Nanomaterials as Sorbents in Wastewater Treatment

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ABSTRACT

Nanotechnology refers to a wide range of tools, technologies and applications consisting of microscopic particles approximately a few hundred nanometers in diameter.These extremely small particles (in their size) also have a set of physical and chemical properties and properties related to their surface, which are suitable for many uses and in different fields. This technology will address and find real solutions to issues related to medicine, energy, agriculture, and even environmental and military issues alike. Which will bring about a technological revolution Scientists interested in nanotechnology indicate that this great technology will contribute to finding solutions to some major global problems, such as providing clean drinking water to the entire population, whose numbers are increasing annually.

Keywords: microscopic particles , medicine, energy

Introduction

Nanomaterials are defined as engineered materials with a least one dimension in the range of 1-100 nm. Particles of "**nano**" size have been shown to exhibit enhanced or novel properties including reactivity, greater sensing capability increased mechanical strength, good sorption properties; electronic, optical and thermal properties. Molecular manipulation implies control over the structure and conformation of a material. For carbon nanomaterials this includes size, length, chirality and number of layers[1, 2]. Nanomaterials are perfect adsorbents, catalysts and sensors because of their great specific surface area and selectivity to the low concentration of pollutants. The high surface area to mass ratio of nanomaterials can greatly improve the adsorption capacities of sorbent materials [3]. Currently, a variety of nanomaterials has been studied such as carbon nanotubes, carbon-based material composites, graphene, nano metal or metal oxides and polymeric sorbents in the removal of pollutants from aqueous solutions and the results demonstrate that these nanomaterials appearance high adsorption capacity [4]. Nanomaterials can be classified in 0-D (spheres and clusters), 1-D (nanowires, nanorods, nanotubes), 2-D (films, plates, and networks) and 3-D (nano crystalline and nanocomposite materials) as shown in Figure (1-1)[5].

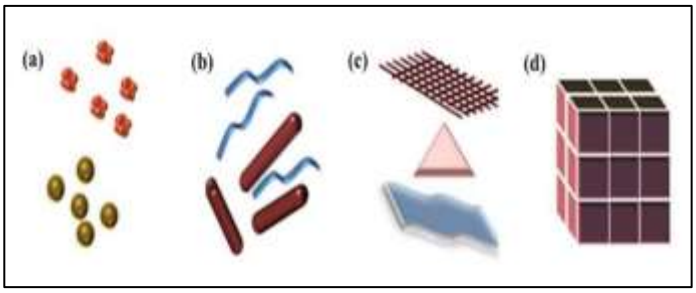


Figure (1): Classification of nanomaterials (a) 0D (b) 1D (c) 2D (d) 3D

1- 4. Allotropes of Carbon

The carbon component of the most elements of a presence on the ground and appears in several forms. These are called allotropes of carbon where can be classified into two carbon allotropes: they are diamond and graphite.

- **Diamond** is the hardest substance known (10 in the Mohs hardness scale), and it is the thermodynamically stable form of carbon above 60 kbar. It is a precious gem and an important abrasive material. It usually crystallizes with a cubic structure and its industrial synthesis has been realized. It also exists in the hexagonal form, less common in nature and with lower hardness (7-8 in the Mohs scale). The two forms can be interconverted under specific conditions. In diamond, each sp^3- hybridized carbon atom covalently bonds to four others, extending three-dimensionally as an array of tetrahedral. Diamond transforms into graphite, the thermodynamically stable allotrope at high pressures, above 1500 °C under vacuum or inert atmosphere [6, 7].
- **Graphite** contains unlimited layers of sp^2-hybridized carbon atoms. Inside a layer (called a graphene sheet), every carbon atom bonds to three others, it gives a hexagonal arrangement. Graphite is anisotropic which has an excellent electrical and thermal conductivity in plane shape (due to the delocalized π and σ bonds) and a poor electrical and thermal conductivity in the accumulate shape (due to the van der Waals force between the layers). The electrical conductivity of graphite can be used for electrochemical electrodes and electric brushes because of the covalent bonding in the plane shape and weak perpendicular to the layers. As a result of this anisotropy, the carbon layers can slide with respect to one another quite easily, thus making graphite a good lubricant and pencil material [8, 9].

There other allotropes of carbon include **fullerenes**, **carbon nanotubes and graphene**.

