Chap. 19 Organic Optoelectronic Nanostructures

19.1 Introduction

- Synthetic polymers: excellent mechanical properties, easy processibility, light weight, low cost

- Conjugates polymers (in the late 1970's): alternating single and double bonds in the series of carbon atoms -> electronic, optical, optoelectronic materials

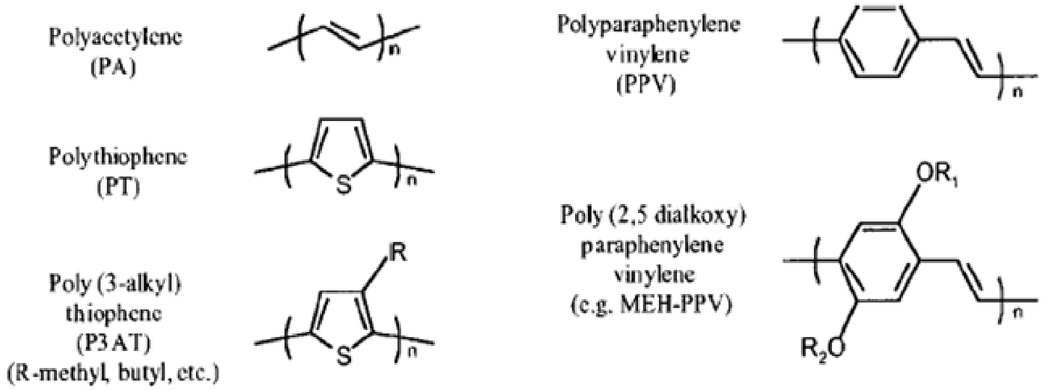


Figure 19.1. Molecular structures of several conjugated polymers. (From Ref. 1 by permission of American Physical Society.)

19.2 Organic and polymeric LEDs

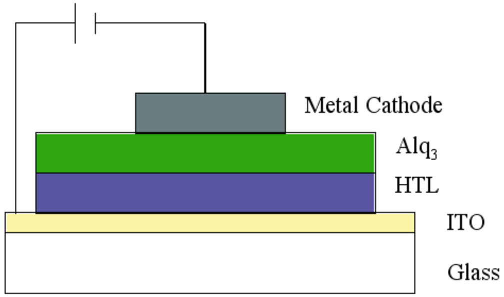


Figure 19.2. Device structure of an organic light-emitting diode.

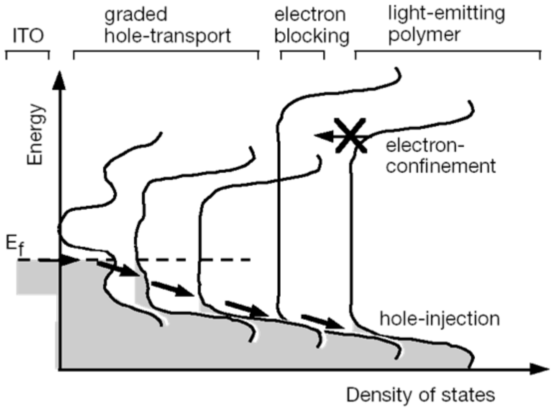


Figure 19.6. Schematic of the electronic density of states across a graded interlayer fabricated using electrostatic layer-by-layer assembly. (From Ref. 13 by permission of Macmillan Magazines Ltd.)

19.3 Photovoltaic Polymers

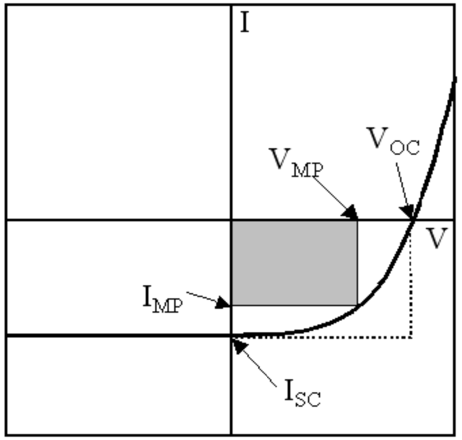
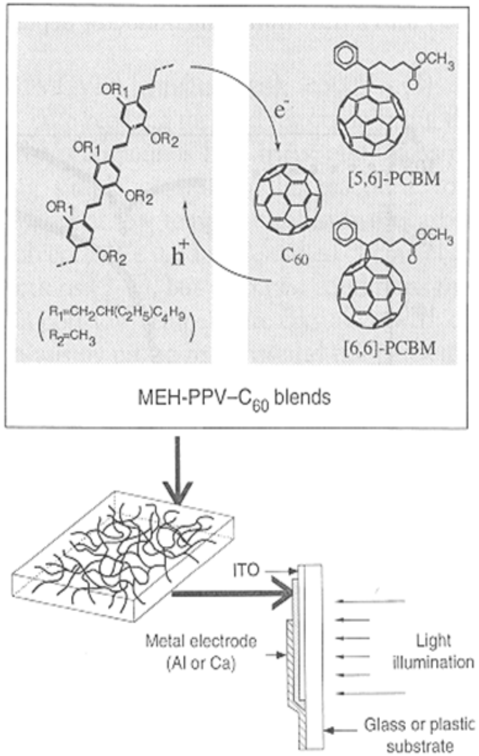


