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Editorial

Editorial Catalysts: Special Issue on "Advances in the Synthesis and Applications of Transition/Noble Metal Oxide Photocatalysts"

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Heterogeneous photocatalysis, due to its high efficiency, safety and profitability, has become an effective technology for solving environmental problems, for example, in wastewater treatment, for the removal of organic pollutants [1,2]. Despite the many advantages of semiconductor photocatalysts (e.g., TiO_2, ZnO, Fe_2O_3, CdS and ZnS), there are also disadvantages, for example, the fast recombination rate of photogenerated electron–hole pairs, low quantum yield and high band gap value. The rapid recombination of the photogenerated pairs ($e-/h+$), following energy activation of the catalyst, inhibits the redox process, and thus, this results in reduced photocatalytic activity [3–5]. It is necessary to study a method for optimizing the semiconductor structure in order to improve separation efficiency and to inhibit recombination efficiency toward enhancing the photocatalytic properties of the semiconductor. The recombination process decreases when the surface of the semiconductor is modified by transition/noble metals. Hence, photocatalysts modified with transition/noble metal oxides can enhance the photocatalytic decomposition of organic pollutants in wastewater. Therefore, it is important to continue the search for new and more efficient photocatalysts that offer an improved performance. Key accomplishments to date are compiled in this Special Issue, as summarized below.

A nanomaterials composite with graphitic carbon nitride was studied for the photodegradation of organic compounds because they help to optimize the degradation process of organic pollutants. In this way, Lai et al. [6] prepared a g-C_3N_4/porphyrin nanocomposite by the self-assembly of monomeric Tetrakis (4-carboxyphenyl) porphyrin (TCPP) molecules with g-C_3N_4 nanomaterials. The band gap energies of the hybrid materials are estimated to be 2.38 and 2.7 eV, which could indicate that the hybrid material is an efficient photocatalyst. The authors concluded that the hybrid C_3N_4/TCPP material exhibited enhanced photodegradation activity toward Rhodamine B at a degradation speed of up to 3.3×10^{-2} min^{-1}, which was superior to other porphyrin photocatalysts. Sert et al. [7] also synthesized a graphitic carbon nitride composite, but they implemented a facile calcination method utilizing urea and zinc nitrate hexahydrate as initiators. The authors investigated several effects—molar ratio of ZnO, amount of catalyst, concentration of organic pollutant and concentration of H_2O_2—in the photocatalytic degradation of crystal violet dye. Their experimental results show that the molar ratio of ZnO in g-C_3N_4 (0.05 mmol ZnO and 0.10 g/L catalyst) has an important role, because in 2 h, the photocatalytic degradation reaches 95.9% in the presence of UV irradiation. Photocatalysis compared to adsorption (32.3%) has a dominant role in crystal violet decolorization. Finally, the results showed no significant decrease in the degradation efficiency of crystal violet in the presence of the g-C_3N_4/ZnO photocatalyst after five consecutive cycles.

Musielak et al. [8] report a new, different method, which is a promising alternative to classical AOP methods—photodynamic therapy (PDT), using curcumin. Curcumin has low solubility in water and high photosensitivity. Therefore, the authors chose a suitable carrier—a suitably processed commercial zeolite of the FAU type. Studies related to the release of curcumin from zeolites were carried out in simulated gastrointestinal conditions using two methods: the first is the classical method of releasing the active substance in the open circulation, and the second is photodynamic release. Musielak et al. found that the photodynamic release of curcumin from zeolites proved to be a more cost-effective and efficient method. The reason for this is that curcumin is very sensitive to light.

