Rapid Synthesis of Anti-Fogging Coatings

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ABSTRACT

Nanostructured coating of silica, titanium oxide and silica - titanium oxide were self-assembled by flame spray pyrolysis onto glass substrate and *in situ* stabilized by rapid aerosol annealing. Although all materials had anti-fogging properties under normal irradiation, the pure titanium oxide nanostructures did not prevent fogging without UV irradiation. The anti-fogging properties were attributed to the ability of preventing water droplet formation on the glass substrate. In fact under normal irradiation, all the coatings had a super-hydrophilic surface. Nevertheless, the super-hydrophilicity mechanisms were distinguished for silica and titanium oxide while for the later it was photochemically-driven for the former it was driven by the surface species. The morphology of the nanostructures varied drastically as a function of the precursor composition. Pure titanium oxide led to aerosol-born nanoparticles which deposit heterogeneously onto the glass substrate forming disconnected, lace-like, agglomerated structures. Silica - titanium oxide nanocomposite led to similar coating's properties as the pure titanium oxide but short spike-like structures distinguished the deposited agglomerates.

1 INTRODUCTION

The wetting properties of surfaces greatly influence their interaction with the environment.[1] Recently, many studies have focused on the development of efficient coating methods for extreme wetting of surfaces features. Self-cleaning,[2] bacteria-resistant, and anti-fogging[3] surfaces are made by depositing either super - hydrophobic or super - hydrophilic coatings. That impact several applications such as sport and sanitary equipment, lenses for optical devices, reading glasses, automobile windscreens, windows and mirrors to name a few. In particular, anti - fogging coatings are feasible by preventing formation of small water droplets on the substrate surface by a high performing super - hydrophilic coating.[3] Furthermore, such coatings should be transparent, mechanically stable and low cost to promote commercialization.

The coating synthesis method and material properties greatly influence film performance in terms of transparency, stability and anti - fogging effect. Metal - oxide coating processes can be subdivided in wet - and dry - methods. Wet - methods have the advantage of relatively high coating mechanical stability, due to utilization of binders, but require long process time (hours / days), large number of steps and may have poor reproducibility of coating morphology. In contrast, dry methods can deposit highly porous nanostructured coatings in short times with good control and reproducibility of coating morphology.[4] In fact, dry synthesis and deposition of nanostructures is obtainable by several methods such as sputtering, spray pyrolysis, cluster beam deposition, classified aerosol deposition, combustion chemical vapor deposition or flame spray pyrolysis (FSP), but only few can be scaled easily to deposit on large surfaces and at low cost.

Here, silica and silica - titanium oxide nanostructured coatings have been deposited by FSP onto glass substrates and *in situ* stabilized by flame annealing. The coatings synthesis mechanism has been investigated for the different materials by analysis of the aerosol and coating properties. The coating transparency, stability and wetting features have been characterized as a function of deposition time (thickness and surface coverage) for each material and correlated to their anti - fogging performance.

2 RESULT AND DISCUSSION

Deposition of nanostructured metal oxide coatings by FSP (Fig. 1) is obtained by three main mechanisms. The predominance of which depends from flame parameters and precursor composition. Droplet deposition (Fig. 1a) occurs if the precursor impact onto the substrate surface before complete combustion or evaporation. In this case reaction of the precursor on the substrate (Fig. 1a) leads to formation of a solid layer (MO_x-solid). Such layers tend to have a large amount of cracks and uncontrolled morphologies as for suboptimal deposition by spray pyrolysis. In contrast, if the precursor is vaporized but only partially reacted it can react further on the substrate (Fig. 1b) as in chemical vapor deposition (CDV). Instead, complete reaction of the precursor in the flame (Fig. 1b) leads to formation of a metal oxide vapor. This vapor can nucleate heterogeneously on the substrate surface (Fig. 1b) as in classical physical vapor deposition (PVD). In both these cases, it is possible to accurately control morphology and growth of the layer. In fact, porous structures with a variety of shapes and also completely dense films are feasible. If the metal oxide vapor is super - saturated (Fig. 1c), homogeneous nucleation can occur in the flame leading to particles formation. This aerosol is deposited onto the substrate by Brownian motion, thermophoresis and impaction (Fig. 1c) leading to highly porous coating (> 98%) with low mechanical stability.

