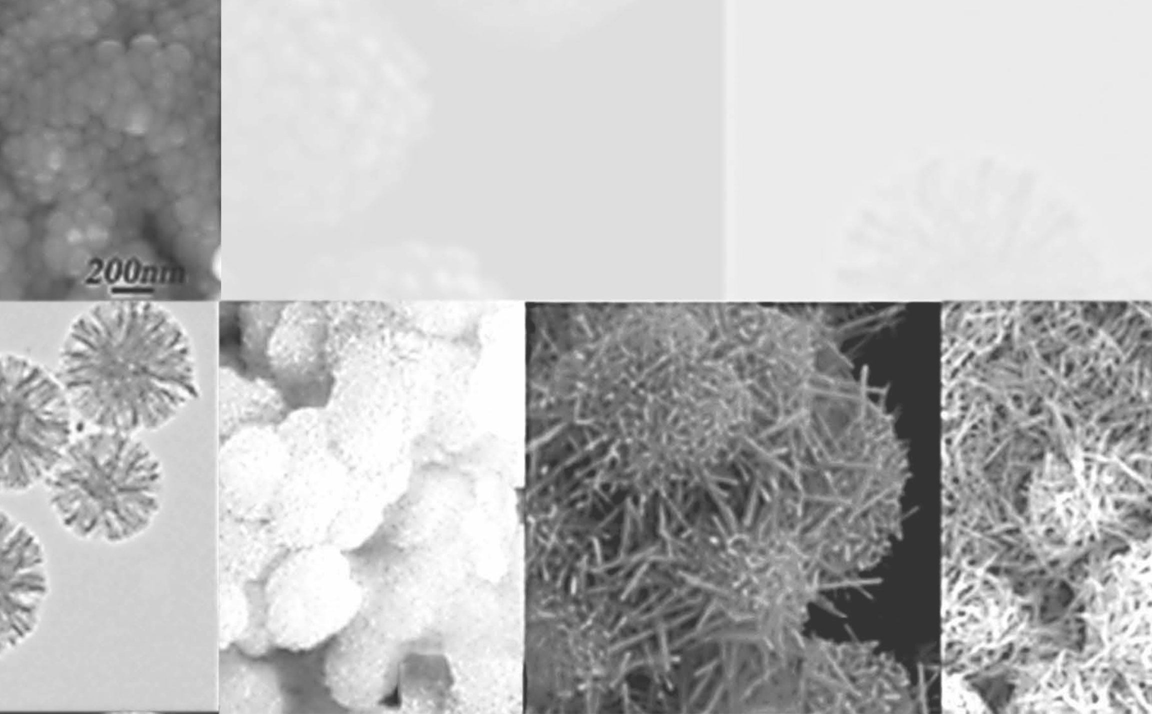

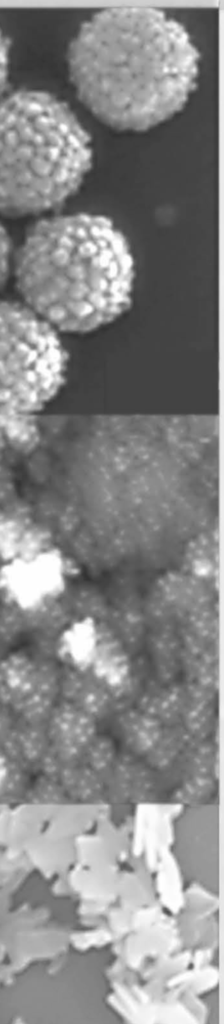

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Contents

Preface

Nanoscience and nanotechnology are interdisciplinary fields that bring together physicists, chemists, materials scientists, biochemists, and engineers to meet current and potential future challenges that humankind faces, including searching for renewable energies for sustainable development and new technologies for carbon capture and environmental protection. Among the current subjects in nanoscience and nanotechnology, nanomaterials are developing fast and explosively and attract a huge amount of attention. They have recently shown emerging applications and continue to show promising potentials in technologies such as solar cells, fuel cells, secondary batteries, supercapacitors, air and water purification, and removal of both domestic and outdoor air pollutants. The application of nanomaterials has also drawn attention to their effects on human health. This book invited experts in the fields of nanomaterials, energy, and environmental science and assembled 13 reviews that discuss the design and fabrication of nanostructured materials and their energy and environmental applications.

This is the first book that summarizes the very recent efforts through nanoscience and technology towards meeting the pressing energy and environmental challenges that human beings are facing. It also points out future directions of nanomaterial development and encourages future efforts, especially by the younger generation.

Finally, I would like to take this opportunity to acknowledge all the authors who had spent their precious time in preparing their great contributions to the book. I would also like to thank Dr. Mingqing Yang, who contributed a lot to the communication with the authors and preparation and publication of the book. I am very grateful to Pan Stanford Publishing for providing me an opportunity to publish this book. I hope that the readers will find the contents both useful and enjoyable.

Junhui He

Beijing

June 2016

Chapter 1

Multifunctional Coatings for Solar Energy Applications

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1.1 Introduction

Transparent surface coatings with suitable optical path differences can suppress the reflection of substrates. Such coatings are usually called “antireflective coatings (ARCs).” Many antireflective surfaces exist in nature. Taking some diurnal butterflies as an example, they use arrays of nonclose-packed nipples (about 300 nm) as antireflective structure (ARS) to reduce reflection from their compound eyes [1,2]. The ARS on the cornea can increase light transmission and suppress reflection losses at the interfaces. Besides these excellent optical properties, the ARS arrays also exhibit self-cleaning capability because of the high fraction of air trapped between arrays [3,4].

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The antireflection phenomenon provides enormous inspirations for scientists to mimic for many important applications. Antireflection technology has been widely used in some high-precision optical components, solar cells, flat panel displays, and light-emitting diode lighting to increase the transmittance of incident light [5–8]. For solar cells, due to reflection at the air–glass interface of the packaging glass and scattering by accumulated dust on outdoor panels, part of incident energy on solar modules is lost. On the one hand, ARC on the glass can help alleviate reflection in systems; on the other hand, the self-cleaning property can, to some extent, solve the dust accumulation problem [5]. Tseng et al. systematically studied the antireflection and light trapping effects. Their results showed a 76.9% enhancement of short-circuit current density compared with that of bare silicon due to suppression of surface reflection [9].

It is common knowledge that smooth surfaces shine more than rough ones. It contains the very basic idea of antireflection that roughness is necessary to reduce reflection of surfaces. The reflection or optical disturbance will be zero if the medium for light propagation does not change or if the two media have the same refractive index (RI) [10]. Therefore, many materials with micro/nanostructure are perspective to fabricate ARC, including silicon, silica, titania, zirconia, zinc oxide, cobalt oxide, tin oxide, carbon, and poly(ethylene terephthalate) (PET), polystyrene (PS), gallium nitride [11–17]. To date, two kinds of approach are available for fabricating ARCs. One is coating porous or multilayered films on the surface of devices, and the other is fabricating sub-wavelength ARS directly on the substrate [18–21]. The corresponding fabrication routes can be classified into bottom-up and top-down modes. The bottom-up technique usually uses nanoparticles as building block to form ARCs. The top-down approach relies on etching or lithography and so on techniques performed with or without masks. Recently, the two-step method with a combination of top-down and bottom-up approaches also attracts much attention [11].

When contamination or fogging occurs on ARCs, however, their optical properties would dramatically deteriorate. Contaminants accumulate and water molecules condense on the surface, leading to scattering and reflection of light. This problem may be solved by creation of a surface that has special wettability (superhydrophilicity or superhydrophobicity) and photocatalytic property. ARCs with