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A Review on Conversion of Nanoparticles in to Photocatalysts

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ABSTRACT

One popular method for enhancing the photoactivity of semi-conductor nanomaterials is impurity doping, which does so via improving photon-capture effectiveness in the visible light spectrum. In the current study, different nanoparticles are used to break down the water's hazardous contaminants. Various microscopes and scanners are used to adapt semi-conductive materials with large band gaps and binding energies. This allows the materials to respond to light absorption and function as a photo-catalyst, although the pure materials have specific restrictions on light absorption and can only intensify pollutants to a limited extent. As a result, different 3D metals are doped into semi-conductive materials utilizing diverse chemical processes to enhance or remove hazardous contaminants from water efficiently. Doping with impurities is one of the usual methods.

Keywords: Photo-catalyst, semi-conductor, Photon-capture efficiency, 3d metals

1.Introduction

In this study, we focus on the literature related to conversion of Nanoparticles in to photo-catalysts and especially on various methods that were used for the synthesis of nanomaterials. It includes doping of different reactive metals in distinct nanoparticles for converting them in to a photo-catalyst.
Humans depend on water for survival, and as the need for clean, safe drinking water grows, there is growing interest in using nanoscale semiconductors in photocatalytic oxidation to remove hazardous pollutants. By providing a variety of strategies, including biodegradation, recycling, preventing corrosion, and treating industrial waste, nanotechnology plays a significant part in preserving the environment. With a wide range of uses, including light-emitting devices, spintronics, transparent conductive oxides, and UV light blockers, oxides are an essential semiconducting material. Our goal is to use nanoparticles to illustrate the difficulties in acquiring convincing proof of successful crystal doping. Due to the wide band gap energy of these materials, valence electrons can be excited onto the conduction band by UV radiation.
For synthesis, dielectric, piezoelectric, and broad band gap nanoparticles are used. To increase the effectiveness of energy transfer processes, semiconductors can be enhanced using rare-earth ions. There are numerous papers that claim the doping of third-dimensional metals can enhance the magnetic and optical properties of nanoparticles.

2.Methods

2.1.Sol-gel Method

Sol-gel method is a wet chemical method, for material preparation under mild condition, of solidifying a compound containing a highly chemically active component through a solution, sol, or gel, and then heat-treating an oxide or other compound. It is used for synthesis of various nanostructures,especially metal oxides nanoparticles.It involves the *production of a homogeneous sol from the precursors and its conversion into a gel*. The solvent in the gel is then removed from the gel structure and the remaining gel is dried. The process is shown in figure 2.1

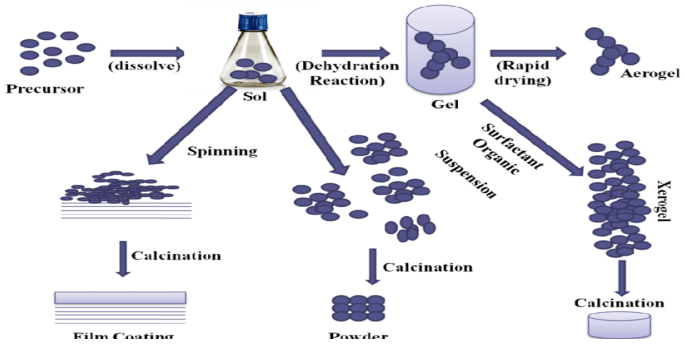

Figure-2.1. Sol-gel method

2.2.High energy ball mill method

High-energy ball milling is a mechanical deformation process that is frequently used for producing nanocrystalline metals or alloys in powder form. This method consists of balls, a mill chamber containing silicon or tungsten carbide ball that are rotating inside the mill(drum). The powder of a material is taken inside the container and made in to nanosized using the ball mill technique. A magnet is placed outside the container to provide the pulling force to the material and this magnetic force increases the milling energy when milling container or chamber rotates the metal balls. The ball to material mass ratio is normally maintained at 2:1 ratio. The conversion of pure nanoparticles to synthesized nanoparticles were described in figure 2.2

