Preface

The development of advanced multifunctional nanomaterials, of deep technological impact at present, was related to both the refinement of the processing methods as well as to the improvement of the investigation tools. In addition, many efforts have been devoted to the comprehension of new physical phenomena specific to such nanosized systems. The remarkable new phenomena observed in nanostructures derive from the interplay between the intrinsic properties of the components, finite size effects and interphase interactions. Finite size effects can modify the density of electronic states, either by the low number of atoms in the structure, overcoming the usual approach for boundary conditions in the solid state (quantum confinement), or by a significant number of atoms placed at the surface/interface of a nanosized system (of reduced coordination and symmetry compared to the bulk). Hence, most of the properties (electrical, optical, magnetic, etc.) of the systems can be unexpectedly tuned by simply tailoring the size of an active phase (in respect to a given application) and implicitly, the relative number of surface/interface atoms. It is worth mentioning that the most general meaning will be assumed for size effects in this book, including not only the influence of a reduced size, but also reduced dimensionality and specific interfacial effects.

When speaking about a reduced size, one should also mention its relationship with the characteristic lengths in the solid state (e.g., electron mean free path, superconducting coherence length, Fermi wavelength, interatomic distance, range of exchange interaction, magnetic single-domain size). If the size is lower than certain characteristic lengths, only the properties associated to those characteristic lengths are significantly modified. While the characteristic lengths cover a wide range of dimensions, from 0.1 nm (e.g., interatomic distances or Fermi wavelengths in metals) to hundreds of nm (the magnetic single domain size or the superconducting coherence length at high temperatures), the involved sizes leading to specific properties are widely spread, as well. On the other hand, if only the influence of the number of surface/interface positions relative to the bulk positions is considered, the size-sensitive effects will involve effective sizes of just a few nanometers (depending on morpho-structural aspects of the system).

The electron band structure of a simple nanosystem also clearly depends on its dimensionality. It is worth to mention that 0-, 1- and 2-dimensional nanosystems, imply that at least one dimension of the system is in the nanometer range. A 0-dimensional nanosystem means that all three dimensions are comparable and in the nanometer range, with a quasi-spherical nanoparticle as a representative exemple. The 1-dimensional nanosystem has two comparable dimensions in the nanometer range, while the third one is much larger, with the nanowire as the representative example. Finally, a 2-dimensional nanosystem means that one dimension is in the nanometer range, whereas the other two are much larger, with the thin film as a representative example. It is just a matter to solve the Schrödinger equation (in the simplest case of a free electron model specific to a conducting solid, for example) with different boundary conditions related to different potential walls imposed by the different dimensionality, in order to find the specificity of the electronic density of states in each case. Moreover, shape and dimensionality have a direct influence on the magnetostatic and the electrostatic energy, as well. Therefore, the dimensionality is an important issue to be taken into account in regard to the size effects and the functionalities of nanosystems.

In addition to the above mentioned very simple nanosized single entity systems, multicomponent nanosystems can also be obtained, where interactions among components (either long distance or via interfaces) might present a specific importance. Three main types of nanosystems/nanomaterials with a dominant role of their finite size effects and interfacial interactions should be mentioned: multilayers, nanopowders, and nanocomposites. The most complex type is the nanocomposite, which consists of a mixture of different well defined phases, at least one being nanosized (the vortex pinning centres in superconductors, for example). Nanopowders contain weakly or strongly interacting nanoparticles, which can be in turn either single or multiphase (e.g., presenting a core-shell structure). Moreover, they can be dispersed in a liquid or a solid matrix forming finally a specific nanocomposite, known as a nanoglobular system. Multilayers can be formed from nanometer thick epitaxial or polycrystalline layers. In all these cases, intercomponent interactions or the involved interfaces may confer additional functionalities to the nanosystems, directly related to various applications. Intensive efforts are made to elucidate the role of interfaces in metal/semiconductor, metal/oxide, oxide/semiconductor, ferroelectric/ferromagnetic, ferromagnetic/antiferromagnetic, ferromagnetic/nonmagnetic, ferromagnetic/superconducting bilayers or much complex multilayer structures, due to their potential and effective applications in electronics, spintronics, or sensoristics.

The present work describes current trends in studying size effects in nanostructures in relation to their modern technological applications. It is based on the know-how at the National Institute of Materials Physics in Bucharest (where most of the authors are) and reflects some of the actual research directions of the institute (see www.infim.ro). The content is organized into three parts and nine chapters, covering different aspects related to size effects in semiconducting, multifunctional, and magnetic/superconducting nanostructures. Although the authors have tried to present each chapter as tutorial as possible, starting from basics and at times forsaking rigor for enhanced clarity, some parts may still require a more in depth study (based on the reported references), depending on the reader expertise. Preparation and characterization tools suitable for a proper engineering of the envisaged size effect related properties, as well as examples of the most important technological applications of nostructures exhibiting such effects are also introduced in each contribution.

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