are also willed by the atomic-scale orientation of compound semiconductors in sub-nanometer scale. Compound semiconductors FET based logic circuits perform 5 folds faster than similar topology circuits based on silicon, whilst dissipating only half of the power. Here a comprehensive review is presented that outlines how compound semiconductor materials mitigate various effects of aggressive scaling in nanometer scale and the adjoining effects.

Keywords: *Compound Semiconductors; RF Performance; Scaling; Field Effect Transistors; High Electron Mobility Transistors.*

1. Introduction

The The revolution of microelectronics may be best reflected through ‘smaller the better’. The indistinct feature of silicon metal-oxide-semiconductor field-effect transistor (MOSFET), a field function, is that its cognitive properties improve as its size is reduced [1]. When it comes to the functioning of the logical concept, the transistor impersonates a switch, and the primal characteristics include the time and energy budget. Since MOSFETs have reduced in size following the geometric scaling rule, the change in speed and magnitude of the transistor density has exponentially increased, while as the switching energy have reduced in the similar manner [2]. Such ‘triple benefits’ of the

MOSFET measurement have enabled the transformation of electronics. Advanced sensible digital circuits are based on p-type and n-type configured transistors with specific characteristics popular by the name metal-oxide-semiconductor (CMOS) compatible transistors (CMOS) and have become an outstanding class of circuits owing to simpleness and distinctly power efficient characteristics allowing for the integration of very dense circuits. Two decades back, the MOSFET scaling moved into the 'power-controlled phase' as electrical power is dispersed by logic chips striking about 100Wcm [3]. Power cannot be increased continuously without being subjected to large packaging and cooling budget which renders the chips ineffective in many operating systems. The continuous constriction of the transistor leads to reduction in working voltage which adversely affects the speed of switching [4]. This problem has caused the operating voltage of CMOS transistors to be dropped to about 1V. This poses a challenge in further scaling of generic CMOS technology transistors.

One of the probable solutions is to induce a new channel material medium where charge carriers will traverse at a much higher speed as compared to silicon. This will allow for voltage reduction without any performance loss. This could be the reason for the attention turning towards compound semiconductors of III-V groups including GaAs, InAs, InP, AlAs and their ternary and quaternary alloys, include the combined elements of column III and V in the periodic table. Majority of III-V compound semiconductors have distinctive electronic and optical properties. These are mostly used in light emitting diodes, lasers, musical instruments, light communication equipment and hearing aids because of indirect energy bandgap which enables to emit and detect light. Some of these, mainly InAs, GaAs, and InGaAs show outstanding properties of electron transport mechanism. Transformers which are mainly based on such materials form the core of many high-frequency and high speed advanced electronic applications [5]. There is a gigantic and advanced industry producing III-V integrated circuits in tremendous scale for wide variety of applications ranging from smart phones, fiber-optic systems, cellular base stations, satellite communications, wireless local area networks, radars, radio astronomy and security systems. The extensive use of hand-held devices and their extensive data usage have been a bonus to the III-V circuit sector, now characterized by massive automation and bold, high-end wafers, sophisticated device design tools, well-designed device reliability, and a rich and competitive industrial system.

At present attempts are being made to replace silicon with other class of materials which can result in devices with remarkable list of attributes. III-V family of materials are receiving considerable attention from worldwide research community. In the recent past the role of compound semiconductor materials like SiGe, AlGaN, GaN have been recognized by International Technology Roadmap for Semiconductor (ITRS). Fundamentally the family of III-V CMOS is receiving attention due to extraordinarily high carrier mobility and tuning ability of energy bandgap. For similar sheet resistance, materials like InAs or InGaAs offer mobility ten times higher to silicon. The exceptionally good response of III-V material-based transistors is often the highlighted feature. It has been experimentally demonstrated for In- GaAs based high electron mobility transistors, the power and current gain exceeds 600GHz and 1THz respectively which is quite remarkable [6]. Although these features are least de-sired for logic applications. A logic transistor is a multi-terminal ON and OFF state switch which requires fast switching speed enabled by high ON state current. The static power dissipation is a liability created by OFF state current. The quest for development of super-fast electronic devices is driven by challenge in limited charge carrier speed in silicon which is being replace by compound materials like GaAs with significantly high charge carrier mobility within same range of applied electric fields. Beside advantage of high mobility compound semiconductor materials offer advantages desirable for logic and microwave devices that aim to operate at high frequencies finding compatibility with optical fiber transmission circuits. It has been demonstrated that FET logic circuits based on