Figure 19.7. Typical current-voltage characteristics of a solar cell under illumination. The identified quantities are discussed in the text.

ISC = the current measured with zero resistance (short circuit)
VOC= the external (applied) bias voltage at which the current is zero (open circuit)
IMP and VMP: the current and voltage at the maximum power point.
Fill factor FF = (IMPVMP)/(ISCVOC); actual output/ideal output.

Figure 19.8. Schematic illustration of photoinduced charge transfer in blends of MEH-PPV and C_{60} derivatives. Also illustrated are the phase separation into a bicontinuous network and the general configuration of polymer photovoltaic device. (From Ref. 17 by permission of American Association for the Advancement of Science.)



Chap. 20 Photonic Crystals

20.1 Introduction

- Photonic (band gap) crystals: spatially periodic structures fabricated from dielectric materials having different refractive indices (proposed by Yablonovich and John in 1987).
- The existence of a band gap in its photonic structure that is able to influence the propagation of em waves in a similar way as the electronic gap of a semiconductor does for electrons.
- A powerful tool to confine, control, and manipulate photons in all 3 dimensions of space.

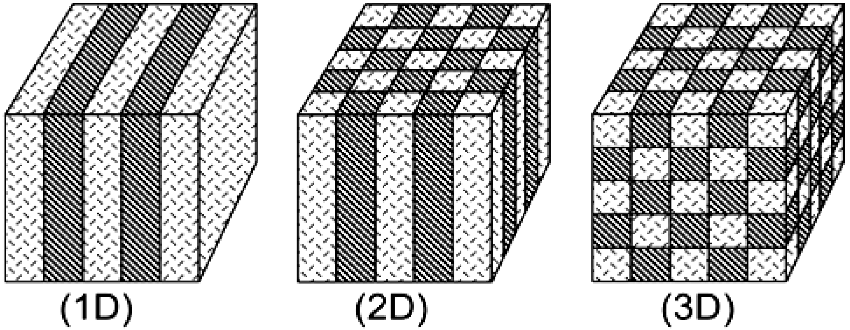


Figure 20.1. Schematic illustrations of 1D, 2D, and 3D photonic crystals patterned from two different types of dielectric materials.

20.3 Photonic Crystals by Microfabrication

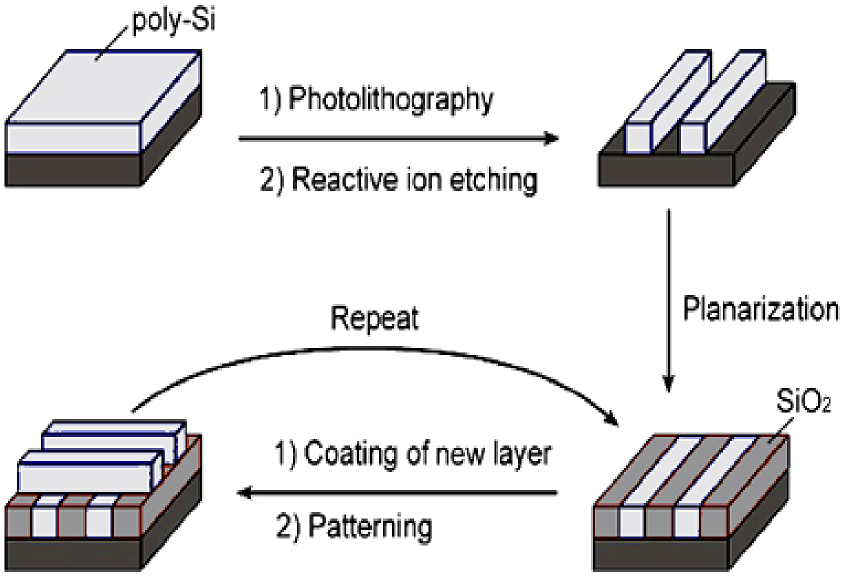


Figure 20.4. A schematic illustration showing the microfabrication of a 3D woodpile lattice of polycrystalline silicon in a layer-by-layer fashion.

