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# Fundamental Principles Of Optical Lithography The

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 Field Guide to Optical Lithography

*Fundamental Principles  
 Of Optical Lithography  
 The*

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## MATHIAS MARISSA

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Dry Etching Technology for  
 Semiconductors Cambridge University  
 Press

Editorial Review Dr. Bakshi has compiled a thorough, clear reference text covering the important fields of EUV lithography for high-volume manufacturing. This book has resulted from his many years of experience in EUVL development and from teaching this subject to future specialists. The book proceeds from an historical perspective of EUV lithography, through source technology, optics, projection system design, mask, resist, and patterning performance, to cost of ownership. Each section contains worked

examples, a comprehensive review of challenges, and relevant citations for those who wish to further investigate the subject matter. Dr. Bakshi succeeds in presenting sometimes unfamiliar material in a very clear manner. This book is also valuable as a teaching tool. It has become an instant classic and far surpasses others in the EUVL field. --Dr. Akira Endo, Chief Development Manager, Gigaphoton Inc. Description Extreme ultraviolet lithography (EUVL) is the principal lithography technology aiming to manufacture computer chips beyond the current 193-nm-based optical lithography, and recent progress has been made on several fronts: EUV light sources, optics, optics metrology, contamination control, masks and mask handling, and resists. This comprehensive volume is comprised of contributions from the world's leading

EUVL researchers and provides all of the critical information needed by practitioners and those wanting an introduction to the field. Interest in EUVL technology continues to increase, and this volume provides the foundation required for understanding and applying this exciting technology. About the editor of EUV Lithography Dr. Vivek Bakshi previously served as a senior member of the technical staff at SEMATECH; he is now president of EUV Litho, Inc., in Austin, Texas.

[Principles of Lithography](#) Nova Science Publishers

A comprehensive edited volume on important and up-to-date nanolithography techniques and applications. The book includes an introduction on the importance of nanolithography in today's research and technology, providing examples of its

applications. The remainder of the book is split into two sections. The first section contains the most important and established nanolithography techniques. As well as a detailed description of each technique, the reader can obtain useful information about the main advantages and drawbacks of each technique in terms of resolution, throughput, number of steps needed, cost, etc. At the end of this section, the reader will be able to decide which technique to use for different applications. The second section explores more specific applications of the nanolithography techniques previously described; as well as new techniques and applications. In some cases, the processes described in these chapters involve a combination of several nanolithography techniques. This section is less general but provides the reader with real examples.

#### **Nanofabrication** SPIE Press

Considered a major field of photonics, plasmonics offers the potential to confine and guide light below the diffraction limit and promises a new generation of highly miniaturized photonic devices. This book combines a comprehensive introduction with an extensive overview of the current state of the art. Coverage includes plasmon waveguides, cavities for field-enhancement, nonlinear processes and the emerging field of active plasmonics studying interactions of surface plasmons with active media.

#### Microolithography SPIE Press

The Art and Science of Optical Design is a comprehensive introduction to lens design, covering the fundamental physical principles and key engineering issues. Several practical examples of modern computer-aided lens design are worked out in detail from start to finish. The basic theory and results of optics are presented early on in the book, along with a discussion of optical materials.

Aberrations, and their correction, and image analysis are then covered in great detail. Subsequent chapters deal with design optimisation and tolerance analysis. Several design examples are then given, beginning with basic lens design forms, and progressing to advanced systems, such as gradient index and diffractive optical components. In covering all aspects of optical design, including the use of modern lens design software, this book will be invaluable to students of optical engineering as well as to anyone engaged in optical design at any stage.

#### Advances in FDTD Computational Electrodynamics Elsevier

This book elucidates the reasons underlying the lasting success of DNQ/N

resist systems by examining the correlation between the chemical structure of the components and the photoresist performance. The basic chemistry of both DNQ sensitizers and novolak resins are explored. Focus also is placed on the chemical basis of application-related facets of the lithographic process. Methods of increasing process performance, such as image reversal, top layer imaging, antireflection layers, and phase shift technology are treated.

