CdTe Quantum Dot-Enhanced Titania Systems for Photocatalytic Oxidative NO_X Storage

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Abstract: Water soluble thioglycolic acid capped CdTe quantum dots (QDs) were employed in an attempt to enhance the visible-light driven catalytic activity of titanium dioxide (a UV-active benchmark photocatalyst) in photocatalytic oxidative NO_x(g) storage in solid state. Our results revealed enhanced NO_x storage efficiencies as well as low NO_2(g) release under visible light irradiation.

Keywords: Photocatalysis, Quantum dots, NO_x abatement.

1. Introduction

Nitrogen oxides (NO_x) are highly hazardous environmental pollutants that can lead to the formation of hydroxyl radicals, tropospheric ozone and acid rain.[1] Increasing anthropogenic utilization of stationary and mobile fossil and biomass combustion systems is known to be the major source of atmospheric pollution via NO_x.[1,2] Abatement of toxic NO_x gases can be achieved by thermal catalytic processes or physical/chemical adsorption systems. However, environmentally friendly, cost-efficient and sustainable alternative photocatalytic systems can also be designed which can exploit readily abundant solar radiation.[2]

One of the most well-known benchmarks for environmental photocatalysts is titanium dioxide with a wide band gap typically varying within 3.0-3.2 eV that can be activated via UV photons.[1-3] This wide band gap prevents efficient absorption of visible light, which corresponds to around 5 times higher intensity compared to UV light.[2,4] In order to increase the photocatalytic efficiency of the titanium dioxide, its visible- light exploitation capability should be enhanced. Although, this can be done by doping of TiO_2 with nonmetal main group elements, recently the research focus has shifted towards utilization of semiconductor quantum dots (QDs) for this purpose.[4] Visible response of the QDs can be modified by tuning their particle size. Furthermore, QDs provide additional advantages such as the generation of hot electrons or multiple charge carriers with a single high-energy photon.[5] In the present work, CdTe QDs were employed as a direct band gap semiconductor (1.44 eV) compatible with the visible window of the solar spectrum to promote titania based photocatalysts. Due to its higher conduction band, CdTe can transfer its conduction band electrons to the conduction band of TiO_2 and the hole that is created on the valence band of TiO_2 can be transferred to the valence band of CdTe; leading to efficient electron-hole separation.[6] Thus, visible light exploitation capacity of TiO_2 can be enhanced along with its photocatalytic activity.

2. Experimental

The colloidal synthesis of water soluble thioglycolic acid (TGA) capped CdTe quantum dots were carried out. Different loadings of TGA capped CdTe quantum dots were physically mixed with titanium dioxide. Photocatalytic activity of these composites were measured under both visible and ultraviolet light exposures and the results were compared to the benchmark TiO_2 photocatalyst (Degussa P25).

3. Results and discussion

Photocatalytic NO_x storage and NO_2 generation activity values were measured for catalysts with varying QD loadings and the corresponding photocatalytic NO oxidation and storage results are presented in terms of percent photonic efficiencies (Figure 1). Figure 1 suggests that promotion of TiO_2 with CdTe does not only

result in the enhancement of the solid state NO_x storage capability, but also leads to a drastic decline in NO_2(g) release. Suppression of the NO_2(g) generation along with simultaneous enhancement in the solid-state oxidative NO_x storage in the QD promoted photocatalysts indicates a superior performance towards photocatalytic NO_x abatement.

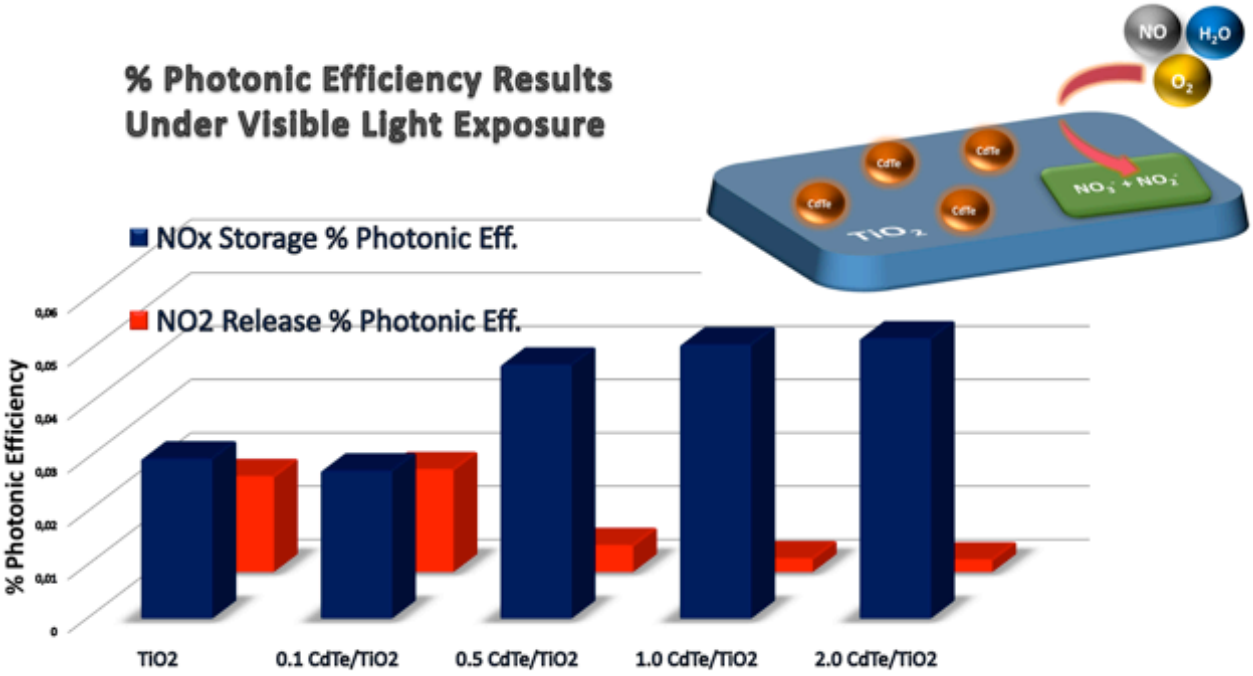

Figure 1. Photocatalytic NO_X storage and NO_2 release properties of CdTe/TiO_2 photocatalysts with varying composition.

4. Conclusions

In the current work, a well-known UV-active benchmark TiO_2 photocatalyst was promoted with CdTe QDs in order to enhance its photocatalytic activity in the visible region. CdTe/TiO_2 photocatalysts revealed excellent NO_x storage efficiencies as well as lower NO_2(g) release under visible irradiation, outperforming the P25 titania conventional benchmark catalyst.

References

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