The Impact of Carbon Nanotubes and Graphene on Electronics Industry

E

Rafael Vargas-Bernal
Instituto Tecnológico Superior de Irapuato, Mexico

Gabriel Herrera-Pérez
Instituto Tecnológico Superior de Irapuato, Mexico

Margarita Tecpoyotl-Torres
Universidad Autónoma del Estado de Morelos, Mexico

INTRODUCTION

A great technological opportunity has been introduced with the discovery of carbon nanomaterials where carbon nanotubes and graphene are their main representatives, which are completely involved in the science, technology and applications on new electronic devices, as an interesting alternative to those devices based on conventional semiconductor materials. They have attracted significantly attention of the scientific and industrial communities thanks to their unique electrical, optical, thermal, mechanical, and chemical properties. Nevertheless, carbon nanotubes and graphene due to their insignificant size, these require be homogeneously embedded into dielectric and light-weight, matrices, which are regularly of the polymeric type giving place to polymer-matrix composite materials (Das, 2013). Several models have been developed to predict the behavior of electrical conductivity of these composite materials based on carbon nanomaterials (Vargas-Bernal, 2013). Various chemical strategies for achieving synthesis of these composites have been proposed around the world, but these are not studied in this paper. The future trend in electronics industry consists in using individual carbon nanotubes and graphene sheets or set of them to design devices, circuits or systems. A lot of electronic devices have been fabricated based on carbon nanotubes and graphene: field-effect transistors, diodes, analog and digital circuits, sensors (biosensors, gas sensors, etc.), solar cells, batteries, supercapacitors, flexible displays, etc. In this paper, the impact of the carbon nanotubes and graphene in electronic devices (discrete devices and/or integrated circuits), optoelectronic devices, photovoltaic devices, energy storage devices, and sensors, is briefly reviewed. This paper has been divided as follows: basic concepts about carbon nanotubes and graphene are described in section entitled Background. Next, different applications in the electronic industry are discussed in section entitled Applications of the Carbon Nanotube and Graphene. A comparison between the performance of the carbon nanotubes and graphene is presented in the next section. Future research directions are described in an additional section. Finally, conclusions about this study are given in the end section.

BACKGROUND

Carbon nanomaterials possess unique properties that can be exploited electrical, thermal, chemical and mechanically to provide applications in areas such as composite materials, energy storage and conversion, sensors, drug delivery, field emission devices, and nanoscale electronic components.

Three different morphologies between carbon nanomaterials can be distinguished: carbon nanotubes, fullerenes and graphene. Carbon nanotubes and graphene have been used more extensively in the electronic industry. Next, a brief description of their properties is made with the purpose of knowing the advantages of these materials for electronic applications. The basic concepts of each type of material have been separated for a better description.

Carbon Nanotubes

A carbon nanotube can be defined as a set of cylinder-shaped graphite sheets. Carbon nanotubes (CNTs) can be categorized by the number of graphite layers in their structure: Single-Wall Nanotubes (SWNTs) containing a single layer (see Figure 1), Double-Wall Nanotubes (DWNTs) with two layers, and Multi-Wall Nanotubes (MWNTs) that contain more of two layers (see Figure 2). Two main physical properties are associated directly with electronic applications: high thermal and electrical conductivity (Vargas-Bernal, 2012). Carbon nanotubes and their compounds exhibit extraordinary electrical properties useful for electronic organic materials, and can be used for a wide range of new and existing applications such as conductive plastics, flat-panel displays either as flexible displays or touch screens, micro-and nano-electronics (transistors), radar-absorbing coating, ultra-capacitors, solar cells, batteries with improved lifetime, hydrogen storage cells, conductors, smart textiles, electrochemical sensors, biosensors, and gas sensors. A more detailed study of their properties in found in Vargas-Bernal, 2012.