*Optical Antennas* Society of Photo Optical  
Contains color and black-and-white illustrations of over three hundred optical illusions, each with brief, explanatory text.  
Fundamentals of Photonics Woodhead Publishing

This new edition of the bestselling *Microolithography: Science and Technology* provides a balanced treatment of theoretical and operational considerations, from elementary concepts to advanced aspects of modern submicron microlithography. Each chapter reflects the current research and practices from the world's leading academic and industrial laboratories detailed by a stellar panel of international experts. New in the Second Edition In addition to updated information on existing material, this new edition features coverage of technologies developed over the last decade since the first edition appeared, including: Immersion Lithography 157nm Lithography Electron Projection Lithography (EPL) Extreme Ultraviolet (EUV) Lithography Imprint Lithography Photoresists for 193nm and Immersion Lithography Scatterometry  
*Microolithography: Science and Technology, Second Edition* authoritatively covers the physics, chemistry, optics, metrology tools and techniques, resist processing and materials, and fabrication methods involved in the latest generations of microlithography such as immersion lithography and extreme ultraviolet (EUV) lithography. It also looks ahead to the possible future systems and technologies that will bring the next generations to fruition. Loaded with illustrations, equations, tables, and time-saving references to the most current literature, this book is the most comprehensive and reliable source for anyone, from student to seasoned professional, looking to achieve robust, accurate, and cost-effective microlithography processes and systems.

**Optical and EUV Lithography** Nova Science Pub Incorporated  
Lithography, the fundamental fabrication process of semiconductor devices, has been playing a critical role in micro-

nanofabrication technologies and manufacturing of Integrated Circuits (IC). Traditional optical lithography including contact and project photolithography has contributed significantly to the semiconductor device advancements. Currently, maintaining the rapid pace of half-pitch reduction requires overcoming the challenge of improving and extending the incumbent optical projection lithography technology while simultaneously developing alternative, next generation lithography (NGL) technologies to be used when optical projection lithography is no longer more economical than the alternatives. Furthermore, NIL is also one of the most promising low-cost, high-throughput technologies for manufacturing nanostructures as this highly technical book will give new insight to.

#### Practical Lithography Springer Science & Business Media

The fabrication of an integrated circuit requires a variety of physical and chemical processes to be performed on a semiconductor substrate. In general, these processes fall into three categories: film deposition, patterning, and semiconductor doping. Films of both conductors and insulators are used to connect and isolate transistors and their components. By creating structures of these various components millions of transistors can be built and wired together to form the complex circuitry of modern microelectronic devices. Fundamental to all of these processes is lithography, ie, the formation of three-dimensional relief images on the substrate for subsequent transfer of the pattern to the substrate. This book presents a complete theoretical and practical treatment of the topic of lithography for both students and researchers. It comprises ten detailed chapters plus three appendices with problems provided at the end of each chapter. Additional Information: Visiting <http://www.lithoguru.com/textbook/index.html> enhances the reader's understanding as the website supplies information on how you can download a free laboratory manual, *Optical Lithography Modelling with MATLAB®*, to accompany the textbook. You can also contact the author and find help for instructors.

#### *The Art and Science of Optical Design* Academic Press

Thin-film coatings are universal on optical components such as displays, lenses, mirrors, cameras, and windows and serve a variety of functions such as antireflection, high reflection, and spectral filtering. Designs can be as simple as a single-layer dielectric for antireflection

effects or very complex with hundreds of layers for producing elaborate spectral filtering effects. Starting from basic principles of electromagnetics, design techniques are progressively introduced toward more intricate optical filter designs, numerical optimization techniques, and production methods, as well as emerging areas such as phase change materials and metal film optics. Worked examples, Python computer codes, and instructor problem sets are included. Key Features: Starting from the basic principles of electromagnetics, topics are built in a pedagogic manner toward intricate filter designs, numerical optimization and production methods. Discusses thin-film applications and design from simple single-layer effects to complex several-hundred-layer spectral filtering. Includes modern topics such as phase change materials and metal film optics. Includes worked examples, problem sets, and numerical examples with Python codes.

