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Review Article

NANOPARTICLES: IMPORTANT ROLE OF NANOTECHNOLOGY IN PHOTOCATALYST

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Abstract:

The purpose of this article is to provide an overview of the development and impact of nanotechnology in the field of photocatalysis. Topics include a detailed understanding of the unique properties of nanoparticles and their relationship to photocatalytic properties. Current applications and research on nanoparticles as photocatalysts are also reviewed. The use of nanoparticles in doping, bonding, capping, sensitization,and organic inorganic nanocomposite semiconductor systems to enhance the photocatalytic and/or optical properties of semiconductor materials is also covered. The use of nanocrystal films in electrochemically assisted photocatalytic processes is also covered. Finally, the use of nanoparticles contributes greatly to providing clear information about the photocata lytic process.

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BACKGROUND ON PHOTOCATALYST:

Industrial or municipal waste water Potentially polluting organic chemicals must be removed or destroyed before they are released into the environment. Such contaminants are also present in g roundwater and surface water and may require treatment to provide safe drinking water (Lindner et al., 1995). The in creasing public concern about these environmental contaminants has created the need for new treatment methods (Z eltner et al., 1996), and photocatalysis has gained widespread attention in the field of pollution abatement. Most of the clean water bodies in lagoons, lakes, streams, rivers and lakes are caused by sunlight, which causes the breakdown of organic molecules into simple molecules Eight and finally into carbon dioxide and other minerals. . products. There are many natural Sensitizers that can accelerate this process. The use of "colloidal semiconductors" and the introduction of catalysts to promote the redox process of semiconductor materials were established in 1976 (Kalyanasundaram, 1983). Since then, laboratory studies have shown that it can increase the efficiency of solar radiation in conventional solar panels (Matthews, 1993). A process that combines the catalysis step with solar energy technology (Zhang et al., 1994a). It has focused mainly on semiconductor photocatalysis of titanium dioxide. It Is used to clean water and air, as well as to solve many environmental problems.

The application of light emitting semiconductors to decompose unwanted organic matter dissolved in air or water is well documented and has been done with a variety of compounds (Hoffmann et al., 1995). Carboxylic acids, amines, herbicides and aldehydes are photocatalytically destroyed in laboratory and field studies. Photocatalytic processes can produce harmful chemicals such as carbon dioxide, water and simple inorganic acids (Ahmed et al., 1984). To remove toxins from wastewater. Current treatments for these pollutants, such as activated ca rbon adsorption and air stripping, focus only on the chemicals present, transferring them to adsorbents or air, but not to nontoxic waste. Therefore, one of the main advantages of the photocatalytic process over existing technologies is that no secondary disposal process is required. Nanotechnology is new and rising field of technology that deal at nanoscale much less than a hundred nm. From final century it becomes the sector of research since the first lecture Richard Feynman in 1959 on "There's lots at the bottom" (Reiss and Hütten, 2005) Nanotechnology furnished us ground-breaking consequences in every field of studies. Essentially, in nanotechnology we look at materials at nanoscale 109, substances at bulk scale show different homes and at nanoscale exclusive terrific homes, at nanoscale with length their floor to quantity ratio increase. This surface to volume ratio belongings in particular as a catalyst increase efficiency hundred percent in comparison to bulk materials. In power quarter, for hydrogen production in water splitting manner through using nanomaterials as a catalyst we will increase the performance of H2 production. In pollution, particularly for water pollution nanotechnology for smooth water is converting the business landscape in each the advanced and the growing global. Nanomaterial have awesome residences inclusive of image catalytic in nature, high floor region, noticeably reliable, high aspect ratio, electrostatic, compressible with out trade in floor region, tunable pore extent, magnetic, short intra-particle diffusion distance, hydrophobic and hydrophilic and so on. Excessive floor to volume ratio property of nanomaterials manage the interplay with micro organism and pollutant. Nanotechnology help us to solve the prevailing hassle of conventional water purification approach. Microbes in water are simply thousand nanometer small while everyday purifiers simply lead with bacteria purifiers using nanotechnology are able to cope with virus with out the use of any chemical, high temperature crushes and energy.

Photocatalyst

A ideal photocatalyst need to be stable, less expensive, Non-poisonous and, of direction, distinctly photoactive.

