Elitenetzwerk Bayern

UNIVERSITÄT BAYREUTH

Elite Study Program in Macromolecular Science

Start Module M026

Modern Research Topics in Macromolecular Science

Faculty of the Elite Study Program

Winter term 2011/12

The scope of the Start Module “Modern Research Topics in Macromolecular Science” is to introduce the students, coming from different backgrounds, to various facets of the broad and interdisciplinary field of Macromolecular Science. It is intended that the students will get a basic understanding of underling concepts, technical terminology and methodologies in the individual subfields of Macromolecular Science beside their main focus. The offered topics cover the fields macromolecular chemistry, colloidal chemistry, biopolymers, biochemistry, microbiology, polymer physics, biophysics, polymer technology, polymer engineering, theory and simulation of macromolecules. The students will select 8 topics from 15 offered topics. Each individual topic has a length of 10 hours and includes lectures, seminars and laboratory illustrations. In addition the students will have a tour and brief introduction of the research facilities.

The following topics will be offered in the winter term 2011/12:

Liquid Crystals: From Low Molecular Weight Materials to Elastomers
Helmut Brand, Theoretical Physics III

The field of liquid crystals will be introduced. In one special topic we cover selected LC phases. The second special topic deals with physical properties and methods. In the project afternoon we will discuss selected literature and in particular the derivation of the Frank elastic energy for a nematic liquid crystal.
Timeframe: Two times half a day, 05.03.-23.03.

Diffusion in Polymers
Werner Köhler, Experimental Physics IV, Polymer physics

Diffusion, the uncorrelated motion of molecules, plays a key role in understanding dynamic processes in macromolecular systems. In the first part of this topic basic concepts of how polymers diffuse in the bulk and in solution are introduced. The difference between self and collective diffusion is discussed and it is shown that a temperature gradient can also induce mass diffusion.
Relevant experimental techniques for the measurement of diffusion coefficients are discussed in the second part, and state of the art experiments can be seen in the laboratory.
The lectures will cover phenomenology of diffusion, including polymer models, linear laws, self diffusion, collective diffusion and thermal diffusion. As experimental techniques, light scattering and transient holography will be covered.
Timeframe: 17.02., 20.02. or 22.03. (whole day)

Fundamentals of fluorescence spectroscopy
Applications to the study of biomolecules
Elisa Bombarda, Experimental Physics IV

The purpose of this module is to introduce the basis of fluorescence spectroscopy to an audience of heterogeneous background (Physics, Chemistry and Biology). The phenomenon of fluorescence will be introduced and an overview on the steady state and time-resolved modes will be given. Among the topics: quantum yield, lifetimes, resonance energy transfer and fluorescence anisotropy. The basic principles will be explained from a practical point of view. Examples taken from investigations on biomolecules will be given.
Timeframe: 07.03. 9:30-12:30, 08.03. 9:30-12:30, 09.03. 9:30-11:30 (Proposed time schedule)

Interactions and Nano-Mechanics in Polymer Systems
Andreas Fery, Georg Papastavrou, Physical Chemistry II

Interfacial forces determine many properties like friction, adhesion, or wetting. In recent years, the atomic force microscope (AFM) has developed into a versatile tool for measuring such forces at the nanometer scale with force resolutions in the order of few tenths of a pico-Newton. Such force measurements allow not only to determine the interaction on the level of single polymer chains but as well to explore mechanical properties of nano- and colloidal objects not accessible by other techniques.
In this module we will demonstrate different experimental approaches based on the AFM. The basic principles governing the stretching response of linear polymers, starting from the Gaussian chain model, will be covered as well as the desorption processes of adsorbed polymers from a solid substrate, which allows to probe the interactions on the monomer level. Models describing the mechanic response of polymer capsules or other nano- to micrometer sized structures under external forces represent another important topic.
Upon interest of the participants it will be possible to arrange a practical demonstration of single molecule and other force experiments with the AFM at the end of the module.
Timeframe: 08.03., 09:00, BZKG

Multifunctional Colloids - From Simple Building Blocks to Modern Devices
Matthias Karg, Markus Retsch, Physical Chemistry Department

