Preface

This book is intended to serve as an introduction to a developing field of engineering biologically inspired surfaces with hierarchical structures. Recent advances in micro- and nanoscience reveal a growing number of surfaces with hierarchical structures, that is, with nanoscale details superimposed on the microscale details, sometimes superimposed on larger macroscale details. Such hierarchical structures are required for certain functions, such as achieving extremely low or extremely high friction and adhesion, and water-repellency. Friction, adhesion, and wetting are complicated processes, which involve effects at different scale levels with different characteristic scale lengths. Engineers are trying to mimic nature in order to design artificial surfaces with desirable properties, referred to as bioinspired or biomimetic surfaces. The field is referred to as biomimetics.

Our purpose is, first of all, to present the qualitative picture of physical phenomena, rather than to provide rigorous mathematical derivations or many technical details, which may be found in the references. We concentrate upon such issues as scale and dimension, linearity and nonlinearity, and the fundamental physical mechanisms and effects involved in the phenomena under consideration. This allows a reader who is not familiar with the field or not a specialist in surface science to grasp quickly the essence of the processes and the issues discussed. On the other hand, we felt it necessary to present a brief discussion of modern analytical and experimental methods and approaches used in mesoscale and multiscale science and recent trends in the development of the surface science and multiscale modeling.

The book is divided into three parts. The first part is devoted to the solid–solid dry friction, which is a traditional subject of study of tribology. In this part, we cover topics such as the statistical and fractal characterization of rough random surfaces and solid–solid contact, which have been developed over the past 30 years and are used widely in engineering. We discuss the measurement techniques and equipment that allows scientists to study surfaces at nanoscale resolution—including scanning probe microscopy, which emerged in the early 1980s. Our emphasis is on the multiscale, hierarchical nature of the dissipation mechanisms, which are becoming evident as more and more data about the nanoscale friction are obtained.

In the second part of the book, we study the solid–liquid friction and wetting of rough surfaces, as well as related capillary phenomena. Rough water-repellent or superhydrophobic surfaces, which are often found in biological systems, in many cases have a complicated hierarchical structure that is required for certain functionality, such as nonwetting, low solid–liquid friction, high friction and adhesion. Leaves of water-repellent plants, such as the lotus, constitute an example of these surfaces. Their surfaces are extremely hydrophobic, and a droplet can flow over them with low energy dissipation. However, the mechanisms involved in the process are complicated and have different characteristic length scales, so the surfaces should also be hierarchical. Roughness-induced superhydrophobicity and the "lotus-effect" have been studied extensively during the past decade with the number of articles in peer-reviewed journals growing exponentially since the early 2000s. This is because the technology that allows us to produce an artificial lotus leaf surface became available. However, there has been no single book that covers the theory of superhydrophobicity, the observation and characterization of natural superhydrophobic surfaces, and the methods of production and characterization of artificial superhydrophobic surfaces. This book's purpose is to cover this gap in the literature.

Another example of natural hierarchical surfaces is the gecko foot, which has an ability to achieve very high adhesion (so that it can climb upon a vertical wall) and detach from the surface at will. These abilities are known as smart adhesion. Smart adhesion, along with other functional hierarchical biological surfaces, such as the shark skin and the moth eye, are studied in the third part of the book. These functional biological surfaces inspired engineers to design artificial surfaces with similar properties. Biomimetic hierarchical surfaces are discussed in that part of the book along with other practical issues, such as techniques to experimentally study the wetting of rough surfaces.

The book is written with a broad multidisciplinary readership in mind. It can serve as a supplementary textbook for a graduate course in surface science, tribology, or nanotechnology. It can be used by engineers and scientists who want to familiarize themselves with the basic concepts of nanotribology and biologically inspired surfaces. The authors hope that the book will be useful to a broad audience of readers from various backgrounds.

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