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# Recent Advances in Cadmium Sulfide (CdS)-Based Photocatalysts

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**Abstract**

Organic compounds from different industries produce a range of problematic pollutants in wastewater. Cadmium sulfide (CdS) based photocatalyst as a typical photocatalytic material, due to its high efficiency and stability, shows great potential in the field of environmental restoration, which has strong visible light absorption, suitable band energy level and excellent electron charge transport performance. Research on degradation of organic pollutants using cadmium sulfide (CdS) based photocatalyst has made significant progress. In order to improve the rate and ability of cadmium sulfide (CdS) based photocatalyst to degrade pollutants, this paper introduces various strategies to modify the shape and structure of photocatalyst to improve its performance. In addition, the reaction conditions were optimized, and the mechanism of photocatalytic degradation was discussed. In conclusion, the research of cadmium sulfide based photocatalysts provides valuable insights for the degradation of organic pollutants and offers hope for future application in ecological environmental protection.

**Keywords:** photocatalysts, CdS, environmental restoration, pollutants, organic compounds

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## 1. Introduction

In the process of industrialization and modernization, organic pollutants are discharged into water bodies through plastic dyes, organic pesticides and other substances in industry and agriculture in the form of wastewater. Energy use is still dominated by oil, coal and natural gas, and the scarcity of energy resources caused by the use of large quantities of fossil fuels is also causing huge organic environmental pollution, and the development of new clean energy has become a new development goal. Solar energy relies on its own high-radiation energy and near-inexhaustible advantages to become the best renewable resources, and how to store and use solar energy effectively has become a subject of concern to scientists (Savio et al., 2015).

Photocatalytic technology is based on semiconductor materials to convert light energy to chemical energy under the excitation of light, which can be converted into hydrogen energy, or can be directly used to catalyze the degradation of pollutants. Photocatalytic technologies do not require the addition of external oxidants or reducing agents compared to traditional physical and chemical biological methods, which are now recognized as new environmentally friendly clean energy sources in the world. Photocatalytic decomposition of water to produce hydrogen has been observed on titanium dioxide electrodes by Fujishima and Honda since 1972 (Fujishima et al., 1972), photocatalytic technology has achieved a great deal of research under continuous research and exploration (Watanabe et al., 1977; Darwent et al., 1981; Eggins et al., 1988). Using semiconductor materials, low-density solar energy can be converted into high-density chemical energy for the treatment of environmental wastewater and degradation of organic pollution, but it is still not mature enough. The contradiction between the low conversion efficiency of solar energy and the reaction rate of catalyst and the actual application requirements needs to be solved.

CdS is an important semiconductor material with high sensitivity to light, high absorption coefficient in visible light range and excellent optical properties. The energy band structure of CdS gives it wide forbidden bandwidth (Sapountzi et al., 2018). At the same time, high absorption coefficient, can achieve the efficient conversion of visible light, which makes CdS as one of the important materials for the preparation of high-efficiency solar cells, photoelectric devices and photocatalytic devices. CdS also has excellent electrical properties, conductivity and high carrier mobility and low carrier composite rate. The carrier consists of free electrons inside the material and the vacancies and holes left behind. CdS can absorb light energy and produce electron-hole pairs, which can improve the photoelectric conversion efficiency (Yang et al., 2013). It is found that CdS can be used to degrade organic pollutants. In this paper, the effect of CdS based photocatalyst on degradation of organic pollutants is discussed.

## 2. Preparation of CdS Based Photocatalyst

### 2.1 Solution Method

The synthesis mechanism of CdS is an important task in the study of CdS formation process and its reaction mechanism (Jie et al., 2024). In studying the synthesis mechanism of CdS, the basic properties, crystal structure and physical properties of CdS were studied (Qiaoqiao et al., 2021). Common methods for synthesizing CdS are solution, hydrothermal and template. Solution method is one of the most commonly used synthetic methods due to its convenience and efficiency. In solution, cadmium salt and sulfide are first dissolved in the appropriate solvent (Tang et al., 2019), and then by adjusting the reaction temperature and reaction time conditions, cadmium ions react with sulphur ions to produce CdS.

### 2.2 Hydrothermal Method

In hydrothermal processes, a moderate amount of CdS precursor and solvent is added to the high-pressure container (Lyell, 1855) and then reacted at high temperature and pressure (Lang et al., 2015). In the process of hydrothermal reaction, the solvent acts as a catalyst to increase the reaction rate and purity of the product. At the same time, temperature and pressure control also have an important impact on the results of the reaction. By rationally adjusting the temperature and pressure, the size and shape of the crystal can be controlled to obtain excellent performance of CdS materials.

### 2.3 The Template Method

The template method is the method of using nanoparticle precursor material with a certain morphological structure as the template to add the reaction material to the template and then remove the template by a specific method (physical or chemical) (Qi et al., 2015). Template and no-template methods are defined by whether the experimental process uses nanomaterials as templates. In addition, the template method is divided into hard template method and soft template method. In experiments to synthesize CdS materials, the template method is commonly used to synthesize CdS hollow structures (Mondal et al., 2007). The main factors influencing the synthesis result are the choice of the template, followed by the environment, reaction temperature, reaction time and other external factors.

