Journal of Physical Chemistry and Functional Materials

Home Page of Journal: https://dergipark.org.tr/jphcfum

A Review on Photocatalyst self-cleaning glass

[a] *Rezhin Mahdi Abdulrahman* *, [a] *Zhiwar Omer Khdr*, [b] *Bestoon Anwer Hamad Ameen*

[a] *Department of Physics, College of Science, University of Raparin, Sulaymaneyah, Iraq*
[b] *Department of Physics, College of Education, Salahaddin University-Erbil, Erbil, Iraq*
* *Corresponding author: E-mail: rezho.mahdy12345@gmail.com*

ABSTRACT

In this research, we have reviewed the recent investigations on the photocatalyst semiconductor in which titanium based on the surface mainly focuses on protecting the environment and human health. This titanium has been widely read and investigated in the past four centuries and it has been shown that in many ways we can benefit from it. Here we need a light energy source to activate the electronics in the semiconductor that then this light energy is converted into chemical energy because of its photochemistry, and that chemical energy is used in reaction chemical on the surface of the cover and electrons and halls have a major role in the chemical effect that eventually produces carbon oxide and water and cleanses the surface of the coating.

ARTICLE INFO

Keywords:
Light energy
Photocatalyst,
TiO_2

Received: 23-04-2021,
Accepted: 19-05-2021
ISSN: 2651-3080

1. INTRODUCTION

The self-cleaning operation is cleaning the face of the windows without human effect can help, only UV light is used to destroy organ dirt and then it is rained down, called this Photocatalyst. Self-cleaning materials that can be easily cleaned with water can be used in many different areas, these materials cleaned with rain drops can say it will reduce cost and have minimal damage to the environment [1]. Due to the increase in the population, use cars, and industrial factories the rate of environmental pollution has increased. In the future, it will be a big danger for humanity and spreading bacteria and viruses. Especially the antibiotic resistance, are still a major there at to human health [2]. Such problems can be done by receiving data and making a suitable and strong plan we can face such problems [3]. In today is world, the rate of buildings is increasing at the same time they have an excessive height and cleaning the windows of these buildings is impossible and dangerous for humans, but this technology that has been developed has become a good solution for these problems the effect of these phenomena has caused decrease in dirt on the windows of the building [4]. The idea of this technology is taken from nature that in fact the grasses have this characteristic for the raining drops. This technology is very used and developed for today is world [5]. Especially the appearance of lotus gala, many scientists are trying to use the characteristics and the health of the living to develop and invent their ideas, such as imitating the water and falling underwater, all based on some different models [6]. of material have been determined that all of them are semiconductor metal (ZnO_2, TiO_2, ZrO_2) etc… [7]. But the most recent type of tio2 semiconductor, which has a lot of use, is because it has a high light and electrical characteristic, low cost [8]. And there is another feature that is antibacterial and dose not let bacteria stay on it is face and cause a place of life for bacteria, despite the fact that it works with UV radiation, but this feature works against bacteria at night [9].

2. TiO_2 as Photocatalys

Photocatalyst is an action that works by taking advantage of sunlight energy, each photocatalyst has its own characteristics and benefits but here we only talk about the effects that have on removing organ poisons. It means it is an action to clean up the environment [10].

Titanium dioxide or oxide of titanium with a chemical formula of TiO2 [11]. Titanium oxide has many polymorphs. The well-known phases of titanium dioxide are naturally occurred rutile (discovered in 1803), anatase (discovered in 1801), and brookite (discovered in 1825), named after their reddish color, extended crystallographic shape, and a mineralogist, respectively [12]. TiO2 has the unique properties. Avery important topic of semiconductor photochemical by one after one investigations, scientists have made photocatalysis develop. Especially the use of the semiconductor titanium dioxide as Photocatalyst to eliminate organ dirt from O2 [13]. Photocatalysis is an active area of research in the field of heterogeneous catalysis owing to its potential applications in environmental cleaning and H-energy production. IN most cases, photocatalytic degradation is conducted over the TiO2 owing to its peculiarities of chemical inertness, no photo corrosion, low cost, and nontoxicity [14]. Also, the use of TiO2 operation is still limited, and it cannot be used more in its limits to steal this because of the lack of quality skills and the need to activate light UV. Photo sent sizing TiO2 has been proved a promising way to extend spectral response from UV area to visible region [15]. Most studies focus on organ photographers while studying non-organic photons is rarely mentioned, photon sting TiO2 with non-organic substitution is higher than that under the organ components have been mostly destroyed during photocatalysis [16].

