Electron Microscopy Of Thin Crystals

Includes bibliographical references and index.

This updated and revised edition of a classic work provides a summary of methods for numerical computation of high resolution conventional and scanning transmission electron microscope images. At the limits of resolution, image artifacts due to the instrument and the specimen interaction can complicate image interpretation. Image calculations can help the user to interpret and understand high resolution *information in recorded electron micrographs. The book contains expanded sections on aberration correction, including a detailed discussion of higher order (multipole) aberrations and their effect on high resolution imaging, new imaging modes such as ABF (annular bright field), and the latest developments in parallel processing using GPUs (graphic processing units), as well as updated references. Beginning and experienced users at the advanced undergraduate or graduate level will find the book to be a unique and essential guide to the theory and methods of computation in electron microscopy. Vanadium dioxide (VO_2) is a material of particular interest due to its exhibited metal to insulator phase* *transition at 68°C that is accompanied by an abrupt and significant change in its electronic and optical properties. Since this material can exhibit a reversible drop in resistivity of up to five orders of magnitude and a reversible drop in infrared optical transmission of up to 80%, this material holds promise in several technological applications. Solid phase crystallization of VO_2 thin films was obtained by a post-deposition annealing process of a VO_{x, x approx 2} amorphous film sputtered on an amorphous silicon dioxide (SiO_2) layer. Scanning electron microscopy (SEM) and electron-backscattered diffraction (EBSD) were utilized to study the morphology of the solid phase crystallization that* *resulted from this post-deposition annealing process. The annealing parameters ranged in temperature from 300°C up to 1000°C and in time from 5 minutes up to 12 hours. Depending on the annealing parameters, EBSD showed that this process yielded polycrystalline vanadium dioxide thin films, semi-continuous thin films, and films of isolated single-crystal particles. In addition to these films on SiO_2, other VO_2 thin films were deposited onto a-, c-, and r-cuts of sapphire and on TiO_2(001) heated single-crystal substrates by pulsed-laser deposition (PLD). The temperature of the substrates was kept at ~500°C during deposition. EBSD maps and orientation imaging microscopy were used to* *study the epitaxy and orientation of the VO_2 grains deposited on the single crystal substrates, as well as on the amorphous SiO_2 layer. The EBSD/OIM results showed that: 1) For all the sapphire substrates analyzed, there is a predominant family of crystallographic relationships wherein the rutile VO_2{001} planes tend to lie parallel to the sapphire's {10-10} and the rutile VO_2{100} planes lie parallel to the sapphire's {1-210} and {0001}. Furthermore, while this family of relationships accounts for the majority of the VO_2 grains observed, due to the sapphire substrate's geometry there were variations within these rules that changed the orientation of VO_2 grains with respect to* *the substrate's normal direction. 2) For the TiO_2, a substrate with a lower lattice mismatch, we observe the expected relationship where the rutile VO_2 [100], [110], and [001] crystal directions lie parallel to the TiO_2 substrate's [100], [110], and [001] crystal directions respectively. 3) For the amorphous SiO_2 layer, all VO_2 crystals that were measurable (those that grew to the thickness of the deposited film) had a preferred orientation with the the rutile VO_2[001] crystal direction tending to lie parallel to the plane of the specimen. The use of transmission electron microscopy (TEM) is presented as a tool for further characterization studies of this material and its applications. In this work TEM* *diffraction patterns taken from cross-sections of particles of the a- and r-cut sapphire substrates not only solidified the predominant family mentioned, but also helped lift the ambiguity present in the rutile VO_2{100} axes. Finally, a focused-ion beam technique for preparation of cross-sectional TEM samples of metallic thin films deposited on polymer substrates is demonstrated.*

Electron Crystallography
Advanced Computing in Electron Microscopy
The Growth of Electron Microscopy
The Principles and Practice of Electron Microscopy

The structure–property relationship is a key topic

in materials science and engineering. To understand why a material displays certain behaviors, the first step is to resolve its crystal structure and reveal its structure characteristics. Fundamentals of Crystallography, Powder X-ray Diffraction, and Transmission Electron Microscopy for Materials Scientists equips readers with an in-depth understanding of using powder x-ray diffraction and transmission electron microscopy for the analysis of crystal structures. Introduces fundamentals of crystallography Covers XRD of materials,

including geometry and intensity of diffracted x-ray beams and experimental methods Describes TEM of materials and includes atomic scattering factors, electron diffraction, and diffraction and phase contrasts Discusses applications of HRTEM in materials research Explains concepts used in XRD and TEM lab training Based on the author's course lecture notes, this text guides materials science and engineering students with minimal reliance on advanced mathematics. It will also appeal to a broad spectrum of readers, including researchers and professionals working *in the disciplines of materials science and engineering, applied physics, and chemical engineering.*

