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## Simulation, Material Systems and Characterization Techniques

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# Preface

The development of future integrated ("smart") micro- and nanosystems is generally focusing on further improvements of functionality and performance, enhancement of miniaturization and integration density, and extension into new application fields. In addition to any of these technological developments, reliability, quality, and manufacturing yield are key prerequisites for the development of any complex innovative ("smart") micro-/nanosystem application. Consequently, new methods, instruments, and tools adjusted to the specific boundary conditions of the miniaturization level down to the nanoscale have to be provided allowing the investigation and understanding of the microstructure, possible failure processes, and reliability risks. In addition, methods and tools allowing the addressing and measurement of locally affected material properties, such as residual stresses, in combination with the microstructure are required. Such instruments and techniques are required to support a focused and rapid technological development and the time-efficient design of components and smart systems.

The particular results of microstructure and stress characterization do not only provide the basis for technological process step improvement but are also required for advanced simulation approaches and models that can be used to consider reliability properties already during the product development stage ("design for reliability" concept). Such concepts gain increasing importance since they allow to reduce time-to-market and development cost.

Present local stress and strain measurements on the nanoscale are based on special transmission electron microscopy techniques such as CBED, HRTEM-GPA, or holographic dark field technology, special scanning electron microscopy techniques such as EBSD or adapted X-ray diffraction techniques such as coherent X-ray diffraction. This book brings together leading groups in these different disciplines to apply these techniques for local strain and stress measurement and its theoretical background.

The book consists of three parts. Part One addresses the fundamentals of stress and strain on the nanoscale including an introduction to thermodynamics, kinetics, and models of elasticity, plasticity, and relaxation. Part Two addresses applications where stress and strain on the nanoscale are relevant such as SiGe devices or nanowires. In Part Three, techniques for measuring stress and strain on the nanoscale are presented such as CBED-TEM, EBSD-REM, different ways to use X-rays, Raman, and nonlinear optical methods.

To our knowledge, it is for the first time that this compendium combines theory, measurement techniques, and applications for stress and strain on the nanoscale. We believe that with increasing complexity of nanoscale devices, the increasing amount of the integration of various technologies, and various aspect ratios, it will be crucial to understand in detail processes and phenomena of nanostress.

This work was stimulated by the cooperation of the Fraunhofer Society, the Max-Planck-Society, the Carnot Association, and the CNRS via the C'Nano-PACA.

This book is dedicated to Prof. Ulrich Gösele, who coinitiated this project.

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