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Graphene Oxide Nanocomposites for Water Purification - A Review

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Abstract: Recently, attention has been drawn towards nanostructured systems, such as nanocomposites, for usage in different fields due to increased concern for environmental sustainability. Various methods have been utilized to synthesize nanocomposites which suit different applications. Graphene /Graphene Oxide have excellent affinity to form composites with other materials. In recent years, some attempts have been made to combine Graphene with other semiconductors to enhance photocatalytic activity for water treatment. There are several visible-light-driven semiconductor photocatalysts such as CdS, TiO₂, ZnO, SnO₂, which show increased photocatalytic water splitting activity by combining with Graphene/Graphene Oxide. This review paper discusses the binary and ternary Graphene Oxide nanocomposites and its applications on the water decontamination.

Keyword: Nanocomposites, semiconductor photocatalysts, water treatment.

I. INTRODUCTION

There are various factors which are responsible for the environmental pollution due to Industrialization and urbanization which cause water contamination as a leading problem. There are various organic contaminants and toxic pollutants which are the root cause for the typical and fatal illness. There always have been the requirements of the clean water [1]. The traditional methods for water purification like two-stage filter, through cloth, clay vessels, clarification and filtration through plant material, etc. which are less effective and are not fully compatible to the environment and disposal of the harmful contaminants [2]. Therefore, effective and environmental friendly technologies for water treatment are developed.

Nanotechnology has enabled the waste water treatment which overcomes the challenges faced by the conventional water treatment technologies. Many researches are conducted in the field of nanomaterial sciences for water treatment purposes [3]. The composites of the nanomaterials open up the path way for the advance, effective and environmental friendly water treatment technologies.

For past few years, the composites of the semiconductor nanocrystals are engaged for the water treatment and for various purposes. These semiconductors have unique structures; some of them have good electronics and optical properties and also large surface to volume ratio. Utilization of solar energy has also gained much attention for fabrication of solar cells and panels [4].

Photocatalytic semiconductors have attracted great interest in both theoretical research and technological applications in the field of waste water treatment. There are various photo catalytic semiconductors such as metal oxide, CdS, ZnS, etc. which show favorable properties such as low toxicity, efficiency, stability and cost effectiveness [5].

In this paper, we are reviewing the outlines of the recent researches and studies conducted in waste water treatment using Graphene Oxide nanocomposites.

II. NANOCOMPOSITIES

A nanocomposite material is constituted of a matrix and a reinforcement consisting of fibers. The matrix itself is comprises of a resin and filler, the main goal is to improve the characteristics of the resin while reducing its cost production. The filler and resin system act as homogeneous material. The reinforcement to the composite material has greater mechanical performance, whereas the role of the matrix is to transmit to the fiber to the external mechanical load and protect the fibers from the external forces [6]. Usually, nanocomposites are classified as inorganic-inorganic nanocomposites (inorganic matrix), organic-organic nanocomposites (organic filler in organic), and hybrid materials, i.e., organic in inorganic or inorganic in organic matrix.

Nanocomposites are suitable alternatives to overcome limitations of microcomposites and monolithics. When the dimensions of composites reaches the nanometer level, interactions at phase interfaces become largely improved, and this is important to enhance materials properties [7].

There are various strategies applied for industrial waste water treatment such as reverse osmosis, ultra-filtration, evaporation and solvent extraction. However, these techniques remove contaminants from water and there is no guarantee that these strategies help in converting them into harmless end-products. Complete degradation can be readily achieved by oxidation, either chemically or

photo-chemically [8]. The main aim of the oxidative processes is to produce and use hydroxyl free radical. These hydroxyl groups act as a strong oxidizing agent for pollutant degradation.

The photocatalytic processes includes oxidation which provide an attractive alternative because they rely on using the radiation energy to promote the pollutants degradation. And further more photocatalysis process is widely used due to their low cost and ease of processing.

III. PROPERTIES OF NANOCOMPOSITES

The nanocomposites are similar to that of composites but the scaling range of the composite materials is reduced to the nanometer range. The two or more different materials are blend in together to obtain the new composites having different and sometimes best properties from the parent materials. For selection criteria of the suitable photocatalysts is very important. It has the capacity of absorbing solar visible light and the ability to separate photoexcited electron from the holes has been emphasized. With the recent studies it is shown that the efficiency of pollutants photodegradation is mainly determined by the properties of the photocatalysts.

