Available online at www.sciencedirect.com

ScienceDirect

Ceramics International 41 (2015) 11719–11725

CERAMICS INTERNATIONAL

www.elsevier.com/locate/ceramint

Raspberry-like superhydrophobic silica coatings with self-cleaning properties

Shanhu Liu[a,b,*], Sanjay S. Latthe[b], Haitang Yang[a], Baoshun Liu[c], Ruimin Xing[a,b]

[a]*Institute of Environmental and Analytical Sciences, College of Chemistry and Chemical Engineering, Henan University, Kaifeng 475001, PR China*
[b]*Photocatalysis International Research Center, Research Institute for Science & Technology, Tokyo University of Science, 2641 Yamazaki, Noda, Chiba 278-8510, Japan*
[c]*State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan, Hubei Province 430070, PR China*

Received 26 April 2015; accepted 25 May 2015
Available online 4 June 2015

Abstract

Here we report, an easy, straightforward and novel way to prepare raspberry-like superhydrophobic silica coatings for self-cleaning applications. The hydrophobic silica particles were obtained by simple condensation of fluoroalkoxysilane (17FTMS) in ethanol at room temperature. These silica particles were embedded into the sol–gel processed silica matrix and deposited on glass plates. On this coating surface, water drops exhibited a contact angle of 152° and rolls off the surface at sliding angle of 10°. This extremely low sliding angle was employed to self-clean the superhydrophobic coating, where dirt particles accumulated on the surface of superhydrophobic coating was efficiently cleaned by quickly sliding water drops. The stability of the microstructure as well as the wetting properties of the coating surface was investigated by scratch resistance and water stream impact test. The superhydrophobic coatings endured against the scratch of applied force of ~150 mN. Such one pot synthesis of raspberry-like superhydrophobic silica coatings may open new avenue in the sublime field of superhydrophobic research.

Keywords: Raspberry-like particles; Sol–gel; Superhydrophobic; Self-cleaning; Contact angle

1. Introduction

On drizzling days, bouncing and freely rolling water drops on enormously superhydrophobic lotus leaves are often observed. A rolling friction between the spherical water drop and lotus leaf surface is always at its minimum. It was confirmed by the scientists Barthlott and Neinhuis that the surface of lotus leaf encompasses of hydrophobic nanoscale wax crystalloids covered uniformly and densely on the microscopic papillae structure [1]. Owing to this low surface energy rough hierarchical micro/nanostructure of lotus leaf, water drop gain a perfect ball shape and slide off the surface in no time. While rapid sliding off, sphere shape water drops eventually catch up the dust particles, generating a clean and lustrous lotus leaf surface [2]. This self-cleaning behavior of lotus leaf is eminently acclaimed as '*Lotus Effect*'. Inspired by nature, an extensive research on developing artificial superhydrophobic coatings on glass, plastic, mesh, fabric, paper, wood, and metals [3–6] for self-cleaning, smart liquid separation, drag reduction and anti-corrosion applications has been carried out.

Owing to dual-scale rough hierarchical morphology, raspberry (RB)-like particles are quite suitable for the fabrication of superhydrophobic surfaces. Abundant air pockets get confined in the dual-scale topology of the RB-like particles and so the water drop sits on the layer of air with contact angle more than 150–160° and eventually takes off the surface. Adequate efforts have been made to synthesize superhydrophobic coatings using these specially designed RB-like featured particles [7–10].

*Corresponding author at: Institute of Environmental and Analytical Sciences, College of Chemistry and Chemical Engineering, Henan University, Kaifeng 475001, PR China.
E-mail address: shanhuliu@henu.edu.cn (S. Liu).