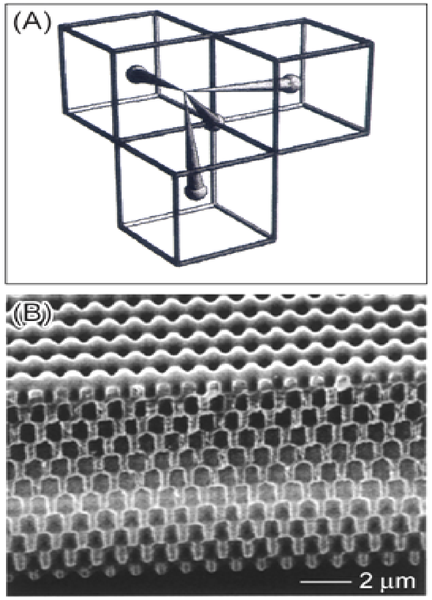


Figure 20.5. (A) A schematic illustration of the experimental setup for holographic patterning that involves the use of four coherent laser beams. (From Ref. 36 by permission of Nature Publishing Group.) (B) The scanning electron microscopy image of a 3D periodic lattice generated in a photoresist through photo-induced polymerization. (From Ref. 37 by permission of American Chemical Society.)

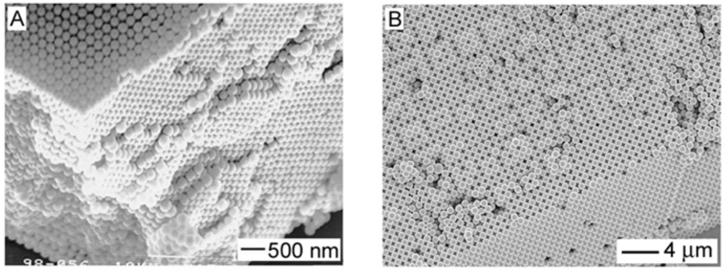


Figure 20.7. Scanning electron microscopy images of two typical examples of 3D opaline lattices that were crystallized from polystyrene beads, with their (111) and (100) crystallographic planes oriented parallel to the surfaces of the supporting substrates, respectively. (From Ref. 63 by permission of WILEY-VCH Verlag GmbH & Co. and from Ref. 66 by permission of American Chemical Society.)

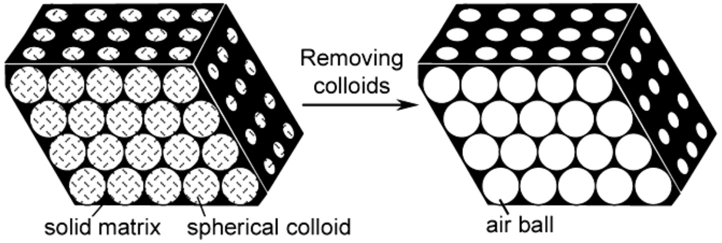


Figure 20.9. A schematic illustration of the experimental procedure that generates 3D inverse opals by templating against an opaline lattice of spherical colloids, followed by selective removal of the colloidal templates. (From Ref. 46 by permission of WILEY-VCH Verlag GmbH & Co.)