Semiconductor nanocrystals such as ZnO, CdSe, CdS and ZnS, have been investigated extensively for their quantum confinement effects and unique size-dependent photoemission properties. The materials are chosen on the basis of the optical materials and photonic crystal structure. Especially, as an important II—VI group semiconductor with a room which exhibits nonlinear optical properties, luminescent properties, quantum size effects and many other significant properties [9]. Graphene-based semiconductor photocatalyst possess remarkable advantages which make it very effective as the supporting materials. They are:

- 1) By introducing graphene into the semiconductor, improves the charge separation and delay the recombination of photogenerated electron-hole pairs, which thus enhances the performance of photocatalyst.
- 2) Due to the unique two dimensional structure of grapheme, it supports the increase of specific surface area of photocatalyst.
- 3) The strong π - π interaction between graphene and organic molecules facilitates the absorption of organic molecules.

Ashish Kumar Sahoo et al, synthesized Graphene nanocomposites of CdS and ZnS successfully by hydrothermal reaction. The investigation shows that the Graphene nanocomposites of CdS and ZnS acts as photocatalyst in the decomposition of methylene blue in the presence of UV light and also as adsorbents in the removal of Cd(II) and Pb(II) ions to an extend of 97 and 99% from contaminated water [2].

Wei Lü et al, the hybrid nanocomposites of graphene based CdS particles were prepared by a one-pot solvothermal route in which the reduction of graphite oxide into graphene was accompanied by the generation of microsized CdS particles. The photocatalytic activity measurements demonstrate that the graphene based micro-CdS photocatalysts show superior photoactivity in degradation of Rh.B under visible light irradiation. The graphene-CdS nanocomposites can be used as the adsorbent for the extraction of organic pollutants [1].

B. Zeng et al, synthesized the metal (Cd, Zn) sulphide nanorods/graphene using microwave technique. The nanocomposites developed shows highly active photocatalytic properties. The nanorods of CdS and ZnS can offer superior, fast, and long-distance electron transport properties. They exhibit an improved photo-activity in the photocatalytic reaction. Therefore, CdS nanorods and ZnS nanorods are considered as a class of novel photocatalysts. The binary nanocomposites can be used for nonselective degradation of pollutants, in both liquid and gas phases [3].

Amr Tayel et al, prepared TiO₂/G and TiO₂/GO binary nanocomposites by hydrothermal methods which falls under sol-gel process. Then it can be mechanically mixed with or without sonication and can be used either in the liquid phase or gas phase. Compared to the bare TiO₂, the nanocomposites have smaller band gap energies, slower rates of recombination between the photoinduced electrons and the holes on the TiO₂ surface, and larger surface areas. G and GO relative to doped TiO₂ which could possibly exhibit higher photocatalytic activity and hence can be used in the treatment of the water pollution [8].

A. Hamdi et al, prepared TiO₂-CdS samples with different CdS loadings to study the dependence of their photocatalytic activities on the CdS relative amount, on the degree of CdS oxidation, and on their photophysical and chemical properties. The coupled CdS-TiO₂ exhibits faster degradation rate than both isolated components of the composite photocatalyst [10].

Chan Lin et al had prepared TiO/ZnO/CdS ternary nanocomposites; it has more conversion efficiency increased from 0.39% to 1.30% than that of the binary composites. The formation of a stepwise band gap structure in the composites with other semiconductor materials has been found to lead to a superior photocatalytic performance because the resulting catalysts not only extend light absorption to the visible region, but also exhibit a suppressed recombination rate of photogenerated electron-hole pairs. The ternary composites can be used for water purification and degradation of organic pollutants [11].

Md. Selim Arif Sher Shah et al had successfully synthesized Ag-TiO-reduced graphene oxide ternary nanocomposites by a simple solvothermal process. The single-step synthetic procedure is followed for the reduction of AgNO₃ and graphene oxide and the

hydrolysis of titanium tetraisopropoxide were spontaneously performed in a mixed solvent system of ethylene glycol, N,N-dimethylformamide and a stoichiometric amount of water without resorting to the use of typical reducing agents. The combined Ag and graphene and TiO₂ ternary nanocomposite enhances the photocatalytic performance. Therefore, this ternary composite is potentially useful for a catalyst for solar water splitting [12].