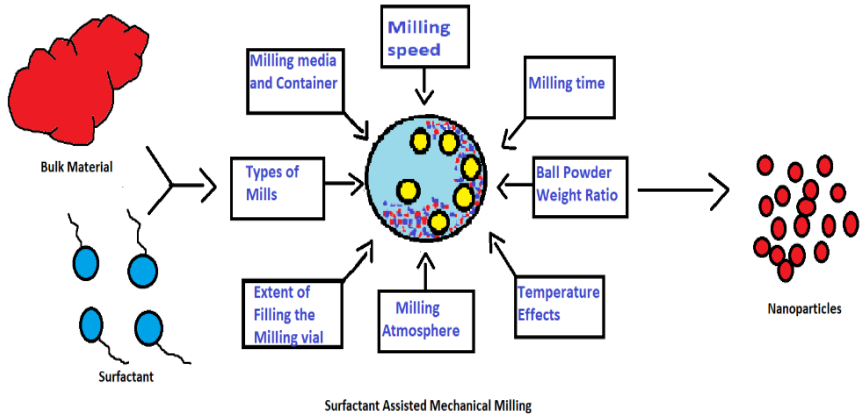

Figure-2.2. Ball milling method

2.3.Hydrothermal method

Hydrothermal synthesis is one of the most commonly used methods for preparation of nanomaterials. It is basically a solution reaction-based approach. In hydrothermal synthesis, the formation of nanomaterials can happen in a wide temperature range from room temperature to very high temperatures. This technique uses a special instrumentation called Hydrothermal Autoclave Reactor.Hydrothermal synthesis is one of the most commonly used methods for preparation of nanomaterials. It is basically a solution reaction-based approach. In hydrothermal synthesis, the formation of nanomaterials can happen in a wide temperature range from room temperature to very high temperatures. This technique uses a special instrumentation called Hydrothermal Autoclave Reactor. The autoclave reactor consists of thick and steel-walled cylindrical vessels having hermetic sealing. The material was dissolved in water and then the solution was stirred and second material was added to solution until complete dissolution to from a clear solution, after that aqueous solution was added drop wise until precipitate was obtained. And then hydrothermal treatment was carried out at required temperature and the solution was cooled and the precipitate was harvested by centrifugation and dried. The hydrothermal method was shown in the figure 2.3.

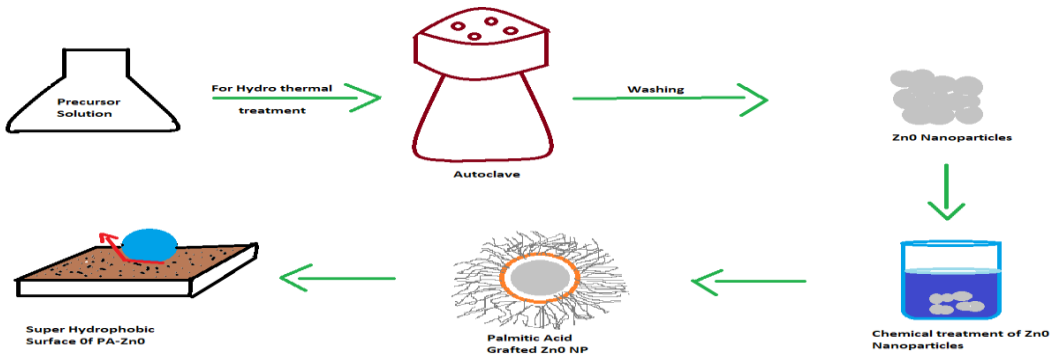

Figure-2.3. Hydrothermal method

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1.4 Dip-Coating

Dip coating is an industrial coating process which is used, for example, to manufacture bulk products such as coated fabrics and condoms and specialized coatings for example in the biomedical field. Dip coating is also commonly used in academic research, where many chemical and nano material engineering research projects use the dip coating technique to create thin-film coatings. The nano particles synthesized using dip coating was show in the figure 2.4