Some other Primary standards for the degradation of organic compound is that the redox capability of the H2O/•OH couple (OH− →• OH + e−; E0 = − 2.eight V) lies inside the Bandgap of the semiconductor (Hoffmann et al., 1995). Several semiconductors have bandgap energies sufficient for catalysing a wide variety of chemical reactions. Those consist of TiO2, WO3, SrTiO3, α-Fe2O3, ZnO And ZnS. TiO2, the semiconductor most very well investi-Gated within the literature, seems to be the most promising for photocatalytic destruction of natural pollution (Howe, 1998). This semiconductor gives the first class compromise among catalytic performance and stability. in an aqueous medium (Aruna et al., 1996). Anatas the titanium dioxide section is a material with a excessive is photocatalytic detoxification (Bahnemann et al.,1993). Binary metal sulfide semiconductors which includes CdS, CdSe or PbS are considered insufficiently solid for catalysis, at the least in aqueous media, as they're without difficulty subject to corrosion (Howe, 1998; Fischer,1989). these substances also are regarded to be toxic. Iron oxides aren't appropriate semiconductors tories due to the fact they without problems undergo photocathodic corrosion (Hoffmann et al., 1995). Band gap for ZnO (3.2 eV) same to anatase. however, ZnO is likewise risky in water, forming Zn(OH)2 on the particles floor. This effects in catalyst deactivation (Howe,1998).

Nanocrystalline photocatalyst

Nanocrystalline photocatalysts are ultrasmall semi Conductor particles that are a few nanometres in Size. At some point of the beyond decade, the photochemistry of Nano semiconductor particles has been one of the Quickest developing studies areas in bodily chemistry (Henglein, 1997). The interest in these small semi-Conductor debris originates from their precise photo physical and photocatalytic houses (Bahnemann,1993). Several overview articles were published concerning the photophysical residences of nanocrystalline Semiconductors (Henglein, 1988; 1989; Wang et al.,1991; Bahnemann 1993; Zeltner et al., 1996; Levy,1997). Such research have established that a few prop-Erties of nanocrystalline semiconductor debris are in Truth unique from those of bulk materials. Nanosized debris, with diameters ranging Between 1 and 10 nm, possess properties which fall Into the place of transition between the molecular And the majority phases (Bahnemann, 1993). In the bulk Material, the electron excited with the aid of mild absorption finds A excessive density of states inside the conduction band, in which It could exist with special kinetic energies (Henglein,1997). Within the case of nanoparticles however, the particle length is the same as or smaller than the scale of the First excited state. As a consequence, the electron and hollow generated upon illumination can't match into this kind of particle Unless they count on a country of higher kinetic power (Weller et al., 1995).

The essential size and changein properties due to nanosize

Quantum-length (Q-size) outcomes arise when the dimensions of The semiconductor debris end up smaller than the Bohr radius of the first excitation kingdom (Hagfeldt et al.,1995). This has been said with the aid of different authors as whilst The particle size of the colloidal particle will become comparable to the DeBroglie wavelength of the rate carriers (Henglein et al., 1987; Weller et al., 1995). There appears to be discrepancy among the suggested Crucial length below which quantization results are Observed. Many values had been quoted in the literature for the identical semiconductor nanoparticles. There Are also discrepancies between the predicted critical Diameter and the actual diameters at which quantization results are determined. These predictions Severely at the powerful loads of the charge vendors (Serpone et al., 1996). Kormann et al. anticipated the excitation radii for titania particles to be between 7.5 and 19 Å. The exciton Radii had been computed via using diverse literature values And calculated by way of the equation recommend by means of Brus (Kormann et al., 1988). Gratzel anticipated an excitation Radius of ~ three Å (Gratzel et al., 1989). Kormann et al. reported quantization outcomes with 20–40 Å titania particles. Qsize outcomes were observed At some stage in particle increase and at the final degree of synthesis Of those transparent colloids. The synthesized anatase TiO2 particles ended in a bandgap shift of zero.15 eV relative to bulk anatase TiO2 whilst the synthesized rutile TiO2, with d ~ 2.five nm, were blue shifted by way of zero.1 eV.