Colloidal particles represent a materials class with a vast range of composition, size, and shape. The unique properties of colloids can mainly be related to their enormous surface to volume ratio and differ significantly from their respective bulk materials. The functionality of such particles can be further enhanced by self-assembly of such building blocks into regular films or arrays, which for instance are known as colloidal crystals.
In this module we want to give a detailed introduction into the synthesis, characterization and application of colloidal particles. We will focus on a range

of materials such as polymers, metals, and metal oxides, which can also be combined to yield composite materials. Important concepts in colloidal science, in particular the stability of colloidal dispersions and forces influencing colloidal stability, will be introduced. The relevance of these concepts will be discussed in the light of self-assembled materials consisting of colloidal building blocks. Such materials are promising platforms for modern sensors and photovoltaic devices.
Timeframe: 02.04. or 03.04. (whole day)

Electro-spinning of (bio)polymers for bio-nanoengineering
Hendrik Bargel, Thomas Scheibel,Biomaterials

Electro-spinning is a method to process continuous fibers in nanoscale dimensions using polymers. Electro-static forces in a high-voltage electrical field control the process of fiber production, which form non-woven fabrics on a collector plate. It is possible to utilize very different polymers in solution or melt, such as polycaprolacton or spider silk proteins. By varying parameters such as molecular weight, viscosity of the solution, flow rate, electrical field, and distance between outlet tip and collector plate, the fiber morphology can be altered for specific needs. The first part of the module comprises a theoretical introduction of several fiber-spinning methods including electro-spinning and a practical introduction of e-spinning of a model polymer. The second part of the course deals with the theoretical background of mechanical analysis of fibrous materials and practical testing of various materials including electro-spun non-woven fabrics.
Timeframe: 2 afternoons, 13:00 - 18:00, Wed/Thu/Fri, 25.-27.03. & 28.-30.03.2012
Note: This topic comprises a practical lab course as main part. Grades will be given for the protocols that every student has to prepare. There will be no separate examination questions for this topic!

Orbitals as a tool for understanding electronic structure – hype or hope?
Stephan Kümmel, Theoretical Physics IV

The concept of orbitals is frequently used in molecular science to interpret experimental results, to develop an understanding of the structure of molecules, or to visualize theoretical insights. However, an “orbital” is not a well defined object. There are different types of orbitals, and different orbitals typically carry different physical or chemical information. Therefore, “looking at orbitals” can either be helpful or it can be grossly misleading. In this topic the quantum mechanical concepts that are needed to understand and correctly interpret molecular orbitals will be explained, and several molecular semiconductors will be discussed as examples.
Timeframe: 19.03. - 30.3. (whole day)

Polymer Foams
Clemens Keilholz, Volker Altstädt, Polymer Engineering

Due to the unique properties of polymer foams, a large number of innovative applications can be realised. These include packaging with reduced material costs, aerospace and automotive parts with good property-to-weight ratios, decreased thermal conductivity, and enhanced acoustic and mechanical damping.
The first part of the module (5 hours) focuses on the fundamental physics of polymer foams, including a detailed discussion of the foaming processes currently utilised both in academia and in industry as well as the resulting structure-property-relationships. Thereby, different types of polymer foams (particle foams, reactive polyurethane foams (PUR), extruded and injection-moulded foams) and their typical properties and applications are introduced. In addition, current scientific approaches towards the control of cell nucleation, cell growth and volume expansion will be presented. Innovations (micro- to nanocellular) and the hierarchical structuring of polymeric foams are also highlighted. Finally, the students will learn how to obtain tailored foam morphologies – and properties.
This oral part is followed by an experimental session (5 hours) taking place in our laboratories and pilot plant stations. More precisely, a practical introduction into foam injection-moulding and foam extrusion is given using commercial machines. Finally, new trends and promising approaches as well as remaining questions will be discussed with the “foaming experts” of Polymer Engineering group.
Timeframe: 3 - 5 appointment suggestions that are possible and preferred by the interested students.

Design of supramolecular architectures for functional materials
Hans-Werner Schmidt, Andreas Bernet, Macromolecular Chemistry I, Bayreuther Institut für Makromolekülforschung (BIMF)

A major challenge in polymer science, with respect to novel functional and even multifunctional materials, is the understanding and control of hierarchical structured supramolecular polymers and nano-objects created by (macro)molecular self-assembly. Such complex self-assembled structures will provide constant progress in materials science and play a key role for innovative solutions. Our goal is to fine-tune specific and complex functionality across all length scales (nano to macro) through molecular design and novel hierarchically structured systems. In this context, we explored in the past years the design and structure-property relations of molecules capable to self-assemble into supramolecular nano-fibers and nano-objects. The molecules were for example tailored to function as nucleating/clarifying agents for semi-crystalline polymers, as charge storage additives in electret materials, as nano-fibers for filtration applications and as efficient organo- and hydrogelators.
Timeframe: 22.03. or 23.03. (whole day)

