Preface

Congratulations on selecting this book.

Now, what are you expecting from this book? The title suggests a scientific content and this may have caught your attention. Perhaps the first words "*In-situ*" have made you look closer at this book. But, what does "*In-situ*" really mean? "*In-situ*"—a Latin phrase—translates to "*in position*" or "*in place*." Hence, "*In-situ Characterization*," therefore means nothing but "*observing while exactly in place where things occur*." These "things" can be reactions, transformations, alterations, and/or changes to a state of equilibrium of matter, or a sample of it. Very often such changes in equilibrium are unstable and only transient in nature. Consequently, they cannot be isolated, or observed before and after such a reaction or transformation. A meticulous examination of these transient stages of dynamic processes is therefore the aim of numerous scientific investigations.

There are a number of techniques—characterization techniques to be precise—that in the past 100 years have set off a tremendous growth and accumulation of scientific knowledge and insight into basically every aspect of applied and theoretical sciences. Let us consider this the static and motionless type of characterization. In 1895 Wilhelm C. Röntgen discovered X-rays. In 1932 Ernst A. F. Ruska invented the electron microscope. In 1946/1947 the synchrotron radiation was discovered and sufficiently high neutron fluxes for neutron scattering became available around the same time with the advent of nuclear reactors. In 1960 the first functional laser was in operation at Bell Labs, and in 1981 the first scanning tunneling microscope was invented at IBM in Zurich. The growth, development, and diversification of any of these and other characterization techniques has led to many groundbreaking discoveries and phenomenal structural and analytical results, often revealing fascinating aspects of matter, nature, and life. Indirect, but more importantly the direct visualization of individual atoms and their structural and electronic configuration in two and three dimensions in space, revealing constitutive laws of a predominant component of matter, is just one phenomenal example of the power of these (motionless) characterization techniques. However, seeing these essential "building blocks" of nature and their constructs at the nanometer and micrometer scale react to external forces, caused for example by changes in their thermodynamic state, invariably raises our level of understanding of the dynamic aspects of nature—we are adding the fourth dimension: time.

Time-resolved studies *per se* are not new. In 1878 Eadweard J. Muybridge's sequence of high-speed photographic recordings revealed for the first time how a galloping race horse has all four hoofs in the air at once. In 1886 Peter Slacher photographed the first supersonic flying bullet. Today, the dynamics of extremely fast processes at the macroscopic scale can be examined by photographically recording approximately one-trillion frames per second—Femto-photography.

Thus, coming back to the "In-situ" aspect, in-situ characterization is therefore nothing but enabling the observation of dynamic processes—"*in place*"—at the micrometer, nanometer, and even atomic scale, by performing time-resolved studies ranging from many hours down to femtoseconds—in some cases even attoseconds. The latter ones pertain to the field of ultrafast science—an emerging field of research with many experiments-in-waiting to be addressed or revisited at a different, much faster timescale. A number of very recent technical and instrumentation developments can be expected to enable more rapid advances in the next decade, while other aspects of ultrafast science are representing severe obstacles that may require some more time until a solution is found. Similar scenarios apply to the "slower" time-resolved characterization methods that are also described in this book, and where the primary focus is not the time aspect. Here the challenges are rather sample and sample environment related, e.g., gaseous or liquid sample, temperature, pressure or electrical conductivity, etc.

This book is certainly not fully comprehensive, and it is meant to give the reader an overview of some of the time-resolved techniques and methods that exist, and what is currently the state of the art. Examples are presented that give the reader insight into what type of experiments are possible with different techniques, what the results look like, and how they are interpreted. Technical and methodological capabilities, but more importantly the controlling and the limiting parameters of each technique are—as usual—the critical elements that decide whether or not a particular experiment can be performed and what type of information and result can be expected.

The idea for this book started at a Materials Research Society meeting in Boston, where a strong interest in the latest developments and experimental capabilities for in-situ and time-resolved studies was continuously demonstrated. The individual chapters deal with time-resolved studies using X-ray absorption spectroscopy, Synchrotron and Free Electron Laser X-ray diffraction, Transmission Electron Microscopy, Neutron Spectroscopy and Scanning Tunneling Microscopy. An additional final chapter describes the detector types for X-rays and electrons that have to follow progress on the source instrumentation and experimental setup side. No suitable detector—no spectrum or image.

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