In order to improve the efficiency and success of synthesis, we need to understand the reaction conditions and factors in the synthesis of CdS, which is a key and indispensable factor in the synthesis of CdS. Generally speaking, the higher reaction temperature facilitates the process of the reaction, but excessive temperature can lead to product instability during the reaction (Pai et al., 2022). In addition, the reaction time and the molar ratio of the reactants can also influence the properties of the synthetic products. Under certain conditions, the reaction time and the molar ratio of the regulating reactants can be extended properly, and the purer and more crystalline CdS can be obtained. The study of the synthesis mechanism of CdS is important for understanding the formation process and reaction mechanism of CdS (Xingang et al., 2022). By exploring the reaction conditions and influencing factors, we can optimize synthesis methods, improve the quality and performance of synthetic products, and provide a better basis for the application of CdS in various fields.

## 3. Common CdS Photocatalytic Degradation of Organic Pollutants

### 3.1 Organic dyes

Organic dye is a common dye type, widely used in textile, printing, dyeing and other industries (Alegbe et al., 2024). As a result, environmental and health threats resulting from the use and release of organic dyes are serious-large quantities of wastewater and exhaust gas from production processes can destabilize the ecological balance (Rania et al., 2022), lead to deterioration of water quality, affect the survival and reproduction of aquatic organisms and potentially trigger climate change; Some organic dyes and their metabolites may be ingested by skin contact, inhalation or ingestion, and are considered to have carcinogenic, teratogenic, and mutagenic potential (Alegbe et al., 2024). How to handle excess organic dyes and reduce the impact of harmful substances on people's daily lives and other organisms has received great attention.

### 3.2 Pesticides

Pesticides are chemicals used to control crop pests and diseases. However, the use of pesticides may lead to residual pesticide residues in crops and foods, known as pesticide residues or agro residues. These pesticide residues may be derived from the spraying of farmland, the application of medicines during planting, the use in storage and transport, and the addition of agricultural products during processing. Long-term exposure to pesticide residues can cause chronic toxicity in the human body, including effects on the nervous system, endocrine system and immune system (Hassaan et al., 2020). In short, controlling pesticide residues is essential for food safety and environmental health.

### 3.3 Organic Solvents

Common organic solvents include ethanol, acetone, xylene, ethyl acetate, methanol, etc. These organic solvents consist mainly of carbon and hydrogen elements and can dissolve many organic compounds, including fats, resins, oils and most plastics, because of their excellent physical properties, they are widely used in industrial processes such as paints, coatings, cleaners and adhesives. They are often well soluble, volatile and stable and are widely used in chemical reactions, dissolution and extraction. However, due to the volatility and toxicity of organic solvents, there is also a risk of leakage and harm to personal and environmental health.

### 3.4 Volatile Organic Compounds (VOCs)

VOCs are organic compounds with high vapor pressure at room temperature. They can evaporate from liquid or solid matter and are present in the atmosphere as gases and are often a major component of air pollution (Siwen et al., 2023). They are precursors to photochemical reactions and can be involved in the formation of ozone and fine particulate matter, negatively affecting atmospheric quality. In addition, VOCs can cause harm to human health, such as respiratory irritation, allergic reactions, headaches, eye tingling and poisoning. In addition, there are a wide range of sources of VOCs, including industrial processes, chemical production, combustion processes, solvent use, automotive exhaust, paints, cleaners, furniture and building materials.

In summary, the problem of these organic pollutants needs to be solved urgently and requires a range of measures. CdS based photocatalysis can be used to solve the problem of organic pollutants and protect the environment and human health. It should be noted, however, that CdS photocatalysis is not effective for all pollutants and its effects depend on factors such as the type, concentration and environmental conditions of the pollutants (Irshad et al., 2024). In addition, CdS photocatalysis technology is still in the research and development stage and may require further optimization and research on some specific contaminants (Lei et al., 2023) (Figure 1).

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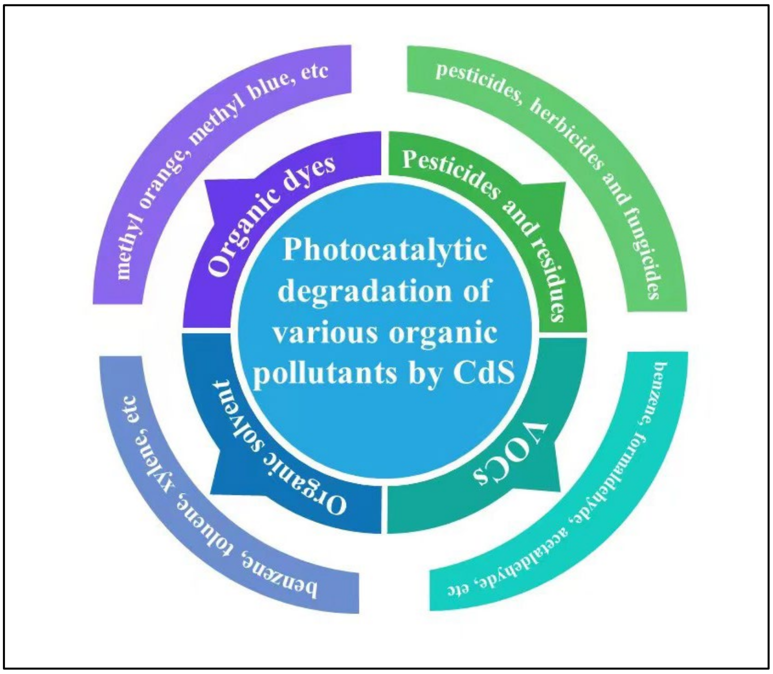


