Nano-Catalyst for Dye Degradation: A Review

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Abstract— Disposal of dye is one of the serious and major issues in our environment. Uncontrolled discharge of dyes leads to environmental pollution which distrusts the ecosystem. Nanostructure materials included metal nanoparticles; metal oxides nanomaterials, carbon-based nanomaterial, and nanocomposites materials, etc. have effective and improved the efficiency of the degradation process. Nanostructure materials have low cost and more reactive for the transformation and detoxification of chemicals either through chemical reduction or catalytic process. Nano-catalyst is the more interested and promising route of degradation of dye compared to chemical reduction because the chemical reduction method has not kinetically favorable.

Keywords: Disposal of Dye, Nano-Catalyst for Dye Degradation

I. Introduction

Nanoscience and nanotechnology is a hot area in research area. These nanostructures materials are ideal systems for exploring a large number of novel phenomena at the nano-scale. [1-2] Nanomaterials have investigating size and dimensionality dependence of nanostructure properties for potential applications. Several routes and various methods are used to synthesize nanomaterials. [3] Top down and bottom up are the robust methods which are used for synthesis of nano-catalyst included hydrothermal synthesis, solvothermal synthesis, pyrolysis, microwave synthesis, wet chemical synthesis, etc. [4-8]

Dyes is useful substances to provide color to substrate in various filed included in pharmaceutical, food, textile, plastic, paper, and photographic industry. Every year during dye processing, a lot of ton dyes are lost in dyeing and finishing operation. So it is phase to mainly several pollution problems. [9-10] Dye waste water has one of the major sources for pollution and these dyes are removing by wastewater treatment. The dyes form the covalent bond or complex with salts or metals by adhering to suitable surfaces in solution phase. According to applications and chemical structure; the dyes are classified as the group of atom which is responsible for dye color called chromophores. [11-13] The chromophores included the functional group of atom/molecule azo, nitro, carbonyl, anthroquinone, etc. The electron withdrawing substituents are attached to chromophores called as auxochromes. The auxochromes are increase the color of chromophores included the hydroxyl, amine, chloride, carboxyl, etc. [14]

The well-known pollutant in environmental science is particularly toxic and carcinogenic compounds present in the dyes. These dyes are exist in wastewaters and caused to be a large hazard due to the pollution of the water resources. [15] Varieties of dyes in wastewaters are highly persistent in the aquatic environment. Some of them are azo dyes, sulfur, disperse dyes, reactive dyes, acidic and basic dyes, etc. which are broadly applied in industry particularly in dyeing and textile processes. [16]

Now a day, nano-catalysis is innovative oxidation processes used for the photo degradation of toxic compounds such as carcinogenic dyes namely Methylene blue, Rhodamine B, pentachlorophenol, etc.[17-18] It is also used for the purification of water. Catalysis is divided into two categories namely heterogeneous catalysis and homogenous catalysis. Heterogeneous catalysis has been magnificently active for the degradation of various toxic materials.19 The degradation has lot of benefits over traditional wastewater treatment techniques such as chemical oxidation, activated carbon adsorption, biological treatment, etc.[20-21] In activated carbon adsorption method, it involves the phase transfer of pollutants without decomposition and thus causes another pollution problem. Whereas, chemical oxidation method does not remove all organic substances and it is fit for the removal of high concentration pollutants. [22] The biological treatment is a very slow process, and requires strict control of appropriate pH and temperature. When compared to these methods, photo catalytic processes have great advantages for the removal of pollutants even at low concentration for industrial waste water.[23] Furthermore in photo oxidation, complete oxidation of organic pollutants take place within short period of time, at very low concentration, without formation of any new hazardous by products.[24]

Titanium dioxide is widely with various dimension used photo catalyst, due to its high oxidation efficiency, non-toxicity, high photo stability, chemical inertness and environmental friendly in nature, it has a wide band gap (~ 3.2eV) and mineralizes a large range of organic pollutants such as herbicides, dyes, pesticides, phenolic compounds, tetracycline, sulfamethazine, etc under UV irradiation.[25-26] Saroyan and his co-workers reported the degradation of azo dye namely Reactive Black 5 (RB5) by graphene Oxide supported manganese oxide (GO-MnO_2).[27] The GO-MnO_2 nano-composite contained a high catalytic activity for the degradation/oxidation of RB5 in ambient conditions without light irradiation that reached equilibrium in 60 min. The addition of H_2O_2 resulted in an increase in the removal/degradation of RB5. The RB5 Degradation occurs due to the cleavage of the azo bonds for the formation of –NH_2 groups. This led to the decolonization of the solution and the formation of new products as aromatic amines and amino-naphthalene sulfonates.[27] The SEM images and EDS mapping of GO-MnO_2 nano-composite is shown in Figure 1-a as well as UV-Vis spectra of RB5 degradation with the effect of H_2O_2.