The exceptional properties of modified semiconductor nanomaterials (i.e., TiO_2 and ZnO) have attracted attention in the field of environmental remediation and water treatment. Gervasi et al. [9] investigated the optical, structural and photocatalytic properties of pure and iron-doped (0.05, 1.0 and 2.5 wt%) anatase/brookite TiO_2 using sol–gel synthesis. The specific surface area increases with increasing amount of iron—from 236 m^2/g (undoped TiO_2) to 263 m^2/g (2.5 wt% Fe)—while the band gap energy decreases from 3.10 eV (undoped TiO_2) to 2.85 eV (2.5 wt% Fe). All of these results, established by Gervasi et al., have an impact on the photocatalytic properties—the sample with 0.05 wt% iron has the highest efficiency and fastest degradation of simazine (77%). The sol–gel method was also used for the preparation of titanium dioxide by another research group—Bachvarova-Nedelcheva et al. [10]—but they doped the semiconductor with TeO_2. The nanopowders TiO_2/TeO_2 were obtained and annealed in the temperature range of 200–700 °C. The photocatalytic properties of the as-prepared samples were tested for the degradation of Malachite Green in the presence of UV light—pure titanium dioxide degrades the dye about 35%, while the powder doped with TeO_2 about 60%. The authors also investigated antimicrobial properties of sol–gel powders. The doped powders exhibited good antimicrobial activity against *E. coli* K12, as the samples heated at higher temperature (400 °C) showed better antibacterial activity (68%) compared to those heated at 200 °C (50%).

The results obtained by Sisay et al. [11] using photocatalytic membranes—multiple nanoparticles (TiO_2, carbon nanotubes, $BiVO_4$) into polyvinylidene fluoride—demonstrates real dairy wastewater treatment. These membranes exhibited lower filtration resistance, better flux and higher FRR than the pristine membrane. The authors found that the factors that affect the filtration resistance are salinity, pH and concentration of lactose. The presence of lactose and higher pH values increased the irreversible resistance and severely reduced chemical oxygen demand rejection. The TiO_2-carbon nanotubes-$BiVO_4$-polyvinylidene fluoride membrane containing all constituents showed the best regeneration performance, exceeding that of the pristine membrane by 30%.

Salomatina et al. [12] studied photocatalytic efficiencies of poly(titanium oxide) dispersed in optically transparent polymeric matrices of different natures under UV and visible light on aqueous solutions of azo dyes and phenols. During the photocatalytic process in poly(titanium oxide) material, a one-electron transition to $Ti^{4+} + e^- \rightarrow Ti^{3+}$ was established, as well as the formation of electron–hole pairs and active oxygen species. Doping with gold and silver nanoparticles reduces the poly(titanium oxide) band gap from 3.11–3.35 to 2.11 eV. Therefore, doping with noble metals leads to the improvement of the photocatalytic properties of the nanocomposites under UV irradiation, and this is the reason for their high activity under the influence of visible light. In this case, azo dyes and phenol were found to be degraded by 90%.

Jaison et al. [13] report the current developments in the degradation of pollutants in the two types of photocatalytic oxidation, using TiO_2—namely, the influence of environmental conditions and catalyst deactivation—and possible solutions. The authors investigated the potential effects of the nature of the reactant, catalyst support, light intensity and relative humidity. The mechanisms of deactivation of photocatalysts and the possibility of reducing catalyst deactivation were also discussed.

Heterogeneous photocatalysts to generate sulfate radicals ($SO_4^{\bullet -}$) from peroxydisulfate ion ($S_2O_8^{2-}$) were successfully prepared by a solvothermal method. Alapi et al. [14] reported the preparation of BiOX (X = Cl, Br, and I) to increase the activity of the peroxydisulfate ion and faster degradation of organic substances in the presence of ultraviolet and visible light illumination. The BiOI efficiency highly exceeds that of BiOBr and BiOCl for PDS activation, even under visible irradiation.

In conclusion, this Special Issue on "Advances in the Synthesis and Applications of Transition/Noble Metal Oxide Photocatalysts" presents research related to the latest advances in the preparation and characterization of photocatalytic materials, with the aim of improving their performance in the removal of organic pollutants from water. We believe that our Special Issue will serve to inspire researchers in this field.

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Conflicts of Interest: The authors declare no conflict of interest.