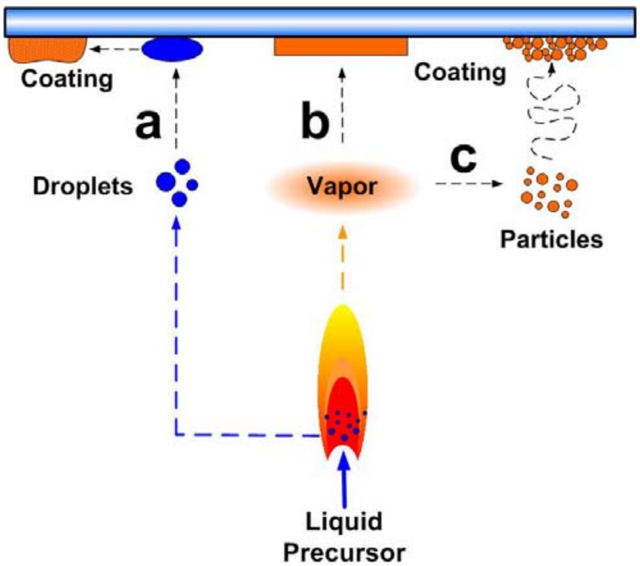

Figure 1: Schematic of coating synthesis by flame spray pyrolysis. Nanostructured coatings are self - assembled by three routes: (a) splashing of precursor droplets and reaction on the substrate surface which leads to cracks formation and uncontrolled morphologies; (b) chemical or physical vapor deposition (PVD) of the oxides vapor on the substrate which lead to controlled morphologies and chemically bonded nanostructures; (c) particles nucleation in the gas phase and deposition.

Synthesis of TiO_2 - SiO_2 (Fig. 2) coating resulted in particles nucleation and deposition (Fig. 1b) as observed for TiO_2 synthesis. The resulting coating morphology (Fig. 2) was similar to the TiO_2 one with agglomerated structures extending throughout the surface. A slight difference is observable in the shape of these agglomerates. In contrast to the soft TiO_2 structures, the SiO_2 - TiO_2 ones tend to form spike - like ending as visible in the SEM analysis (Fig. 2).

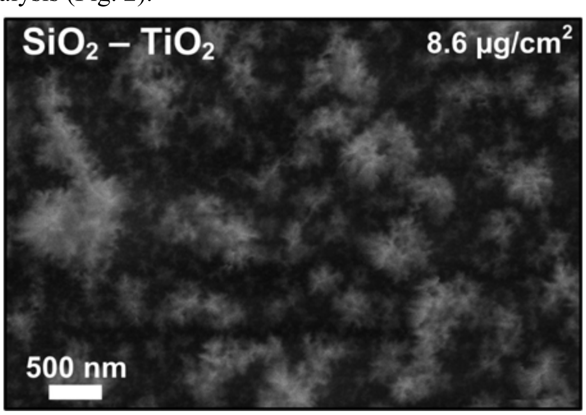

Figure 2: SEM top view of a 8.6 μg/cm^2 SiO_2 - TiO_2 coating. The coating consists of lace - like structures made of air born particles with spike - like endings.

3 CONCLUSIONS

Rapid synthesis of water stable, transparent anti - fogging coating of SiO_2, TiO_2 and SiO_2 - TiO_2 by direct flame aerosol deposition and *in situ* annealing on transparent glass substrates was achieved. The anti -fogging properties were attributed to the super - hydrophilicity of the coatings not allowing formation of water droplets on the glass surface. The coating super - hydrophilicity was attributed to super - hydrophilicity of the deposited nanostructures, which was due to the photocatalytic effect for TiO_2 and to the super-hydrophilic nature of flame - made SiO_2 else. In fact, deactivation of TiO_2 led to non - super - hydrophilic surfaces.

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