General Mechanism for Photocatalytic Reaction

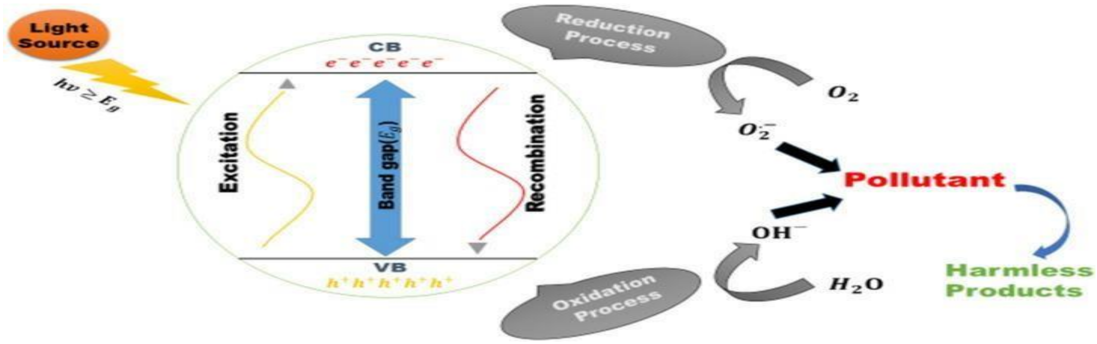
In photo-catalysis, a photograph catalyst is used. Reaction fee in particular relies upon at the crystal shape of catalyst and the electricity of incoming photons of visible or UV mild. As a catalyst which substances are used, they acts as a sensitizer for the irradiation of mild-inspired redox methods relying on their digital shape. Digital shape is defined by the filled valence and vacant conduction band. If the band gap of the catalyst is equal or less than the strength of incident light, the electrons living in valence band will soak up the photon and they may reach to the conduction band. Holes are left in valence band. They play the key function, Donor molecules are oxidized through these holes, also the hydroxyl (robust oxidizer) is produced when H2O react with these holes. Electron found in conduction band is absorbed with the aid of water to make superoxide ion, that is a reducing agent. So we can say that, this unfastened electron is causing redox reactions to occur. These pairs of free electrons and holes can carry out oxidation discount response with any material which comes in touch with the catalyst and convert it into the desired merchandise.

Oxidation Mechanism

When light is irradiated on the catalyst, electron hole pair is generated by the promotion of valance electron to the conduction band. The hole created on the catalyst captures water molecule to oxidize it into hydroxyl radical which has very strong oxidizing powers. If any organic pollutant is their react with these hydroxyls and then decomposes. If the whole process takes place in the presence of oxygen, than chain reactions takes place between organic molecule's intermediate radicals and oxygen molecules. The end product is CO_2 and H_2O in case of organic pollutant.

Reduction Mechanism

Reduction of atmospheric oxygen occurs in the form of pairing reaction. Oxygen is easily reducible, so its reduction is an alternative to production of hydrogen. The electrons of conduction band reacts with oxygen to form In photocatalytic reaction, oxidation and reduction reaction occur simultaneously. We need such kind of materials or those catalyst for photocatalytic reaction which support both oxidation and reduction reaction. In general, on the base of electronic properties, materials are divided in three basic categories conductor, insulator and semiconductor.superoxide ion. The anion can also attach themselves with the intermediate in oxidation reaction producing peroxides and then change into water. Reduction process can easily take place in Organic matter as compared to water. That's why, high concentration of organic matter enhances the photocatalytic activity by increasing the probability of number of holes which eventually reduces the recombination rate of the carriers as shown in Fig. 1 . In case of conductor, valence band and conduction band is overlap In photocatalytic reaction, oxidation reduction reaction in simultaneously. We need such kind of materials or those catalyst for photocatalytic reaction which support both oxidation and reduction reaction. In general, on the base of electronic properties, materials are divided in three basic categories conductor, insulator and semiconductor. In case of conductor, valence band and conduction band is overlap. For photocatalytic reaction necessary condition is oxidation and reduction simultaneously, but in conduction only free electron are available. Form conductor, we perform only oxidization reaction at a time not both reaction simultaneously. Best conductor are alkali, alkaline earth metals and transition metals. They have no suitable band gap or mostly they were overlap with each other in conduction and valence band. For catalytic activity they were not suitable for reaction. In case of insulator, they have high band gap then high energy required to perform oxidation and reduction reaction. We cannot split water molecule by using insulator as a catalyst or high energy is required. We need, that type of catalyst which activates in visible region or in the ultraviolet region. In case of semiconductor, which have moderate band gap and they have capabilities of oxidation and reduction perform or support simultaneously. When light falls, free electron hole pairs is generated. Necessary condition for a semi-conductor to be a photo-catalyst, is the low recombination rate. Moreover, those semiconductor whose absorption wavelength (350–700 nm) in visible region or band gap in (1.5–3.5 eV) suitable for photocatalytic activity. Because they perform catalytic activity in the visible light. Generally semiconductors have a wide range of band gap but for a photo catalyst of UV visible region, we require only 1.5–3.5 eV bandgap semiconductor. Metal oxide generally falls in this category. Metal oxides are very important for different electronic applications and in photo-catalysis. They full fill all of our requirements as a photo-catalyst. Metal oxides have auspicious light absorption, electronic structure, band gap and carrier transportation, which makes them suitable for this job. Most important and fundamental property a photo-catalyst should have, is its band gap. Band Gap should be in the range of UV–visible range for low cost. Other properties are stability of the structure. Morphology, reuse-ability, high surface area etc. Metal oxides for example oxides of chromium, zinc, vanadium, cerium and titanium have all these properties. So they are used as photo-catalysts. When photo-catalyst is exposed to the visible light, it absorbs the photon and electron in valance shell is excited the upper conduction band creating an electron and hole pair. This e−/h+ pair causes the redox reaction to occur on the surface of the metal oxide which decomposes the pollutants. On the bases of nanomaterials morphology, size, chemical and physical properties nanomaterials are classified in different categories such as carbon based, metal, ceramic, semiconductor and polymeric nanoparticles.