M. Khairy et al, had prepared TiO₂ based nanoparticles and also compared pure TiO₂ and TiO₂ doped with Cu and Zn were synthesized and tested for their potential use in advanced water treatment applications under UV and visible light. The photocatalytic activities of the synthesized nano particles were investigated for degradation under visible light irradiation while methyl orange (MO) acting as the dyeing pollutant which is also a commercial dye. The catalytic degradation rate under both UV and visible radiation decreases according to: Ti_{2Cu}> Ti_{2Zn}> Ti_{pure} [13].

Jun Zhang et.al prepared RGO-Zn_{0.8}Cd_{0.2}S sample for enhancing high H₂-production rate. Compared with the pristine Zn_{0.8}Cd_{0.2}S, the RGO-Zn_{0.8}Cd_{0.2}S sample showed a significantly enhanced hydrogen production performance by a factor of 4.5. The results shows that the unique features of RGO make it an excellent supporting material for Zn_{0.8}Cd_{0.2}S nanoparticles as well as a good electron collector and transporter. It shows that by using RGO as a support enhances the H₂-production photoactivity of Zn_{0.8}Cd_{0.2}S nanoparticles and also demonstrate that RGO is a promising substitute for noble metals in photocatalytic H₂-production [14].

Mohammad Mansoob Khan et al, studied heterogeneous photocatalysis which employs metal oxides such as TiO₂, ZnO, SnO₂ and CeO₂ that has proved to be efficient in degrading a wide range of distinct pollutants into biodegradable compounds and eventually mineralizing them to harmless carbon dioxide and water. Both the hydrogen and oxygen radicals and anions can react with pollutants to degrade or otherwise transform them to lesser harmful byproducts. The metal oxides can be used as a photocatalyst to decompose toxic organic compounds, photovoltaics, prevent fogging of glass and even split water into hydrogen and oxygen. The heterogeneous photocatalysis is a promising self-cleaning, antibacterial and deodorization system. The applications of such photocatalytic process are mostly needed for the purification of waste water, by removal of bacteria and other pollutants, as this can render water reusable [15].

IV. APPLICATIONS OF PHOTOCATALYTIC SEMICODUCTOR COMPOSITES IN VARIOUS FIELDS

The photocatalytic semiconducting materials can be doped with other materials for forming the best composites. The binary nanocomposite of Graphene/graphene oxide is doped in TiO₂ by hydrothermal method. By varying the composition of the graphene/graphene oxide shows the recombination of the electrons holes pair is delayed and reduces the large band gap which lead to light absorption and higher photo catalytic activity and can be used in the water decontamination and purification of the waste water [8].

When graphene is mixed with CdS, it shows improved photo catalytic properties forming π - π conjugate net and the conductivity of graphene makes it an effective electron acceptor, which leads to the degradation of organic pollutants [1].

The combined graphene based ternary nanocomposite enhances the photocatalytic performance. GO acts as a supporting material and also causes the structural changes in the lattice constants and band gap energy of the fellow materials. Therefore, this ternary composite can be used for a catalyst for solar water splitting [11].

Reduced graphene oxide when mixed with the Zn_xCd_{1-x}S shows the significance enhancement in hydrogen production. RGO make an excellent supporting material as well as a good electron collector and transporter [14].

The coupling of graphene with other nanomaterials, like oxide semiconductors, synergistically increases the photo-efficiency of nanoparticles. Moreover, graphene behaves as an antibacterial agent by impairing the metabolic pathway of bacterial cell and, also, is believed to disrupt the bacterial membrane by its sharp edges. Therefore graphene-based materials have the significant potential as a photocatalyst in the field of water purification, especially for water disinfection [17].

IV. CONCLUSION

This article reviewed some aspects on these fast growing researches on the nanocomposites in various applications. There are different methods for the synthesis of nanocomposites materials each of which has its own advantages and drawback. The different synthetic procedures for the preparation of photocatalytic materials should be considered necessary because different type of proportions, ratio of the doped materials and also the process used for synthesizing the nanocomposites can drastically affect the outcome and applications of the photocatalytic nanocomposites. Graphene-based semiconductor photocatalyst possess remarkable advantages, therefore, the graphene-based semiconductor photocatalysts suggest that they can be used as a promising class for supporting the semiconducting photocatalysts for the applications in environmental remediation and energy conversion.



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