**Figure 1**. Illustration of organic pollutants in wastewater

## 4. Mechanism of Degradation of Pollutants in CdS

In general, photocatalytic degradation can be divided into two different pathways. First, some pollutants (e.g., organic dyes, pesticides and concentrations, organic solvents, volatile organic compounds) can be excited by absorbing light energy, and then photoelectrons on the excited pollutant molecules are transferred to energy-level matching photocatalysts. These electrons are then adsorbed on $O_2$ on the surface of the photocatalyst, resulting in a variety of reactive oxygen species, thereby facilitating the degradation of organic pollutants (Figure 2). Notably, photocatalytic degradation of organic pollutants is usually performed under aerobic conditions. Oxygen can improve the photocatalytic activity of the system by capturing photoelectrons and converting them into super aerobic radicals. Under the action of light, electrons transition from the valence band to the guide band, while the valence band of the photocatalyst creates a void with strong oxidation. As a result, these holes can chemically react directly with organic pollutant molecules, transforming them into more harmless products.

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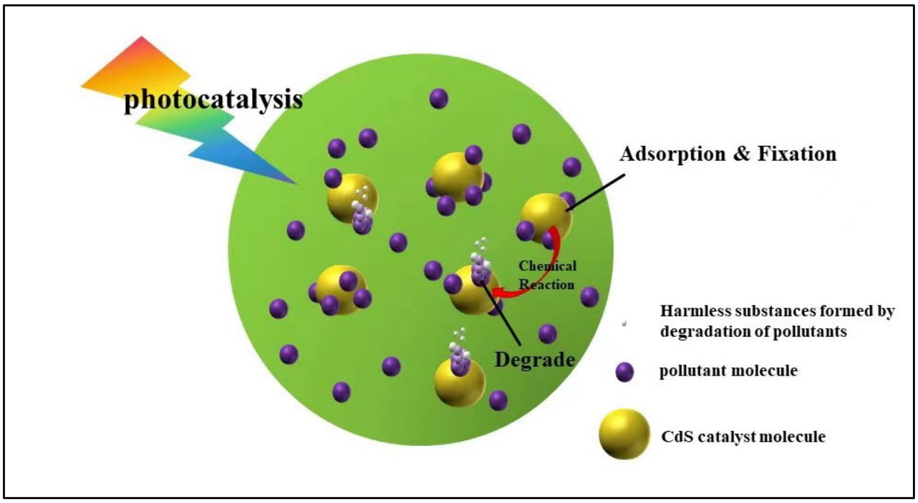


**Figure 2.** Concept diagram of photocatalytic degradation of organic pollutants

CdS is an effective catalyst for the degradation of pollutants. Its mechanism mainly includes adsorption, reduction and catalytic oxidation as well as photocatalytic processes (Dai et al., 2020). CdS has high adsorption properties, can adsorb and fix the pollutant molecules, remove the pollutant molecules from the solution, thereby reducing its concentration. The rich active sites on the surface of CdS can react chemically with pollutant molecules to further promote the degradation process. The higher reduction capacity of CdS can degrade pollutants by a reduction reaction, reacting with oxides in pollutant molecules (Luo et al., 2019) and reducing them to less toxic or non-toxic substances. The high catalytic activity on the surface of CdS can also catalyze and accelerate the oxidation reaction, oxidation of harmful substances in pollutant molecules to harmless substances, so as to achieve the degradation and management of pollutants. The process of photocatalytic degradation of CdS pollutants is realized by the generation and reaction of photogenic electron-hole pairs. Firstly, under light conditions, CdS can absorb light energy and produce photogenic electron-hole pairs. Photoelectrons can react with oxygen molecules to generate reactive oxygen species, such as hydroxyl radicals and superoxy radicals, triggering oxidation reactions (Kampouri et al., 2019). Photogenic holes can be reduced with water or oxygen molecules to generate hydroxide radicals and hydroxide ions and participate in organic degradation reactions. The generation and reaction processes of these active species work together to achieve efficient degradation of pollutants. Its advantages lie in its cheap, easy and non-toxic properties, as well as good light absorption and photoelectron-hole separation effect. With the development of research and technological improvement, the photocatalytic degradation of CdS pollutants will play an increasingly important role in environmental protection and treatment.