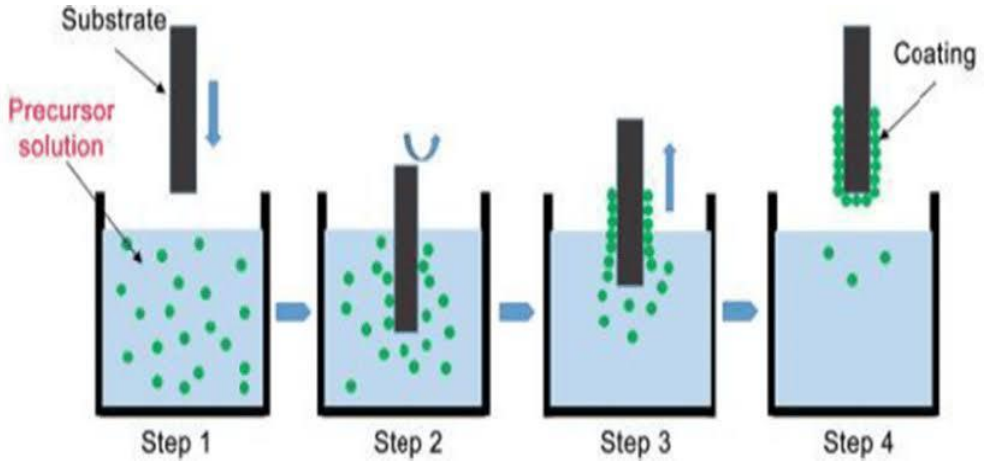

Fig-2.3. Hydro thermal metho

4. Results and Discussions

4.1 Metals doped Zn0 nanoparticles

The photo catalytic activity and absorption capacity of Zn0 nanoparticles were improved by doping the following metals that are discussed below,

4.1.1 Mn doped Zn0 nanoparticles

Manganese doped Zinc oxide nanoparticles were synthesized using sol-gel method. It was found that the nanoparticles size was reached to 30µm and reacts to visible light 70% more than the undoped particles. The shift in wave length was shown in the figure 2.1, the grain size of nanoparticles was increased from (1µm to 30µm) as agglomeration of Mn increases by 15%. Due to this, particles degrade the dyes more effectively. The band gap increased from 3.35eV nanoparticles to 3.42eV when the absorption spectra was shifted towards lower wavelength. As the band gap increases the nan0material's reacts efficiently to the sun light. Hence the modified nanoparticles can be used as photo catalysts to removes the toxic pollutants present in water [1].

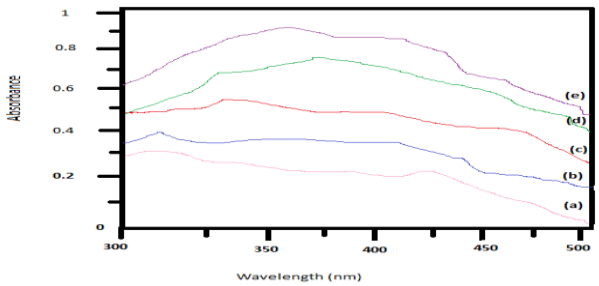

Figure .4.1. Increase in the band gap in Kev

4.1.2 Fe doped Zn0 nanoparticles

The Fe doped Zn0 nanoparticles are prepared using high energy ball milling technique. It was observed that there is improvement in photocatalytic activity as there is a 98.7% extreme degradation of methylene blue dye under sun light due to milling for 40 hrs. and the crystalline structure changed as the band gap was reduced to 2.55eV. The photocatalytic activity of the nanoparticles was shown in figure 2.2, Fe doped Zn0 is shifted to higher angles due to ionic difference of Zn (~0.74 Å) and Fe (~0.64 Å). As the nanoparticles were shifted, they absorb more visible light. The crystal size gradually decreases from 0 h (~90 nm) to 40 h (~25 nm) by taking equal intervals of ball milling and the reduced crystalline size helps in degradation of dyes effectively.Therefore, the enhanced photo-catalyst abolish the inorganic dyes present in the water [2].

