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Abstract. Nanopolymers with different structures, shapes, and functional forms have recently been prepared using several techniques. Nanopolymers are the most promising basic building blocks for mounting complex and simple hierarchical nanosystems. The applications of nanopolymers are extremely broad and polymer-based nanotechnologies are fast emerging. We propose a nanopolymer classification scheme based on self-assembled structures, non self-assembled structures, and on the number of dimensions in the nanometer range (nD).

1. Introduction

Nanotechnology searches for the development and integration of nanostructured materials to produce creative products for the benefit of the humankind. Specially, interest in nanostructured polymers, or nanopolymers, is rapidly growing because they offer a variety of possibilities to construct nano-scale parts, self-assembly structures at different scales, new properties due to the down-scaling of size and new phase transitions. It is clear that nanopolymers will be in the mainstream of future nanotechnology manufacturing. A classification of nanopolymers is needed to explore the extensions of existing techniques as well as to develop new approaches.

Here we present a nanopolymer classification scheme based on (a) self-assembled nanostructures (lamellar, lamellar-within-spherical, lamellar-within-cylinder, lamellar-within-lamellar, cylinder-within-lamellar, spherical-within-lamellar, and colloidal particles with block copolymers), (b) non self-assembled nanostructures (dendrimers, hyperbranched polymers, polymer brushes, nanofibres, nanotubes, nanoparticles, nanospheres, nanocapsules, porous materials, and nano-objects), and (c) number of nanoscale dimensions (1-nD (thin films), 2-nD (nanofibres, nanotubes, nanostructures on polymeric surfaces) and 3-nD (nanospheres, nanocapsules, dendrimers, hyperbranched polymers, self-assembled structures, porous materials, nano-objects)). Illustrative examples are given and discussed.

2. Self-assembled Nanostructures

Interest in nanostructured polymers are growing rapidly because of their sized-coupled properties. Combination of self-assembly at different length scales leads to structural hierarchies. It offers rich possibilities to construct nanostructured matter, nanoscale parts, and switching (responsive) properties based on the phase transitions of the self-assembled structures. Routes for bottom-up construction of

nanostructures based on polymeric self-assembly are presented in Ref.1.. It is schematically shown how different sizes of construction units can be systematically combined to render progressively higher levels of structural hierarchy and incorporate different length scales. Different nanostructures may be classified as lamellar, lamellar-within-spherical, lamellar-within-cylinder, lamellar-within-lamellar, cylinder-within-lamellar, spherical-within-lamellar, and colloidal particles with block copolymers. Block copolymers may be self-structured to form small-scale domains whose size and geometry depend on the molecular weights of the polymer chains and their mutual interactions. The domains have a very uniform distribution of sizes and shapes. Various morphologies can be prepared from amphiphilic block copolymers in solution of small molecule solvents. Various self-assembled structures also are allowed by physically bonding the oligomeric repulsive side chains to homopolymer deposition.

3. Non Self-assembled Nanostructures

Typical non self-assembled structures may be classified as dendrimers, hyperbranched polymers, polymer brushes, nanofibres, nanotubes, nanoparticles, nanospheres, nanocapsules, porous materials, and nano-objects, among others.

Dendrimers are nanoparticles formed by the addition of shells of branched molecules to a central core. Dendrimers are widely recognized as the most versatile compositionally and structured nanoscale building blocks available.

Hyperbranched polymers are also formed by a central core, but with multiple polydisperse polymers, including linear polymer segments, with multiple functional endgroups in the periphery.

Polymer brushes are assemblies of polymer chains which are tethered by one end to a surface or interface. They permit tailoring surface properties for converting hydrophobic surfaces to hydrophilic surfaces, and vice-versa, colloid stabilization, and may enhance assemblies of different chemical species.

Polymer nanofibers is a broad term, generally referring to fibers with diameters less than 1 micron. They are usually produced by electro-spinning. Several value-added nonwoven applications, including filtration, barrier fabrics, wipes, personal care, medical and pharmaceutical applications may benefit from the interesting technical properties of nanofibers and nanofiber webs.

Polymer nanotubes may have several applications. Nanotubes with such dimensions may be used to store or transport gases or fluids, fuel cells, near field optics, nano-electronics and combinatorial chemistry for applications in the areas of catalysis, drug release and encapsulation.

Polymer nanoparticles, nanospheres, nanocapsules may be defined as nanometric colloidal carriers. Polymeric nanoparticles present high stability when in contact with biological fluids and their polymeric nature allows controlled drug release. Nanoparticles represent drug delivery systems suitable for most of the administration routes, even if a rapid recognition by the immune system limits their use as injectable carriers. Nanoparticles may be prepared either from preformed polymers, such as polyesters (i.e. polylactic acid), or from a monomer during its polymerization, as in the case of alkylcyanoacrylates. According to the technologies used, nanospheres or nanocapsules can be obtained. Typical nanospheres consist of a dense polymeric matrix, in which the drug can be dispersed. Nanocapsules present a liquid core surrounded by a polymeric shell.

4. Number of nanoscale dimensions (nD)

We may also classify the nanopolymers based on the number of dimensions in the nanometer range, as follows.

(A) 1-nD (one nanoscale dimension): homogeneous polymeric thin- or ultra-thin-films.

(B) 2-nD (two nanoscale dimensions): nanofibres, nanotubes, nanoconduits, nanostructures on polymeric surfaces.

(C) 3-nD (three nanoscale dimensions): nanospheres, nanocapsules, dendrimers, hyperbranched polymers, self-assembled structures, porous materials, nano-objects.

(D) 1-nD, 2-nD and 3-nD combinations: nanopolymer scaffolds and tissues, nanopolymers anchored to substrates or interlayers, nanocomposites, among other compositions.

5. Conclusions

Nanopolymers are the most promising basic building blocks for mounting complex and simple hierarchical nanosystems and their applications are extremely broad. Nanopolymers may be classified by their self-assembly and non-self-assembly capabilities, and by the number of the dimensions in the nanometer range (nD).

Reference

[1]   Ikkala O, Brinke ten G 2004 *Chem. Commu.* 2131