Abstract

Drinkable water scarcity poses a growing global threat and is gaining even more attention due to constant industrialisation and population growth. In response, advanced water treatment methods have emerged, with photocatalysis attracting significant interest due to its capability for the complete mineralisation of persistent organic pollutants using light energy, which is unattainable with conventional methods.

Titanium dioxide (TiO_2) is the most often chosen material for photocatalytic applications due to its low cost, wide availability, chemical stability, and non-toxicity. Yet, despite four decades of research, photocatalytic systems remain underutilised in industrial applications. This gap stems from a disproportionate focus on photocatalytic materials modification while neglecting their applicational aspects, among which the form of the photocatalyst largely determines the feasibility of its operation on an industrial scale. Concerning the latter, immobilised photocatalysts are more often chosen, sacrificing their specific surface area and reducing efficiency due to thermal degradation. The low-pressure cold spray (LPCS) process, a kinetic-driven deposition technique, addresses this by retaining material properties through low-temperature processing. However, depositing oxide powders like TiO_2 via LPCS is challenging due to their inherent brittleness. A promising solution involves using agglomerated TiO_2 particles, which deform via agglomerate flattening and break-up during deposition. Another underexplored aspect is photocatalyst longevity. Scarce data on aged photocatalyst behaviour hinders predictions of property degradation over operational cycles, despite the economic and environmental benefits of reusability.

In this thesis, the combination of sol–gel synthesis with the LPCS technique for the fabrication of photocatalytic TiO_2 coatings is researched. The sol–gel method produces amorphous, self-agglomerated TiO_2 powder, enabling LPCS deposition. This synergistic approach ensures homogeneity, scalability, and functional retention. To enable the deposition of the oxide powder via LPCS, the sol-gel-derived TiO_2 powder is amorphous and self-agglomerated. The photocatalytic performance of the resulting coatings is evaluated via

methylene blue (MB) model pollutant degradation under UV light. Additionally, to study the ageing of a photocatalyst, two experiments are carried out: (1) continuous long-term ageing in a humid chamber to simulate structural degradation and (2) multi-cycle decomposition tests to evaluate photocatalytic stability. Furthermore, the powder synthesis is modified to determine the influence of powder agglomeration on the LPCS deposition process and the properties of the resulting coating.

Results demonstrate that LPCS-immobilised TiO_2 coating material partially crystallises into the anatase phase and degrades methylene blue effectively under UV light. Long-term ageing negatively affects the adsorption properties of the photocatalyst, decreasing its effectiveness. The multi-cycle decomposition test shows that a more crystalline photocatalyst yields more repetitive rates of MB decomposition reactions. Additionally, the regeneration of the photocatalyst between the consecutive tests enables maintaining its initial effectiveness. What is more, the TiO_2 coatings have low cohesion, and their adhesion mechanism is determined by the coatings' degree of crystallinity. Two types of adhesion mechanisms are proposed: predominantly amorphous coatings rely on chemical bonding, while coatings with a higher number of crystalline grains adhere via mechanical bonding. Ageing tests show that chemically bonded coatings strengthen over time due to the increase in the number of bonds established, whereas mechanically bonded interfaces weaken due to reduced surface contact. Despite the ageing-weakening, the mechanically bonded coatings have superior adhesion. Lastly, the synthesis of the TiO_2 is altered by increasing the pH and varying the solvent (between isopropanol, methanol and acetone), which affects the self-agglomeration of the powders and directly influences their deposition efficiency. As a result, coating adhesion is affected, while higher pH increases dye adsorption, causing the photocatalyst fouling and decomposition rate to decrease.

The results show the possibility of photocatalyst production via non-standard methods, like sol-gel and LPCS, and discuss photocatalyst longevity and adhesion mechanisms while identifying key challenges: enhancing coating cohesion and extending light absorption into the visible spectrum.