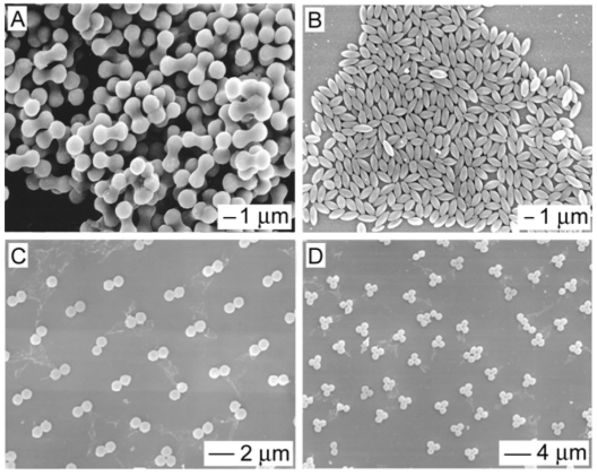


Figure 20.13. Scanning electron microscopy images of several typical examples of colloids with various nonspherical shapes: (A) peanut-shaped iron oxide colloids synthesized using a wet chemical method; (From Ref. 108 by permission of WILEY-VCH Verlag GmbH & Co.) (B) ellipsoidal polystyrene beads fabricated by stretching a polymer thin film containing spherical polymer beads; (From Ref. 107 by permission of American Chemical Society.) (C, D) dimeric and trimeric units assembled from spherical polymer beads through the confinement of physical templates. (From Ref. 13 by permission of American Physical Society.)

Chap. 21 Biomimetic Nanostructures

21.2 Worm Micelles and Vesicles from Block Copolymers

- Amphiphiles in aqueous solution; membrane (lamellar), rod-like (columnar), or spherical (vesicular) morphology

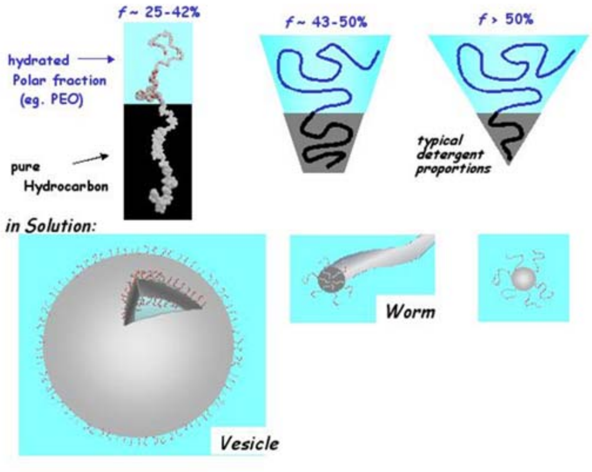


Figure 21.2 Schematics of molecular shapes which arise in hydration of the polar chains of amphiphiles. Such shapes underlie the formation of various morphological phases: vesicles, worms, and spheres. Vesicles predominate when the polar fraction, *f*, of most simple amphiphiles is in the indicated range. Polyethyleneoxide (PEO) is a typical, non-ionized polar chain with a high oxygen content (red atoms) that facilitates hydration. The hydrocarbon segments of the amphiphiles interact with each other, driving aggregation and excluding water to create a hydrophobic core. A vesicle is sketched with a small section removed to reveal the core's nano-scale thickness *d*. Rod-like worm micelles form when the polar segments are made slightly longer, while spheres form for even longer polar segments. (From Ref. 14 by permission of Elsevier Science.)

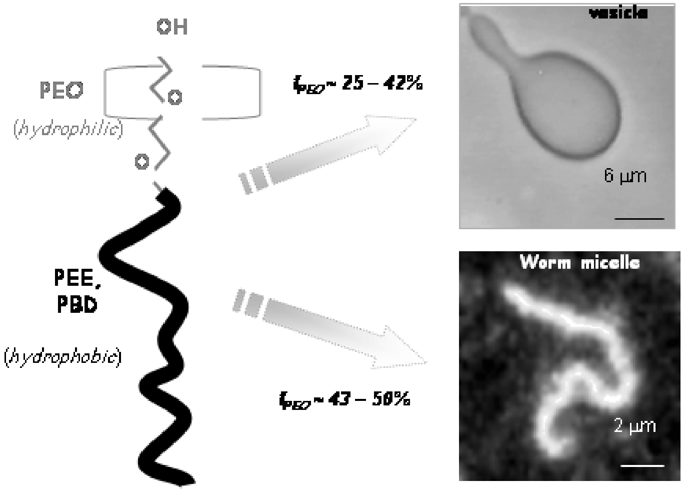


Figure 21.3 Synthetic polymer membranes and worms made by self-assembly of PEO-based diblocks in water. The weight or volume fraction of the hydrophilic PEO (polyethylene oxide) block is specified by f. The hydrophobic, hydrocarbon block of the copolymers thus far studied consists of either PEE (polyethylethylene) or its crosslinkable analog PBD (polybutadiene). Note that an increased f by just a few percent leads to worm micelles instead of vesicles. Cryo-TEM has already shown that the worm micelles, made of block copolymers of molecular weight MW ~ 4 kDa, have hydrophobic cores of ~10 nm.