Graphene Quantum Dots Immobilized Mesoporous N-TiO_2 Thin Film membranes for Photocatalytic Applications

Namal Wanninayake[1], Syed Z. Islam[2], Allen Reed[1], Joseph Strzalka[3], Stephen E. Rankin[2,*] Doo Young Kim[1, *]

[1]Department of Chemistry, University of Kentucky, Lexington, KY, 40506-0055
[2]Department of Chemical and Materials Engineering, University of Kentucky, Lexington, KY, 40506-0046
[3]Advanced Photon Source, Argonne National Laboratory, Argonne, IL, USA

Titanium Dioxide is one of the most common material for photocatalytic membranes due to their low cost, non-toxicity and high chemical stability. However, the performance of TiO_2 is limited due to its large band gap and fast charge recombination. Therefore, recently we reported that the plasma-induced N_2/Ar treatment is an efficient method to enhance the visible-light absorption and the photocatalytic activities of mesoporous TiO_2. Our previous work showed that, after N_2/Ar plasma treatment of TiO_2, the band gap of TiO_2 was significantly reduced (from 3.5 eV to 2.9 eV), and the photocatalytic water oxidation of nitrogen-doped TiO_2(N-TiO_2) showed 70 times performance enhancement compared to undoped TiO_2 under solar simulator (AM1.5G). In this study, we further modified N-TiO_2 by interfacing with Graphene Quantum Dots(GQDs) because GQDs reduce the charge recombination in N-TiO_2 membrane and simultaneously enhance its antibiofouling and antibacterial properties. Furthermore, the recent emergence of GQDs has opened a new era for developing membranes with high separation performance due to their other properties such as high specific surface area, biocompatibility, and unique size. In this study, the cubic ordered mesoporous TiO_2 films were prepared by a surfactant templated sol-gel method. Then, TiO_2 films were treated with N_2/Ar plasma for the incorporation of substitutional N atoms. The direct immobilization of GQDs on to N-TiO_2 was accomplished by hydrothermally reacting GQDs and N-TiO_2. The pore orientation of TiO_2 before and after the plasma treatment was confirmed by the Grazing-Incidence Small-Angle X-ray Scattering Technique. The photocatalytic performance was evaluated for water oxidation by employing chronoamperometry. The kinetic photocurrent decay analysis revealed that GQDs reduce the charge recombination thus enhances the photocatalytic activity of N-TiO_2. GQD-immobilized N-TiO_2(GQD-N-TiO_2) showed about 346 times photocurrent enhancement compared to unmodified TiO_2, indicating the significant role of GQDs. We conclude this enhancement originates from the synergistic effect of N-TiO_2 and GQDs, including proper band alignment, efficient charge separation at the GQD/N-TiO_2 interface and the surface catalytic sites induced by GQDs. Therefore, we believe that GQD-N-TiO_2 has a tremendous potential to be used as an efficient photocatalytic membrane to remove toxic pollutants in water purification applications in future.

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