Applied Energy xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

TiO_2/silane coupling agent composed of two layers structure: A super-hydrophilic self-cleaning coating applied in PV panels ☆

Hong Zhong [a], Yan Hu [a], Yuanhao Wang [b,*], Hongxing Yang [a,*]

[a] Renewable Energy Research Group (RERG), Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China
[b] Faculty of Science and Technology, Technological and Higher Education Institute of Hong Kong, New Territories, Hong Kong, China

HIGHLIGHTS

- A self-coating with composited layer structure can applied in PV panels is proposed.
- This coating is consisted of TiO_2 and KH550.
- pH in hydrothermal reaction is an important factor to control the self-cleaning property and light transmittance of coating.
- This coating can increase the output of PV panels in outside test.

ARTICLE INFO

Article history:
Received 19 January 2017
Received in revised form 9 April 2017
Accepted 20 April 2017
Available online xxxx

Keywords:
Super-hydrophilic
TiO_2
Silane coupling agent
PV panels

ABSTRACT

To improve the properties of anti-dust for PV modules, the concept of self-cleaning has been proposed for many years. However, the traditional self-cleaning coating is unstable in nature environment, which limited its application in the PV panels. Therefore, this study aims to design a novel super-hydrophilic coating with high stability and corrosion resistance, which would be very advantageous to apply in the PV panels. The super-hydrophilic self-cleaning coating is composed of 3-triethoxysilylpropylamine (KH550) and TiO_2. KH550 is a kind of surface modification agent, which creates more active groups on the surface of glasses. TiO_2 is prepared by a hydrothermal reaction with titanium ethoxide, and the influence of pH is investigated as an important factor during the application in PV panels. The composition was measured by UV/VIS/NIR spectrophotometer, and the particle size distribution and the surface structure were characterized by Scanning Electron Microscope (SEM). The TiO_2 nanocrystal was investigated by X-Ray Diffraction (XRD) and Transmission Electron Microscope (TEM). The water contact angle (WCA) was measured by contact angle instrument. It was found that the static water contact angle on the surface of super-hydrophobic coating was as lower than 5°, which show an excellent super-hydrophilic property. Abstract should state the principal results and conclusions briefly, and the significance of this study.

1. Introduction

The application of photovoltaic power station was increased with over 150 gigawatts (GW) capacity in the past 4 years, more than the cumulative installation volume in the previous 4 decades [1]. PV installations have been expected with a great significant for the observed rapid decrease in system prices, the lower cost of capital, and PV's market maturation. PV installed capacity in the world is likely to be more than doubled in a few years, d and PV is installed faster than any other renewable energy technologies [2]. The solar PV panel as the core component of the solar power system remains long-running, so the effect of the dust deposition on the system efficiency is significant. The sources of the dusts include the tiny inorganic particle formed by the motion of sand, soil and wind, the below dust due to the industry, building, and transportation, and organic dust form the biomass of animals and plants [3–5]. The researches about the effect of the dust-fouling on PV panel have been studied for many years all around the world. Due to the different air quality in different area, the effect of the dust-fouling on PV panels are quite different. In dry and less

☆ This paper was presented at the 8th International Conference on Applied Energy (ICAE2016), October 8–10, 2016, Beijing International Convention Center (Original paper title: "TiO2/Silane Coupling Agent Composed Two Layers Structure: A Novel Stability Super-Hydrophilic Self-cleaning Coating Applied in PV Panels" and Paper No.: 834).

* Corresponding authors.
E-mail addresses: yuanhaowang@yahoo.com (Y. Wang), behxyang@polyu.edu.hk (H. Yang).

http://dx.doi.org/10.1016/j.apenergy.2017.04.057
0306-2619/© 2017 Published by Elsevier Ltd.

rainfall area, the dust has a great effect on efficiency of the PV panels. Nimmo and Said [6] discovered that a reduction of efficiency reaches 26%–40% in Saudi Arabia after 6 month without washing. Sayigh [7] showed another result that the efficiency of solar thermal collector decreased 30% after 3 days without washing. In 1981, Wakin proposed that 17% of efficiency degradation for the PV panel occurred after 6 days in Kuwait. EI-Nashar, [8] who comes from The United Arab Emirates showed that the transmittance of glass reduced 70% because of the dust in summer.

Conventional cleaning methods involving sanitizing materials and solutions are necessary to maintain the freshness of the surface of PV panels. Besides of the economic burden, extensive cleaning potentially leads hazardous substances to the environment and ecosystem. Inspired by the surfaces with a high intrinsic ability to clean themselves in nature, the self-cleaning surface, has attracted huge research curiosity in past decades due to its unique mechanism and high adaptability [9–14]. The concept of self-cleaning was based on the super-hydrophobic or super-hydrophilic nature of certain plant leaves. The most well-known example for super-hydrophobic is the lotus leaf, which allows the water droplets rolling off the surface with dirt to obtain a cleaning surface. This surface, as shown in Fig. 1, demonstrates a water contact angle (WCA) higher/larger? than 150° and a small water sliding angle lower/smaller? than 2°. On the contrary, water film can be formed on a super-hydrophilic surface to detach the dirt components from substrate. As show in Fig. 2, the WCA is extremely small or even zero and the water film makes the dirt components movable along with the water flow on the surface. Thus, both super-hydrophobic [15–18] and super-hydrophilic surface [19–20] can be efficiently cleaned only with the aid of water.

