Tremendous progress has been made in the field of surface-bound soft material gradients in recent years, with intriguing new areas of investigation opening up and advances in bioanalytics changing the way high-throughput screening methods are used in the design and discovery of catalysts and new materials.

This volume provides the first complete, up-to-date summary of the progress in this field, showing readers how to harness the powerful properties of soft matter gradients in the design and development of modern functional materials.

Contributed chapters from experts in diverse fields help bridge areas of materials science, chemistry, and biomaterials, covering fabrication techniques, gradients in self-assembled monolayers, polymer gradients, dynamic gradient structures, structure and assembly, mechanical properties, sensors, biomaterial applications, protein adsorption on gradient surfaces, and organization of cells and microtubules on gradient surfaces.

Readers will learn how to implement the techniques described in the book in their own work, while improving efficacy and lowering research and production costs. "Soft Matter Gradient Surfaces" is an invaluable resource for chemists, physicists, biologists, and engineers, and anyone who would like to take advantage of these amazing soft matter building blocks.

JAN GENZER is a professor of chemical and biomolecular engineering at North Carolina State University. His research interests include material self-assembly and directed assembly and behavior of polymers at surfaces, interfaces, and in confined geometries using experimental methods and computational approaches.
SOFT MATTER
GRADIENT SURFACES

Methods and Applications

Edited by

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Although it was first introduced by the French physicist Madeleine Veyssié around 1970, the term *soft matter* caught true attention only after Pierre-Gilles de Gennes used it in his Nobel speech in 1991. Soft matter represents a very rapidly developing subset of structures generally called *condensed matter*. It encompasses both naturally occurring structures (i.e., biomolecules) and synthetic substances (i.e., liquids, liquid crystals, colloids, membranes, gels, foams, and many subsets thereof). These structures range in size from a single chemical repeat unit to molecular clusters to large macromolecules made up of thousands of repeat units. One feature that distinguishes soft materials from hard condensed matter is that the former can be deformed readily by applying some external force (i.e., mechanical, electrical, or magnetic). Governed by short and long range interactions, the individual soft matter building blocks can organize into well-ordered structures, spanning nanoscopic (molecular) to mesoscopic (cluster-like) length scales. Although in most instances, the organization takes place spontaneously via self-assembly driven primarily by van der Waals interactions, additional fine tuning can be achieved by applying an external field or by forcing the self-assembly to take place in the confined spaces of various geometries. Nowadays, the field of soft materials represents an exciting meeting arena for chemists, physicists, biologists, and engineers who design, build, and probe the characteristics of both the individual blocks and larger assemblies made up of those blocks.

Self-assembly of soft materials at or near interfaces or surfaces offers additional benefits in that (i) it provides control over system dynamics, that is, depending on the system setup, the building blocks can be either completely mobile or immobilized temporarily or permanently; (ii) novel self-assembly motifs can be generated that are not necessarily obtainable in bulk; and (iii) the spatial
distribution of the assembly patterns can be adjusted by depositing the individual building blocks onto substrates of various geometries and chemistries. The characteristics of the discrete building blocks as well as their spatial arrangement, in turn, endow such structures with unprecedented properties and functionalities. Numerous publications have reported on the interfacial assembly of soft materials and the advantages they provide in controlling functionality of surfaces, and studying important physico-chemical phenomena by means of sophisticated analytical methods and tools.

Initial research effort was focused on the organization of “soft” materials on chemically homogeneous interfaces. However, recent advances in methods of fabricating chemically structured interfaces enabled control over the spatial arrangement of soft materials. A variety of lithographic and other assembling methods have been developed that decorate substrates with soft materials exhibiting well-defined shapes, sizes, and dimensionalities. The robustness, simplicity, and versatility of such assembling technologies made these tools popular among scientists and engineers. Yet, these methods are inherently limited in their ability to readily fabricate substrates whose physico-chemical character changes gradually as a function of position and/or evolves in time (though some notable exceptions exist). A question immediately arises as to whether the means of generating substrates displaying spatio-temporal change of at least one physico-chemical characteristic, that is, chemical composition, charge, molecular mobility, or modulus, are really needed. It is the hope of the authors of this collection to convince the reader that soft matter gradients, which show such gradual change in properties, represent unique structures that can play a pivotal role in the development of modern functional materials.

Over the past half century, material gradients, both continuous and discrete, have enabled fast screening of physico-chemical phenomena in a systematic manner. These structures have facilitated major breakthroughs in combinatorial chemistry and materials science, especially in the design and discovery of catalysts and drugs, thereby bringing about rapid technological developments with improved efficiency and lower research and production costs. While the application of gradients in combinatorial screening represents perhaps the most prevalent utilization of gradient surfaces, it is not the only one. For example, techniques of fabrication of gradient assemblies have often been used as facile means of monitoring a given physico-chemico–biological process by “recording” it gradually and systematically on the substrate. Gradient patterns on surfaces can also be utilized as surface-bound “directional engines” capable of acting as molecular and macromolecular motors for moving objects whose dimensions are comparable with the spatial extent of the gradient. This, coupled with the ability to change the physico-chemical character of the substrate in real time using techniques and processes discussed later in this book, may offer unique new opportunities for controlling the motion of liquids and/or certain biological species such as living cells. Finally, gradient structures have also inspired the development of new analytical approaches and measurement tools.
While the progress in generating and utilizing soft material gradient surfaces has been summarized in several review articles written during the past two decades, to the best of our knowledge, no dedicated monograph has been published that provides an overview of the field and summarizes the rapid development witnessed by this field over the past few years. With this volume, we intend to close this gap and provide an up-to-date collection of topics pertaining to the latest developments in the field of soft material gradient research. Combinatorial/high throughput methods utilizing “hard materials” have not been covered because these have been the subject of other monographs.

I would like to extend my most profound thanks to all the authors who contributed to this book. It has been an exciting opportunity to work with all of you in putting this book together. I hope that the readers will find the contributions included in this book informative and stimulating. Perhaps, reviewing the contributions in this book will bring about new ideas of how to implement the advances made in the fabrication of soft matter gradients in your own research.

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