3. Literature review of Photocatalyst synthesizes

In this section we deceased the technique of preparation and synthesis of samples by commonly used to get nanoparticle preparation and the doping martial in literatures. In this chapter we show that the photocatalytic activity of difference dopants TiO2 for H2 production.

3.1. Sol-gel method

In materials science, the sol-gel process is a method for producing solid materials from small molecules. The method is used for the fabrication of metal oxides, especially the oxides materials science, the sol-gel process is a method for producing solid materials from of silicon (Si) and titanium (Ti) [17]. The process involves conversion of monomers into colloidal solution (sol) that acts as the precursor for an integrated network (gel) of either discrete particles or network polymers. That road was found here in 1800 because of this road of mixing material [18] Sol-gel technology finds applications in the development of new materials for catalysis [19]. Sol-gel is one of the most exploited methods; it is used mainly to produce thin film and powder catalysts. Many studies revealed that different variants and modifications of the process have been used to produce pure thin films or powders in large homogeneous concentration [20]. Sol-gel related methods of doping TiO2 photocatalysts, with emphasis on the efficiency of the catalysts prepared by the method in any considered photocatalytic activity. This has been considered important, as numerous researches are currently going on in this field. Sol-gel is a simple way of low temperatures and is generally used in nanoparticle and has a lot of benefits [21]. Prepared Pt doped TiO2 hollow spheres using the sol-gel method for hydrogen production activity [22]. Properties of gel-derived and conventionally prepared ceramics, examines films in detail, and presents a variety of applications [23]. Several steps and conditions are applied in a sol-gel process to control the final morphology as suggested by Mehrotra and Singh. Fig.1.

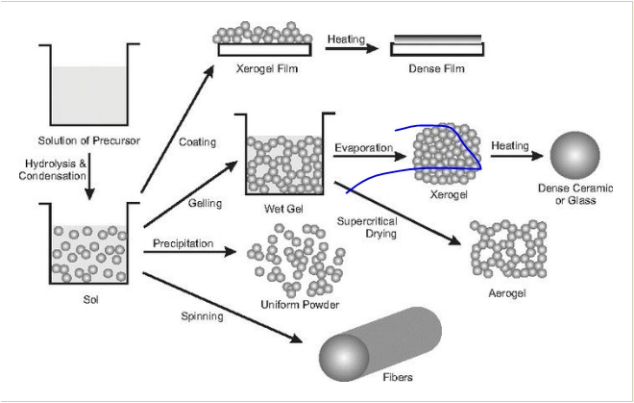

Figure 1. Different sol-gel process steps to control the final morphology of the product [24].

3.2. Hydrothermal/ solvothermal methods

These are two processes, hydrothermal and solvothermal methods are generally used in Nano organic chemistry for the cysts non amputees nano materials with various morphologies for different apps. The hydrothermal method is a processes of crystallizing a substance at a high temperature and high vapor pressure using an aqueous solution of the material [25]. Compared to hydrothermal method, the solvothermal method uses a non-aqueous solvent, has better control of the properties of TiO_2 and the temperature can be increased much higher meaning high boiling point solvents can be used. The difference between these two styles is that water used as a processor previously reacts chemically under organized temperatures and pressure from the treatment materials found on the sealed autoclavable steel ships, which requires two stages; as well as all the unique blessings that are in place. In addition, this system carefully organizes several parameters that affect its creation such as PH, temperature [26].

3.3. Solid State Reaction Methods

Solid state chemical reaction for nano material production is a method used in photocatalysis. TiO_2 photocatalytic materials were successfully synthesized by solid state reaction. Comparing to other method, the solid state reaction is very cheap and does not need special equipment or solvent to perform, during this process. The powders of the nano materials obtained by the were carefully mixed, after which the powder mixture was transferred to clean crucible alumina and calcined at high temperature. The TiO_2 photocatalytic materials were obtained by annealing the precursor in the temperature rang (300-800) Celsius [27].

3.4. Nano-structured TiO_2.

Among the various statisticians used to improve the performance of photocatalyst tio2.hcluding using crystal structure and its surface. We must consider the stability of the structures and size when using them in the fields [28]. For the nano-titanium morphology and surface area, various ordered structures have been studied. Tio2 nano-tubes [29]. Anodic tio2 nano-tubes have been reported to allow a high control over the separation of photo generated charge carriers in photocatalytic reactions this allows for engineering rise to enhanced photocatalytic efficiencies and selectivities [30].

