

rather, it will become recognized as the first comprehensive reference text for researchers working in both fields.

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Optical Properties of Semiconductor Quantum Dots

Ulrike Woggon

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Scientists from disciplines ranging from condensed matter physics to cell biology are currently exploring the properties of nanocrystals. The fascination with these structures stems from their strongly size-dependent physical and chemical properties—intermediate between those of molecules and bulk solids. The systematic variation of properties with size follows simple scaling laws, and nanocrystals are often described as artificial atoms, or quantum dots, to emphasize the extent to which they may be viewed as elementary building blocks for more complex materials.

Semiconductor nanocrystals display a wealth of fascinating size-dependent characteristics. In cadmium sulfide, for example, the bandgap can be tuned from 4.5 to 2.5 eV as the size is varied from the molecular regime to the macroscopic crystal. The energy above the bandgap required to add an excess charge decreases by 0.5 eV, the melting temperature increases from 400° to 1600° C, and the pressure-induced phase transition from a four- to a six-coordinate phase decreases from 9 to 2 GPa. It is remarkable that this richness of effects is observed in a material with the same chemical composition merely by virtue of changing the crystal size.

Such semiconductor quantum dots show potential for applications in optoelectronic devices and electrical circuits. In her book *Optical Properties of Semiconductor Quantum Dots*, Ulrike Woggon covers concisely recent research on some of these remarkable size-dependent properties and their applications.

One of the interesting characteristics of nanostructures is that high-quality material may be prepared by a wide range of methods from molecular beam epitaxy to colloid chemistry. In the book, Woggon focuses primarily on optical properties of quantum dots grown in glassy matrix, a topic to which she has made substantial contributions.

As noted in the introduction to the

book, the growth of quantum dots in glasses dates back as far as the 1930s, and today these samples are commonly found in many labs, where they are used as sharp-cut color filter glasses in optics. The perfected growth techniques are well described, and the book could serve as a convenient tutorial on this topic.

Sample quality affects directly all of the properties of quantum dots, and the optical ones in particular. For example, high photoluminescence yields are required for applications using quantum dots as chromophores in light-emitting diodes. Emission yields also depend on the surface quality and, since in the quantum dot regime the surface-to-volume ratios are extremely large, proper passivation of surface dangling bonds is a particular concern. It is thus appropriate that, although the preparation and characterization of quantum dot samples are not the focus of the book, the current technologies are amply described.

Alternative approaches to preparation of semiconductor quantum dots are their growth in solution and their strain-induced growth in a semiconductor matrix. Both approaches are the subject of intense present investigation in many laboratories around the world. The coverage of such an active and rapidly evolving research subject in a book obviously has inherent dangers. Woggon evades them by providing ample references to very recent results. (The interested reader is still advised to consult the most recent literature on these topics.)

In the description of electronic states of quantum dots, detailed explanations are provided. Beginning with the simplest particle-in-a-box models, the electron and hole quantum-dot electronic states are calculated as eigenstates of the spherical potential well described in many quantum mechanics textbooks. This simple description predicts the blue shift associated with quantum confinement and the appearance of discrete electronic states.

More advanced descriptions for the level structure of quantum dots are also discussed. Among these, the most important topics treated are the effects of band mixing, the fine structure of the exciton close to the bandgap and nonlinear optical properties of quantum dots.

The book works well in its intended use as a reference source for experts in the field. It is also appropriate for graduate-level researchers who are interested in learning more about the optical properties of quantum dots.

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