Under light exposure (photons), according to formula CdS+hv→$e^-$cb+hv+vb, the conduction of CdS and the generation of electrons and positive holes in valence bands, these electrons and holes can react directly with organic molecules. Such as hv+vb+Organic→Oxidation products, Hydroxyl radicals can also be formed, such as hv+vb+$H_2O$absrobed→OH·+$H^+$, then oxidizing organic molecules such as Organic→Degradation products, Electrons can also react with organic compounds to provide reduced products. Specifically, cadmium sulfide-based photocatalysts degrade pollutants including photocatalytic oxidation and photocatalytic reduction. During photocatalytic oxidation, photoelectrons of cadmium sulfide-based photocatalysts react with oxygen molecules to generate oxygen free radicals (Salcedo et al., 2020). These oxygen radicals have a strong oxidation ability to oxidize organic groups in pollutant molecules and degrade them into harmless substances such as carbon dioxide and water (Baishnisha et al., 2021). During photocatalytic reduction, the photogenic hole of cadmium sulfide-based photocatalyst reacts with water molecules to generate hydrogen radicals. These hydrogen radicals have the ability to reduce some oxygen-containing pollutants and degrade them into harmless substances.

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## 5. Other Applications of CdS Based Photocatalyst

### 5.1 $H_2$ production

The energy problem has been a problem that needs to be solved in recent centuries. Hydrogen is an important source of combustion products for water, which is not only environmentally sound but also useful. Semiconductor photocatalytic hydrogen production technology provides a new way of thinking, which means that inexhaustible solar energy can be converted into stored chemical energy, can be compared to artificial photosynthesis, in the field of materials and energy (Chang et al., 2019).

The physiochemical process of photocatalytic cleavage of water is roughly the process of hydrolysis of semiconductor photocatalytic materials to produce hydrogen and oxygen. According to thermodynamic factors and laws, water cracking is required to obtain energy from the outside world. Unable to react on its own capacity, 237.2 kJ/mol energy is required according to the study (Wang et al., 2018). Specifically, semiconductor materials absorb photon energy under photon excitation, creating free electrons transitioning from valence to conduction bands ($e^-$) With the ability to restore, the valence zone will form a hole ($h^+$) Electrons with oxidation capability in excited state ($e^-$) and ($h^+$) are not stable. They quickly compose so that the absorbed light is released in heat or other forms. Photoelectric hole pairs can also be rapidly migrated to the surface of semiconductor materials. Photoelectrons that are then migrated to the surface of the material can undergo a reduction reaction with protons in the water (Wu et al., 2020) (Figure 3). The factors that influence photocatalytic hydrogen production according to others are band structure, material form and size, crystal structure and crystallinity, catalysts, sacrificial conditions and light transmission.

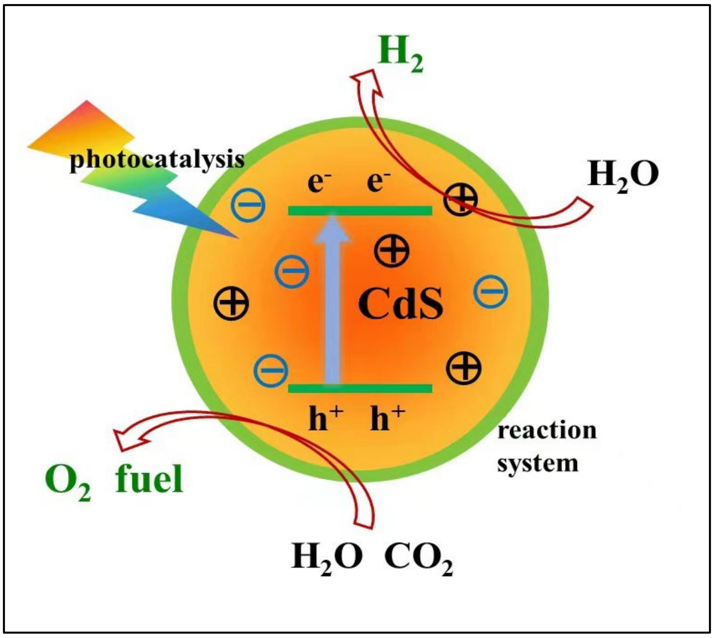


**Figure 3.** Mechanism diagram of $H_2$ production and $CO_2$ reduction by cadmium sulfide

Hydrogen production from cadmium sulfide is an important means in which efficient real estate $H_2$ depends on the energy band structure of the semiconductor catalyst. Cadmium sulfide is less bandwidth than electrolytic hydrochemical potential (1.23 ev) High, the potential of the conduction floor must be more negative than the reduction potential of water, valence band top potential than the oxidation potential of water correction, but the general energy needs to be greater than 2 ev (Wu et al., 2019). Photosensitizers are also essential in the process of excitation of the charge transfer on the surface of cadmium sulfide. Photosensitizers can absorb light energy, convert it into electrons and hole pairs, and promote the charge transfer on the surface of cadmium sulfide. Commonly used photosensitizers include organic dyes, semiconductor nanomaterials, etc. Hydrogen production from cadmium sulfide also provides a feasible way to solve energy shortages and environmental pollution. In the future, we can further explore new photosensitizers and regulatory strategies to improve the efficiency and stability of hydrogen production from cadmium sulfide and promote its application in the field of energy conversion.

