1.6 Main Research Areas in Condensed Matter Physics

The final goals of the investigation of condensed matter are to identify suitable materials for specific applications and to produce and process them economically at large scale, both of which depend on the microstructures and physicochemical properties of these materials. The relations between processing, structures, properties, and performance are illustrated in Figure 1.20. The goal and means in this research is therefore to define the intrinsic physicochemical properties of materials that affect their performance in the desired application. When this is accomplished, suitable structures on different scales (starting from the atomic scale, including the essential elements and the necessary composition, then continuing to the microscopic and finally the macroscopic scale) can be designed in accordance with the relations between microstructures and properties of materials. Finally, suitable processing methods can be developed for the desired structures. The logical chain of relations is from processing to structure, then to properties and finally to the material's performance in application.

The study of condensed matter or materials includes two main aspects: materials science and materials engineering. Materials science involves investigating the relations between the structures and properties of materials. Materials engineering is about designing or engineering the structure of a material so as to produce a predetermined set of properties. The key to success is the precise characterization of composition, structure, and properties of the materials including the development of suitable characterization methods, since the characterization part is crucial for the study of all relations between material structures, properties, and performance and thus also for the design and fabrication of materials with desired functions and structures.

In this book, some of the most important advanced characterization methods for the investigation of materials are presented, including X-ray crystallography, X-ray diffraction, X-ray absorption (EXAFS and XANES), electron microscopy (SEM, TEM), energy dispersion spectroscopy (EDS), X-ray photoelectron spectroscopy (XPS), wavelength-dispersion X-ray spectroscopy (WDXS), electron probe microanalysis (EPMA), AFM, Fourier-transform infrared (FTIR) spectroscopy, and

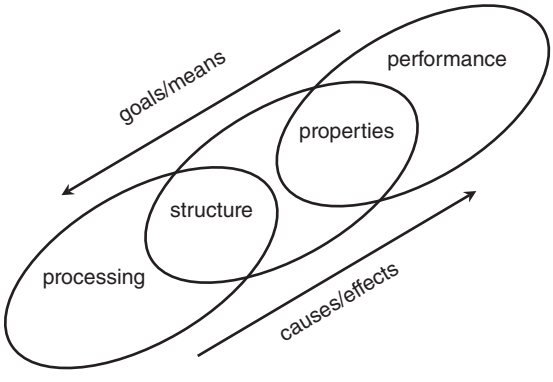

Figure 1.20 Relationships between processing, structures, properties, and performance in materials science and engineering.

so on. Their basic physical and chemical principles will be introduced and the corresponding instruments will be described. Some typical experiments will be provided to students as a training course, which will enable them to characterize the properties of typical samples (such as magnetoplasmonic thin films and nanostructured or 2D materials) using the described instruments.

Questions for Thinking

1.1 Describe the classification of matter and explain the characteristics of the different types.

1.2 Describe the different elementary particles and how they can be classified on the basis of their fundamental interactions.

1.3 Define the fundamental constants and explain their context and meaning.

1.4 Describe how scientists can deduce the existence of dark matter from gravitational observations and electromagnetic measurements and explain the proposed relation between dark matter and the accelerated universe.

1.5 Define condensed matter, explain its classification and describe the main properties of the different types.

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