Electron Microscopy of Thin CrystalsElectron Microscopy of Thin CrystalsKrieger Publishing CompanyElectron Microscopy of Thin CrystalsBy P.B. Hirsch And OthersElectron Microscopy of Thin Crystals 4. ImprElectron microscopy of thin crystalsElectron Microscopy of Thin CrystalsElectron Microscopy of Thin CrystalsElectron Microscopy of Thin CrystalsElectron Microscopy of Thin Crystals, by

P. B. Hirsch [and Others].ELECTRON MICROSCOPY OF THIN CRYSTALS- LECTURES GIVEN AT A SUMMER SCHOOL- INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY.Electron Microscopy of Thin Crystals. By P.B. Hirsch [and Others], Etc. [Based on the Lectures Given at the Summer School of the Institute of Physics and the Physical Society, Held in Cambridge, July 1963. With Illustrations.].High Resolution Electron Microscopy of Thin Protein CrystalsThe Growth of Electron MicroscopyAcademic Press During the last five years transmission electron

microscopy (TEM) has added numerous important new data to mineralogy and has considerably changed its outlook. This is partly due to the fact that metallurgists and crystal physicists having solved most of the structural and crystallographic problems in metals have begun to show a widening interest in the much more complicated structures of minerals, and partly to recent progress in experimental techniques, mainly the availability of ion-thinning devices. While electron microscopists have become increasingly interested in minerals

(judging from special symposia at recent meetings such as Fifth European Congress on Electron microscopy, Man chester 1972; Eight International Congress on Electron Microscopy, Canberra 1974) mineralogists have realized advantages of the new technique and applied it with increasing frequency. In an effort to coordinate the growing quantity of research, electron microscopy sessions have been included in meetings of mineralogists (e. g. Geological Society of America, Minneapolis, 1972, American Crystallographic Association,

Berkeley, 1974). The tremendous response for the TEM symposium which H. -R. Wenk and G. Thomas organized at the Berkeley Conference of the American Crystallographic Association formed the basis for this book. It appeared useful at this stage to summarize the achievements of electron microscopy, scattered in many different journals in several different fields and present them to mineralogists. A group of participants as the Berkeley symposium formed an Editorial Committee and outlined the content of this book.

Electron Microscopy I - Proceedings Of The 5th

Asia-pacific Electron Microscopy Conference

Electron Microscopy Characterization of Vanadium Dioxide Thin Films and Nanoparticles

Physics of Image Formation and Microanalysis

Mechanism of Evaporation of Metal Crystals

to the Second Edition Since the first (1986) edition of this book, the numbers of installations, researchers, and research publications devoted to electron energy-loss spec troscopy (EELS) in the electron microscope have continued to expand. There has been a trend towards intermediate accelerating voltages and field-emission sources, both favorable to energy-loss spectroscopy, and sev eral types of energy-filtering microscope are now available commercially. Data-acquisition hardware and software, based on personal computers, have become more convenient and user-friendly. Among university re searchers, much thought has been given to the interpretation and utilization of near-edge fine structure. Most importantly, there have been many practi cal applications of EELS. This may reflect an increased awareness of the potentialities of the technique, but in many cases it is the result of skill and persistence on the part of the experimenters, often graduate students. To take account of these developments, the book has been extensively revised (over a period of two years) and more than a third of it rewritten. I have made various minor changes to the figures and added about 80 new ones. Except for a few small changes, the notation is the same as in the first edition, with all equations in SI units.

Periodic atomic structures in thin crystals and artificially fabricated periodic structures in transmission gratings have long been used to coherently split electrons by means of electron diffraction for applications such as interferometry, holography and imaging. Due to their reliance on transmission through matter, however, these methods are prone to electron scattering and absorption and are therefore lossy to some extent. This loss becomes a major issue for quantum electron microscopy (QEM), an interaction-free measurement scheme with electrons as probe particles. QEM relies on single electrons completing many round trips inside an electron resonant cavity, splitting and re-coupling during each round trip, effectively multiplying the probability of loss by the number of round trips. Thus, in one of the designs for QEM, the use of reflective diffraction gratings as lossless electron beam splitters is proposed. In this thesis, diffractive electron mirrors were fabricated by integrating one-dimensional diffraction gratings with tetrode electron mirrors. Optical interference lithography was used to fabricated silicon diffraction gratings with pitches varying from 200 nm to 500 nm. Furthermore, a proof-of-principle experiment to demonstrate their function as electron mirrors inside a scanning electron microscope was developed. It was demonstrated that the constructed tetrode electron mirrors satisfied the requirements of QEM for electron energies up to 3 keV. Finally, in a similar experiment, the fabricated diffractive electron mirrors were tested to demonstrate their function as lossless beam splitters. Preliminary results point to the evidence for electron diffraction, suggesting that diffractive electron mirrors could be used as as lossless electron beam splitters for QEM and other applications.