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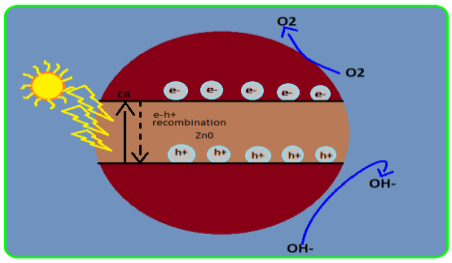

Figure .4.2. Photocatalytic activity of nanoparticles

4.1.3 Co doped Zn0 nanoparticles

Cobalt doped Zinc oxide nanoparticles were developed using Hydro-thermal method. The results show that the band gap of nanoparticles was reduced from 3.20 eV to 3.11 eV and the peak was up to 300nm in the ultraviolet region. The changes in the particles were shown in figure 2.3, also the synthesized nanoparticles degrade 20% Methyl orange in 60min. The photocatalytic activity was improved as the diameter of co doped Zn0 nanowires is increased to 200nm. The absorption capacity was improved due to concentration of Co and recombination of photo-excited electron hole pairs which separates the photo generated charge carriers. Finally, the mutated nanoparticles help in reducing the pollutants in the water [3].

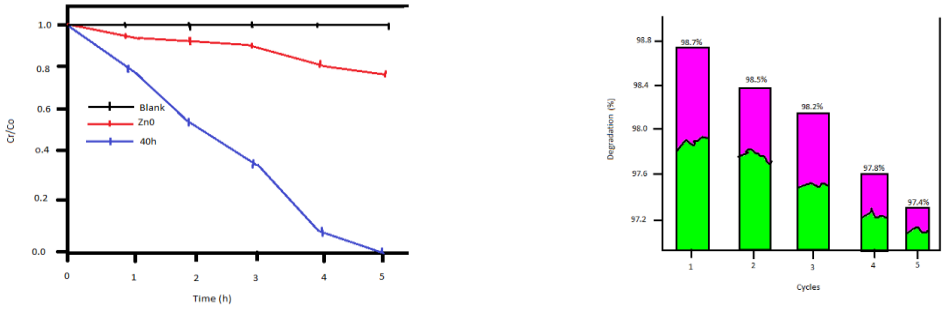

Figure. 4.3. Changes in Zn0 nanoparticles by doping Fe

4.1.4 Cr doped Zn0 nanoparticles

Chromium doped Zn0 nanoparticles were successfully synthesized by eco-friendly and cost-effective sol–gel technique. It was observed that the chromium doped zinc oxide nanoparticles were found to give enhanced photo degradation efficiency (75.5 %) than the pure zinc oxide nanoparticles (51.2 %). The absorption capacity of the particles is shown the figure 2.4, crystalline size is decreased to 24nm by 3% doping concentration of Cr and as the size is reduced the photocatalytic efficiency is increased. The absorption spectrum was decreases with increase in exposure time from 0 to 180 min which degrades the 75.5% 0f methylene blue. So, it was concluded that the reoriented Zn0 nanoparticles works as a photo-catalyst to remove the pollutants in water [4].

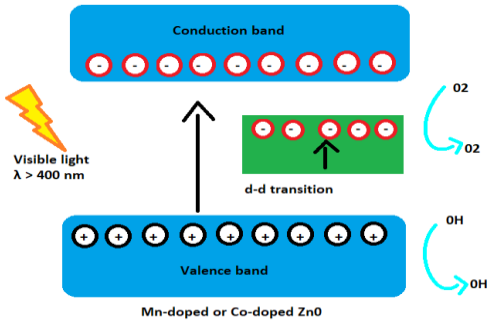

Figure.4.4. Absorption UV light

4.1.5 Cu doped Zn0 nanoparticles

Copper doped Zinc oxides have been synthesized using microwave assisted method. Through experimentation it was found that the particles vary between 20 to 35 nm and exhibits a catalytic activity of 89.9% than the pure once. The grain size was increased to 35nm with higher dopant concentration so the nanoparticles act as a antibacterial against the bacteria. The degradation and increase in particle size was shown in figure 2.5 and 2.6, wavelength was recorded between 350 to 800 nm as there is a growth in crystalline size which helps in absorption of UV spectra. From the investigation, it confirms that Cu-Zn0 Nanoparticles with higher dopant (0.03%) concentration acted as efficient catalyst and antibacterial which can be used for eliminating the toxic pollutants and bacteria from the water [5].

