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## Soft Matter Characterization

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With 664 Figures and 38 Tables

 Springer

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# Preface

Soft matter (or soft condensed matter) refers to a group of systems that includes polymers, colloids, amphiphiles, membranes, micelles, emulsions, dendrimers, liquid crystals, polyelectrolytes, and their mixtures. Soft matter systems usually have structural length scales in the region from a nanometer to several hundred nanometers and thus fall within the domain of “nanotechnology.” The soft matter length scales are often characterized by interactions that are of the order of thermal energies so that relatively small perturbations can cause dramatic structural changes in them. Relaxation on such long distance scales is often relatively slow so that such systems may, in many cases, not be in thermal equilibrium.

Soft matter is important industrially and in biology (paints, surfactants, porous media, plastics, pharmaceuticals, ceramic precursors, textiles, proteins, polysaccharides, blood, etc.). Many of these systems have formerly been grouped together under the more foreboding term “complex liquids.” A field this diverse must be interdisciplinary. It includes, among others, condensed matter physicists, synthetic and physical chemists, biologists, medical doctors, and chemical engineers. Communication among researchers with such heterogeneous training and approaches to problem solving is essential for the advancement of this field.

Progress in basic soft matter research is driven largely by the experimental techniques available. Much of the work is concerned with understanding them at the microscopic level, especially at the nanometer length scales that give soft matter studies a wide overlap with nanotechnology.

These volumes present detailed discussions of many of the major techniques commonly used as well as some of those in current development for studying and manipulating soft matter. The articles are intended to be accessible to the interdisciplinary audience (at the graduate student level and above) that is or will be engaged in soft matter studies or those in other disciplines who wish to view some of the research methods in this fascinating field.

The books have extensive discussions of scattering techniques (light, neutron, and X-ray) and related fluctuation and optical grating techniques that are at the forefront of soft matter research. Most of the scattering techniques are Fourier space techniques. In addition to the enhancement and widespread use in soft matter research of electron microscopy, and the dramatic advances

in fluorescence imaging, recent years have seen the development of a class of powerful new imaging methods known as scanning probe microscopies. Atomic force microscopy is one of the most widely used of these methods. In addition, techniques that can be used to manipulate soft matter on the nanometer scale are also in rapid development. These include the aforementioned scanning probe microscopies as well as methods utilizing optical and magnetic tweezers. The articles cover the fundamental theory and practice of many of these techniques and discuss applications to some important soft matter systems. Complete in-depth coverage of techniques and systems would, of course, not be practical in such an enormous and diverse field and we apologize to those working with techniques and in areas that are not included.

Part 1 contains articles with a largely (but, in most cases, not exclusively) theoretical content and/or that cover material relevant to more than one of the techniques covered in subsequent volumes. It includes an introductory chapter on some of the time and space-time correlation functions that are extensively employed in other articles in the series, a comprehensive treatment of integrated intensity (static) light scattering from macromolecular solutions, as well as articles on small angle scattering from micelles and scattering from brush copolymers. A chapter on block copolymers reviews the theory (random phase approximation) of these systems, and surveys experiments on them (including static and dynamic light scattering, small-angle X-ray and neutron scattering as well as neutron spin echo (NSE) experiments). This chapter describes block copolymer behavior in the “disordered phase” and also their self-organization. The volume concludes with a review of the theory and computer simulations of polyelectrolyte solutions.

Part 2 contains material on dynamic light scattering, light scattering in shear fields and the related techniques of fluorescence recovery after photo bleaching (also called fluorescence photo bleaching recovery to avoid the unappealing acronym of the usual name), fluorescence fluctuation spectroscopy, and forced Rayleigh scattering. Part 2 concludes with an extensive treatment of light scattering from dispersions of polysaccharides.

Part 3 presents articles devoted to the use of X-rays and neutrons to study soft matter systems. It contains survey articles on both neutron and X-ray methods and more detailed articles on the study of specific systems - gels, melts, surfaces, polyelectrolytes, proteins, nucleic acids, block copolymers. It includes an article on the emerging X-ray photon correlation technique, the X-ray analog to dynamic light scattering (photon correlation spectroscopy).

Part 4 describes direct imaging techniques and methods for manipulating soft matter systems. It includes discussions of electron microscopy techniques, atomic force microscopy, single molecule microscopy, optical tweezers (with

applications to the study of DNA, myosin motors, etc.), visualizing molecules at interfaces, advances in high contrast optical microscopy (with applications to imaging giant vesicles and motile cells), and methods for synthesizing and atomic force microscopy imaging of novel highly branched polymers.

Soft matter research is, like most modern scientific work, an international endeavor. This is reflected by the contributions to these volumes by leaders in the field from laboratories in nine different countries. An important contribution to the international flavor of the field comes, in particular, from X-ray and neutron experiments that commonly involve the use of a few large facilities that are multinational in their staff and user base. We thank the authors for taking time from their busy schedules to write these articles as well as for enduring the entreaties of the editors with patience and good (usually) humor.

R. Borsali

R. Pecora

September 2007



## Editors-in-Chief



**Dr Redouane Borsali** is a CNRS Director of Research and since 2007 the Director of CERMAV, Centre de Recherche sur les Macromolécules Végétales, CNRS-UPR 5301, located on the Campus University of Grenoble, France. He studied physics at the University of Tlemcen, Algeria and received his Master and Ph.D. in polymer physics at the Institute Charles Sadron (Louis Pasteur University, Strasbourg, France) in 1988. After his postdoctoral research position at the Max-Planck-Institute for Polymer Research (MPI-P) at Mainz, Germany, he joined, in 1990, the CNRS (Grenoble, France) as a researcher. In 1995/1997, he spent a sabbatical leave at Stanford University and at IBM Almaden Research Center, CA, USA as a visiting scientist. In 2000, he joined the LCPO, a Polymer Research CNRS Laboratory, as the Polymer Physical-Chemistry Group Leader till 2006 and back to Grenoble in 2007 as the Director of CERMAV. His main research activities are focused on the study of the physical-chemistry properties: the structure, the dynamics, and the self-assemblies of “soft matter” and particularly of controlled architecture polymers such as block copolymers, polymer mixtures, polyelectrolytes including polysaccharides, nanoparticles such as micelles, vesicles, and rod-like morphologies, using scattering techniques. He has organized three international meeting on polymers and colloids, and he is the author or co-author of over 140 research articles and two books.





**Robert Pecora** is a professor of chemistry at Stanford University. He received his A.B., A.M. and Ph.D. degrees from Columbia University. After postdoctoral work at the Université Libre de Bruxelles and Columbia University, he joined the Stanford University faculty in 1964. His research interests are in the areas of condensed phase dynamics of small molecules, macromolecules, and colloids of both materials and biological interest. He is one of the developers of the dynamic light scattering technique and has utilized this and many of the other techniques described in these volumes in his research. His recent work emphasizes dynamics in dispersions of rodlike polymers, polyelectrolytes, and composite liquids. He is the author or coauthor of over 134 research articles and five books.

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