3.5. Immobilized TiO_2

Another used of titanium dioxide nanomes described above is the formation of water carrying uniforms that make it difficult to be cleared so it creates barriers to photocatalytic use of industrial standards [31].

As a result, many studies have attempted the modification of tio2 nano-particles on support materials such as clays, quartz, stainless and steel [32]. An important substance supporting tio2 nanos by Chinese, chemical and mechanical morphology, temporary exchange ability, toxic nature, low cost and availability. So the tio2 nanothirsty has attracted a lot of attention to use in both climate cleaning and prepared by a large number of researchers [33].

3.6. Other methods

Also there are other various techniques for preparing titanium dioxide (TiO_2) are the following: Deposition methods, Oxidation methods, Sonochemical and microwave-assisted methods, Templute based methods and Electrochemical anodization.

4. Application of titanium dioxide nanoparticles.

Right now nanoparticles material they have invaded an Important area in the researches. Because of the characteristics and benefits of various uses such as: TiO_2 nanoparticles. And that's to make the environment safe. So all science and technology are in the service of protecting the environment through (adsorption, absorption, filtration, catalysis) here we care more about the TiO_2 catalysis. Because it can be prepared in various way and cost less. And it is considered an environment friend [34]. TiO_2 in the material that is used in hundreds of products without knowing that we used it very day. The applications of TiO_2 nanoparticles are shown in Fig. 2.

Figure 2. Generally, the high rate of use of tio2 in these fields [35].

4.1. TiO_2 nanoparticles use to reduce the toxicity of the drugs.

If the herbs are used in natural medicine, then they should not poison to be harmless, this is a hypothesis for the future that the can be avoided from this damage. TiO_2 is the nature of the element with low toxicity, and unseen biological effects. The size and type of cell damage that strongly depends on the chemical and physical properties of the including size, crystal structure and photo activation [36].

4.2. TiO_2 nanoparticles use in water cleaning.

It to clean the water that has been infected with bacteria and viruses through waste water especially the water on earth and underground water which has a lot of benefits in human life and in the environment [37].

4.3. TiO_2 nanoparticles use in agriculture.

Used to be gamic (shown male and female flowers). So titanium can facilitate the increase in grain products. Especially corn. So again the environment and humane will benefit from this product [38].

4.4. TiO_2 nanoparticles use in medicine.

Is used to eradicate bacteria and viruses, which means it works as an antibacterial. Except for this used to monitor skin and fixed. TiO2 nanoparticles commonly used nanoparticles in medical applications and hence in cancer studies. New therapeutics and therapies will be developed and nanotechnology for this aim will be an important approach for the researchers [39].

4.5. TiO_2 nanoparticles use in coating.

4.5.1. Self-cleaning operation

The operations of self-cleaning glass in the past has been investigated a lot by researchers. It is currently used in many fields and benefited from it as a human and environmental assistant. The environmental protection side is destroying all kinds of harmful bacteria and viruses. In order for this cleaning action to happen on glass. It must first be covered with a spherical substance, which in this study we use TiO_2 as a cover. Self-cleaning equipment has a significant focus on both energy and environment. Recently, to understand the principles of self-cleaning. There has been a lot of explanation on it and many products have been made [40].

4.5.2. Photocatalytic water splitting

In the 21st century, humans faced a unique serious energy, and they became environmental problems such as the destruction of stone sources and the destruction of the environment worldwide [41]. Therefore, it is expected that these problems will be solved as soon as possible to create a unique and suitable society, this energy change system is shown in Fig. 3.

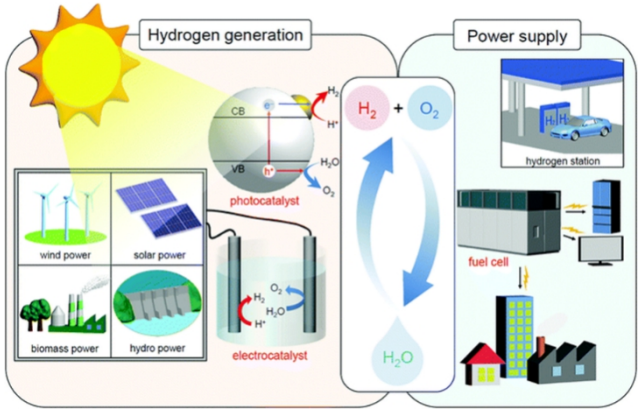

Figure 3. schematic of the energy conversion system expected for constructing a sustainable society. Note that sunlight also produces wind, biomass, and hydro power in addition to solar power [42].