As a complement to The Beginnings of Electron Microscopy, Advances in Imaging and Electron Physics is pleased to present Volume 96, The

Growth of Electron Microscopy. This comprehensive collection of articles surveys the accomplishments of various national groups that comprise the International Federation of Societies of Electron Microscopy (IFSEM).

Domains in Ferroic Crystals and Thin Films

Electron Microscopy of Defects in Crystals

Structural refinement of single crystals using digital-large angle convergent beam electron diffraction

Electron Microscopy of Thin Crystals. By P.B. Hirsch [and Others], Etc. [Based on the Lectures Given at the Summer School of the Institute of Physics and the Physical Society, Held in Cambridge, July 1963. With Illustrations.].

Reviewed is the authors research on the nucleation, growth and epitaxy of condensed gas crystals. Briefly described are observations of various epitaxial systems, computations of the material parameters needed to understand the nucleation and growth of rare gases on graphite, and the theory of nucleation of thin films.

At present, the marketplace for

professionals, researchers, and graduate students in solid-state physics and materials science lacks a book that presents a comprehensive discussion of ferroelectrics and related materials in a form that is suitable for experimentalists and engineers. This book proposes to present a wide coverage of domain-related issues concerning these materials. This coverage includes selected theoretical topics (which are covered in the existing literature) in addition to a plethora of experimental data which occupies over half of the book. The book presents experimental findings and theoretical understanding of ferroic (non-magnetic) domains developed during the past 60 years. It addresses the situation by looking specifically at bulk crystals and thin films, with a particular focus on recently-developed microelectronic applications and methods for observations of domains with techniques such as scanning force microscopy, polarized light microscopy, scanning optical microscopy, electron microscopy, and surface decorating techniques. "Domains in Ferroic Crystals and Thin Films" covers a large area of material properties and effects connected with static and dynamic properties of domains, which are extremely relevant to materials referred to as ferroics. In other textbooks on solid state physics, one large group of ferroics is customarily covered: those in which magnetic properties play a dominant role. Numerous books are specifically devoted to magnetic ferroics and cover a wide spectrum of magnetic domain phenomena. In contrast, "Domains in Ferroic Crystals and Thin Films" concentrates on domain-related phenomena in nonmagnetic ferroics. These materials are still inadequately represented in solid state physics textbooks and monographs.

An up-to-date edition of the indispensable guide to electron microscopy and analysis.

Electron Microscopy and Electron Diffraction

Electron Microscopy of Thin Crystals, by P. B. Hirsch [and Others].

Electron Microscopy and Strength of

Crystals

The discovery of the Nanotube in 1991 by electron microscopy has ushered in the era of Nanoscience. The atomic-resolution electron microscope has been a crucial tool in this effort. This book gives the basic theoretical background needed to understand how electron microscopes allow us to see atoms, together with highly practical advice for electron microscope operators. The book covers the usefulness of seeing atoms in the semiconductor industry, in materials science (where scientists strive to make new lighter,stronger, cheaper materials), and condensed matter physics (for example in the study of the new superconductors). Biologists have recently used the atomic-resolution electron microscope to obtain three-dimensional images of the Ribosome, work which is *covered in this book. The books also shows how the ability to see atomic arrangements has helped us understand the properties of matter. This new third edition of the standard text retains the early section of the fundamentals of electron optics, linear imaging theory with partial coherence and multiple-scattering theory. Also preserved are updated earlier sections on practical methods, with detailed step-by-step accounts of the procedures needed to obtain the highest quality images of the arrangement of atoms in thin crystals using a modern electron microscope. The sections on applications of atomic resolution transmission electron microscopy (HREM) have been extensively updated, including descriptions of HREM in the semiconductor industry, superconductor research, solid state chemistry and nanoscience, as well as metallurgy, mineralogy, condensed matter physics, materials science and* *biology. Entirely new sections have been added on electron holography , aberration correctors, field-emission guns, imaging filters, HREM in biology an don organic crystals,super-resolution methods, Ptychography, CCD cameras and Image plates. New chapters are devoted entirely to scanning transmission electron microscopy and Z-contrast, and also to associated techniques, such as energy-loss spectrocospy, Alchemi, nanodiffraction and cathodoluminescence. Sources of software for image interpretation and electron-optical design are also given.*

