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Editorial

Carbon Nanoelectronics

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1. Introduction

Initiated by the first single-walled carbon nanotube (SWCNT) transistors [1,2], and reinvigorated with the isolation of graphene [3], the field of carbon-based nanoscale electronic devices and components (Carbon Nanoelectronics for short) has developed at a blistering pace [4]. Comprising a vast number of scientists and engineers that span materials science, physics, chemistry, and electronics, this field seeks to provide an evolutionary transition path to address the fundamental scaling limitations of silicon CMOS [5]. Concurrently, researchers are actively investigating the use of carbon nanomaterials in applications including back-end interconnects, high-speed optoelectronic applications [6], spin-transport [7], spin tunnel barrier [8], flexible electronics, and many more.

Interest in Carbon Nanoelectronics is fueled by the many unique and extraordinary physical properties of carbon nanomaterials comprising sp^2 bonded carbon atoms with a hexagonal structure. The sp^2 hybridization results in three in-plane electronic orbitals primarily responsible for carbon-carbon bonding and an out of plane p_z (π) orbital that is primarily responsible for low-energy electronic transport. Expanding this simple single atomic bonding model into an infinite lattice of carbon atoms, each providing one π orbital (*i.e.*, 2 π-orbitals per unit cell), leads to the tight-binding bandstructure first reported by Wallace in 1947 [9]. The uniqueness of these materials is apparent in the bandstructure that reveals a linear E-$\boldsymbol{k}$ low-energy bandstructure with vanishing effective mass and extremely high, and nearly symmetric, electron and hole mobility. The strongly bonded structure promotes mechanical robustness at high temperatures and under large currents loads, in addition to a thermal conductivity exceeding diamond; robust mechanical and thermal properties are important even for electronic applications. The single atomic-layer thinness of carbon nanomaterials suppresses their susceptibility to short channel effects [10] and are very attractive for harsh environments [11–14].

Ultimately, carbon nanomaterials are well suited for nanoelectronic applications and warrant the significant ongoing research interests that seek to bring their promise to fruition.

2. The Present Issue

I am honored to be the Guest Editor for this special issue, which consists of six papers including three regular submissions and three review papers. Delightfully, several great researchers within this area have contributed articles and I would like to take this opportunity to thank them for their excellent contributions. Also, I would like to thank the many reviewers who helped in the evaluation of the manuscripts. Furthermore, I would like to acknowledge Prof. Mostafa Bassiouni, the Editor-in-Chief, who invited me to guest edit this special issue, Ms. Xiaoyan Chen, Assistant Editor, and the Electronics Editorial Office staff who worked diligently to maintain a rapid, but rigorous, peer-review schedule minimizing the time to publication.

The diversity among topics in this special issue reflects the diversity within the field of carbon nanoelectronics. In [15], Roslyak *et al.* theoretically investigate the effects of electron traps on charge transport in graphene nanoribbons concurrently exposed to a longitudinal surface acoustic wave potential. Their numerical calculations predict the formation of sliding tunnel-coupled quantum dots resulting from the strong transverse electronic confinement of graphene nanoribbons. Aimed at employing graphene devices in radiation environments, Esqueda *et al.*, experimentally and theoretically investigate total ionizing dose effects in top-gated epitaxial graphene field-effect transistors (GFETs) [16]. The research compliments and expands the growing body of experimental results pertaining to the radiation response of graphene and carbon nanotubes. Furthermore, the authors support their work by developing a charge-dependent mobility degradation model that accurately describes their experimental data.

Two papers in this special issue pertained to the magneto-transport/spin-transport properties of graphene. In [17], Bodepudiemail *et al.* observe a large perpendicular-to-plane magnetoresistance in multilayer graphene grown on metallic substrates. The magnetoresistance ratios exceed 100%, and unlike typical magnetic field sensing devices comprised of layered ferromagnet/non-magnetic layers, the origin of the magnetoresistance is unique and unrelated to spin injection and transport. In a Review article, J. Haruyama provides a detailed summary of spin-related phenomena in graphene, and also highlights his group's recent experimental results revealing the spontaneous emergence of large-amplitude ferromagnetism in graphene nanomeshes with hydrogen terminated edges [18].

The final two papers in this special issue are very comprehensive Review articles. Soldano, Talapatra, and Kar provide a comprehensive overview of carbon-based nanostructures used for interconnect applications [19]. The authors discuss the performance metrics necessary to surpass existing approaches, highlight the potential advantages of carbon-based nanostructures in addition to lower resistance, and propose strategies and architectures for rational integration. Moreover, techniques for minimizing defects and enhancing conductivity are also provided. In [20], A. E. Islam reviews the variability and reliability aspects associated with single-walled carbon nanotube transistors. Particular attention is paid to the inherent statistical performance variation that results at beginning-of-life, and how the performance variation depends on the underlying device geometry categorized by three classes of devices comprising either individual-SWCNTs, SWCNT networks, or aligned SWCNTs. The absolute reliability of SWCNT devices is class dependent, yet the root causes of failure are common among all classes. A.E. Islam summaries the primary failure modes and proposes approaches for how they may be overcome.

In conclusion, the Carbon Nanoelectronics special issue highlights many key aspects of the current state of the field, presents many current advances, and provides insight regarding the prospective direction of the field.

Conflicts of Interest

The author declares no conflicts of interest.

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