Here we talk about a development in the catalyst because of the distribution of water under the visible light [43], and we emphasize the water splitting. In fact, the photocatalyst talks about the chemical works that are accelerated by chemical energy and this chemical energy is basically light energy that has been converted to chemical energy and is used in reaction chemical [44]. TiO2, as the most used photocatalyst, has various benefits with excellent chemical stability and large surface area, intoxication, and low costs. However, the vast energy band space (3.0- 3.2 eV) is only flowing with UV rays (wavelength < 400 nm), so that less than 5% of the sun's energy is effectively used [45]. Although the process of changing solar energy to hydrogen was efficiency 1.1% [46]. But this efficiency is very low for such water splitting in produce hydrogen. So we need to improve the process of changing sun's energy to produce hydrogen for about (5-10) % [47].

This action happens in some steps after one. When the light is located in the semiconductor. That this light must be equal or larger than the semiconductor gap band to stimulate the electrons, and this will cause the creation of pairs of electrons and holes the electrons will also be active and go to the face of the glass cover each electrons will be involved in the (Reduction) action and holes will be involved in the (oxidation) action. and equation (1)-(8) demonstrate the basic reaction process of a semiconductor to generate the photocatalytic radical [48]. Show that Figure 4.

Excitation: Photon (hv) + Semiconductor → e−CB + h+VB (1)

Recombination: e− + h+ → energy (2)

Oxidation of H2O: H2O + h+VB → •OH + H+ (3)

Reduction of adsorbed O2: O2 + e− → O2•− (4)

Reaction with H+: O2•− + H+ → •OOH (5)

OH + pollutant → → →H2O + CO2 (6)

O2•- + pollutant → → →CO2 + H2O (7)

•OOH + pollutant → CO2 + H2O (8)

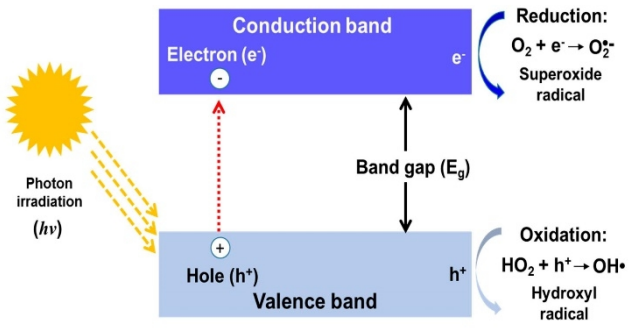

Figure 4. Schematic illustration of the photocatalytic reaction process of a semiconductor. Adapted with

permission from Reference [11]. Copyright (2012) Elsevier [49].

which can escape the charge-annihilation reaction, migrate to the surface, where the photoexcited electrons can reduce atmospheric oxygen to generate superoxide radicals (• O2 –) or hydroperoxyl radicals (HO2 •). The valence band hole can also oxidize surface adsorbed water or OH– and produce •OH. These reactive oxygen species can convert organic pollutants into CO_2 and water resulting in the cleaning of the surface. A major limitation in developing self-cleaning materials based [50].

5. Conclusions

In this chapter, we have given an overview of the development of modified TiO2 catalysts and its future prospects from a scientific point of view. We note that the field has experienced major advances in the last 5 years especially in the area of modifying TiO2 with carbon nanomaterials. Based on the literature we have covered here. we believe that there is still quite a lot that can be achieved in improving the performance of TiO2 catalysts for photocatalytic applications.

References

[1]. Parkin, I. P.; Palgrave, R. G. J. Mater. Chem. 2005, 15, 1689-1695.

[2]. T. Singhal, A Review of Coronavirus Disease-2019 (COVID-19), Indian J. Pediatr. 87 (2020) 281–286. doi:10.1007/s12098-020-03263-6.

[3]. A. Almakki, E. Jumas-Bilak, H. Marchandin, P. Licznar-Fajardo, Antibiotic resistance in urban runoff, Sci. Total Environ. 667 (2019) 64–76. doi: 10.1016/j.scitotenv.2019.02.183.

[4]. D. Chen, F. Li, A.K. Ray, External and internal mass transfer effect on photocatalytic degradation, Catalysis Today 66 (2001) 475–485.