This unique one-volume handbook provides a quick and concise reference guide for practising ophthalmologists, retinal specialists, vitreo-retinal fellows, ophthalmology residents and optometrists on the latest recommendations for managing common vitreo-retinal disorders seen in everyday retina practise. It provides *comprehensive and essential information on diagnosis and management in outline and table format for conciseness and quick access. Color illustrations of important clinical manifestations are provided in an appendix.Dr Susanna Park is a Professor of ophthalmology and Director of Vitreo-retinal Fellowship and Ocular Oncology at the University of California Davis Eye Center. She has over 20 years clinical experience as a vitreo-retinal specialist and published over 100 journal papers and book chapters on the subject.*

This groundbreaking text has been established as the market leader throughout the world. Profusely illustrated, the book provides the necessary instructions for successful hands-on application of this versatile materials characterization technique.

Symposium on Advances in Electron Metallography and Electron

Probe MIcroanalysis
Electron Microscopy in Mineralogy
Diffractive Electron Mirror for Use in Quantum Electron Microscopy
Transmission Electron Microscopy

This book has its origins in the intensive short courses on scanning elec tron microscopy and x-ray microanalysis which have been taught annually at Lehigh University since 1972. In order to provide a textbook containing the materials presented in the original course, the lecturers collaborated to write the book

Practical Scanning Electron Microscopy (PSEM), which was published by Plenum Press in 1975. The course con tinued to evolve and expand in the ensuing years, until the volume of material to be covered necessitated the development of separate intro ductory and advanced courses. In 1981 the lecturers undertook the project of rewriting the original textbook, producing the volume Scan ning Electron Microscopy and X-Ray Microanalysis (SEMXM). This vol ume contained substantial expansions of the treatment of such basic material as electron optics, image formation, energy-dispersive x-ray spectrometry, and qualitative and quantitative analysis. At the same time, a number of chapters, which had been included in the PSEM vol ume, including those on magnetic contrast and electron channeling con trast, had to be dropped for reasons of space. Moreover, these topics had naturally evolved into the basis of the advanced course. In addition, the evolution of the SEM and microanalysis fields had resulted in the devel opment of new topics, such as digital image processing, which by their nature became topics in the advanced course.

The aim of this book is to outline the physics of image formation, electron specimen interactions and image interpretation in transmission electron mic roscopy. The book evolved from lectures delivered at the University of Munster and is a revised version of the first part of my earlier book Elek tronenmikroskopische Untersuchungs- und Priiparationsmethoden, omitting the part which describes specimen-preparation methods. In the introductory chapter, the different types of electron microscope are compared, the various electron-specimen interactions and their applications are summarized and the most important aspects of high-resolution, analytical and high-voltage electron microscopy are discussed. The optics of electron lenses is discussed in Chapter 2 in order to bring out electron-lens properties that are important for an understanding of the function of an electron microscope. In Chapter 3, the wave optics of elec trons and the phase shifts by electrostatic and magnetic fields are introduced; Fresnel electron diffraction is treated using Huygens' principle. The recognition that the Fraunhofer-diffraction pattern is the Fourier transform of the wave amplitude behind a specimen is important because the influence of the imaging process on the contrast transfer of spatial frequencies can be described by introducing phase shifts and envelopes in the Fourier plane. In Chapter 4, the elements of an electron-optical column are described: the electron gun, the condenser and the imaging system. A thorough understanding of electron-specimen interactions is essential to explain image contrast.

This book describes how to see atoms using electron microscopes. This new edition includes updated sections on applications and new uses of atomic-resolution transmission electron microscopy. Several new chapters and sources of software for image interpretation and electron-optical design have also been added.

