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A Review of: "Nanocrystals Forming Mesoscopic Structures, by Marie-Paule Pileni (Ed.)"

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Book Review

Nanocrystals Forming Mesoscopic Structures, by Marie-Paule Pileni (Ed.), Wiley-VCH, 2006; 346 pp.; $175.

This book provides a comprehensive review of current research on the formation of mesoscopic two- and three-dimensional structures of inorganic materials. Various fundamental aspects of the self-assembly of semiconductor, magnetic, and metal nanoparticles are presented in 13 chapters, most of which discuss either the self-organization process or optical and magnetic properties of structures formed on solid substrates. The remaining chapters are devoted to other types of systems, such as nanocrystals formed in solid matrixes and liquid-crystalline phases of mineral particles in solution. Although the focus of the book is on fundamental principles, current applications of the various systems are summarized and referenced at the end of each chapter, and potential uses are mentioned. This text is a timely complement to recent books that cover other aspects such as the synthesis of nanoparticles, their electronic properties, or their applications in biological systems or catalysis.

The first three chapters introduce nomenclature and various types of 2D and 3D structures with and without crystalline order. Chapter 1 covers general physical principles behind self-assembly in the presence and absence of an external magnetic field, together with the effects of particle-size distribution and organic coatings. Numerous examples of 2D and 3D structures formed at different conditions are shown in excellent transmission electron microscopy (TEM) and scanning electron microscopy (SEM) images here and throughout the book. Chapter 2 gives a detailed description of how the phase and resulting regular shape of individual nanocrystals of magnetic materials give rise to specific types of close-packed self-assembled arrays. The effects of an external magnetic field are described more fully in Chapter 3, where the self-assembly of magnetic nanocrystals on substrates is discussed in terms of interactions between magnetic dipoles. The strength and the direction of the magnetic field control the formation of chain- or stripe-like structures or hexagonal arrays of cylinders, and it is shown that the aggregate size is in agreement with recent theoretical predictions.

The following two chapters present two very different approaches to the problem of forming well-defined 3D structures: one discusses the incorporation of isolated nanoparticles in solid matrixes by forming them *in situ*, and the other discusses the formation of ordered 3D suprastructures of nanoparticles with the help of self-assembling organic systems. In Chapter 4, metal nanocrystals are produced in prefabricated mesoporous silica and titania and in films formed by block copolymers and layer-by-layer self-assembly of polyelectrolytes. Typical methods involve introducing precursors (metal ions in solution) into the matrix, followed by a reduction reaction to get a composite material containing the desired metal as isolated spheres. Chapter 5 describes the aggregation of preformed nanoparticles, mediated either by binding to polymers or by interactions between surfactant coatings on their surfaces. The second part of this chapter, a discussion of the formation and applications of colloidal crystals, adds to the information on self-assembly in Chapters 1–3 and contains a large number of good illustrations.

An interesting process for creating regular nanosized structures is shown in Chapter 6, where patterns formed in supported polymer films as a result of solvent evaporation are used as molds for further surface patterning. The complex issue of 3D organization of anisotropic nanoparticles in a suspension into mineral liquid crystals is addressed in Chapter 7. In these unusual systems, nematic structures such as wires, ribbons, and tubules may form, as well as lamellar and columnar phases. The alignment of ribbons in an electric field has been demonstrated, which is of interest for future applications. Some of the characterization techniques and physical properties of these systems are discussed, and current challenges are outlined.

The majority of the remaining chapters describe collective optical (Chapters 8, 9, and 11) and magnetic properties (Chapter 10) arising in self-organized mesoscopic structures. In Chapter 8, several advanced spectroscopic techniques are used to study ordered and disordered self-assemblies of silver nanocrystals, demonstrating that induced dipolar interactions are present in a compact hexagonal network. Chapter 9 focuses on one of these techniques, scanning tunneling-induced photon emission (luminescence), which is able to address a single nanoparticle in a monolayer. Different types of surface plasmon resonance measurements for characterization of self-assembled monolayers are discussed in Chapter 11, together with possible application of these as biosensors. Chapter 10 describes collective magnetic properties of the self-assembled structures of magnetic nanocrystals from Chapters 1–3. Here, the focus is on magnetic particles separated by organic monolayers, so that magnetic dipole

interactions dominate over possible exchange interactions. Both the type of structure (1D, 2D, 3D) and the internal order plays a role for the collective magnetic properties.

The final two chapters give brief overviews of surface patterning techniques using nanospheres, block copolymer structures and nanocrystals as lithographic masks (Chapter 12), and the observed crack formation in 3D suprastructures (Chapter 13).

Because of its clarity, the introductory first chapters, and the high quality of the illustrations, this book is a very good introduction to nanoparticle assemblies. Another very appealing feature is that most chapters describe experimental procedures and characterization methods, clearly indicating their advantages and disadvantages. Because the book describes current research on both formation and properties of different structures and is an excellent source of literature references, it can be recommended to anyone interested or already involved in this new and exciting field.

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