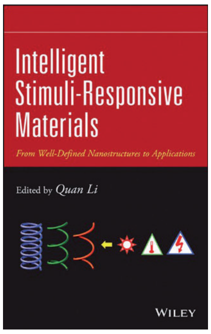
Intelligent stimuli-responsive materials : from well-defined nanostructures to applications

Intelligent Stimuli-Responsive Materials

Materials that change shape, color, transparency, or functionality when stimulated by an external trigger are receiving a lot of attention. Such stimuli-responsive or "smart" materials are recognized as a key to solving society's future challenges, ranging from sustainable energy to health care. One can think of materials that respond to environmental changes by altering topography and color, to reduce the energy cost of cars and buildings, or of drug delivery and release systems that can be triggered by external stimuli for targeted medicine. The most popular types of materials used are liquid crystalline (LC) polymers or hydrogels. Small changes in the molecular ordering of LC materials can cause large dimensional changes, and differences in swelling and shrinkage of gels due to the adsorption or desorption of a solvent can result in size changes. To make such systems, it is necessary to control all length scales, from the molecular building blocks to the final devices, as triggers most often operate at the molecular level. Inspiration for the design of these materials comes from biological stimuli-responsive systems. In the book *Intelligent Stimuli-Responsive Materials: From Well-Defined Nanostructures to Applications*, the editor, Quan Li, provides an up-to-date overview of such materials. He is director of the Organic Synthesis and Advanced Materials Laboratory of the Liquid Crystal Institute at Kent State University, Ohio, and is an expert in this field. Fundamentals and principles are discussed in the book, with a focus on hierarchical nanostructured materials, methods, and applications in a broad range of fields. The book comprises 13 chapters, which comprehensively cover different stimuli-responsive materials and discuss their developments, advances, challenges, analytical techniques, and applications. Four chapters have been written by the editor, while the others are from leading scientists in the field.



Intelligent Stimuli-Responsive Materials
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The first chapter deals with nature-inspired stimuli-responsive self-folding polymer films that consist of two materials, of which at least one can change its volume. In most cases the second material is a hydrogel that responds to pH, temperature, solvent, or light. A variety of films have been made by cutting, using microwell-like substrates, photolithography, and even desktop printing, yielding an exciting range of self-folding shapes such as tubes, cubes, pyramids, and even a dodecahedron. The next chapter discusses stimuli-responsive nanostructures formed by self-assembly of rigid–flexible block molecules. Rigid–flexible block molecules are excellent supramolecular building blocks, because in selective solvents the flexible side-chains assemble into various nano-sized structures, including tubules, toroids, porous capsules, and helical fibers. The chapter also describes unique types of responsive nanostructures that change shape and morphology when exposed to changes of temperature, pH, different solvents, and the presence of specific molecules.

Organic electronic materials are discussed in Chapter 3, focusing on stimuli-directed control of alignment in semiconducting discotic liquid-crystalline nanostructures. Such alignment has the important effect of enhancing the charge transport properties in electronic devices. In these liquid crystals, alignment can be achieved, for example, by inducing alignment layers, by zone casting and melting, by applying magnetic or electric fields, or by exposure to infrared light. However, the author concludes that we are still far from making rational connections between molecular structure, bulk self-assembly organization, and the performance of devices. Anions have also been used to control the supramolecular organization in self-assembled (semiconducting) materials, as described in Chapter 4.

The next three chapters (5 to 7) deal with electrically responsive and photoresponsive liquid crystals. Chiral liquid crystalline phases are able to reflect light in colors that can be changed according to the light intensity, which is interesting for applications that include polarizers and "smart" switchable reflective windows. Light as a stimulus has been used to fabricate photomechanical materials that can undergo a plethora of interesting and useful motions. So-called "bent-core" liquid crystals are also discussed; these have macroscopic polar order, which makes them electrically responsive.

Molecular transport through responsive silica nanoporous membranes is reviewed in Chapter 8. Here the transport can be controlled by, for example, pH, light, and temperature, which is interesting for the design and construction of drug-release systems and sensors. Responsive organic–metallic hybrid nanoparticles can also be made, as an alternative to polymer films (Chapter 9). Exciting results have been obtained by using predominantly light and magnetism as stimuli, which is of special interest for biomedical applications. In particular, gold nanoparticles are discussed in view of their extraordinary sensitivity to NIR light.

Gels that swell or shrink in response to biomolecules such as saccharides and proteins have been developed in order to monitor physiological changes (Chapter 10). Gels that are self-oscillating can also be made (Chapter 11). The chapter gives striking examples of how, based on the well-known Belousov–Zhabotinsky reaction, it is possible to couple chemical and mechanical oscillations in a polymer system. Gels and other materials can also be applied to create stimuli-responsive surfaces, which are interesting for biomedical applications (Chapter 12). An important theme of research in this field is to mimic the dynamic behavior of the extracellular matrix, which is important for tissue engineering, repair, and regeneration. The last chapter of the book (Chapter 13) is devoted to responsive π-conjugated materials for applications ranging from electronic noses to artificial muscles. The book ends with a comprehensive index of key-words, materials, techniques, and topics.

The chapters in the book do not exhaustively cover the fascinating field of responsive materials, but give an excellent flavor of the diverse topics in this area. Recent developments are presented in a clear form, with black-and-white and color figures. The book is well-suited for undergraduate and graduate students, as well as scientists from different backgrounds. For students, it gives an excellent introduction about the basic principles, fabrication methods, performance, and challenges in developing these materials, while for the scientists it shows the latest breakthroughs and serves as an inspiration for solving problems or sparking new ideas. From this book it becomes clear that the potential of stimuli-responsive materials is enormous. It is a superb guide to the subject, and I enthusiastically recommend reading it.

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