[5]. D. Byun, J. Hong, J. H. Saputra Ko, Y. J. Lee, H. C. Park, B.-K. Byun and J. R. Lukes, J. Bionic Eng., 2009, 6, 63–70.

[6]. R. N. Wenzel, Ind. Eng. Chem. 28, 988 (1936).

[7]. W. Liu, S. Chen, W. Zhao, S. Zhang, Study on the photocatalytic degradation of trichlorfon in suspension of titanium dioxide, Desalination 249 (2009) 1288–1293.

[8]. M.F.J. Dijkstra, H. Buwalda, A.W.F. de Jong, A. Michorius, J.G.M. Winkelman, Experimental comparison of three reactor designs for photocatalytic water purification, Chemical Engineering Science 56 (2001) 547–555.

[9]. Journal of photochemistry and photobiology C: Photochemistry reviews 1 (1), 1-21, 2000 Volume 1, Issue 1, 29 June 2000, Pages 1-21.

[10]. N. Sakai, A. Fujishama, T. Watanabe, K. Hashimoto, J. Phys. Chem. B 107 (2003) 1028.

[11]. A. Mills, S. LeHunte, An overview of semiconductor photocatalysis, J. Photochem. Photobiol. A: Chem. 108 (1997) 1–35.

[12]. A. Fujishima, T.N. Rao, D. Tryk, Titanium dioxide photocatalysis, J. Photochem.Photobiol. C: Photochem. Rev. 1 (2000) 1–21.

[13]. E. Keidel, Furben Zeitung 34 (1929) 1242-1243. [14]. Linsebigler, A. L.; Lu, G. Q.; Yates, J. T., Jr. Chem. ReV. 1995, 95, 735

[15]. De Angelis, F.; Fantacci, S.; Selloni, A.; Nazeeruddin, M. K.; Gratzel, M. J. Am. Chem. Soc. 2007, 129, 14156.

[16]. Bessekhouad, Y.; Robert, D.; Weber, J. V. Catal. Today 2005, 101,315

[17]. C. Jeffrey Brinker, George W. Scherer, Sandia National Laboratories (1990).

[18]. Asahi, R.; Morikawa, T.; Ohwaki, T.; Aoki, K.; Taga, Y. Science 2001, 293, 269. (b) Irie, H.; Wanatabe, Y.; Hashimoto, K. J. Phys. Chem. B 2003, 107, 5483.

[19]. C.J. Brinker, G.W. Scherer, Sol-gel Science: The Physics and Chemistry of Sol-gel Processing, Academic Press, Boston, MA, 1990.

[20]. S. Bu, Z. Jin, X. Liu, T. Yin, Z. Cheng, J. Mater. Sci. 41 (7) (2006) 2067–2073.

[21] F. Han, V.S.R. Kambala, M. Srinivasan, D. Rajarathnam, R. Naidu, Appl. Catal. A: Gen. 359 (2009) 25–40.

[22]. Zhu et al., 2016.

[23]. C.J. Brinker, K.D. Keefer, D.W. Schaefer, R.A. Assink, 1982 JOURNAL OF NON-CRYSTALLINE SOLIDS.

[24]. Mehrotra RC, Singh A. Recent trends in metal alkoxide chemistry. Progress in Inorganic Chemistry. 1997; 46:239-454

[25]. Reis KP, Ramanan A, Whittingham MS. Hydrothermal synthesis of sodium tungstates. Chemistry of Materials. 1990; 2:219-221

[26]. Sun, T., Liu, E., Fan, J., Hu, X., Wu, F., Hou, W., Yang, Y., Kang, L., 2013. High photocatalytic activity of hydrogen production from water over Fe doped and Ag deposited anatase TiO2 catalyst synthesized by solvothermal method. Chem. Eng. J. 228, 896–906

[27]. Umadevi, M., R. Parimaladevi, and M. Sangari. "Synthesis, characterization and photocatalytic activity of fluorine doped TiO2 nanoflakes synthesized using solid state reaction method." Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 120 (2014): 365-369.

