ADJUSTABLE WETTING PROPERTIES OF PAPERBOARD BY LIQUID FLAME SPRAY PROCESS

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Here we demonstrate how to control the wetting properties of paperboard by utilizing liquid flame spray process (LFS), which can be used for creating nanoparticles on surfaces. In our study commercial double pigment coated paperboard was coated by TiO_x and SiO_x nanoparticles using titanium (IV) isopropoxide (TTIP) and tetraethylorthosilicate (TEOS) precursors dissolved in isopropanol (IPA). We observe a very large difference in water contact angles (CA) between TiO_x and SiO_x coated samples with 151° and 21°, respectively. For the reference sample the water CA is 60°. These values are taken 2 seconds after the droplet placement, when the water droplet contact area with the paperboard has stopped to change, but when evaporation has not yet affected the measured values. Figure 1 presents the water CAs as a function of time with the corresponding water droplet images on the coatings and the reference paperboard sample.

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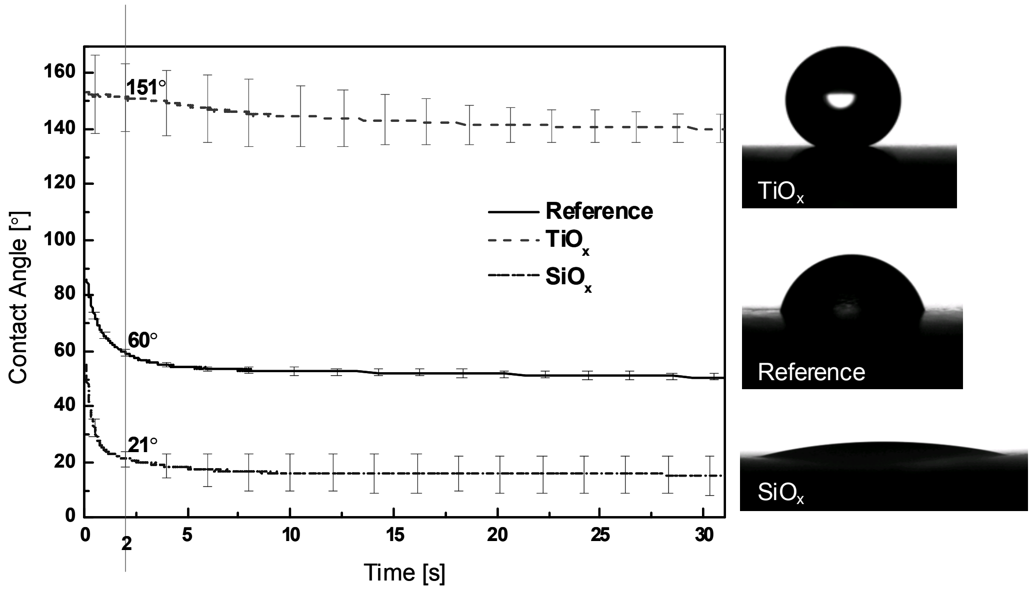

Figure 1: Water contact angle (CA) for reference (solid), TiO_x (dash) and SiO_x (dash dot) coatings as a function of time. The subfigures to the right display the captured images from the measurement at the 2.0 s. The error bars display standard deviations from three measurements.

The surface of paperboard samples was characterized using commercial scanning electron microscopy (SEM) and atomic force microscopy (AFM). Results of topographical characterization are presented in Figures 2 a-f). The SEM image of the reference paperboard sample in Figure 2 a) shows well the platy-like kaolin particles immersed in organic binder, which was used in the coating of the commercial paperboard. Figs. 2 c) and e) illustrate the surface after the LFS process with TiO_x and SiO_x nanoparticle coatings, respectively. The nanoparticles are distributed evenly on the surface, and the morphology of both TiO_x and SiO_x nanoparticles appears similar. SEM images clearly show a significant difference between the reference and the nanoparticle coated samples. The paperboard surface is fully covered with spherical particles of approximately 40 – 80 nm in diameter. The estimation of exact sizes is difficult due to particle agglomeration. For a more detailed picture about surface characteristics AFM analysis was applied. Figs 3 b), d) and f) display the surface topography of the reference, the TiO_x and the SiO_x nanoparticle coated samples. For TiO_x particles the surface of the nanoparticles appears to contain nanoscale nodular features, which lead to high nanoscale roughness and may explain the observed superhydrophobic behavior. SiO_x sample is composed from spherical particles, which seem to be larger than TiO_x particles, and which remain on the surface as larger and more flat aggregations. In both cases spheres tend to connect to each another creating complex structures.

