World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:17, No:07, 2023

Surface Defect-engineered Ceo$_2$−x by Ultrasound Treatment for Superior Photocatalytic H_2 Production and Water Treatment

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Abstract : Semiconductor photocatalysts with surface defects display incredible light absorption bandwidth, and these defects function as highly active sites for oxidation processes by interacting with the surface band structure. Accordingly, engineering the photocatalyst with surface oxygen vacancies will enhance the semiconductor nanostructure's photocatalytic efficiency. Herein, a CeO2$_{-x}$ nanostructure is designed under the influence of low-frequency ultrasonic waves to create surface oxygen vacancies. This approach enhances the photocatalytic efficiency compared to many heterostructures while keeping the intrinsiccrystal structure intact. Ultrasonic waves induce the acoustic cavitation effect leading to the dissemination of active elements on the surface, which results in vacancy formation in conjunction with larger surface area and smaller particle size. The structural analysis of CeO_{2-x} revealed higher crystallinity, as well as morphological optimization, and the presence of oxygen vacancies is verified through Raman, X-rayphotoelectron spectroscopy, temperature-programmed reduction, photoluminescence, and electron spinresonance analyses. Oxygen vacancies accelerate the redox cycle between Ce_4+ and Ce_3+ by prolongingphotogenerated charge recombination. The ultrasound-treated pristine CeO_2 sample achieved excellenthydrogen production showing a quantum efficiency of 1.125% and efficient organic degradation. Ourpromising findings demonstrated that ultrasonic treatment causes the formation of surface oxygenvacancies and improves photocatalytic hydrogen evolution and pollution degradation. Conclusion: Defect engineering of the ceria nanoparticles with oxygen vacancies was achieved for the first time using low-frequency ultrasound treatment. The U-CeO_{2-x}sample showed high crystallinity, and morphological changes were observed. Due to the acoustic cavitation effect, a larger surface area and small particle size were observed. The ultrasound treatment causes particle aggregation and surface defects leading to oxygen vacancy formation. The XPS, Raman spectroscopy, PL spectroscopy, and ESR results confirm the presence of oxygen vacancies. The ultrasound-treated sample was also examined for pollutant degradation, where $1O_2$was found to be the major active species. Hence, the ultrasound treatment influences efficient photocatalysts for superior hydrogen evolution and an excellent photocatalytic degradation of contaminants. The prepared nanostructure showed excellent stability and recyclability. This work could pave the way for a unique post-synthesis strategy intended for efficient photocatalytic nanostructures.

Keywords : surface defect, CeO_{2-x}, photocatalytic, water treatment, H_2 production
Conference Title : ICNNWP 2023 : International Conference on Nanotechnology and Nanomaterials for Water Purification
Conference Location : Ottawa, Canada
Conference Dates : July 03-04, 2023