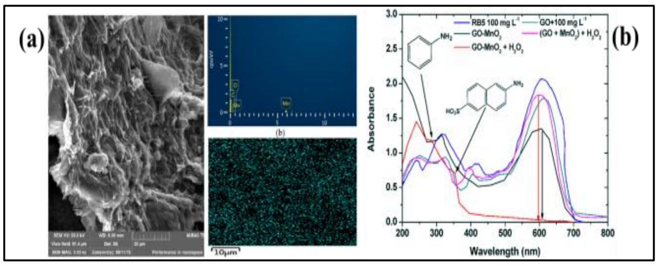

Fig. 1: SEM Images of GO-MnO2, SEM-EDS, SEM- maps of Mngnised distributed on GO-MnO_2 nanoconposite, (b) UV-Vis spectra of RB5 degradation with the effect of H_2O_2.[27]

Mahanthappa et. al. reported the CuS, CdS and CuSeCdS nanocomposite synthesized by hydrothermal method.28 The photocatalytic activities of the as-prepared materials have been evaluated by the degradation of methylene blue (MB) dye in the presence of hydrogen peroxide (H_2O_2) which used as an oxidant under visible light irradiation. MB dye (10 ppm) was degraded by about 80%, 59% and 99.97% for CuS, CdS and CuSeCdS nanocomposites respectively at 10 min. Figure 2-(a) and Figure 2-b show the degradation efficiency of MB in various amounts of CuSeCdS nanocomposites concentration and apparent degradation rate constant of various amounts of catalyst, respectively.[28]

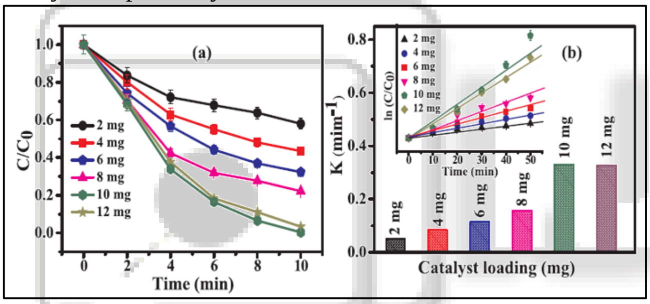

Fig. 2: (a) The degradation efficiency of MB in various amounts of CuSeCdS nanocomposite concentration and (b) The apparent degradation rate constant of various amounts of catalyst. [28]

Feng and his co-workers reported the synthesized of hydrophilic CNT-hybrid metal oxides (ZnO and TiO_2) membranes were prepared by atomic layer deposition. [29] The photocatalytic performance of the newly formed hybrid metal oxides on CNTs surface was enhanced by hindering the recombination of photo-induced electron-holes. Figure 3-(a) shows the proposed mechanism for the photo-degradation of MB by the hybrid metal oxides deposited carbon nanotube membranes.[29] The MB photo-degradation efficiency was significantly improved to ~99% by the (30ZnO + 30TiO_2) deposited CNT membrane after 100 min irradiation and the membrane could be reused for many times. UV–vis absorbance spectra of MB solutions before and after 100 min degradation with (ZnO+TiO2) deposited CNT membrane is shown in Figure 3-(a). Inset in Figure 3-(a) is the physical appearance of MB samples before and after photo-degradation.[29]

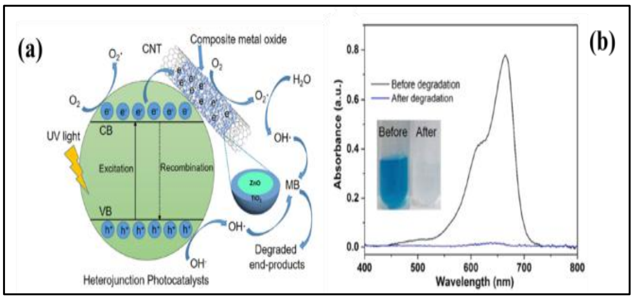

Fig. 3: (a) Proposed mechanism for the photodegradation of MB by the hybrid metal oxides deposited CNT membranes. (b) UV–vis absorbance spectra of MB solutions before and after 100 min degradation with (ZnO+TiO_2) deposited CNT membrane. Inset in (a) is the physical appearance of MB samples before and after photodegradation. [29]

Veisi et. al. reported the Silver nanoparticles decorated on thiol-modified magnetite nanoparticles (Fe_3O_4/SiO_2-Pr-S-Ag) as a nano-catalyst for degradation of organic dyes.30 The Figure 4-(a) shows the TEM images of Fe_3O_4/SiO_2-Pr-S-Ag nanoparticles. Fe_3O_4/SiO_2-Pr-S-Ag nanoparticles show high catalytic activity as recyclable nano-catalyst toward degradation of 4-nitrophenol (4-NP) (Figure 4-(b)), rhodamine B (RhB) (Figure 4-(c)), and Methylene blue (MB) (Figure 4-(d)) in the presence of $NaBH_4$ in water at room temperature with the help of UV–Vis spectroscopy, catalysis reactions were examined.