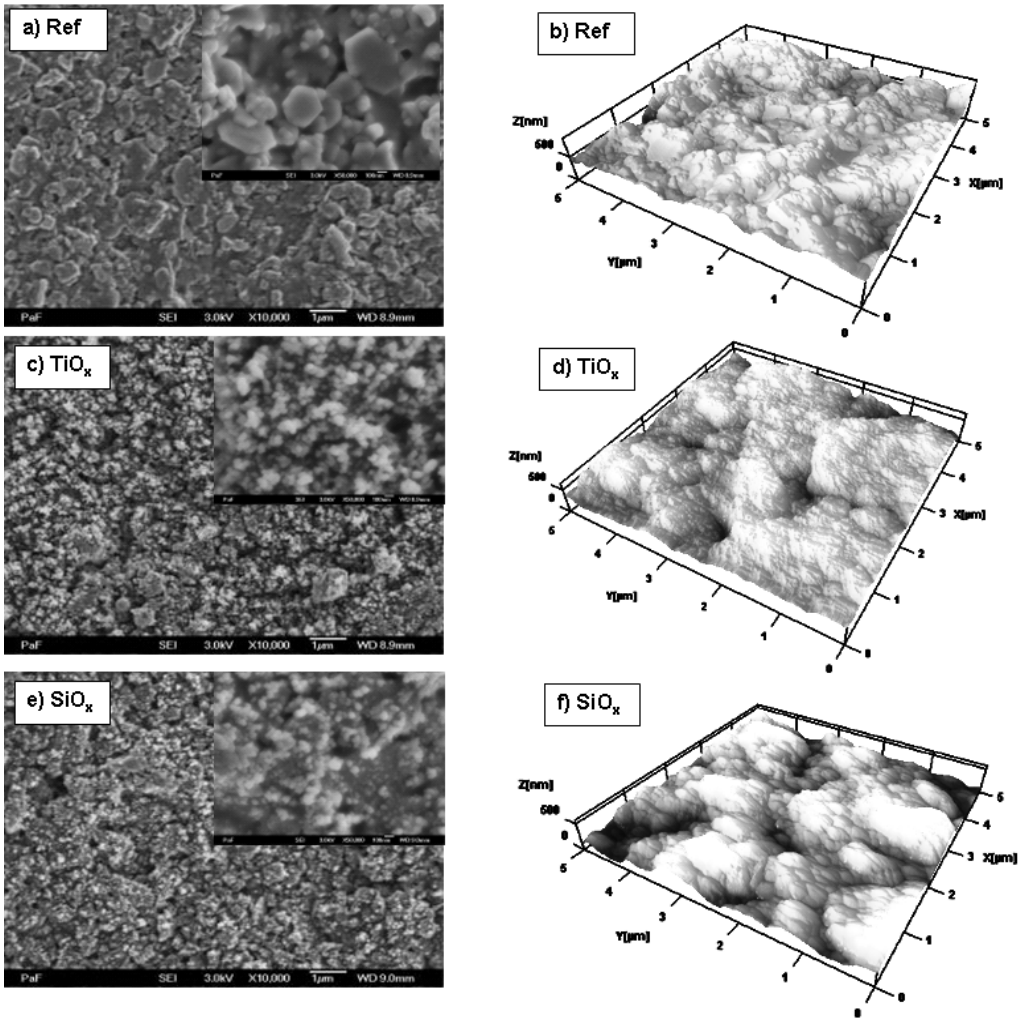

Figure 2: SEM (to the left) and AFM (to the right) images of the reference sample a, b), TiOx nanoparticle coating c, d) and SiOx nanoparticle coating e, f).

In conclusion, we have demonstrated a method to adjust surface hydrophilicity and hydrophobicity of paperboard. Superhydrophobic surfaces with water contact angle as high as 151° were fabricated by TiO_x coatings and superhydrophilic surfaces with a water contact angle as low as 21° were achieved by SiO_x coatings. In both cases nanocoatings were created by the liquid flame spray method, which, as far as the authors know, has not been used for similar purpose before. Our experiments provide useful information and suggest a new method for paper industry. In addition, both surfaces can be produced by an on-line coating method and successfully applied on paper substrates. We believe that our findings are providing a route for designing other functional surfaces simply by choosing different liquid precursors.

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