Chapter 30
The Impact of Carbon Nanotubes and Graphene on Electronics Industry

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

ABSTRACT

Since their discovery in 1991, carbon nanotubes (CNTs), by Sumio Iijima, and graphene, by Andre Geim and Konstantin Novoselov in 2004, have been extensively studied around the world. Both materials have electronic, thermal, magnetic, optical, chemical, and mechanical extraordinary properties. International technology roadmap for semiconductors (ITRS) has predicted that these nanomaterials are potential replacements of the conventional materials used in the manufacturing of integrated circuits. Two of the technological aspects that both materials share and have reduced their extensive use are processing and dispersion required to homogenize the electrical properties of the materials based on them. Fortunately, these problems are being solved thanks to the ongoing investigation, and in a short time the materials used in today's electronics industry will be replaced by devices based on these novel materials. The impact of the applications of both materials in the electronics industry as well as future trends in the following decades are discussed in this chapter.

DOI: 10.4018/978-1-5225-7766-9.ch030

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