VIDEO ARTICLE

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Graphene and 2D Materials for Transistor, Memristor, Synaptic and Light-Stimulated Devices

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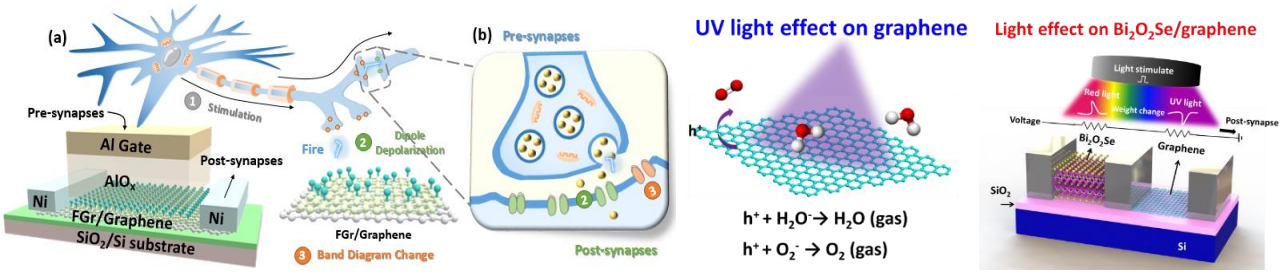
Graphical Abstract



Abstract

Graphene and two-dimensional material based electronic applications has been proposed and experimentally demonstrated, including transistors, memristors, and artificial synapses. Graphene is the very attractive material taking advantages of its unique lattice structure. The high carrier mobility alleviates the RC delay issue in circuit level and its weak surface van der Waals interaction enables ultra-low energy consumption in a memristor device architecture. Moreover, those surface properties lead graphene into neuromorphic devices as demonstrated in current study. A novel graphene based insulator, fluorographene, is firstly applied as gate dielectric in a field effect transistor. To identify the dielectric quality, dielectric constant, breakdown electric field and thermal stability are investigated. The scalable and one-step fabrication of single atomic-layer transistors is demonstrated by the selective fluorination of graphene using a low-damage CF4 plasma treatment, where the generated F-radicals preferentially fluorinated the graphene at low temperature (<200 °C) while defect formation was suppressed by screening out the effect of ion damage. The fluorographe was also used as decoupling for graphene as its substrate and mobility was improved much. Graphene nanodiscs (GNDs), functionalized using NH3 plasma, as charge trapping sites (CTSs) for non-volatile memory applications have been investigated. Moreover, the graphene based memristor exhibits high reliability and robustness. Inspired by its internal ion migration, a state-of-art neuromorphic operations was demonstrated to mimic human brain functions. The weak van der Waal interaction of graphene interface, graphene based neuromorphic memristor exhibit ultra-low spiking energy consumption and also demonstrate a programmable metaplasticity fashion. A fluorographene based synaptic transistor was demonstrated also. Finally, a new two-dimensional (2D) material, Bi2O2Se, and graphene have the characteristics of positive and negative light-stimulated photocurrent, respectively. Based on these properties, the light-stimulated synaptic device can be realized by a proper operation in measurement.

The modulation of the light pulse on the device simulated the excitation and inhibition behavior similar as in biological synapses. A circuit level based on graphene and 2D material-electronic is the good candidate to be developed in future and combining with the concept of artificial neuron network (ANN).

Keywords: Fluorographene; memristors; artificial synapse; Bi2O2Se; light-stimulate.

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Biography of Presenting Author

Chao-Sung Lai is the Dean of college of engineering, Chang Gung University from 2012. He received the B. S. and ph. D. degrees from National Chiao Tung University, Hsinchu, Taiwan, in 1991 and 1996, respectively. In 1996, he joined National Nano Device Laboratories, Hsinchu, where was engaged in the research of silicon-on-insulator devices. He then, in 1997, joined Chang Gung University, Taoyuan, Taiwan, as an Assistant Professor. He has been engaged in the research of the characterization and reliability of MOSFETs, Flash memory, high-k dielectrics, metal gates, and biosensors. From 2001 to 2002, he visited the Department of Electrical Engineering, University of California, Berkeley, for visiting research on fin-shaped FETs. Since 2007 to 2013, he had been the Chairman of the Department of Electronic Engineering and the Director of the Biosensor Group of the Biomedical Research Center, Chang Gung University, for the research-related bio-transistor application on ions, proteins, DNA, and biomarker analysis. From 2012, he is the Dean of Engineering College of Chang Gung University. He holds 12 U.S. patents and 60 Taiwan patents, and he is the author of more than 200 journal papers, 200 conference papers, 30 international invited talks, and 2 book chapters. Dr. Lai is the leading guest editor of the SCI journals, including Microelectronics

Reliability (2010), Nano-Scaled Research Letters (2011), and Solid-State Electronics (2012), and Nano-Scaled Research Letters (2014), Chemosensors (2020), ECS Journal of Solid State Science and Technology (2021). He won Lam Research Award in 1997 and distinguished award from Electron Devices and Materials Association in 2011. He was the President, Association of Chemical Sensors in Taiwan from 2016 to 2018. He is the President of Electron Devices and Materials Association from 2019. He has served as organizing committees for several international conferences, including general chair (IEEE-INEC 2011), (IEEE-ISNE 2015) and international advisory committee (IEEE-ISNE 2016) and (IEEE-EDSSC 2017).

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