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Fabrication of high-performance antifogging and antireflective coatings using faujasitic nanozeolites

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ABSTRACT

Colloidal solution of zeolite Y and silica nanoparticles were deposited on glass slides by a dipping method and dried under mild conditions to prepare thin transparent coatings. The thickness of the coatings was controlled by the number of dipping cycles. The zeolite coatings showed antireflection properties with a maximum transmittance of 98% and the average transmittance of 97% in the wavelength range of 400–700 nm. The zeolite coatings also exhibited superhydrophilicity with a water contact angle of ~4.5°, and exhibited good antifogging properties. Over a six-month period under ambient conditions, there were no significant changes in the antifogging property. The zeolite coatings fared better as antireflection/antifogging coatings prepared with the same number of dipping cycles, as compared to the silica. For films with comparable thickness, the zeolite films also exhibited superior properties and the porous structure of the zeolite, its hydrophilicity and the void structure created by packing of the nanoparticles were considered relevant for rapid dispersion of the water into the film.

1. Introduction

With environmental changes of temperature or humidity, tiny water droplets will condense unevenly on smooth transparent surfaces forming a fog, causing light scattering and leading to reducing of transparency and image distortion [1]. Materials with both anti-fogging (AF) coatings and anti-reflective (AR) properties can reduce water condensation on the surfaces as well as increase light transmission. Such materials are used in windshields, eyeglasses, swimming goggles, mirrors, cameras, solar cells, lenses in endoscopic surgery and display devices in analytical instrument [2–12]. Different types of superhydrophilic, superhydrophobic and zwitter-wettable coatings have been developed to improve antifogging or antireflective properties of various surfaces [2–12]. The reason that superhydrophilic coatings with water contact angles smaller than 5° can be applied as antifogging surfaces is primarily due to the capillary effect [8], which promotes adsorption and spreading of condensed water droplets rapidly with subsequent reduction in light scattering [9,10]. Various methods to prepare anti-fogging or antireflective coatings on substrates have been reported, including spraying, spinning, dipping, electro-chemical deposition, plasma method, layer-by-layer method [3–18]. However, many of these methods require complicated procedures, long deposition times, repeated processing or expensive devices to fabricate AF or AR surfaces. High temperature calcinations are often necessary to remove organic materials within the coatings [3,4,9,17,18]. There is considerable research to develop innovative materials as well as facile methods for mass production of AF/AR surfaces.

Nano-particles such as SiO_2, TiO_2 and ZnO are frequently used in preparing superhydrophilic and nanotextured surfaces to introduce antifogging or antireflective properties [2–6,8–14]. Usually nanoporous materials or nanoparticles are chosen as the candidate for preparing AR coatings, since a larger fraction of nanopores will lead to lower refractive index and satisfy the AR requirement [12]. Zeolites (molecular sieves) are crystalline microporous aluminosilicates with molecular porosity, and thin films and membranes prepared with nanozeolites have been applied in fields of catalysis, gas separation, sensor, ion exchange processes [17–29]. There have been several studies using zeolites to fabricate AR coatings [17,18,22–25], though AF coatings with zeolites is not reported. Zeolite films have been shown to exhibit better mechanical strength [18]. Various different zeolites, including zeolite A, silicalite, zeolite L, zeolite beta, have been examined, often using binders that are then calcined out. Zeolite Y, belonging to the faujasite (FAU) family has a three-dimensional pore architecture with 13 Å supercages connected through 7.4 Å windows [26]. Owing to its unique pore structure and the recent commercial availability of nanozeolite Y,