References

1. Daneshvar, N.; Rabbani, M.; Modirshahla, N.; Behnajady, M. Kinetic modeling of photocatalytic degradation of Acid Red 27 in UV/TiO_2 process. *J. Photochem. Photobiol. A* **2004**, *168*, 39–45. [CrossRef]
2. Behnajady, M.; Modirshahla, N.; Hamzavi, R. Kinetic study on photocatalytic degradation of C.I. Acid Yellow 23 by ZnO photocatalyst. *J. Hazard. Mater. B* **2006**, *133*, 226–232. [CrossRef] [PubMed]
3. Sakthivel, S.; Shankar, M.; Palanichamy, M.; Arabindoo, B.; Bahnemann, D.; Murugesan, V. Enhancement of photocatalytic activity by metal deposition: Characterisation and photonic efficiency of Pt, Au and Pd deposited on TiO_2 catalyst. *Water Res.* **2004**, *38*, 3001–3008. [CrossRef] [PubMed]
4. Utami, F.; Rahman, D.; Sustini, E.; Abdullah, M. Immobilization of TiO_2 on transparent plastic and its application in photocatalytic wastewater treatment. *J. Phys. Conf. Ser.* **2019**, *1171*, 6–13. [CrossRef]
5. Yang, X.; Qiu, L.; Luo, X. ZIF-8 derived Ag-doped ZnO photocatalyst with enhanced photocatalytic activity. *RSC Adv.* **2018**, *8*, 4890–4894. [CrossRef] [PubMed]
6. Lai, H.; Nguyen, G.; Tran, N.; Nguyen, T.; Tran, C.; Nguyen, D.; Chang, S.; Chung, W.; Nguyen, D.; Thi, H.; et al. Assembled porphyrin nanofiber on the surface of g-C_3N_4 nanomaterials for enhanced photocatalytic degradation of organic dyes. *Catalysts* **2022**, *12*, 1630. [CrossRef]
7. Sert, B.; Bilici, Z.; Ocakoglu, K.; Dizge, N.; Rad, T.; Khataee, A. Preparation of S-scheme g-C_3N_4/ZnO heterojunction composite for highly efficient photocatalytic destruction of refractory organic pollutant. *Catalysts* **2023**, *13*, 485. [CrossRef]
8. Musielak, E.; Feliczak-Guzik, A.; Jaroniec, M.; Nowak, I. Photodynamic light-triggered release of curcumin from hierarchical FAU zeolite. *Catalysts* **2023**, *13*, 394. [CrossRef]
9. Gervasi, S.; Blangetti, N.; Freyria, F.; Guastella, S.; Bonelli, B. Undoped and Fe-doped anatase/brookite TiO_2 mixed phases, 2 obtained by a simple template-free synthesis method: Physico-3 chemical characterization and photocatalytic activity towards 4 simazine degradation. *Catalysts* **2023**, *13*, 667. [CrossRef]
10. Bachvarova-Nedelcheva, A.; Iordanova, R.; Naydenov, A.; Stoyanova, A.; Georgieva, N.; Nemska, V.; Foteva, T. Sol-gel obtaining of TiO_2/TeO_2 nanopowders with biocidal and 2 environmental applications. *Catalysts* **2023**, *13*, 257. [CrossRef]
11. Sisay, E.; Kertész, S.; Fazekas, Á.; Jákói, Z.; Kedves, Z.; Gyulavári, T.; Ágoston, Á.; Veréb, G.; László, Z. Application of $BiVO_4$/TiO_2/CNT composite photocatalysts for membrane fouling control and photocatalytic membrane regeneration during dairy wastewater treatment. *Catalysts* **2023**, *13*, 315. [CrossRef]
12. Salomatina, E.; Shelud'ko, P.; Smirnova, L. Photocatalytic decomposition of azo dyes and phenols using polymer composites containing nanostructured poly(titanium oxide) doped with gold or silver nanoparticles under light irradiation in a wide wavelength range. *Catalysts* **2023**, *13*, 423. [CrossRef]
13. Jaison, A.; Mohan, A.; Lee, Y. Recent Developments in Photocatalytic Nanotechnology for Purifying Air Polluted with Volatile Organic Compounds: Effect of Operating Parameters and Catalyst Deactivation. *Catalysts* **2023**, *13*, 407. [CrossRef]
14. Alapi, T.; Veres, B.; Náfrádi, M.; Farkas, L.; Pap, Z.; Covic, A. Application of BiOX photocatalyst to activate peroxydisulfate ion-investigation of a combined process for the removal of organic pollutants from water. *Catalysts* **2023**, *13*, 513. [CrossRef]