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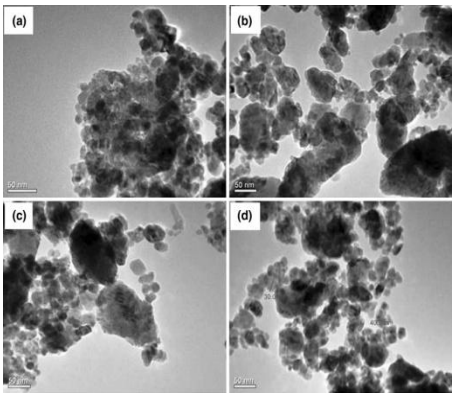

Figure. 4.5. Degradation of methylene

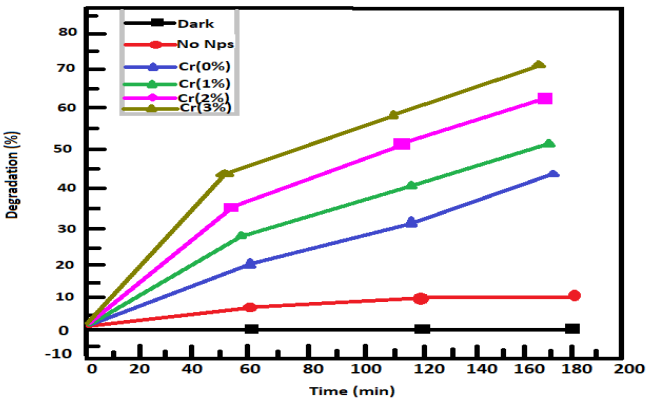

Figure. 4.6. Increase in Particle size

4.1.6 Y doped Zn0 nanoparticles

Yttrium doped Zn0 nanoparticles were prepared using micro-wave assisted method. The material used is nanoflower like structure for doping. It was observed that there is a blue shift when exposed to UV radiation and there is increase in photocatalytic degradation efficiency using nanoflowers like structures. Due to high peak rise in the particle size from 489 nm and 520 nm as there are emissions because of oxygen vacancies the nanoparticles have high intensity of light absorption. The peak position was described in figure 2.7, as the concentration of Yttrium is increasing the degradation of methylene blue dye also increasing. Therefore, Yttrium doped Zinc oxide nanoparticles has high degradation efficiency and there is high absorption intensity [6].

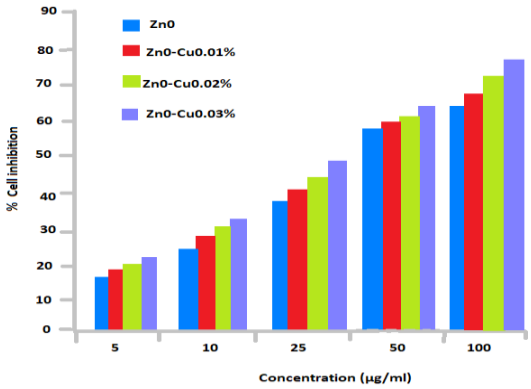

Figure.4.7. Increase in concentration and peak positions of Cu and Zn0

4.1.7 Ni doped Zn0 nanoparticles

The Nickel doped Zinc oxide nanoparticles were synthesized using wet chemical approach. The study showed that there is a significant hypochromic shift due to quantum confinement effect and the band gap also tuned to the region of lower wavelength and the crystals have hexagonal from. The degradation of methyl blue rates high. As the particles are exposed to sun light the photo excitation process in a specific wavelength has reached to range of 398nm-776nm with the distortion of lattice. Size distribution of particles is shown in figure 2.8. The degradation of methyl blue has increased from 40.65% to 79.35% as the concentration of OH− radicals and oxygen species are radicals. Hence the there is a high-rate degradation and the photocatalytic efficiency also increased [7].

