The Role of Two-Dimensional Materials in Electromagnetic Interference Shielding

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INTRODUCTION

The extensive use of electronic and wireless technologies has led to the need to develop materials that present high performance shielding against electromagnetic interference (EMI), which avoid pollution by electromagnetic waves that affect the operation and life time of electronic devices as well as the Human health (Song, 2017; Wang, 2017; Liu, 2019). Commonly, metallic materials are used in practical ways to increase the shielding effectiveness (SE) through an appropriately designed assembly process. Unfortunately, the high density of devices that require it and the poor environmental stability of metals have impeded their massive use. In addition, materials with light weight and good chemical stability are also required for applications in the automotive, aerospace and electronics industries.

Research in the area of materials engineering has introduced two-dimensional materials in the last decades as an alternative option to increase the efficiency of electromagnetic shielding. Two-dimensional materials are defined as crystalline materials of a single layer of two-dimensionally arranged allotropic atoms based on elements or compounds (two or more covalently bonded elements). In the following paragraphs, the fundamental role that these materials play in the future of electromagnetic shielding is introduced. The advent of two-dimensional materials in the area of electromagnetic interference will mitigate the harmful effects of excessive use of electronic and telecommunications devices through electromagnetic shielding for commercially, industrially and militarily used systems. In this way, the manufacture of electronic systems must include an electronic packaging that involves the application of two-dimensional materials used as electronic fillers in composite materials based on polymeric, ceramic or metallic matrices. From a commercial point of view, the integration of two-dimensional materials will provide a high added value to products that include more efficient electromagnetic shielding than that achieved with current technologies.

Carbon-based nanomaterials such as graphene and carbon nanotubes have recently been introduced to control electromagnetic interference or mitigate contamination by electromagnetic radiation, and because they offer characteristics such as low density, high electrical conductivity and good chemical resistance (Dhakate, 2015; Xu, 2018; Zhao, 2018a). Of these nanomaterials, graphene is a two-dimensional carbon material with a higher electrical conductivity than carbon nanotubes, which further increases the shielding effectiveness (Bhattacharjee, 2017; Liu, 2019). To use the multifunctional properties of these nanomaterials in practical applications, it is necessary to implement nanocomposites that contain them regularly embedded in polymer matrices. Two-dimensional materials must be incorporated in small quantities and form efficient conductive networks within the composite material that will be formed by exploiting their high intrinsic electrical conductivity, large aspect ratio, good dispersion, and homogeneous distribution.

Carbonitrides and/or carbides based on transition metals called MXenes represent other highly conductive two-dimensional nanomaterials that can be used to provide electromagnetic interference

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shielding when incorporated into polymeric materials such as polystyrene (Sun, 2017a; Cao, 2018; Fan, 2018; Liu, 2018; Raagulan, 2018; Cao, 2019). Additionally, two-dimensional materials are attractive for their light weight, flexibility, hydrophobicity, good durability, strong absorption capacity, and shielding against electromagnetic interference up to 70 dB that are not offered by bulk materials. These two-dimensional materials must be used functionalized or used in combination with metals (Liu, 2019) or ceramics (Sharif, 2017; Jin, 2018; Ru, 2018) embedded in polymer matrices based on thermoplastics, thermosets or conductive polymers. Other two-dimensional materials that exhibit shielding properties are black phosphorus (BP), transition metal dichalcogenides (MoS_2), and carbon nitride (C_3N_4). Multiple two-dimensional materials with van der Waals structure or heterostructures have also been used (Zhao, 2018b).

The purpose of this chapter is to describe the impact that two-dimensional materials (or 2D materials) are having on the development of materials used for electromagnetic interference shielding, particularly the impulse of materials such as graphene and MXenes. The advances in the last decade are analyzed and alternatives are proposed that will come in the next decades. The shielding mechanisms presented by two-dimensional materials are analyzed in detail and the specific applications in which these materials can be used are presented.

BACKGROUND

In this section, the chapter describes the basic concepts associated with the technical principles on which the shielding to electromagnetic interference is based. The overly exhaustive use of technologies operating in the high-frequency range has led to a new type of pollution called electromagnetic interference (EMI) (Bhattacharjee, 2017). Any device that transmit, distributes or uses electrical energy produces electromagnetic interference, which can have a damaging impact on the performance of other devices or the surrounding environment. This problem has been accentuated more because the electronic devices have reduced the size of their components and operate at much faster speeds, which can encourage the malfunction and/or degradation of the devices. This electromagnetic pollution has not been completely restricted, since it is also affecting the human being as well as the surrounding environment due to the absence of adequate shielding. The largest problems of electromagnetic interference are observed in applications where large amounts of data are used such as electronic equipment, industrial equipment and communication systems (Cao, 2019). Systems present two types of interference: electronics and radiation sources. Electromagnetic shielding involves the blocking of electromagnetic radiation so that it does not pass through a blocking or shielding material (Dhatake, 2015). Electromagnetic interference shielding is used in applications such as the radar absorption, aviation, portable electronic devices, camouflage materials, automotive systems, aerospace systems, and military systems (Raagulan, 2018). Materials that are capable of absorbing and attenuating incident microwaves used in military applications are called microwave absorbing materials (Wang, 2018). Since the late 1940s, many researchers around the world have turned their attention to studying microwave absorbing materials with two specific properties: lightweight and high absorption efficiency. In addition, these materials must have matching properties of optimal impedance (to ensure that the electromagnetic waves enter the material) and high attenuation constant (to consume the energy of the electromagnetic wave). An excellent electromagnetic wave absorbing material must be capable of absorbing waves over a wide range of frequencies, having a low density, lightweight, large surface area, and good thermal and chemical stability (Prasad, 2018).