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Design Strategies for Doping Metal Oxide Nanomaterials for Enhanced Photocatalytic Performance

ABSTRACT

Photocatalytic metal oxide nanomaterials have attracted significant attention for environmental remediation and sustainable energy applications because of their chemical stability, non-toxicity, and strong photocatalytic potential. However, their practical efficiency is often limited by wide band gaps, insufficient visible-light absorption, and rapid electron-hole recombination. This keynote highlights doping and codoping as strategic approaches for overcoming these limitations and advancing visible-light-responsive photocatalytic nanomaterials. Particular emphasis is placed on how dopant engineering modifies the structural, electronic, and surface properties of metal oxides to improve photocatalytic activity. Doping introduces defect states and alters electronic structures, enabling band-gap narrowing, enhanced light absorption, oxygen vacancy formation, and improved charge carrier dynamics. Nevertheless, single dopant incorporation may also generate recombination centers that restrict photocatalytic efficiency. Consequently, codoping has emerged as a more effective strategy because the simultaneous incorporation of multiple dopants creates synergistic interactions that stabilize defect states, promote efficient charge separation, and optimize surface reaction pathways. Recent studies employing controlled sol-gel synthesis demonstrate that codoping frameworks can systematically regulate dopant concentrations, leading to developed nanostructures with enhanced visible-light responsiveness and accelerated photocatalytic degradation of organic pollutants. Characterization techniques, including XRD, SEM, FTIR, XPS, UV–Vis, and photoluminescence analyses, reveal the direct relationship between defect engineering and photocatalytic performance. Overall, this keynote demonstrates how the transition from conventional doping to synergistic codoping establishes a robust framework for designing next-generation metal oxide nanomaterials for sustainable environmental and energy-related applications.

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BIOGRAPHY

Funda Ak Azem received her Ph.D. in Metallurgical and Materials Engineering from Dokuz Eylul University in 2008. She began her academic career as a research assistant in 1999 and was promoted to associate professor in 2023. Her research focuses on semiconductor and metal oxide nanomaterials for photocatalytic, optical, and biosensing applications, as well as carbon-based nanomaterials, biomaterials, and corrosion science. Her work emphasizes the design of advanced nanostructures through doping, defect engineering, and morphology control to enhance functional performance in environmental and energy-related applications.

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