In carbon based nanoparticles divided into two main categories carbon-nanotubes and carbon-fullerenes. Carbonnanotubes (CNTs) are basically graphene sheet that are rolled in the form of tubes. Graphene tubes are hundred time stronger than steel. Furthermore, CNTs are further divided in single wall carbon-nanotubes (SWCNTs) and multiwall carbon-nanotubes (MWCNTs), these tubes have specific property thermally-conductive along the length wise while the insulator across the tube.

Application of photocatalyst

1 .Water Splitting

Photo catalysis can be applied for the production of hydrogen gas which is a potential energy source. Hence the energy extracted by this method is low cost and also it produces no harmful side products which could possibly pollute our environment. That's many researchers are working on this method of obtaining clean energy.

Factors affecting photo catalysts activity

Band gap energy Energy difference of conduction and valence band of Photo-catalyst or semiconductor metal oxide is represented by Band Gap (Eg). To make hydrogen evolution feasible, thermodynamic potential of conduction band should be higher than potential level of acceptor. Band gap is responsible for charge separation to reduce recombination rate and activity under a specific wavelength. General intentions are to decrease the band gap so that photo-catalyst can be activated in visible region. This will enhance the efficiency of hydrogen production.

Surface area/structure One method of lowering the band gap is by altering the surface texture of catalyst. Photocatalytic activity is also affected by the different Crystal structures and surface area. Larger surface area contains higher number of active sites increasing the likelihood of reaction to take place. Moreover, for small size particle, it is easy for photo electron and hole to reach the surface by traveling shorter distance decreasing the recombination rate.

Light intensity Intensity of irradiated light is a key factor for the photo-catalytic efficiency since it has two regimes. Generally, activity is improved by increasing intensity of irradiated light having energy approximately equal or greater than band gap energy or threshold energy because the rate of forward reaction i.e., consumption of photo electron and hole to form hydrogen and oxygen, is higher than the backward reaction.

Temperature Temperature enhances the photo-catalytic activity by facilitating the production of electron hole pair. At higher temperature, desorption of products from catalyst surface enhances the activity. Because it gives opportunity for more electron hole pairs to generate which are then utilized for oxidation and reduction reaction.

pH Hydrogen production by water splitting depends on concentration of proton i.e., pH of solution, because the photogenerated electron reduces proton. Mostly in reported paper production rate of H2 is basic medium is large as compared to acidic mostly H2 in strong basic medium is large (pH>10).

CONCLUSION:

This article reported history of photocatalytic activity their importance in different application and role in current pollution and energy crises. Photocatalytic process initiate under the light and catalyst, nanomaterials are best suitable photo-catalyst for photocatalytic activity, in nanomaterials most efficient photo-catalyst are semiconductor due to their remarkable photocatalytic activity and wide band gap in visible region because our focus is cost effective and environmental friendly photo-catalyst. In energy sector, H2 production from photocatalytic technique becomes emerging and efficient technique in current situation. In pollution related problem, photocatalytic technique is cost effective, environmental friendly and most efficient approach against organic, inorganic, heavy metal and microbe's pollutant.

