Efficient photocatalytic TiO_2 and Bi_2O_3 thin films by ultrasonic spray pyrolysis

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Deposition of transparent thin films with low material quantity and excellent adhesion properties expand the application of photocatalysis. One challenge to overcome the performance of the thin film photocatalyst is to boost their photocatalytic activity to the state of the art of nanopowder based materials. One possibility is to take advantage of thin film deposition onto the large well-illuminated surfaces (e.g. windowpanes) that could lead to the enhanced treatment capability. In this perspective ultrasonic spray-pyrolysis (USP) has been proven as an easily scalable method for production of uniform thin films on large areas.[1]

The aim of study was to deposit TiO_2 and Bi_2O_3 thin films by USP and to investigate the influence of the processing variable including precursor solution composition and the deposition temperature on the photocatalytic activity.

TiO_2 thin films were prepared from titanium(IV) isopropoxide solution at deposition temperature of 350 °C and annealed for 1 h at 500 °C. The composition of precursor solution was optimised by varying the amount of acetylacetone in solution.[1] Bi_2O_3 thin films were prepared from bismuth(III) acetate solution. The deposition temperature was optimised in the range of 250 - 450 °C and air annealed in the temperature range of 300 - 550 °C. Both materials, TiO_2 and Bi_2O_3 films, were tested for photocatalytic oxidation of methyl orange (MO) dye in aqueous solutions under UV-A and VIS light. In addition, TiO_2 activity to oxidise volatile organic compounds (VOCs) in gas-phase was studied. [2,3]

Both TiO_2 and Bi_2O_3 thin films showed the optical transparency of ca 80% and good mechanical and chemical stability. TiO_2 anatase 380-nm films with increased amount of acetylacetone in precursor solution showed high photocatalytic oxidation ability to degrade VOCs as individual pollutants (such as acetone, acetaldehyde, hepatane and toluene) and in their mixtures under UV-A and VIS light. Film with titanium(IV) isopropoxide: acetylacetone molar ratio 1:8 oxidised 9-ppm mixture of VOCs under UV-A at catalyst surface area of 360 cm^2 (residence time of 46.8 s) and up to 90% of mixture under VIS light at catalyst surface area of 600 cm^2 (residence time of 78 s). The photocatalytic activity of the film with increase amount of acetylacetone was enhanced owing to the incorporation of carbon, which influenced the electronic structure and charge separation of the film. The photocatalytic activity of TiO_2 thin film was enhanced owing to the reduction in electron-hole pair recombination and production of higher amount of hydroxyl radicals.

Bi_2O_3 films deposited at temperatures 350-450 °C consisted of pure β-Bi_2O_3 phase. The deposition and annealing at temperatures above 450 °C resulted in presence of mixed oxidation states $3^+/5^+$ of bismuth and formation of additional phase - Bi_4O_7. However, deposition at 300 °C resulted in amorphous film, and post-annealing at 350 °C leads to the crystalline β-Bi_2O_3 phase. These films reached MO conversion of 47% after 5 h under UV-A irradiation, which was the highest photocatalytic activity for 10 ppm of MO dye oxidation. The conversion of MO on the TiO_2 thin film was insignificantly higher compared to the Bi_2O_3 film.

Results of this study showed that deposition of amorphous films at lower temperature with crystallization during post-annealing leads to the enhancement in photocatalytic activity for both TiO_2 and Bi_2O_3 films. Moreover, the optimisation of both precursor composition and deposition temperatures are important in production of thin films by spray pyrolysis.

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References

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