http://dx.doi.org/10.1016/j.ceramint.2015.05.137
0272-8842/

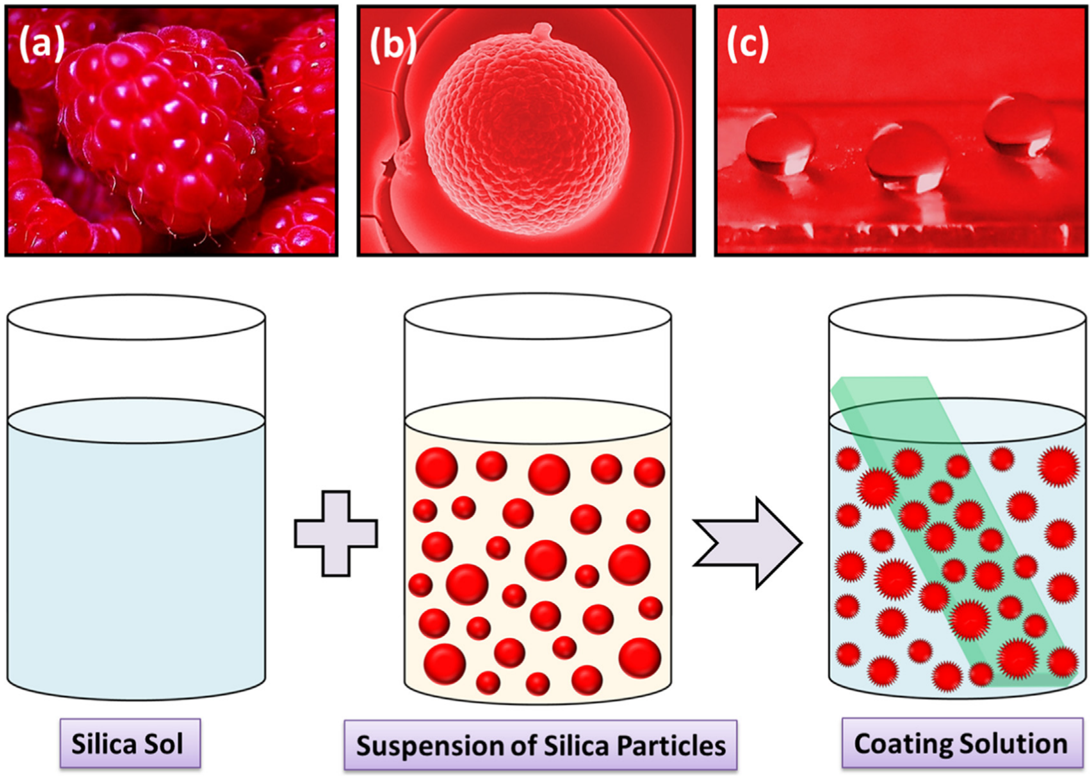

Fig. 1. Schematic of the synthesis of hydrophobic silica particles and subsequent preparation of superhydrophobic coating, (a) picture of raspberry fruit, (b) raspberry-like silica particle and (c) superhydrophobic wetting state of the coating.

Normally, the RB-like particles were synthesized by assembling numerous fine nanoparticles on the surface of big size core particles [11–13]. First report on the preparation of superhydrophobic coatings using RB-like particles was attempted by Ming and researchers in 2005 [14]. The RB-like silica particles (composed of fine silica particles covalently attached on the surface of core silica particles) were chemically deposited on the epoxy polymer films and subsequently covered by poly(dimethylsiloxane) (PDMS) layer to achieve superhydrophobicity. Despite Tsai and Lee [15] have achieved RB-like microstructure by chemical adsorption of small diameter silica particles (20 to 90 nm) on the big size silica particles (500 nm) and assembled on protonated amine-modified glass substrates and consequently the surface energy of the coating was lowered by dodecyltrichlorosilane treatment. Puretskiy and Ionov [16] have demonstrated the synthesis of RB-like particles by effectively confining silica nanoparticles on the surface of poly(glycidyl methacrylate) brush layer covered silica microparticles. Qian et al. [17] have prepared RB-like particles by covering sol–gel processed silica particles on the poly(acrylic acid)-functionalized PS particles and the water repellency was achieved by modifying the coating surface with dodecyltrichlorosilane. Conversely, Xu et al. [18] have prepared SiO_2/PS RB-like particles by decorating PS nanoparticles on submicron MPS-functionalized silica core particle through radiation miniemulsion polymerization. A particulate coating prepared by these RB-like particles showed superhydrophobicity without further chemical modification.

In almost all the reports available on the synthesis of RB-like particles have used complex and tedious multi-step procedures as well as post surface chemical modification to render superhydrophobicity. A literature confirms that fine particle covering over large size particle is inevitable for the synthesis of RB-like particles. In this paper, we report a simple, veracious and novel approach to develop raspberry-like superhydrophobic silica coatings for self-cleaning applications. The hydrophobic silica particles were obtained by simple condensation of fluoroalkoxysilane (17FTMS) in ethanol at room temperature. These silica particles were embedded into the sol–gel processed silica matrix and deposited on glass plates which showed superhydrophobic properties without any surface chemical modification.

2. Experimental section

2.1. Materials

The chemicals used are tetraethylorthosilicate (TEOS) (Sigma-Aldrich Chemie, Germany), (Heptadecafluoro-1, 1, 2, 2-tetrahydrodecyl)trimethoxysilane (17FTMS) (Gelest, Inc. Morrisville, PA), ethanol and nitric acid (69%) (S D Fine-Chem Ltd., India). The glass substrates were bought from Polar Industrial Corporation (India).

2.2. Preparation of superhydrophobic coatings

A schematic of the synthesis of hydrophobic silica particles and subsequent preparation of superhydrophobic coating is illustrated in Fig. 1.