- **Fullerenes** (called buckyballs when spherical) were discovered experimentally for the first time in September 1985 by vaporization of graphite upon laser heating. It consists of a group of layers wrapped of graphene. They can be found in three unique forms: spherical, elliptical and tubes. The structure of the C_{60} buckyball is a combination of 12 pentagonal and 20 hexagonal rings appears a spheroid shape with 60 vertices for 60 carbons[10].
- **Carbon nanotubes (CNT)** consist of graphitic sheets, which have been rolled up into a cylindrical shape. The length of CNT is in the size of micrometers with diameters up to 100 nm. CNT form bundles, which are entangled together in the solid-state giving rise to a highly complex crosslinking. It depending on the arrangement of the hexagon rings along the tubular surface. CNT can be metallic or semiconducting due to their extraordinary properties. CNT can be considered as attractive candidates in diverse nanotechnological applications, such as fillers in polymer matrixes, molecular tanks, biosensors, and many others as shown in Figure(1-2) [11, 12]

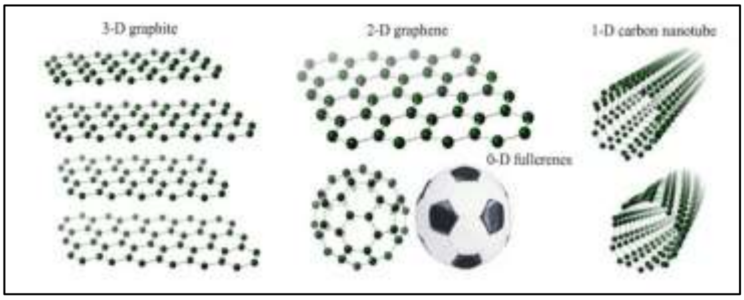


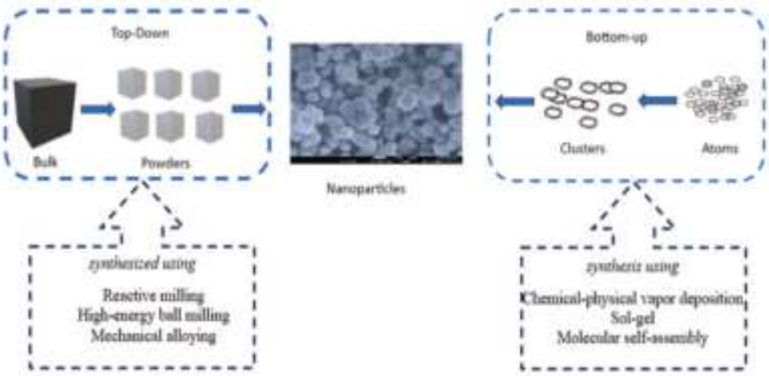
Figure (2): Types of allotropes of carbon [13]

Properties of nanoadsorbents

The nano-sized materials are effective in the process of adsorption due to their unique properties. These include high surface area, increased number of sorption sites, small intraparticle diffusion distance, low-temperature modification, flexible surface chemistry, and customizable pore size .The morphology and shape of nanoadsorbents also play a significant role in their capability to adsorb various contaminants. It is established that the behavior of nanoadsorbent to toxic components is affected by the change in morphology Diverse morphologies can be designed for nanoadsorbents by creating a delicate balance among surface area, elastic deformation, and the energy from polar charges. When compared to traditional adsorbents, the superior physical, and chemical characteristics of nanoadsorbents make them preferable for the process of adsorption Additionally, it should be noted that the intrinsic compositions, inherent surface properties, external functionalization, and apparent size of nanomaterials contribute to their physical, chemical, and material attributes Furthermore, it was observed that adsorption efficiency is directly linked with the surface functionality in addition to the competitive affinity of pollutants for nanoadsorbents, the rate of surface charge, and the availability of active surface sites The surface modification of the magnetic or iron-based nanoparticles eliminates the oxidation of the material. In addition, surface modification improves the stability and adsorption capacity The surface modification techniques include coatings the magnetic nanoparticles such as silica-based coating that improve the stability of the particles in acidic environments Furthermore, surface modification eliminates the particle-particle aggregation condition as well as improves the dispensability of the core-shell structure in the event of suspension medium Hence, the scientific findings clearly showcase that the nanomaterials are effective in adsorption-based wastewater treatments.

Synthesis of nanoadsorbents

The nanosorbent materials are synthesized mainly using two processes: namely top-down process and the bottom-up process as shown in Fig. 3. In the top-down process, the nanoadsorbent is synthesized using a traditional approach and subsequently, the particle size is reduced by erosion with methods such as reactive milling, high-energy ball milling, and mechanical alloying. Whereas in the bottom-up method, a modern synthesis approach is involved by which the nanoadsorbent is formed atom by atom or molecule by molecule. The bottom-up method is similar to processes such as chemical-physical vapor deposition, sol-gel, and molecular self-assembly [



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