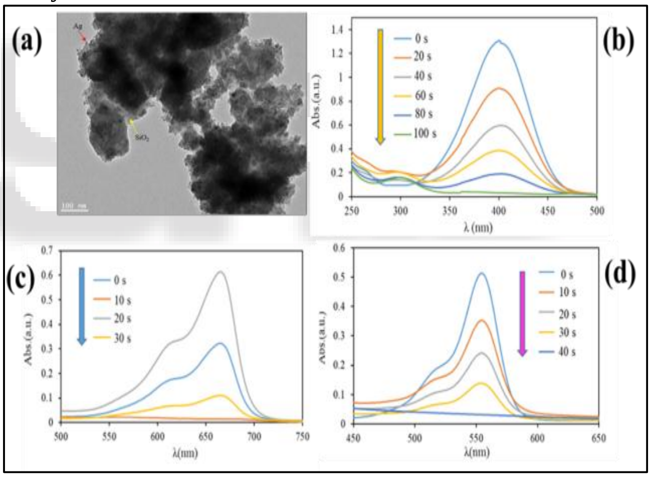

Fig. 4: (a) TEM image of Fe_3O_4/SiO_2-Pr-S-Ag nanocatalyst. (b) Time dependent UV–vis spectral 4-nitrophenol (c) Time dependent UV–vis spectral of MB (d) Time dependent UV–vis spectral of Rhodamine B.30

Wadhwani and his co-worker presented work based on decolorization of textile dyes such as direct black 22(DB) and reactive yellow 186 (RY) has been studied using sodium borohydride ($NaBH_4$) as a reducing agent and bacteriogenic gold nanoparticles as nano-catalysts. [31]

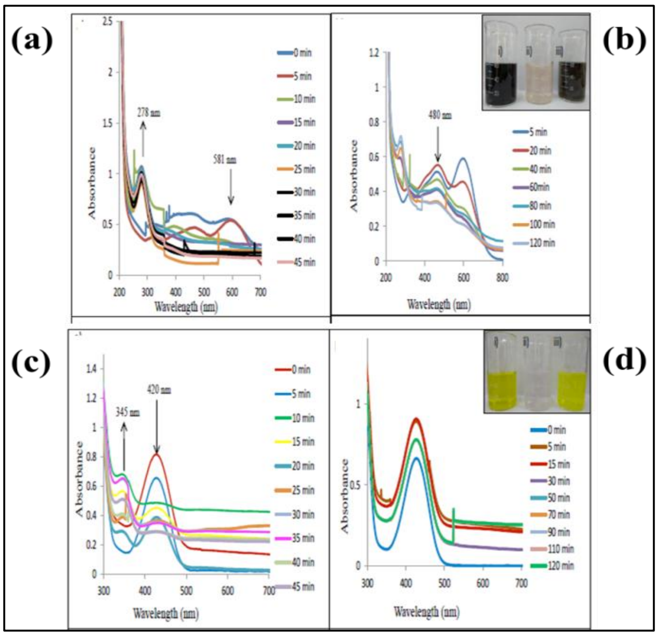

Fig. 5: UV-Visible absorbance spectra for decolourization of DB (a) with AuNP, (b) without AuNP, (inset : i) only DB , ii) DB+NaBH4+ AuNP, iii) DB+NaBH4) (c) UV-Visible absorbance spectra for decolourization of RY with AuNP, (d) without AuNP, (inset : i) only RY , ii) RY+$NaBH_4$+ AuNP, iii) RY+$NaBH_4$)[31]

The literature review, get more attention to consider the durability test of the nano-catalysts which explored and focusing only on the initial or fresh catalytic activity for dye degradation as well as remove the toxic substance in wastewater.

II. Conclusions

Organic dyes are the major pollutants present in industrial wastewater. It has effects on the environments and destructs the fora and fauna. The nano-catalyst is useful for the water purification. Here, we have summarized the low cost, highly efficient metal based as well as carbon-based nano-catalyst for the process of dye degradation. The degradation has lot of benefits over traditional wastewater treatment techniques such as chemical oxidation, activated carbon adsorption, biological treatment, etc. The nano-catalyst has the advance and faster process to remove the hazards dyes which are more applicable for environmental prevention.

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