Controlled wettability of paperboard by nanoparticles using liquid flame spray process

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ABSTRACT

Liquid flame spray process (LFS) was used for depositing TiO_x and SiO_x nanoparticles on paperboard to control wetting properties of the surface. By the LFS process it is possible to create either superhydrophobic or superhydrophilic surfaces. Changes in the wettability are related to structural properties, which were characterized using scanning electron microscope (SEM) and atomic force microscope (AFM). The surface properties can be ascribed as a correlation between wetting properties of the paperboard and the surface texture created by nanoparticles.

INTRODUCTION

Recently wetting phenomena have raised a growing interest in numerous industrial processes, especially in research and development of new materials and surfaces. The wetting properties of surfaces are governed by hydrophobicity and hydrophilicity phenomena. Here we demonstrate how to control the wetting properties of a paperboard by applying a liquid flame spray (LFS) process, which can be used for creating and depositing nanoparticles on surfaces. Such a thermal spray process has a high temperature and high velocity flame, where injected hydrogen and oxygen act as combustion gases providing both nebulization of organic solvent and atomization of the liquid precursor into the flame. The major advantage of the LFS process is the broad spectrum of metal or metal oxide nanoparticles, which can be created using different liquid precursors, and for a detailed description of the LFS process, see Refs. [1–4].The LFS method is already well established, for example, in glass and optics industry where LFS created nanoparticles can be used to enhance performance [5]. In the present study, LFS as a novel coating method for paperboard has been applied, which to our knowledge has not been systematically studied before. The purpose of this work is to correlate the changes in wetting properties of paperboard with nanosized TiO_x and SiO_x coatings produced by the LFS process.

EXPERIMENTAL: MATERIALS AND METHODS

In our study commercially available double pigment coated paperboard (200 g/m^2, Natura, Stora Enso, Skoghall, Sweden) was used as a substrate and coated by TiOx and SiOx nanoparticles using titanium (IV) isopropoxide and tetraethylorthosilicate precursors dissolved in isopropanol. Contact angle (CA) measurements were performed by a commercial contact angle goniometer KSV CAM 200 (KSV Instruments Ltd., Finland). Surface morphology of the paperboard samples was first obtained using a scanning electron microscopy (SEM) (Jeol JSM-6335F) and a more detailed surface characterization was performed by atomic force microscope (AFM) NTEGRA Prima instrument (NT-MDT, Moscow, Russia). All the images were captured using the tapping mode at ambient conditions (RT 24°C $\pm$ 1°C and RH 38 $\pm$ 5 %).

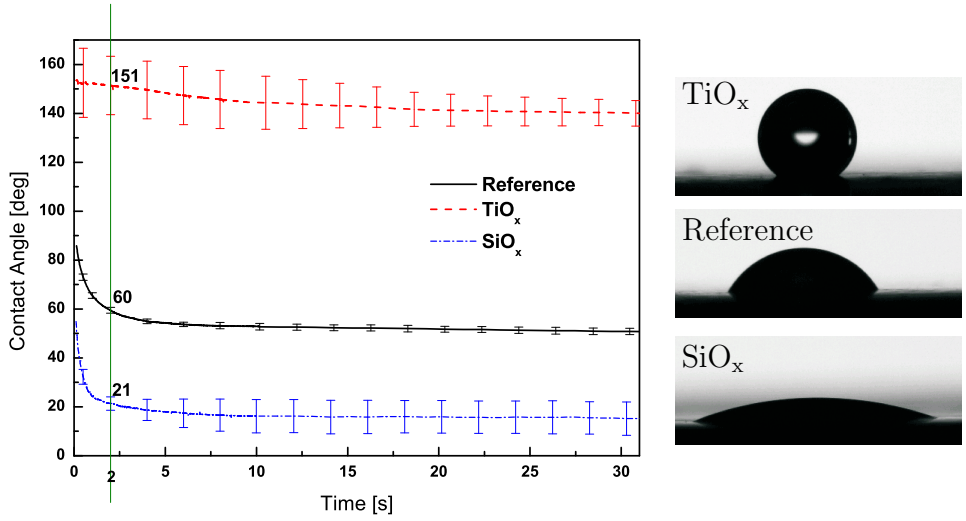

Figure 1: Water contact angle (CA) for TiO_x (red) and SiO_x (blue) coatings as a function of time. The subfigures to the right display the captured images from the measurement at the 2.0 s. The error bars display standard deviation from three parallel measurements

RESULTS AND DISCUSSION

A very large difference in water contact angles (CA) was observed between TiO_x and SiO_x coated samples with 151° and 21° , respectively. For the reference sample the water CA is 61°. 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. Topographical characterization by SEM and AFM was also performed, and the results are presented in Figures 2 a-f). The SEM images clearly show a significant difference between the reference (Fig. 2a) and the nanoparticle coated samples illustrated in Figs. 2 c) and e), where paperboard surface is fully covered with spherical particles of approximately 40 - 80 nm in diameter. For a more detailed picture about surface characteristics AFM analysis was applied. Figs 2 b), d) and f) display the surface topography of the reference, the TiOx and the SiOx nanoparticle coated samples, respectively. For TiOx particles the surface of the nanoparticles contains spiky features, which result in higher roughness and can potentially explain the observed superhydrophobic behavior. SiOx sample is composed from spherical particles, which seem to be larger than TiOx particles, and which remain on the surface as larger and more flat aggregations. In both cases spheres tend to connect to each another.

