Arabian Journal of Chemistry (2015) **8**, 749–765

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

REVIEW

Corrosion behavior of superhydrophobic surfaces: A review

Adel M.A. Mohamed [a,b], **Aboubakr M. Abdullah** [a,c,*], **Nathalie A. Younan** [a]

[a] *Center for Advanced Materials, Qatar University, Doha 2713, Qatar*
[b] *Department of Metallurgical and Materials Engineering, Faculty of Petroleum and Mining Engineering, Suez University, Box 43721, Suez, Egypt*
[c] *Chemistry Department, Faculty of Science, Cairo University, Giza 12613, Egypt*

Received 18 January 2014; accepted 7 March 2014
Available online 24 March 2014

KEYWORDS

Superhydrophobic;
Materials;
Surfaces;
Corrosion;
Protection

Abstract Superhydrophobic surfaces have evoked great interest in researchers for both purely academic pursuits and industrial applications. Metal corrosion is a serious problem, both economically and operationally, for engineering systems such as aircraft, automobiles, pipelines, and naval vessels. Due to the broad range of potential applications of superhydrophobic surfaces, there is a need for a deeper understanding of not only how to fabricate such surfaces using simple methods, but also how specific surface properties, such as morphology, roughness, and surface chemistry, affect surface wetting and stability. In this article, a comprehensive review is presented on the researches and developments related to superhydrophobicity phenomena, fabrication of superhydrophobic surface and applications. A significant attention is paid to state of the art on corrosion performance of superhydrophobic coatings.

Contents

---

[*] Corresponding author at: Chemistry Department, Faculty of Science, Cairo University, Giza 12613, Egypt. Tel.: +20 974 4403 5672; fax: +20 974 4403 3889.
E-mail addresses: abubakr_2@yahoo.com, bakr@qu.edu.qa (A.M. Abdullah).

Peer review under responsibility of King Saud University.

ELSEVIER **Production and hosting by Elsevier**

http://dx.doi.org/10.1016/j.arabjc.2014.03.006

1. Introduction

Superhydrophobic surfaces have evoked great interest in researchers for both purely academic pursuits and industrial applications. Many review articles covering different aspects of superhydrophobicity have been published (Bhushan and Jung, 2011; Ma and Hill, 2006; Nakajima et al., 2001; Quere, 2005; Roach et al., 2008; Xue et al., 2010). Superhydrophobic surfaces (SHS) exhibit extremely high water repellency, where water drops bead up on the surface, rolling with a slight applied force, and bouncing if dropped on the surface from a height.

It is well known that the degree to which a solid repels a liquid depends upon two factors: surface energy and surface morphology. When surface energy is lowered, hydrophobicity is enhanced. Chemical compositions determine the surface free energy and thus have a great influence on wettability (Woodward et al., 2000). However, certain limitations are encountered and superhydrophobic surfaces cannot be obtained only by lowering the surface energy. For example, the $-CF_3-$ terminated surface was reported to possess the lowest free energy and the best hydrophobicity, but the maximum contact angle on flat surfaces could only reach 120° (Nishino et al., 1999).

In superhydrophobic surface, the surface morphology plays a crucial role effecting wettability. Roughening a surface can not only enhance its hydrophobicity due to the increase in the solid–liquid interface (Wenzel, 1936, 1949) but also when air can be trapped on a rough surface between the surface and the liquid droplet. Since air is an absolutely hydrophobic material with a contact angle of 180°, this air trapping will amplify surface hydrophobicity (Ogihara et al., 2013; Sun et al., 2005). Hierarchical micro- and nanostructuring of the surface is thus responsible for superhydrophobicity.

Surface wetting behavior can generally be broken into 4 different regimes, based on the value of water contact angle (WCA). The two most conventional regimes are the hydrophilic and hydrophobic regimes, defined as WCAs in the range of $10° < \theta < 90°$ and $90° < \theta < 150°$, respectively. The hydrophobic coatings are intensively used in plenty of engineering applications, however; the hydrophilic coatings are widely used in paint and varnish industries. Although the applications of hydrophobic and hydrophilic regimes, the other superhydrophobic and superhydropholic regimes, which describe the extremes of surface wetting behavior, are wholly more interesting. Superhydrophilicity, which is characterized by WCAs in the range of $\theta < 10°$, within 1 s of the initial wetting, describes nearly perfect wetting. In contrast, superhydrophobicity, described by WCAs of $\theta > 150°$, describes a state of nearly perfect non-wetting (Fig. 1).

In addition to high contact angles, superhydrophobic surfaces exhibit very low water contact angle hysteresis CAH ($<10°$). Contact angle hysteresis is the difference between advancing and receding contact angle. This leads to the rolling and bouncing of the water droplets, which will entrain particle contaminants from the surface leading to a self-cleaning property of superhydrophobic surfaces. The physical reason of self-

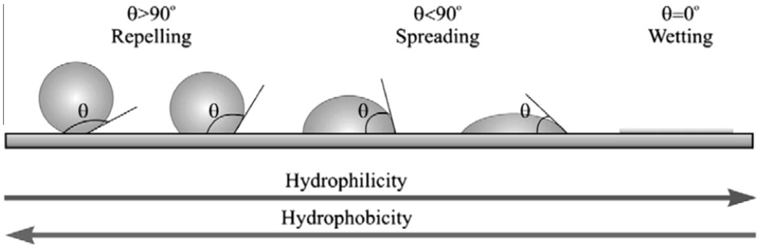

Figure 1 Schematic of contact angle (CA) for a water drop placed on surfaces of different hydrophobicities (Krasowska et al., 2009).