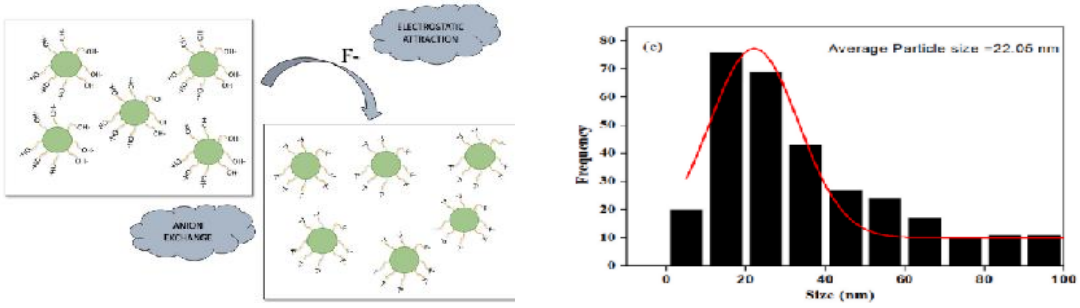

Figure .4.8. Size distribution and Adsorption mechanism of Al doped Zn0 nanoparticles

4.1.8 Ce doped Zn0 nanoparticles

Ce doped Zn0 nanoparticles were synthesized by the wet chemical solution route. It was found that there is higher angle peak shift and also decrease in both length and diameter of particles. The band gap has been reduced and there is a significant increase in dielectric constant. The nanoparticles size is in the range of 80-120nm and 16-20nm because higher peak shift. The Degradation of methylene blue increase in concentration was shown in figure 2.9, band gap reduced to 3.22ev to 3.08eV due absorption of UV rays. From the results, it concludes the Ce doped Zn0 nanoparticles with high peak shift and low band gap have more light absorption capacity [8].

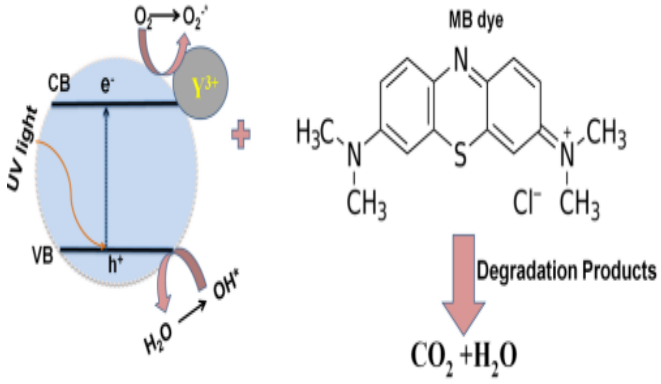

Figure. 4.9. Degradation of methylene blue increase in concentration of Y ion

4.1.9 Ag doped Zn0 nanoparticles

Ag doped Zn0 nanoparticles are prepared by Hydrothermal method. The results show that the degradation rate has increased to 46.6% in 30 mins and there is a significant photocatalysis. Wave length shift and hysterics was shown in figures 2.10 and 2.11. There is high photocurrent generation of 206 nA has the concentration of Ag increases. Mo is degraded at 40.6% rate under UV irradiation with the high reaction rate of 0.01746 min. The study reveals that the Ag doped Zn0 nanoparticles can used as an excellent photocatalyst. [9]