### 5.2 $CO_2$ reduction

In recent years, as global $CO_2$ emissions continue to increase, the greenhouse effect of climate warming, sea level rise, extreme climate increase, increase in pests and diseases and other hazards ,$CO_2$ emission reductions are of increasing concern (Arya et al., 2020).The mechanism of CdS reduction $CO_2$ can be summarized as follows: Under light conditions, when the light energy is greater than or equal to the band gap Eg of semiconductor, CdS absorbs the photon energy and produces electrons. ($e^-$) Transition from valence band to higher energy guide belt, void ($h^+$) remains, i.e., produce photogenic electron-hole pairs in the semiconductor and migrate from inside the semiconductor to the surfactant site (Wang et al., 2020). where the electron is passed to the reducing agent for $CO_2$ reduction; The hole is involved in the reduction of $O_2$, thus maintaining the balance of the reaction. $CO_2$ is a thermodynamic stabilizing molecule consisting of O=C=O linear structures characterized by σ and π bonds. The C=O key can be 750 kJ/mol so breaking the chemical bond to restore it is difficult. It takes a lot of energy to break the C=O key and make it form the C-H key (Liu et al., 2020). This process involves the involvement of multiple electrons and a corresponding number of protons, which often requires conditions such as sacrificial agents, catalysts, photosensitizers, visible light, and partial ultraviolet light.

CdS has high photostability and photoelectric conversion efficiency, which makes it an ideal catalyst. By rationally designing and changing the morphological and structural characteristics of CdS, the catalytic performance and stability of CdS can be further improved, thereby further improving the efficiency of CdS reduction $CO_2$.

## 6. Improving the Performance of CdS Based Photocatalysts for Degradation of Organic Pollutants

There is no intermediate energy level between the pure CdS valence band and the conduction band, the photoelectron and hole composite rate is high, the surface area is small, resulting in poor catalytic performance and cyclic stability. The results show that the efficiency of CdS can be improved by regulating its crystalline phase and morphology, constructing heterogeneous knots, and regulating the energy band structure. These regulatory approaches are highlighted below.

### 6.1 Change structures

#### 6.1.1 Crystal and Morphology

In crystal structures, different atoms exposed to the outer layer of the crystal and their arrangement affect photocatalytic activity. So, choosing the right CdS is important to improve its catalytic efficiency. Photoelectron and hole compounding can also be inhibited by adjusting the shape and size of the crystals (Kato et al., 2003), thus increasing the efficiency of CdS-based photocatalysts to degrade organic pollutants. CdS crystals are divided into cubic zinc and hexagonal zinc (Shanavas et al., 2012) (Figure 4). they differ in the way they are arranged (Zhu et al., 2004). CdS at different temperatures will get different crystal phases, at no more than 100 °C is CdS that will usually get quadratic phases (Cao et al., 2004), over 300 °C is the CdS that will get the hexagonal phase (Lozada-Morales et al., 2001) and research shows that hexagonal CdS has higher photocatalytic activity than cubic CdS (Nakaoka et al., 1995; Sahu et al., 1998), and therefore CdS-based photocatalysts in production should form hexagonal CdS as far as possible.

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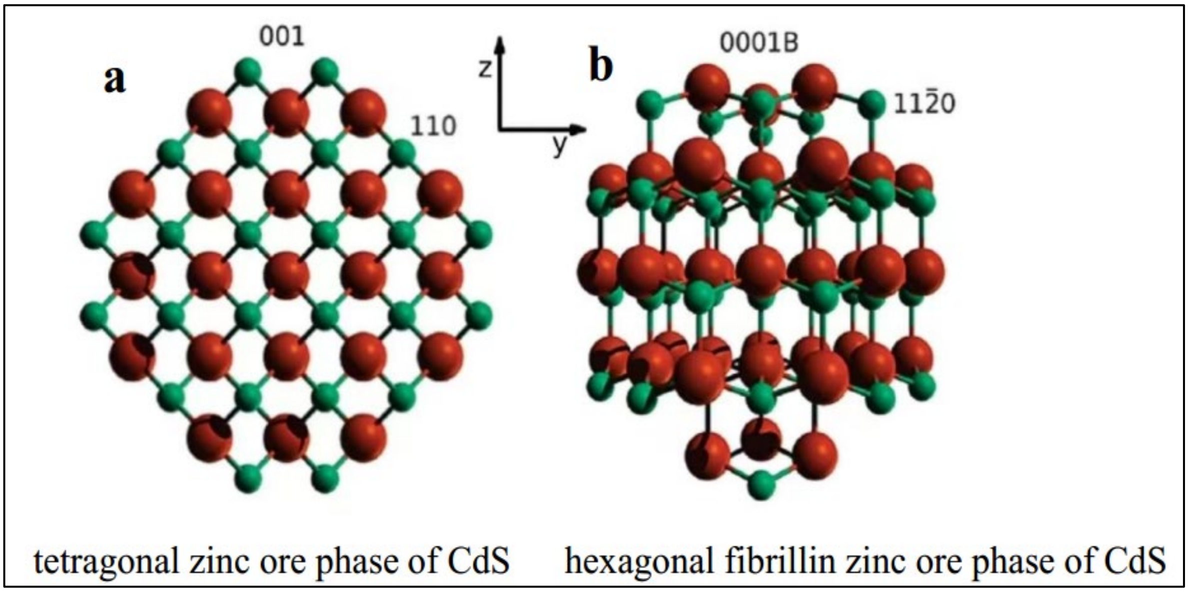


