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Editorial

Nanoelectronic Materials, Devices and Modeling: Current Research Trends

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1. Introduction

As CMOS scaling is approaching the fundamental physical limits, a wide range of new nanoelectronic materials and devices have been proposed and explored to extend and/or replace the current electronic devices and circuits so as to maintain progress in speed and integration density [1]. The major issues, including low carrier mobility, degraded subthreshold slope, and heat dissipation, have become worse as the size of the silicon-based metal oxide semiconductor field effect transistors (MOSFETs) decreased to nanometers while the device integration density increased. High electron mobility transistors (HEMTs) based on wide bandgap semiconductors, such as silicon carbides (SiC) and gallium nitrides (GaN) [1], are proposed to enhance the carrier mobility for high-speed logic devices. The HEMTs are also very attractive for high-power and high-frequency applications. While conventional semiconductors were studied to improve the current electronics, a new phase of materials is being explored and tested for new-concept devices. For example, topological insulators that have insulating bulk and gapless surfaces have exhibited unique properties for transistor applications [2].

2. The Current Research Trends

Each of the seventeen articles collected in this special issue proposes a solution to a specific problem related to the above-mentioned major challenges. The carrier mobility is a very good and convincing indicator in improving transistor performance. GaN vertical FETs with an additional back current blocking layer have been proposed and simulated for high-power electronics [3]. AlGaN/GaN metal–insulator–semiconductor HEMTs have been studied and exhibit a high breakdown voltage and an on–off current ratio [4]. The two-dimensional electron gas of an $In_xAl_{1-x}N$/AlN/GaN HEMT has been studied and modeled by considering the polarization and quantum mechanical effects [5]. A steep subthreshold slope (SS) is another target for transistor performance improvement in switching speed. This issue collected two approaches to achieve a steep SS: (1) using the insulator–metal phase transition of VO_2 to achieve a decent SS of 42 mV/dec [6]; (2) using an L-shaped tunneling FET to improve the SS [7]. In addition, the drain-induced barrier lowering (DIBL) effect and leakage of a partial isolation FET for sub-0.1 μm have been studied [8].

New concepts of data storage and memory devices are another focus of this issue. A partial isolation type saddle-FinFET has been proposed for sub-30 nm DRAM applications [9]. A new method for neural networks based on resistive switches has been proposed for pattern storage and recognition [10]. A CMOS-compatible Ag/HfO_2-based synaptic was studied for application in an

artificial neuromorphic system [11]. New analog memristive characteristics and conditioned reflex have been reported in Au/ZnO/ITO devices [12].

In addition to the research in transistors and memory devices, this issue has collected important research on solar cells based on ZnO/Si heterojunctions [13], Bi-doped and Bi-Er co-doped optical fibers [14], high-performance graphene electrolyte double-layer capacitors [15], quantum-dot and sample-grating semiconductor optical amplifiers [16], a transmission method to determine the complex conductivity of thin strips [17], and a high-efficiency CMOS power amplifier with a dual-switching transistor [18].

3. Future Trends

The future research in nanoelectronic materials and devices will continue to find the solutions to address the challenges of current electronics in switching speed, power consumption, and heat dissipation. New device concepts and new materials will be carried over to future nanoelectronics to enhance or replace the current devices. A new growing interest is the integration of nanomaterials and devices into smart systems for stand-alone applications. For example, a robotic vessel equipped with vision sensors [19] and a smart nanoelectronics sensor system governed by machine-learning intelligence will be of great interest to the academic society and industry.

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