REFERENCES:

1. Bagabas A., et al. Room-temperature synthesis of zinc oxide nanoparticles in different media and their application in cyanide photodegradation. Nanoscale Research Letters. 2013;8(1):516.
2. Bai X., et al. Enhanced oxidation ability of g-C3N4 photocatalyst via C60 modification. Applied Catalysis B: Environmental. 2014;152:262–270.
3. Baruah S., et al. Enhanced visible light photocatalysis through fast crystallization of zinc oxide nanorods. Beilstein Journal of Nanotechnology. 2010;1(1):14–20.
4. Chong M.N., et al. Application of H-titanate nanofibers for degradation of Congo Red in an annular slurry photoreactor. Chemical Engineering Journal. 2009;150(1):49–54.
5. Chu D., et al. Formation and photocatalytic application of ZnO nanotubes using aqueous solution. Langmuir. 2010;26(4):2811–2815.
6. Dubey P.K., et al. Synthesis of reduced graphene oxide–TiO2 nanoparticle composite systems and

its application in hydrogen production. International Journal of Hydrogen Energy. 2014;39(29):16282–16292.
7. Fajrina N., Tahir M. A critical review in strategies to improve photocatalytic water splitting towards hydrogen production. International Journal of Hydrogen Energy. 2019;44(2):540–577. [Google Scholar]
8. Giannakis S., et al. Iron oxide-mediated semiconductor photocatalysis vs. heterogeneous photo-Fenton treatment of viruses in wastewater. Impact of the oxide particle size. Journal of Hazardous Materials. 2017;339:223–231. [PubMed] [Google Scholar]
9. Gogniat G., et al. The bactericidal effect of TiO2 photocatalysis involves adsorption onto catalyst and the loss of membrane integrity. FEMS Microbiology Letters. 2006;258(1):18–24. [PubMed] [Google Scholar]
10. Hafez H.S. Highly active ZnO rod-like nanomaterials: Synthesis, characterization and photocatalytic activity for dye removal. Physica E: Low-Dimensional Systems and NanostructuBahnemann D.W., D. Bockelemann, R. Goslich, M. Hilgendorf
11. Chan S.H.S., et al. Recent developments of metal oxide semiconductors as photocatalysts in advanced oxidation processes (AOPs) for treatment of dye waste-water. Journal of Chemical Technology & Biotechnology. 2011;86(9):1130–1158. [Google Scholar]
12. Danwittayakul S., et al. Enhancement of photocatalytic degradation of methyl orange by supported zinc oxide nanorods/zinc stannate (ZnO/ZTO) on porous substrates. Industrial & Engineering Chemistry Research. 2013;52(38):13629–13636. [Google Scholar]
13. Di J., et al. Novel visible-light-driven CQDs/Bi2WO6 hybrid materials with enhanced photocatalytic activity toward organic pollutants degradation and mechanism insight. Applied Catalysis B: Environmental. 2015;168:51–61. [Google Scholar]
14. Elsabahy M., Wooley K.L. Design of polymeric nanoparticles for biomedical delivery applications. Chemical Society Reviews. 2012;41(7):2545–2561. [PMC free article] [PubMed] [Google Scholar]
15. Gamage J., Zhang Z. Applications of photocatalytic disinfection. International Journal of Photoenergy. 2010;2010 [Google Scholar]
16. Pham T.-D., Lee B.-K. Novel adsorption and photocatalytic oxidation for removal of gaseous toluene by Vdoped TiO2/PU under visible light. Journal of Hazardous Materials. 2015;300:493–503. [PubMed] [Google Scholar]
17. Prasad G., et al. Photocatalytic inactivation of Bacillus anthracis by titania nanomaterials. Journal of Hazardous Materials. 2009;165(1–3):506–510. [PubMed] [Google Scholar]
18. Ren H., et al. Photocatalytic materials and technologies for air purification. Journal of Hazardous Materials. 2017;325:340–366. [PubMed] [Google Scholar]
19. Roy K., Sarkar C., Ghosh C. Photocatalytic activity of biogenic silver nanoparticles synthesized using potato (Solanum Tuberosum) infusion. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy. 2015;146:286–291. [PubMed] [Google Scholar]
20. Saif M., et al. Evaluation of the photocatalytic activity of Ln3+–TiO2 nanomaterial using fluorescence technique for real wastewater treatment. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy.2014;128:153–162. [PubMed] [Google Scholar]