Graphene

Graphene is a two-dimensional allotrope of carbon with hexagonal lattice in atomic-scale, as shown in Figure 3 (Vargas-Bernal, 2015c). This material is a thin layer of pure carbon where each atom has four bonds, one σ-bond with each of its three neighbors and one π-bond that is oriented out the plane. Just as the carbon nanotube, graphene has many extraordinary properties such as 100 times stronger than steel by weight, conducts heat and electricity with great efficiency and is almost transparent. From the electronic point of view, it presents the effect of a bipolar transistor, ballistic transport of electrical charge, and large quantum oscillations. A lot of electronic devices have been developed

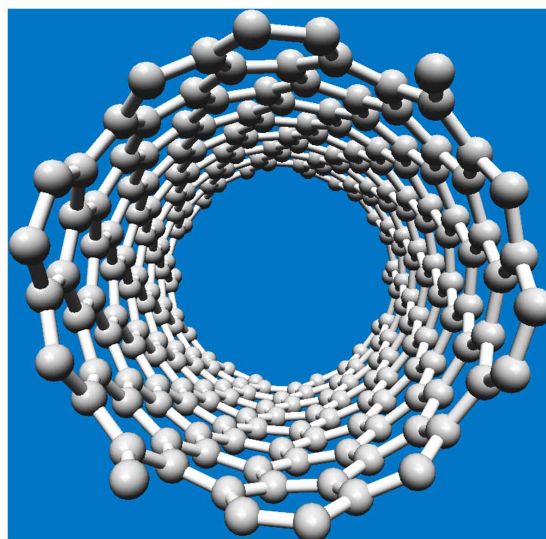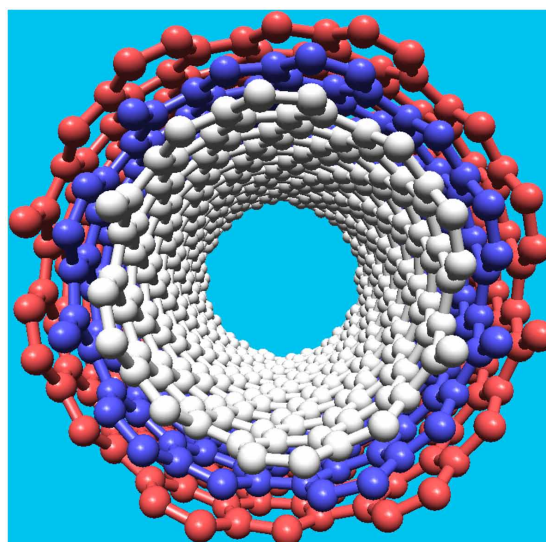*Figure 1. Structure of the single-wall carbon nanotube (SWNT)*

Figure 2. Structure of the multi-wall carbon nanotube (MWNT)

Related Content

Big Data Issues and Challenges
Stephen Kaisler, Frank Armour, William Moneyand J. Alberto Espinosa (2015). *Encyclopedia of Information Science and Technology, Third Edition (pp. 363-370).*
www.irma-international.org/chapter/big-data-issues-and-challenges/112346

Theoretical Analysis of Different Classifiers under Reduction Rough Data Set: A Brief Proposal
Shamim H. Ripon, Sarwar Kamal, Saddam Hossainand Nilanjan Dey (2016). *International Journal of Rough Sets and Data Analysis (pp. 1-20).*
www.irma-international.org/article/theoretical-analysis-of-different-classifiers-under-reduction-rough-data-set/156475

Service Quality and Perceived Value of Cloud Computing-Based Service Encounters
Eges Egedigwe (2018). *Encyclopedia of Information Science and Technology, Fourth Edition (pp. 1129-1140).*
www.irma-international.org/chapter/service-quality-and-perceived-value-of-cloud-computing-based-service-encounters/183825

A System to Match Behaviors and Performance of Learners From User-Object Interactions: Model and Architecture
José Guillermo Hernández-Calderón, Edgard Benítez-Guerrero, José Rafael Rojano-Cáceresand Carmen Mezura-Godoy (2019). *International Journal of Information Technologies and Systems Approach (pp. 82-103).*
www.irma-international.org/article/a-system-to-match-behaviors-and-performance-of-learners-from-user-object-interactions/230306

Understanding the Reasons for Gender Difference in Online Information Processing of Consumers: Based on Theories
Ceyda Tanrikulu (2019). *Gender Gaps and the Social Inclusion Movement in ICT (pp. 230-252).*
www.irma-international.org/chapter/understanding-the-reasons-for-gender-difference-in-online-information-processing-of-consumers/218447