**Figure 4.** (a) Cubic zinc blende phase cadmium sulfide; (b) Hexagonal wurtzite phase CdS (Shanavas et al., 2012). The large red ball represents Cd and the other ball represents S.

There is no intermediate energy level between the pure CdS valence band and the conduction band, the photoelectron and hole composite rate is high, the surface area is small, resulting in poor catalytic performance and cyclic stability. The results show that the efficiency of CdS can be improved by regulating its crystalline phase and morphology, constructing heterogeneous knots, and regulating the energy band structure. These regulatory approaches are highlighted below.

The morphology of CdS greatly affects the absorption and transmission path of light, and different dimensions of CdS have different catalyst activity (Li et al., 2012). CdS can be divided into zero-dimensional, one-dimensional, two-dimensional planar and three-dimensional planar structures (Table 1). zero-dimensional CdS exhibits greater photocatalytic capability (Gurin et al., 1999; Pal et al., 2004). but is relatively unstable and needs to be fixed to the carrier to inhibit agglomeration to form large particles (Chen et al., 2007); At present, the most in-depth research is one-dimensional structure of CdS, due to the small particle diameter, photoelectron and hole composite through the path is short, reducing the possibility of composite, with high photocatalytic activity (Tongying et al., 2014; Liu et al., 2015); The two-dimensional planar structure exposes more active crystals relative to the one-dimensional structure and improves its catalytic properties (Tao et al., 2003); 3D structures improve the performance of CdS photocatalytic materials by increasing the specific surface area of CdS, such as spherical and floral (Lin et al., 2008; Chen et al., 2008), such a structure can absorb more visible light.

**Table 1.** The strength and Morphological structure of Cadmium sulfide in each dimension

| **Dimension** | **Feature** | **Morphological structure** |
|---|---|---|
| Zero Dimension | Excellent photocatalytic reaction driving force | Zero Dimension |
| One-dimensional | High catalytic activity and large specific surface area | One-dimensional |
| Two-dimensional | Larger surface area and thin thickness | Two-dimensional |
| Three-dimensional | Enhanced intraporous interaction time drinking absorption efficiency | Three-dimensional |

The different forms of CdS nanoparticles have become a new research hotspot, and the design and preparation of high-performance CdS nanoparticles are progressively developing. Direct contact between CdS nanoparticles and reactants facilitates photocatalytic efficiency and separation and transfer between carriers, providing a basis for improving photocatalytic reaction efficiency (Katz et al., 2002). CdS nanorats are one-dimensional nanostructures that enhance the absorption and scattering of light for long distance charge transmission (Ma et al., 2015); CdS nanosheets have a large specific surface area and a short migration distance (Liu et al., 2018), conducive to light absorption and transfer and improved photocatalytic performance (Xiong et al., 2018). Studies show that the thinner the photocatalytic activity of CdS nanoparticles the higher, but the absorption rate of the thin CdS nanoparticles decreases. In order to improve the utilization of light energy, CdS nanoparticles are designed into hollow spheres (Prieto et al., 2016). The light energy is reused by reflection of light on the basis of the two-dimensional structure.

6.1.2 Construction of heterojunction photocatalyst

The heterogeneous junction catalyst is made of CdS catalyst and other metal or semiconductor photocatalytic compound. The advantage of heterogeneous junction is that it can form electric field inside, photoelectron and cavity move directionally inside, reducing the composite efficiency of both. Heterogeneous knots can be divided into three heterogeneous knot structures according to the position of the two semiconductor conductors and valence bands (Figure 5). There have been many reports on the study of heterogeneous knots. The construction of heterogeneous knots serves as a synergy between the two semiconductors, greatly improving the efficiency and longevity of photocatalytic carriers. A CdS/g- $C_3N_4$/CuS Composite Photocatalyst Prepared by Simple Low Temperature Solid Phase Method (Cheng et al., 2017). The photocatalytic yield at 240 nm is 57.56μmol $g^{-1}$ $h^{-1}$. The catalytic efficiency is obviously high. The heterogeneous knots formed by pure CdS, CdS and g-$C_3N_4$ play a synergistic role. CdS- $Bi_2O_2CO_3$ composite photocatalyst is $Bi_2O_2CO_3$ modified (Ao et al., 2015), the formation of heterogeneous junctions between the two improves the ability of charge transfer and photocatalytic activity.