In generally, super-hydrophobic surfaces are composited by some organic materials with micro- and nano-structure. However, most of the super-hydrophobic surfaces will fail, when they are exposed in the air. Because they would be damaged by some environmental factors which include chemical reaction with some solution and air, ultraviolet aging, erosion by some particles and germs, even mechanical wear, which limit the application of the super-hydrophobic coating in PV panels.

Most of super-hydrophilic self-cleaning coatings are composited of TiO_2 which is a kind of photocatalyst [12]. These coatings can chemically break down dirt when exposed to light. However, with the poor dispersion and adhesion, this coating show a short life time and low transmittance. Despite the commercialization of a hydrophilic self-cleaning coating in a few products, the field is far from mature. Also, there are many other materials to process a super-hydrophilic surface. Hu Yan [6] showed a controllable water contact angle of super-hydrophilic coating with TEOS and silane coupling agent. But the lifetime of this coating is not long enough which limited its application in the PV panels.

2. Experiment

2.1. Nanosized TiO_2 synthesis

Nanosized anatase TiO_2 was prepared by the following route and the structures of raw materials was shown in Fig. 3. Titanium ethoxide (30 ml, Ti 7.3 wt.%) (guaranteed reagent grade from Alfa-Aesar) was diluted with absolute ethyl alcohol (100 ml) under vigorous stirring. After rotary evaporation, the pale brown colloid was obtained, then the hydrochloric acid (36%) and nitric acid (60%)

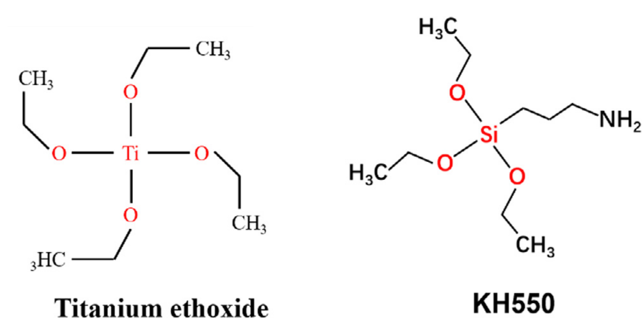

Fig. 3. The structure of Titanium ethoxide and KH550.

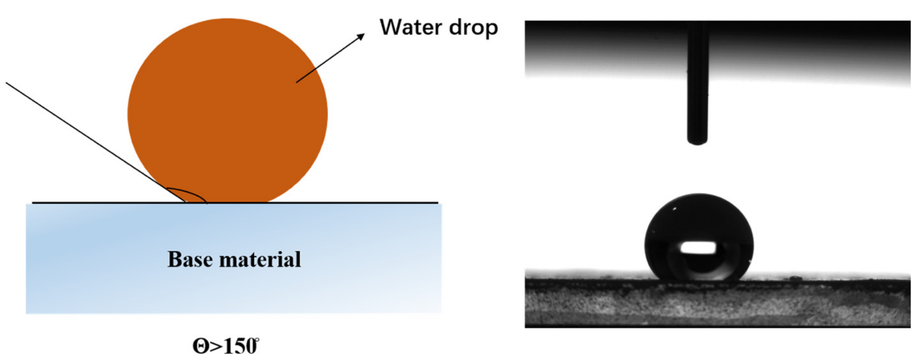

Fig. 1. Super-hydrophobic surface.

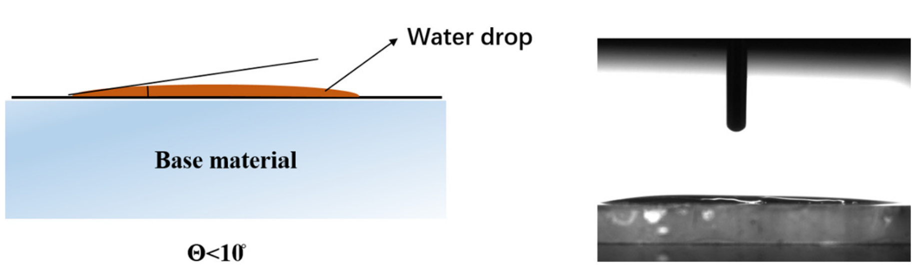

Fig. 2. Super-hydrophilic surface.

Please cite this article in press as: Zhong H et al. TiO_2/silane coupling agent composed of two layers structure: A super-hydrophilic self-cleaning coating applied in PV panels. Appl Energy (2017), http://dx.doi.org/10.1016/j.apenergy.2017.04.057