Speciality polymers: supramolecular aspects of polymer synthesis and polymer structure

The control of the microstructure of semiconductor materials on the subnanometre atomic scale has led to a widely publicized breakthrough in technology, as it allowed further miniaturization of electronic devices and exploitation of quantum effects in the design of functional semiconductor components. It is much less well known to the public, and even to experts in general materials science, that the outstanding properties of modern polymer materials in terms of toughness, elasticity, strength and transparency also depend on the ability to tailor the microstructure of composites and blends on the nanometre scale. Strangely enough, the consequences and implications of structure formation on this scale have been realized in the polymer area – historically speaking – more by trial and error than by rational planning. Nevertheless, the consequences for technology, applications and industrial success are overwhelming. The microstructure of polymer materials, for which engineering plastics may serve as an example, is a consequence of processes which are partly controlled by thermodynamics and partly by kinetics in the shaping of the final objects. It is thus difficult to attain a specific supramolecular structure under practical circumstances, other than by following a recipe in a meticulous manner.

Thus, it is no wonder that a more rational approach to the formation of molecular architectures of solid polymers is the leading theme in materials research in the polymer area. In fact, supramolecular chemistry, nanostructures, nanocomposites, and control of properties by molecular architecture are the catch-phrases found increasingly in texts describing the present and future directions of research in materials science.

The quest for supramolecular chemistry leads immediately to the question of how to handle individual molecules and, if this is not possible, how to handle a defined collection of molecules with the aim of constructing topologically desired and well-defined architectures. At this point dimensionality comes into play. It is certainly much easier to collect and organize molecules in two dimensions, i.e. on surfaces, than in three dimensions. Starting from a two-dimensionally organized structure, one can then try to construct three-dimensional materials by consecutively adding further layers. The rational construction of organic solids composed of different types of molecules in a topologically well-defined architecture is the goal. An important implication is to attain well-defined surfaces of materials giving rise to defined surface interactions with other materials.

The consequence of this line of thought is the increasing number of research groups which embark on the chemistry and physics of monomolecular layers of macromolecules on planar surfaces or multilayer assemblies. Exploitation of chemisorptive processes may lead to so called self-organized layers on reactive surfaces. Kinetically controlled assembly techniques, notably the famous Langmuir–Blodgett–Kuhn process, give rise to extremely well defined model solids. Frequently amphiphilic molecules are investigated because they exhibit self-organizing properties. In the presence of a second component, usually water as a solvent, they show spontaneous compartmentalization of the system. Micelles and vesicles are formed which in turn are also characterized by their spherical lamellar structure and the overwhelming contribution of the surfaces to the overall properties of the system. The search for direct correlations between molecular structure, molecular interactions, tendency to self-organize and the final physical properties is also the key element in all current research on liquid crystal forming polymers.

Although such ideas and goals seem to be rather academic at first, they do in fact have a highly practical character; keywords, among others, are wetting, adhesion, biocompatibility, membrane and sensor applications, lubrication and corrosion resistance, microlithographic processes and pattern formation. Moreover, the increasing demand for a better definition of the surface properties of conventional polymers has focused attention on the fact that new or improved analytical methods are necessary to probe surfaces and interfaces of organic materials down to the subnanometre scale. The methods developed for the study of metals, ceramics and semiconductors, such as XPS, SIMS or LEED are helpful but do not satisfy all requirements. The elucidation of molecular orientation, conformation, and dynamic processes at the surface or in layered structures is the goal, creating the need for a variety of highly surface-sensitive spectroscopies.

In general, more quantitative descriptions and methods to study supramolecular architectures and assemblies are necessary to advance the status of the field from the rather qualitative level at which it rests at present.

The Speciality Polymers '91 Conference, held at Mainz on 30 September–2 October 1991 was entirely dedicated to this subject, with particular emphasis on quantitative assessment of structure, dynamics and properties of supramolecular architectures. A representative part of the lectures given during this conference will be found in this issue of *Polymer*.

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