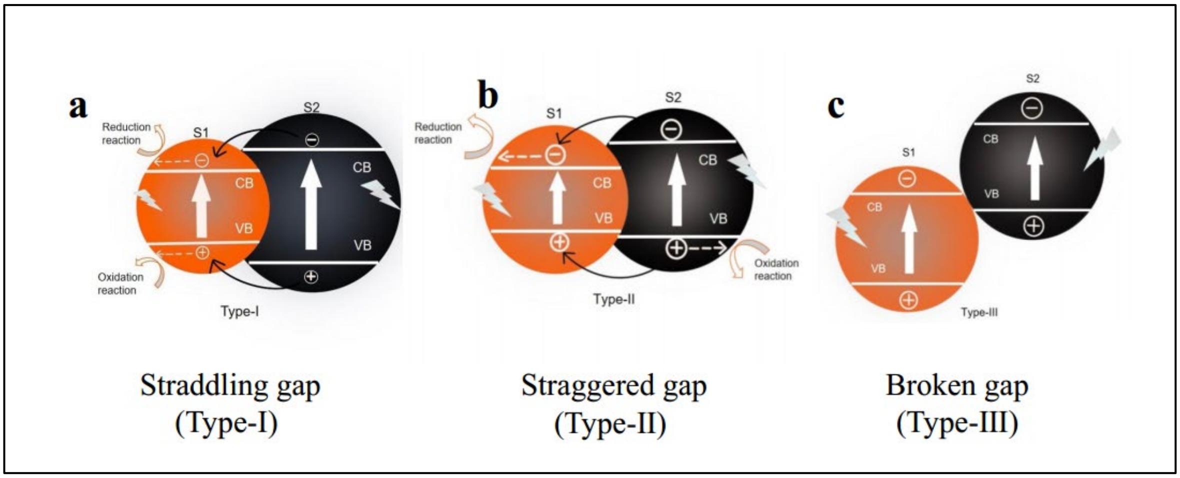


**Figure 5.** Three types of heterojunction structures (straddling, staggered and broken) schematic diagram.

6.1.3 Regulating band structure

CdS has a no-bandwidth of about 2.4 eV, a feature that meets both the requirements for absorbing visible light and the requirements for the location of the guide belt. Generally speaking, improving the redox capacity of cadmium sulfide can be achieved by broadening the prohibition. But it also reduces light absorption, you need to find a balanced position between the two to get the best photocatalytic performance. It is therefore possible to properly regulate the energy band structure for photoxidation or reduction of the site adjustment. The control of the energy band structure can be achieved by doping (Zhang et al., 2010) and synthesizing solid solutions (Villoria et al., 2010).

### 6.2 Varying Conditions

#### 6.2.1 Surface loading cocatalyst

Because photocatalytic reactions occur on the surface of the material, Strong conductive materials can be modified on CdS surface load catalysts to change the environment to improve photocatalytic activity. The use of catalyst facilitates the separation of photogenic carriers. Inhibiting the compounding of photogenic electrons and holes (Yan et al., 2009), which is known to be effective in improving photocatalytic capacity. Current catalysts are available in a variety of precious metals, sulphides and transition metal oxides.

Schottky Junction (Yan et al., 2009) is an interface for contact between catalysts and metals. It accelerates the separation of photocatalytic carriers and thus improves the photocatalytic properties of photocatalytic materials. It is a good light capture trap (Figure 6). Most precious metal catalysts are prepared by photodeposition. The results show that the properties of photocatalysts are related to the proportion and variety of additives. The aim is to improve photocatalytic activity (Chen et al., 2010). Pt as a common precious metal catalyst (Sahu et al., 2009), can be carried to inhibit compounding, improve photocatalytic activity while inhibiting photocorrosion (Jang et al., 2007). The advantage of precious metals is that the reduction potential is higher, and the function is higher. At the same time, the bond energy with the hydrogen atom is very small. However, due to the high price of precious metals, the realization of industrial production and pipeline engineering are very difficult, so look for efficient non-precious metal catalysts that can be replaced.

