

Photocatalyst Nanomaterials for Environmental Challenges and Opportunities

Editorial

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Climate change caused by fossil-fuel use and other natural causes as well as Western and Asian economic growth driven by excessive consumption is among the biggest environmental challenges of the 21st century. Advances in nanotechnology bring a new tool set to remediate environmental challenges such as pollutant removal, anti-terror, air/liquid/soil filtration, and carbon dioxide conversion to hydrocarbons. As innovative engineered nanomaterials emerge, it is critical to establish the fundamental science of these new materials so that their utility is optimized and unintended consequences of their use are avoided.

The potential of photoelectrocatalyst nanomaterials is significant for environmental clean-up, pollution control, chemical/biological weapon remediation, emission filtration, and carbon dioxide conversion. In principle, catalyzed reactions energized by natural sunlight can be used to clean water, remove toxic chemicals, and create fuel and synthon stock and can be achieved using titanium dioxide particle systems [1]. Photoactive properties of titanium dioxide particles such as super-hydrophilicity, self-cleaning, and anti-bacterial qualities, were enhanced by doping with novel metals (Pt, Pd, Au, Ag, Cu, or Ni) and carbon nanomaterials (carbon nanotubes, graphene) [2-8]. Further tailoring of TiO₂ nanoparticle systems is under development to be used for air and water pollution removal for industrial and defense purposes. Even though photocatalytic reaction of TiO₂ was developed in the early 1970's [9], nanoscaled applications of the materials is improving catalytic efficiency and allowing smarter functionalities through chemical and physical alteration.

A potential promise of TiO₂ nanoparticles science is the catalytic conversion of carbon dioxide into useful hydrocarbons driven by sunlight energy. Carbon dioxide is a thermodynamically stable molecule and a significant amount of energy is required for cata-

lytic reaction; however photocatalyst utilizing TiO₂ nanoparticles have been shown to convert CO₂ and water vapor into hydrocarbon fuels using sunlight [10]. Modification of TiO₂ nanoparticles by doping with metals can tune band-gap properties and decrease exciton recombination rates, which eventually increase the availability of electron and holes for chemical conversion of substrates (CO₂ and H₂O, for example) and increases visible light sensitivity which allows for more efficient harvesting of the solar spectrum. Other nanoparticle systems can be assembled with the TiO₂ particles to tune and improve catalytic efficiency. Carbon nanomaterials are such a promising material due to their light absorption properties, electron storage capabilities, and electronic behavior, tunable from metallic to semiconductor. Additionally smart TiO₂ systems can be developed into sensors such as anti-terrorism and bioweapon neutralization due to their chemical and electrical properties. As Dr. Richard Feynman said, "there's plenty of room at the bottom" [11]; we envision there is still a lot of room for TiO₂ nanotechnology to innovate positively for human and earthly welfare.

In conclusion, new photocatalyst nanomaterials like TiO₂ coupled with metals, functional polymers, and carbon nanomaterials are targeted to yield smart materials that exhibit outstanding photocatalytic reactivity under sunlight, biological and chemical inertness, nontoxicity, long-term stability, and that can be interfaced with electronic and photonic systems. As this science develops, the sustainability of such materials and their net impact on global health will be a focus of the fields of engineering and science. Optimally, the application of these smart materials can mitigate the deterioration of our natural environment and improve clean air, potable water, and wastewater treatment through the removal of toxic pollutants. Further applications include the inactivation of organisms such as bacteria, viruses, and cancer. The impact of efficient, sustainable photocatalytic particles has many useful and practical applications that could ultimately result in a simpler, more efficient, and equitable economic systems.

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