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Ultrasound assisted preparation of stable water-based nanocrystalline TiO_2 suspensions for photocatalytic applications of inkjet-printed films

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ABSTRACT

The use of titania photocatalytic materials in industrial applications is strongly dependent on the stability, nanoparticle size distribution, ease of deposition and cost of the relevant titania precursor solutions or suspensions. The present contribution presents the preparation of inkjet-printed titania films, derived from stable water-based suspensions. The suspensions were synthesized by applying a "top-down" synthetic strategy, namely the ultrasonication of commercially available titania powder (Evonik Aeroxide P25). Crucial parameters, such as suspension stability, energy input requirements, particle size distribution, surface characteristics, compatibility with industrially proven inkjet systems and photocatalytic performance were investigated. The developed synthetic procedure proves environmentally friendly, low cost and most suitable for large scale production of titania thin films, by inkjet printing commercially available ceramic tiles.

1. Introduction

Titanium dioxide heterogeneous photocatalysis has proved to be among the most effective advanced oxidation processes (AOPs). The ability of solar or artificial light to promote the production of strongly oxidizing species ($OH^{\bullet}$ and $O_2^{\bullet -}$ radicals) on the semiconductor surface enables applications with a low operating temperature, low energy consumption and low cost [1]. This property makes the material – especially on the nano-scale – suitable for a wide range of applications including natural contaminated systems [2,3], air purification [4] and antimicrobial protection [5]. TiO_2 on the nano-scale has previously been used in solar cells [6], gas sensors [7], dielectric applications [8] and extensively as a photocatalytic material for self-cleaning surfaces such as glass [9,10] and fabric [11]. The photocatalytic performance of the TiO_2 coating strongly depends on the preparation method and the application method. The application of TiO_2 suspensions on surfaces for the formation of thin films has previously been demonstrated by the doctor blade method [12], electrophoretic deposition [13], plasma spraying [14] and inkjet printing [15–17].

Even though photocatalytic applications appear very promising, the deposition of large surface area titania films for industrial or commercial use has been limited, as titania suspension precursors have not been adequately coupled with an industrially proven deposition technique, such as spraying, rotary drum deposition or inkjet printing. Chemical vapour deposition (CVD) provides good quality and transparent films but at high cost; while doctor blade deposition is an affordable and simple deposition technique, but it produces thick and opaque films: simply unacceptable properties in most everyday applications.

In parallel, crucial factors that affect the industrial adoption rate of photocatalytic applications have largely been neglected: the cost, volatile organic content, flammability, stability and shelf life of titania precursor suspensions. The sol–gel synthetic technique is promising in fine-tuning specific materials properties; however, the (i) high cost of raw metal alkoxides or salts, (ii) large shrinkage during processing, (iii) health hazard of alcohol or non-polar organic solvents and (iv) extended processing time do not lower the industrial adoption barriers. This fine, "bottom-up" synthesis strategy (from alkoxides or salts to nanoparticles) has been thoroughly studied for the preparation of titania nanoparticles, even though it is susceptible to temperature variations or raw materials purity.

This contribution presents the synthesis of stable, completely water-based titania suspensions, specially designed to be applied by inkjet printing. Instead of applying the "bottom-up" sol–gel process, the "top-down" ultrasonication of commercially available titania powder has been selected. The selection of a physical,

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