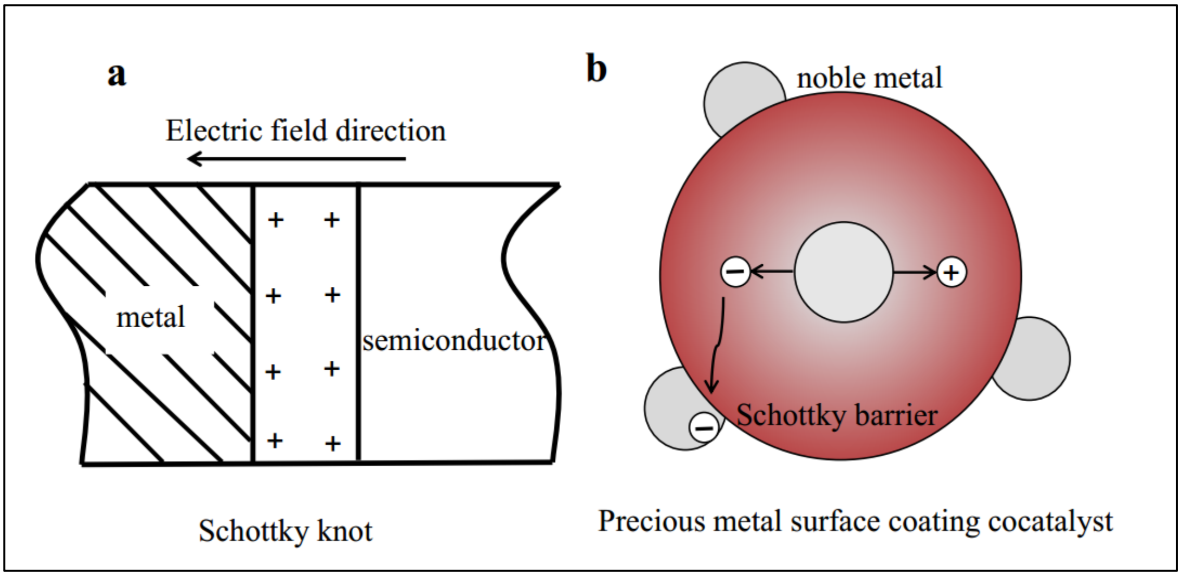


**Figure 6.** (a) The schematic diagram of Schottky junctions; (b) Supported cocatalysts on the surface of precious metals (Yan et al., 2009)

Transition metal oxides are photocatalysts introduced by researchers to replace precious metal catalysts. Good electrolytic properties, including oxide sulphides and carbides, we want to reduce the cost of preparing catalysts without reducing the photocatalytic properties. Studies show that the catalytic properties of $Mo_2C$ composite photocatalysts obtained by $Mo_2C/CdS$ modification of non-precious metals are more than twice that of Pt/CdS modification (Zong et al., 2008), and the former compound catalyst is less prone to corrosion and more stable.

#### 6.2.2 Dual co-catalyst

On the basis of load catalysts, a dual catalysis system has been proposed in recent years. Photocatalytic electrons and holes are separated better than a single catalytic system, usually including primary catalysts, reduction catalysts and oxidation catalysts (Meng et al., 2019). More troublesome is that dual catalysts are usually synthesized by multiple reactions, but in this process it is necessary to pay attention to the impact of the first step of the second catalyst binding, and to the first catalyst shedding and deformation, so the process of double catalysts formation needs to be optimized.

## 7. Conclusions

After the introduction and summary of this study, we can conclude that cadmium sulfide-based photocatalysts are feasible and efficient in the degradation of organic pollutants. Hydrogen from cadmium sulfide as a catalyst can be used as a clean energy source, and CdS can also mitigate the impact of greenhouse effects on the planet. We summarize the basic mechanism of degradation of organic pollutants by cadmium sulfide-based photocatalysts and put forward several strategies to improve their catalytic properties.

Firstly, by adjusting the crystal phase and morphology of CdS crystal, the surface structure of CdS catalyst can be optimized and the exposure of its active site can be increased. In addition, the construction of heterogeneous photocatalyst is also an important strategy to improve the photocatalytic efficiency of CdS base. By introducing other semiconductor materials or metal oxides, heterogeneous junction interfaces can be formed to improve the separation efficiency of photogenic electron-hole pairs and further enhance catalytic activity.

Secondly, the regulation of CdS energy belt structure is also the key to improve photocatalytic efficiency. By controlling the doping, alloying or nanochemistry of CdS, the energy band structure of CdS can be adjusted to change the light absorption and distribution of photogenic electron-hole pairs, thus improving the photocatalytic activity. In addition, the effect of CdS based photocatalysis can be further enhanced by using the method of surface load catalyst. The introduction of catalysts such as precious metals and transition metals can provide additional catalytic active sites to facilitate the process of the reaction.

However, CdS still faces some challenges in the degradation of organic pollutants. First, CdS itself is toxic and can pose potential risks to the environment and human health. Therefore, in the application of cadmium sulfide-based photocatalyst, attention needs to be paid to its toxicity problems, and the corresponding safety measures. In addition, the photoelectric properties of CdS also have certain limitations, such as narrow absorption range and fast composite rate of photoelectron-hole pairs. Therefore, future research can further explore solutions to these problems to improve the efficiency and stability of cadmium sulfide-based photocatalysis.

In summary, CdS based photocatalysts have great potential for degradation of organic pollutants. By regulating the crystal structure of CdS, constructing heterogeneous photocatalyst, regulating the energy band structure and the surface load catalyst, the efficiency and stability of the photocatalysis of CdS can be improved. However, we also need to focus on the toxicity of CdS and the limitations of photoelectric properties and are committed to finding solutions. Future research can further explore CdS materials and combine a variety of strategies to achieve better cadmium sulfide-based photocatalytic degradation of organic pollutants. This will provide important guidance for environmental protection and sustainable development.

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**Declaration of Conflicting Interests**

All authors declare that they have no conflicts of interest.

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