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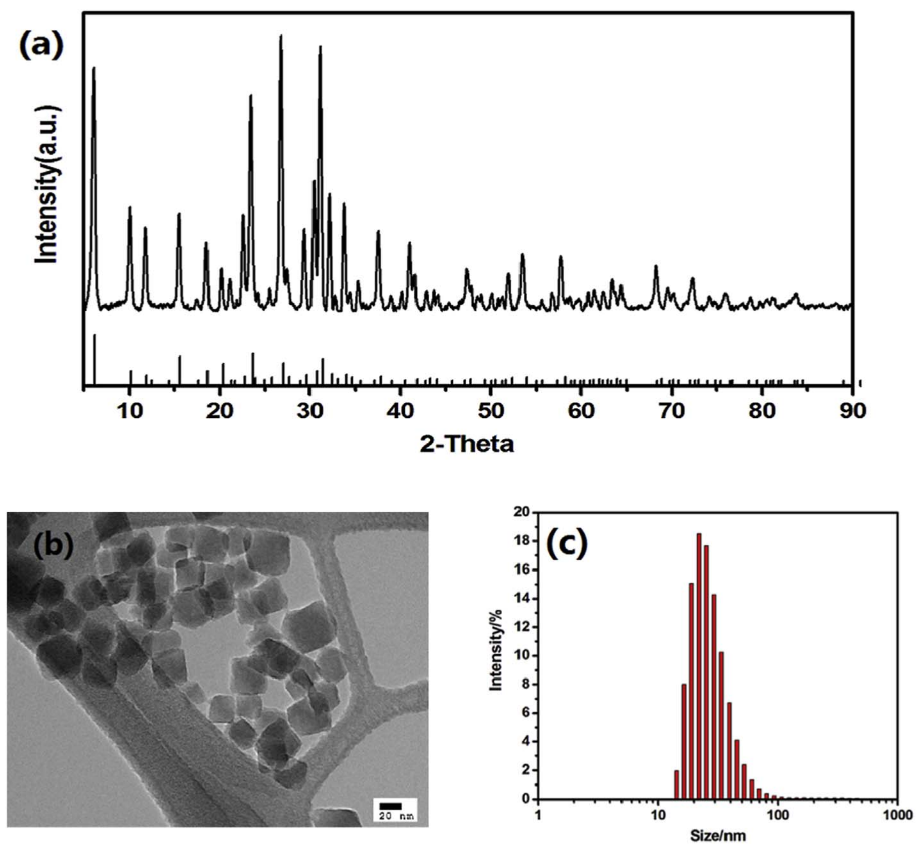

Fig. 1. (a) XRD of zeolite particles and standard card of zeolite Y, (b) TEM image of zeolite particles, (c) particle size distribution for colloidal zeolite.

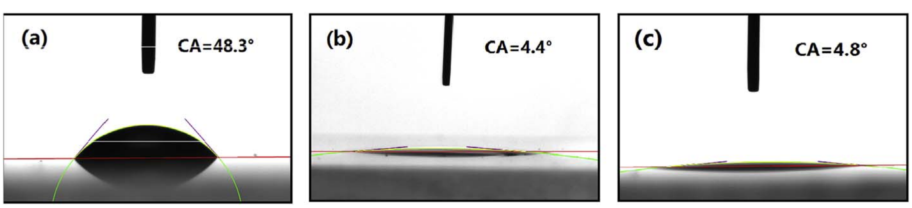

Fig. 2. Water contact angle on (a) blank glass slide, CA = 48.3°, (b) nanozeolite Y (DZ3) coated glass slide, CA = 4.4° (typical standard deviation ± 0.1°), (c) nanosilica coated (DS3) glass slide, CA = 4.8°.

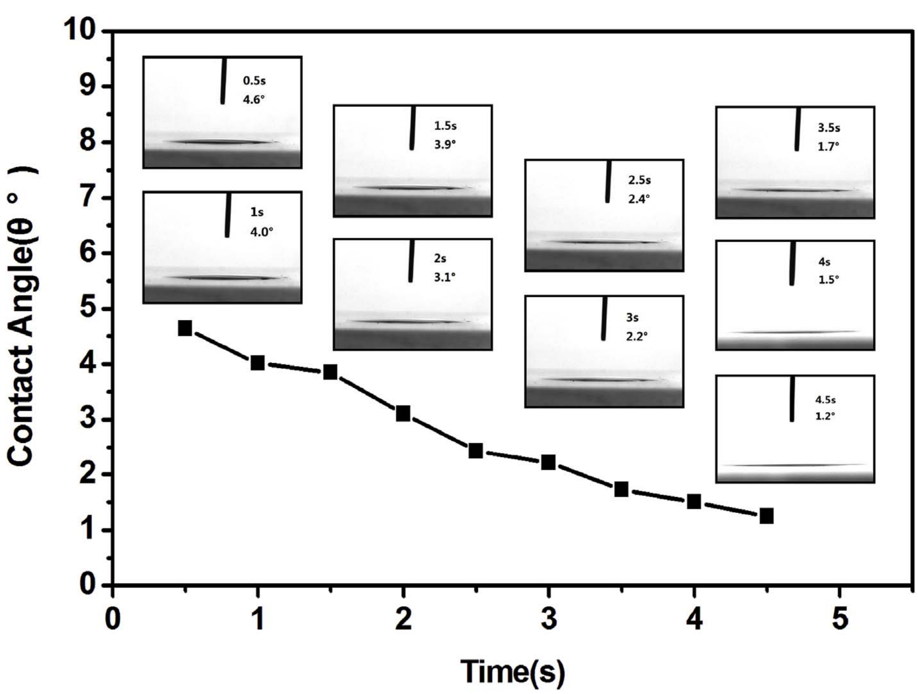

Fig. 3. Water contact angle change over time of DZ3: CA at 0.5s, 1s, 1.5s, 2s, 2.5s, 3s, 3.5s, 4s, 4.5s.