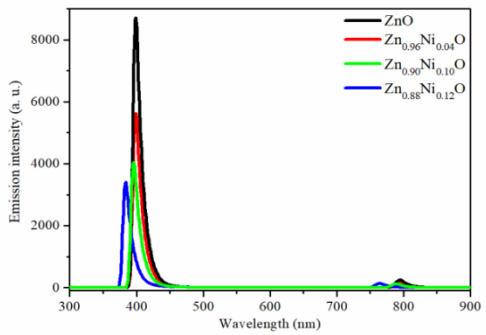

Figure.4.10. Wave length shift

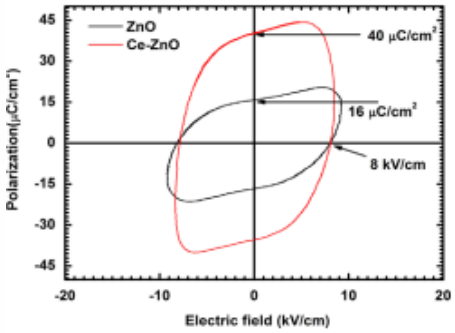

Figure. 4.11. Hysteresis loop of Zn0 and Ce

4.1.10Al doped Zn0 nanoparticles

Aluminum doped Zinc oxide nanoparticles were synthesized by sol-gel method. The study confirms that the particle removal rate is increased and the adsorption capacity is also improved and there is a interaction between particles and adsorbent. The capacity of nanoparticle is increased to 110 mg/g due to defluorination efficiency. The Photo-catalytic mechanism of Ag doped Zn0 nanoparticle is shown in figure 2.12, and removal rate also raised to 76% as the regeneration of adsorbent has increased. Therefore, the doped nanoparticles have high pollutant removal rate it can be used as an efficient photocatalyst [10].

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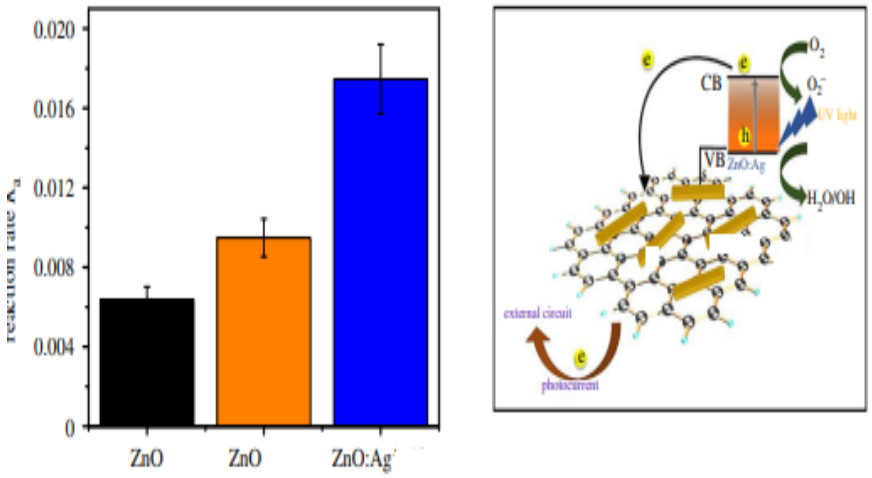

Figure. 4.12. Photo-catalytic mechanism of Ag doped Zn0 nanoparticle

Table. 1. Metals Doped Zn0 Nanoparticles

S.NO	MATERIALS	OPTIMIZATION	PARTICLE SIZE	PERCENTAGE OF RISE	METHODS
1.	Manganese (Mn)	Concentration of Manganese	1µm - 30µm	70%	Sol-gel
2.	Iron (Fe)	40 hrs. of ball milling	~25 nm	98.7%	High-energy ball milling
3.	Cobalt (Co)	Recombination of Of photo-excited hole pairs	200nm	65%	Hydro-thermal
4.	Chromium (Cr)	0 to 180 min exposure to sun light	24nm	75.5%	Sol-gel
5.	Copper (Cu)	High absorption of UV spectra	0nm - 35nm	89.9%	Micro-wave assisted
6.	Yttrium (Y)	High intensity of UV radiation	489nm-520nm	60%	Micro-wave assisted
7.	Nickel (Ni)	Distortion of lattice due to specific wavelength	398nm-776nm	79.35%	Wet chemical approach
8.	Cerium (Ce)	High peak shift	80nm-120nm in length and 16nm-20nm in dia	85%	Wet chemical solution route
9.	Silver (Ag)	High photo-current generation	0nm -54nm	40.46%	Hydro thermal
10.	Aluminum (Al)	Defluorination efficiency	0nm - 45nm	76%	Sol-gel

5.Conclusion

From literature it is well known that the nanoparticles having wide and direct band gap material has been shown to demonstrate photocatalytic activities. The doping of nanoparticles given promising results for degradation of organic dye with visible light irradiation when used as suspended colloids. The results conclude that the nanomaterials can be used as immobilized photocatalysts for water and environmental detoxification from organiccompounds, inorganic compounds like arsenic and bacteria. The developmentof such photocatalysts may be considered a breakthrough in large-scale utilization of heterogeneous photocatalysis via visible light to address water contamination and environmental pollution.

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