*Optical Communications Rules of Thumb*  
McGraw Hill Professional

This consistent and systematic review of recent advances in optical antenna theory and practice brings together leading experts in the fields of electrical engineering, nano-optics and nano-photonics, physical chemistry and nanofabrication. Fundamental concepts and functionalities relevant to optical antennas are explained, together with key principles for optical antenna modelling, design and characterisation. Recognising the tremendous potential of this technology, practical applications are also outlined. Presenting a clear translation of the concepts of radio antenna design, near-field optics and field-enhanced spectroscopy into optical antennas, this interdisciplinary book is an indispensable resource for researchers and graduate students in engineering, optics and photonics, physics and chemistry.

Plasmonics: Fundamentals and Applications John Wiley & Sons

A practical guide to semiconductor manufacturing from process control to yield modeling and experimental design *Fundamentals of Semiconductor Manufacturing and Process Control* covers all issues involved in manufacturing microelectronic devices and circuits, including fabrication sequences, process control, experimental design, process modeling, yield modeling, and CIM/CAM systems. Readers are introduced to both the theory and practice of all basic manufacturing concepts. Following an overview of manufacturing and technology, the text explores process

monitoring methods, including those that focus on product wafers and those that focus on the equipment used to produce wafers. Next, the text sets forth some fundamentals of statistics and yield modeling, which set the foundation for a detailed discussion of how statistical process control is used to analyze quality and improve yields. The discussion of statistical experimental design offers readers a powerful approach for systematically varying controllable process conditions and determining their impact on output parameters that measure quality. The authors introduce process modeling concepts, including several advanced process control topics such as run-by-run, supervisory control, and process and equipment diagnosis. Critical coverage includes the following: \* Combines process control and semiconductor manufacturing \* Unique treatment of system and software technology and management of overall manufacturing systems \* Chapters include case studies, sample problems, and suggested exercises \* Instructor support includes electronic copies of the figures and an instructor's manual Graduate-level students and industrial practitioners will benefit from the detailed examination of how electronic materials and supplies are converted into finished integrated circuits and electronic products in a high-volume manufacturing environment. An Instructor's Manual presenting detailed solutions to all the problems in the book is available from the Wiley editorial department. An Instructor Support FTP site is also available.

Fundamentals of Semiconductor Manufacturing and Process Control BoD - Books on Demand

The three volumes in the PRINCIPLES OF ELECTRON OPTICS Series constitute the first comprehensive treatment of electron optics in over forty years. While Volumes 1 and 2 are devoted to geometrical optics, Volume 3 is concerned with wave optics and effects due to wave length. Subjects covered include: Derivation of the laws of electron propagation from Schrödinger's equation Image formation and the notion of resolution The interaction between specimens and electrons Image processing Electron holography and interference Coherence, brightness, and the spectral function Together, these works comprise a unique and informative treatment of the subject. Volume 3, like its predecessors, will provide readers with both a textbook and an invaluable reference source.

*Lithography* Springer Science & Business Media

Lithography, the fundamental fabrication

process of semiconductor devices, has been playing a critical role in micro-nanofabrication technologies and manufacturing of integrated circuits (IC). Optical lithography was the first and the earliest microfabrication technology used in semiconductor IC manufacturing. It is still the main tool of lithography in today's very large scale integrated circuits and MEMS. This book presents topical research from across the globe in the study of lithography; its principles, processes and materials. Topics discussed herein include nanofabrication in electron beam lithography; submicron gratings prepared by laser interference lithography; thermal electric field imprinting lithography; local anodic oxidation and other alternative lithography techniques; as well as nanosphere lithography to enable plasmonic applications.

Fundamental Principles of Optical Lithography CRC Press

Photomasks, the printing masters for the fabrication of integrated circuits, have become a necessity of modern semiconductor manufacturing. This book details the science and technology of industrial photo mask production, including fundamental principles, industrial production flows, and technological evolution.