CONCLUDING REMARKS

In conclusion, we have demonstrated a method to modify surface hydrophilicity or hydrophobicity on paperboard by nanoparticle coatings. 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 on the paper surface by the liquid flame spray method, which, as far as the authors know, has not been used for similar purpose before. In both cases nanocoatings can be produced by an on-line coating liquid flame spray method and successfully applied on paper substrates. The experiments provide useful information and suggest a new method for paper industry providing a route for designing other functional surfaces simply by choosing different process parameters.

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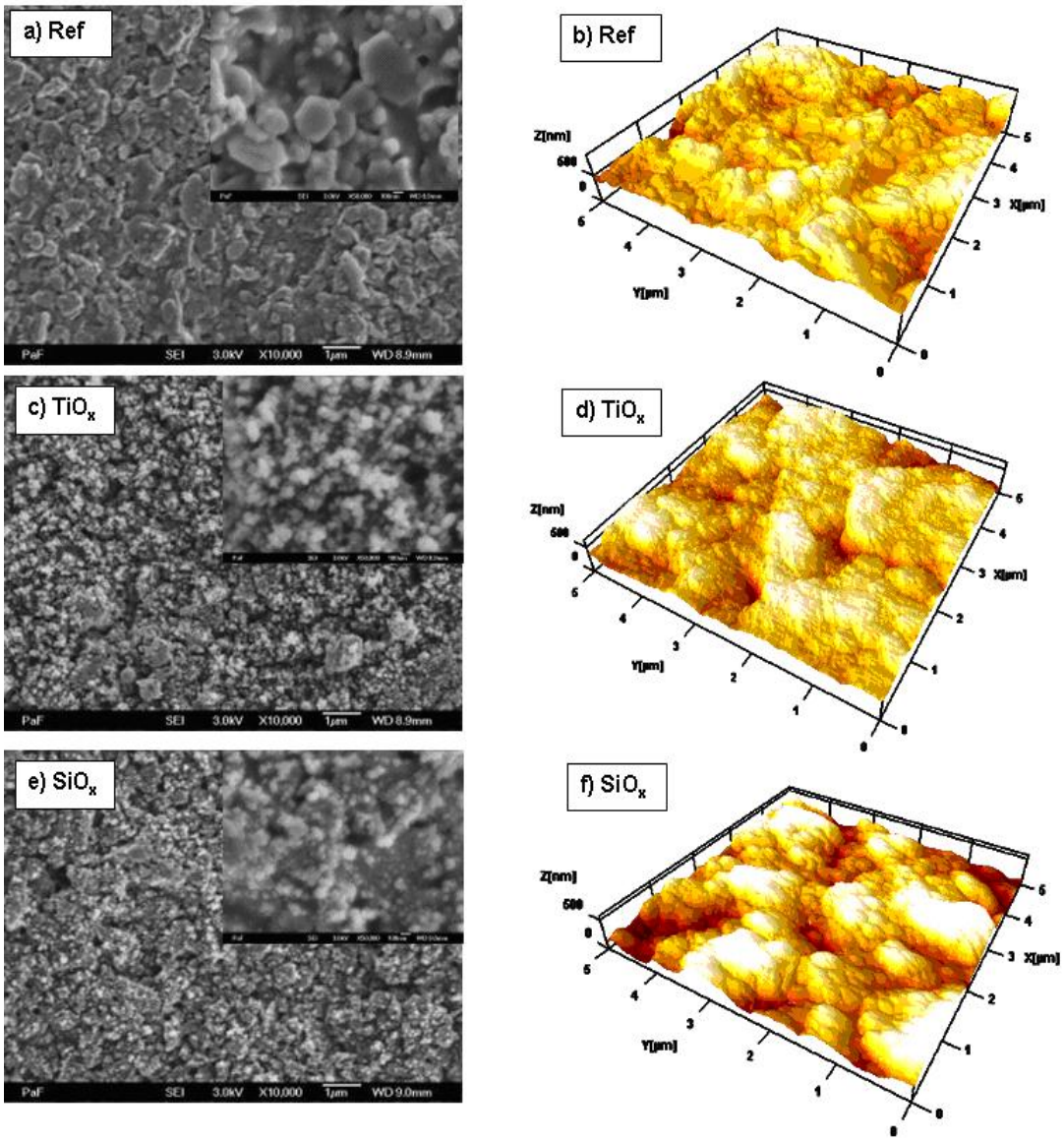

Figure 2: SEM (to the left) and AFM (to the right) images of the reference sample a, b), TiOx nanoparticle coating c, d) and SiOx nanoparticle coating e, f).

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