[28]. Lin J, Liu X, Zhu S, Liu Y, Chen X. Anatase TiO (2) nanotube powder film with high crystallinity for enhanced photocatalytic performance. Nanoscale Research Letters. 2015; 10:110

[29]. Tang H, Zhang D, Tang G, Ji X, Li C, Yan X, et al. Low temperature synthesis and photocatalytic properties of mesoporous TiO2 nanospheres. Journal of Alloys and Compounds. 2014; 591:52 - 57

[30]. Zhou X, Liu N, Schmuki P. Photocatalysis with TiO2 nanotubes: “Colorful” reactivity and designing site-specific Photocatalytic centers into TiO2 nanotubes. ACS Catalysis. 2017;7(5):3210-3235

[31]. Mishra A, Mehta A, Sharma M, Basu S. Impact of ag nanoparticles on photomineralization of chlorobenzene by TiO2/bentonite nanocomposite.

Journal of Environmental Chemical Engineering. 2017;5(1):644-651

[32]. Feng D, Xu S, Liu G. Application of immobilized TiO2 photocatalysis to improve the inactivation of Heterosigma akashiwo in ballast water by intense pulsed light. Chemosphere. 2015; 125:102-107

[33]. Belver C, Han C, Rodriguez JJ, Dionysiou DD. Innovative W-doped titanium dioxide anchored on clay for photocatalytic removal of atrazine. Catalysis Today. 2017; 280:21-28

[34]. C Han, E Sahle-Demessie, A Shah, S Nawaz, L ur-Rahman, Sustainable Catalysis - Energy-efficient Reactions and Applications, 2018

[35]. Studies on the titanium dioxide nanoparticles: biosynthesis, applications and remediation

[36]. Kumar B, Cumbal L (2014) Light harvesting titanium nanocatalyst for remediation of methyl orange. Int J Chem Mol Nucl Mater Metall Eng 8:196–199.

[37]. Theron J, Walker J, Cloete T (2008) Nanotechnology and water treatment: applications and emerging opportunities. Crit Rev Microbiol 34:43–69

[38]. Morteza E, Moaveni P, Farahani H, Kiyani M (2013) Study of photosynthetic pigments changes of maize (Zea mays L.) under nano TiO2 spraying at various growth stages. Springerplus 2:1–5

[39]. Wiesenthal A, Hunter L, Wang S, Wickliffe J, Wilkerson M (2011) Nanoparticles: small and mighty. Int J Dermatol 50:247–254

[40]. Montazer M, Seifollahzadeh S (2011) Enhanced self-cleaning, antibacterial and UV protection properties of nano TiO2 treated textile through enzymatic pretreatment. Photochem Photobiol 87:877–883

[41]. R. S. Stein and J. Powers, The Energy Problem, World Scientific, Singpore, 2011

[42]. Z. W. Seh, J. Kibsgaard, C. F. Dickens, I. Chorkendorff, J. K. Nørskov and T. F. Jaramillo, Science, 2017, 35, eaad4998

[43]. Fujishima, A. & Honda, K. Nature 238, 37–38 (1972).

[44]. Li X, Yu J, Wageh S, Al-Ghamdi AA, Xie J. Graphene in photocatalysis: A review. Small. 2016:1-57. DOI: 10.1002/smll.201600382

[45]. Schneider, J.; Matsuoka, M.; Takeuchi, M.; Zhang, J.L.; Horiuchi, Y.; Anpo, M.; Bahnemann, D.W. Understanding TiO2 photocatalysis: Mechanisms and materials. Chem. Rev. 2014, 114,

[46]. Q. Wang, T. Hisatomi, Q. Jia, H. Tokudome, M. Zhong, C. Wang, Z. Pan, T. Takata, M. Nakabayashi, N. Shibata, Y. Li, I. D. Sharp, A. Kudo, T. Yamada and K. Domen, Nat. Mater., 2016, 15, 611 —615

[47]. Z. Wang, C. Li and K. Domen, Chem. Soc. Rev., 2019, 48, 2109 —2125

[48]. Mills, A.; Davies, R.H.; Worsley, D. Water-purification by semiconductor photocatalysis. Chem. Soc. Rev. 1993, 22, 417–425.

[49]. Pelaez, M.; Nolan, N.T.; Pillai, S.C.; Seery, M.K.; Falaras, P.; Kontos, A.G.; Dunlop, P.S.M.; Hamilton, J.W.J.; Byrne, J.A.; O'Shea, K.; et al. A review on the visible light active titanium dioxide photocatalysts for environmental applications. Appl. Catal. B-Environ. 2012, 125, 331–349.

[50]. S. Banerjee, S.C. Pillai, P. Falaras, K.E. O'shea, J.A. Byrne, D.D. Dionysiou, J. Phys. Chem. Lett. 5 (2014) 2543–2554.