Applied Physics A (2021) 127:794
https://doi.org/10.1007/s00339-021-04938-3

Applied Physics A
Materials Science & Processing

Nanoarchitectonics for polymer-ceramic hybrid coated ceramic tiles for antibacterial activity and wettability

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Received: 28 May 2021 / Accepted: 13 September 2021

Abstract
In the present study, polymer-coated and Si_3N_4-modified glaze was developed to provide a synergetic effect of an antibacterial and superhydrophobic property on ceramic tile surface. The fact that the antibacterial activity of Si_3N_4 is not yet known in the tile industry and in many applications is unique aspect of the study. In addressing this issue, antibacterial effect was tested against gram-positive S. aureus and gram-negative P. aeruginosa. More significantly, the antibacterial and superhydrophobic surfaces were obtained firing at industrial kiln without changing the standard furnace regime for tile production. The superhydrophobic and antibacterial properties of the developed surfaces were determined by contact angle, surface energy, roughness, scanning electron microscopy, X-ray diffraction and antibacterial tests and the results compared with the commercial porcelain stoneware tiles. Superhydrophobic and antibacterial effect formation occurred due to micro-nano hybrid surface structure formed by Si_3N_4 crystals. The 155 ° water contact angle was reached on industrial tile surfaces. The Si_3N_4-modified surfaces resulted in a bacteria population reduction of over 99.97% and 99.11% for S. aureus and P. aeruginosa, respectively. It has found that the surface hydrophobicity is a clear determining factor for microbial growth and proliferation.

Keywords Si_3N_4 · Antibacterial · Wettability · Hybrid surfaces · Porcelain stoneware tiles · Construction materials

1 Introduction

The ceramic tile industry has been a traditional industry for many years with limited innovation or emerging techniques. The sector has developed in the last 10 years due to increasing competition, an expanded market and functional product demand. This situation triggers many innovations from different perspectives. Functional coatings/surfaces are the most popular way to provide feeling of warmth, self-cleaning, mechanical and chemical resistance, phosphorescence, anti-reflective, anti-fog, antibacterial properties, etc., to revive the ceramic industry [1–14]. From a technical point of view, one of the most impressive innovations in recent years is the superhydrophobic and antibacterial properties of tiles with nanocoatings that provide healthier environments for hospital operating theaters, laboratories, food facilities, schools, the malls, etc. [1, 3, 4, 6–9].

Todays, antibacterial coatings/surfaces can minimize global outbreaks. The long-term survival and resistance of bacteria and other microorganisms are very important social and material engineering problem. It is also important to develop antibacterial solutions in industrial, public and domestic areas for the prevention of pandemic outbreaks. The demand for ceramic tiles for bacterial problems is huge due to their chemical durability and easiness to clean. Generally, ceramics are furnished in high humidity places, such as bathrooms or kitchens, where durable microorganisms can infect people. Staphylococcus aureus and Pseudomonas aeruginosa are the most typical bacteria in homes in wet areas. However, while ceramic surfaces are easy to clean and sterilize, they do not have a spontaneous antibacterial efficacy. On the other hand, hospital infections are one of the most common causes of death [15]. Too many people got hospital infections, and the cost of these infections is billions of dollars. The hospital infections can be reduced with antibacterial ceramics. On the other hand, thanks to superhydrophobicity and its water-repellent

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Published online: 26 September 2021