Laser Fundamentals SPIE Press

*Fundamentals and Applications of Nano Silicon in Plasmonics and Fullerenes: Current and Future Trends* addresses current and future trends in the application and commercialization of nanosilicon. The book presents current, innovative and prospective applications and products based on nanosilicon and their binary system in the fields of energy harvesting and storage, lighting (solar cells and nano-capacitor and fuel cell devices and nanoLEDs), electronics (nanotransistors and nanomemory, quantum computing, photodetectors for space applications; biomedicine (substance detection, plasmonic treatment of disease, skin and hair care, implantable glucose sensor, capsules for drug delivery and underground water and oil exploration), and art (glass and pottery). Moreover, the book includes material on the use of advanced laser and proximal probes for imaging and manipulation of nanoparticles and atoms. In addition, coverage is given to carbon and how it contrasts and integrates with silicon with additional related applications. This is a valuable resource to all those seeking to learn more about the commercialization of nanosilicon, and to researchers wanting to learn more about emerging nanosilicon applications. Features a variety of designs

and operation of nano-devices, helping engineers to make the best use of nanosilicon. Contains underlying principles of how nanomaterials work and the variety of applications they provide, giving those new to nanosilicon a fundamental understanding. Assesses the viability of various nanosilicon devices for mass production and commercialization, thereby providing an important source of information for engineers.

*Atomic Layer Processing* Elsevier

The fabrication of an integrated circuit requires a variety of physical and chemical processes to be performed on a semiconductor substrate. In general, these processes fall into three categories: film deposition, patterning, and semiconductor doping. Films of both conductors and insulators are used to connect and isolate transistors and their components. By creating structures of these various components millions of transistors can be built and wired together to form the complex circuitry of modern microelectronic devices. Fundamental to all of these processes is lithography, i.e., the formation of three-dimensional relief images on the substrate for subsequent transfer of the pattern to the substrate. This book presents a complete theoretical and practical treatment of the topic of lithography for both students and researchers. It comprises ten detailed chapters plus three appendices with problems provided at the end of each chapter. Additional Information: Visiting <http://www.lithoguru.com/textbook/index.html> enhances the reader's understanding as the website supplies information on

how you can download a free laboratory manual, *Optical Lithography Modelling with MATLAB®*, to accompany the textbook. You can also contact the author and find help for instructors.

*Harnessing Light* McGraw Hill Professional

Advances in photonics and nanotechnology have the potential to revolutionize humanity's ability to communicate and compute. To pursue these advances, it is mandatory to understand and properly model interactions of light with materials such as silicon and gold at the nanoscale, i.e., the span of a few tens of atoms laid side by side. These interactions are governed by the fundamental Maxwell's equations of classical electrodynamics, supplemented by quantum electrodynamics. This book presents the current state-of-the-art in formulating and implementing computational models of these interactions. Maxwell's equations are solved using the finite-difference time-domain (FDTD) technique, pioneered by the senior editor, whose prior Artech House books in this area are among the top ten most-cited in the history of engineering. This cutting-edge resource helps readers understand the latest developments in computational modeling of nanoscale optical microscopy and microchip lithography, as well as nanoscale plasmonics and biophotonics. *Nanofabrication* Springer Science & Business Media  
Laser Fundamentals provides a clear and comprehensive introduction to the physical and engineering principles of laser operation and design. Simple

explanations, based throughout on key underlying concepts, lead the reader logically from the basics of laser action to advanced topics in laser physics and engineering. Much new material has been added to this second edition, especially in the areas of solid-state lasers, semiconductor lasers, and laser cavities. This 2004 edition contains a new chapter on laser operation above threshold, including extensive discussion of laser amplifiers. The clear explanations, worked examples, and many homework problems will make this book invaluable to undergraduate and first-year graduate students in science and engineering taking courses on lasers. The summaries of key types of lasers, the use of many unique theoretical descriptions, and the extensive bibliography will also make this a valuable reference work for researchers.

**Nanoelectrochemistry** Springer Science & Business Media

Intended to update scientists and engineers on the current state of the art in a variety of key techniques used extensively in the fabrication of structures at the nanoscale. The present work covers the essential technologies for creating sub 25 nm features lithographically, depositing layers with nanometer control, and etching patterns and structures at the nanoscale. A distinguishing feature of this book is a focus not on extension of microelectronics fabrication, but rather on techniques applicable for building NEMS, biosensors, nanomaterials, photonic crystals, and other novel devices and structures that will revolutionize society in the coming years.