Color Formation in Organic Light Emitting Devices (OLEDs) - A Combined Chemistry and Physics Approach
Peter Strohriegl, Macromolecular Chemistry I
Anna Köhler, Experimental Physics II

Colors have attracted people for thousands of years. In the first part of the interdisciplinary course, a short introduction in the basics of color formation and color mixing will be given. Afterwards, the principles of Organic-Light Emitting Devices (OLEDs) will be introduced with special emphasis on the different materials used.
The second part of the course gives an introduction to the photophysics of OLEDs. In such devices the physical principles of energy transfer from a host material to a guest molecule are used to generate different colors in an energy efficient way. The detailed understanding of the photophysics of organic semiconductors has paved the way for the commercialization of full color OLED-displays.
Timeframe: 01.03., 02.03., 22.03. or 23.03. (whole day)

Structure and Dynamics of Bio-Macromolecules
Stephan Schwarzinger, Paul Rösch, Department of Biopolymers

Proteins and nucleic acids are the polymeric building blocks of life. Their three-dimensional structures are investigated in the field of structural biology. In our department we focus on heteronuclear, multi-dimensional nuclear magnetic resonance (NMR) spectroscopy as main tool to elucidate structural and dynamical properties of bio-macromolecules. This technique is supplemented by optical spectroscopy (circular dichroism and fluorescence spectroscopy). The teaching module consists of a lecture series introducing biopolymer structure and concepts underlying the biophysical techniques used for structure determination. The lecture series will cover the following methodologies:

Prof. Birgitta Wöhrl: *From gene to protein*

PD Dr. Stephan Schwarzinger: *Optical spectroscopy – from methods to results*

Dr. Kristian Schweimer: *NMR spectroscopy – methodology*

The lectures will be completed by a lab tour dealing with the technical aspects and the instruments that are required for the presented techniques.

Timeframe: Whole day March/April according to students' suggestion (except 11.03. – 18.03.)

Advanced Laser Techniques: Confocal Raman and Fluorescence Lifetime Imaging (FLIM) Microscopy and Holographic Data Storage
Lothar Kador, BIMF

Confocal microscopy is a powerful technique for imaging samples in all three dimensions of space. It can easily be combined with the analysis of secondary radiation such as, *e.g.*, Raman scattering or fluorescence light. We will

especially discuss the methods of confocal Raman microscopy, which yields information on the chemical composition of the sample, and confocal fluorescence lifetime imaging (FLIM) microscopy, which maps the excited-state lifetime of fluorophores. In the latter case, emphasis will be laid on experiments in the frequency domain which use a cw laser amplitude-modulated in the radio-frequency (rf) regime. In this context, some fundamentals of rf experiments will be touched. In the second part of the lecture, an introduction to holography and its application to high-density data storage in polymers will be given. The project part will be devoted to practical demonstrations of one of these techniques.
Timeframe: One whole day according to students' suggestions (except 22.-24.02., 12.-16.03., 26.-30.03.)

Principles of Selforganization
Walter Zimmermann, Theoretical Physics I

Patterns are ubiquitous in nature. One observes layered structures, stripe patterns, squares, hexagons, travelling or standing waves, oscillatory patterns, spirals etc. .Some of them are dissipative patterns and exist only far from thermal equilibrium. Others are driven by competing length scales. For several patterns, occurring in real systems, also the underlying driving mechanisms are discussed and explained. Patterns in different systems are driven by different mechanisms, but many patterns undergo identical bifurcations scenarios. For such generic types of bifurcation scenarios elementary (polynomial) normal forms are given, discussed and analyzed by elementary methods. What is a stability band of spatial patterns? This is illustrated by an elementary textbook example from mechanics, by a bar embedded in an elastic medium. This example is very similar to the famous Swift-Hohenberg (SH) model, which covers the minimum number of contributions for describing spatial patterns in one spatial dimension. What is an Eckhaus-stability-boundary? What is the role of the universal number $\sqrt{3}$ in this context? The meaning of the Eckhaus-stability-boundary and the role of $\sqrt{3}$ is illustrated by examples from fluid dynamics and for Turing patterns occurring in biology and chemistry. Is the Eckhaus-stability pattern relevant for an understanding of the dynamics of the skin-pattern of the "zebra"-fish or other biological patterns? Is biological pattern formation purely driven by the genes?
Optional: Using and/or developing a Matlab program for simulating and visualizing the dynamics of patterns (near the Eckhaus-boundary).
Timeframe: 06.03. - 16.03.(whole day)