Introduction to Conventional Transmission Electron Microscopy

Proceedings of the First Berkeley International Materials Conference: the Impact of Transmission Electron Microscopy on Theories of the Strength of Crystals

Electron microscopy of thin crystals

Electron Microscopy of Thin Crystals

We explore the capability of digital-large angle convergent beam electron diffraction (D-LACBED) data for the structural refinement of single crystals. To achieve this, we use three materials as test cases. We use corundum for atomic position refinement, copper and gallium arsenide for Debye-

Waller factor (DWF) refinement. D-LACBED patterns are found to be extremely sensitive to atomic position, within 0.4 pm of reference X-ray values. The patterns are less sensitive to DWF (using the independent atom model - IAM) but nonetheless give good agreement to X-ray and Mossbauer radiation values for copper. We find the IAM to be insufficient for accurate refinement of gallium arsenide due to the influence of previously suggested strong anharmonicity and bonding within the material. Finally, we use simulation to explore the sensitivity of D-LACBED patterns *through most re fineable structural parameters, providing context to the aforementioned results. During the analysis we see that higher g-vector patterns within the D-LACBED data may be more sensitive to structural parameters in general.*

This book provides an introduction to the fundamental concepts, techniques, and methods used for electron microscopy at high resolution in space, energy, and even in time. It delineates the theory of elastic scattering, which is most useful for spectroscopic and chemical analyses. There are also discussions of the theory and practice of *image calculations, and applications of HRTEM to the study of solid surfaces, highly disordered materials, solid state chemistry, mineralogy, semiconductors and metals. Contributors include J. Cowley, J. Spence, P. Buseck, P. Self, and M.A. O'Keefe. Compiled by experts in the fields of geology, physics and chemistry, this comprehensive text will be the standard reference for years to come.*

In the modern world of ever smaller devices and nanotechnology, electron crystallography emerges as the most important method capable of *determining the structure of minute objects down to the size of individual atoms. Crystals of only a few millionths of a millimetre are studied. This is the first textbook explaining how this is done. Great attention is given to symmetry in crystals and how it manifests itself in electron microscopy and electron diffraction, and how this symmetry can be determined and taken advantage of in achieving improved electron microscopy images and solving crystal structures from electron diffraction patterns. Theory and practice are combined; experimental images, diffraction patterns, formulae* *and numerical data are discussed in parallel, giving the reader a complete understanding of what goes on inside the "black boxes" of computer programs. This up-to-date textbook contains the newest techniques in electron crystallography, including detailed descriptions and explanations of the recent remarkable successes in determining the very complex structures of zeolites and intermetallics. The controversial issue of whether there is phase information present in electron micrsocopy images or not is also resolved once and for all. The extensive appendices include computer* *labs which have been used at various courses at Stockholm University and international schools in electron crystallography, with applications to the textbook. Students can download image processing programs and follow these lab instructions to get a hands-on experience of electron crystallography.*

Electron Microscopy Investigation of Silicon-on-insulator Structures Formed by Selective Epitaxial Growth of Silicon and Epitaxial Lateral Overgrowth of Oxide

Electron Energy-Loss Spectroscopy in the Electron Microscope

High Resolution Electron Microscopy of Thin Protein Crystals

Advanced Scanning Electron Microscopy and X-Ray Microanalysis

This book covers the fundamentals of conventional transmission electron microscopy (CTEM) as applied to crystalline solids. In addition to including a large selection of worked examples and homework problems, the volume is accompanied by a supplementary website (http://ctem.web.cmu.edu/) containing

interactive modules and over 30,000 lines of free Fortran 90 source code. The work is based on a lecture course given by Marc De Graef in the Department of Materials Science and Engineering at Carnegie Mellon University.

This report includes: DISLOCATION CONFIGUATIONS IN DEFORMED SILVER SINGLE CRYSTALS, by H.J. Levinstein and W.H. Robinson. 1962. Ag single crystals oriented for single slip were deformed incrementally in both simple shear and tension, and the dislocation arrangements

were observed after each increment of strain by optical examination of the etch pitted surface or by examining replicas of these surfaces by electron microscopy. in addition, some observations were made on specimens deformed in compression. For a given specimen several increments of strain were made during stage I of the deformation and also duing stage II. The principal facts which emerged from these observations are that stage I is characterized by slip bands consisting of clusters of dislocations which are cellular in appearance. The segments of these clusters which are straight are very short, probably no more than 1 microns, and a given portion of a dislocation moves only a short distance, of the order of 5 to 10 microns, before being stopped. These results agree with those of transmission electron microscopy of thin foils taken from bulk specimens which have been strained. But they do not agree with observations on thin foils strained in the electron microscope. (Author).

A Textbook for Materials Science

By P.B. Hirsch And Others
High-Resolution Transmission Electron Microscopy
High-Resolution Electron Microscopy