

Bei Yu · David Z. Pan

# Design for Manufacturability with Advanced Lithography

 Springer

# Design For Manufacturability With Advanced Lithography

**Michael Orshansky, Sani Nassif, Duane Boning**



## **Design For Manufacturability With Advanced Lithography:**

Design for Manufacturability with Advanced Lithography Bei Yu, David Z. Pan, 2015-10-28 This book introduces readers to the most advanced research results on Design for Manufacturability DFM with multiple patterning lithography MPL and electron beam lithography EBL The authors describe in detail a set of algorithms methodologies to resolve issues in modern design for manufacturability problems with advanced lithography Unlike books that discuss DFM from the product level or physical manufacturing level this book describes DFM solutions from a circuit design level such that most of the critical problems can be formulated and solved through combinatorial algorithms *Design for Manufacturability* Artur

Balasinski, 2013-10-05 This book explains integrated circuit design for manufacturability DfM at the product level packaging applications and applies engineering DfM principles to the latest standards of product development at 22 nm technology nodes It is a valuable guide for layout designers packaging engineers and quality engineers covering DfM development from 1D to 4D involving IC design flow setup best practices links to manufacturing and product definition for process technologies down to 22 nm node and product families including memories logic system on chip and system in package Design for

Manufacturability and Statistical Design Michael Orshansky, Sani Nassif, Duane Boning, 2007-10-28 Design for Manufacturability and Statistical Design A Comprehensive Approach presents a comprehensive overview of methods that need to be mastered in understanding state of the art design for manufacturability and statistical design methodologies Broadly design for manufacturability is a set of techniques that attempt to fix the systematic sources of variability such as those due to photolithography and CMP Statistical design on the other hand deals with the random sources of variability Both paradigms operate within a common framework and their joint comprehensive treatment is one of the objectives of this book and an important differentiation *Design for Manufacturing with Advanced Lithography* Bei Yu, 2014 Shrinking the feature

size of very large scale integrated circuits VLSI with advanced lithography has been a holy grail for the semiconductor industry However the gap between manufacturing capability and the expectation of design performance becomes critically challenged in sub 16nm technology nodes To bridge this gap design for manufacturing DFM is a must to co optimize both design and lithography process at the same time DFM for advanced lithography could be defined very differently under different circumstances In general progress in advanced lithography happens along three different directions 1 New patterning technique e g layout decomposition for different patterning techniques 2 New design methodology e g lithography aware standard cell design and physical design 3 New illumination system e g layout fracturing for EBL system stencil planning for EBL system In this dissertation we present our research results on design for manufacturing DFM with multiple patterning lithography MPL and electron beam lithography EBL addressing these three DFM research directions in advanced lithography For the research direction of new patterning technique we study the layout decomposition problems for different patterning technique and explore four important topics 1 layout decomposition for triple patterning 2 density balanced layout

decomposition for triple patterning 3 layout decomposition for triple patterning with end cutting 4 layout decomposition for quadruple patterning and beyond We present the proof that triple patterning layout decomposition is NP hard Besides we propose a number of CAD optimization and integration techniques to solve different problems For the research direction of new design methodology we will show the limitation of traditional design flow That is ignoring triple patterning lithography TPL in early stages may limit the potential to resolve all the TPL conflicts We propose a coherent framework including standard cell compliance and detailed placement to enable TPL friendly design Considering TPL constraints during early design stages such as standard cell compliance improves the layout decomposability With the pre coloring solutions of standard cells we present a TPL aware detailed placement where the layout decomposition and placement can be resolved simultaneously In addition we propose a linear dynamic programming to solve TPL aware detailed placement with maximum displacement which can achieve good trade off in terms of runtime and performance For the EBL illumination system we focus on two topics to improve the throughput of the whole EBL system 1 overlapping aware stencil planning under MCC system 2 L shape based layout fracturing for mask preparation With simulations and experiments we demonstrate the critical role and effectiveness of DFM techniques for the advanced lithography as the semiconductor industry marches forward in the deeper sub micron domain

SOC-Based Solutions in Emerging Application Domains Veena S. Chakravarthi, Shivananda R. Koteshwar, 2025-04-09 Working in the ever evolving field of smart chip design within an AI powered design environment the authors of this book draw on their experiences in successfully developing system on chip SoC solutions having grappled with the emerging design environment innovative tools domain specific challenges and major design decisions for SOC based solutions They present the first comprehensive guide to navigating the technical challenges of SOC based solutions in emerging application domains covering various design and development methodologies for system on chip solutions for emerging target applications When diligently applied the strategies and tactics presented can significantly shorten development timelines help avoid common pitfalls and improve the odds of success especially in AI powered smart EDA environments The book provides a detailed insight into SoC based solutions for various applications including artificial intelligence AI post quantum security feature enhancements 3D SOC quantum SOC photonic SOC and SOC solutions for IoT high performance computing SOC and processor based systems The coverage includes architecture exploration methods for targeted applications compute intensive SoCs lightweight SoCs for IOT applications advanced technology node solutions and solutions including hardware software co designs and software defined SoCs The strategies best applied in these highly advanced technology developments are discussed in a guest chapter by a practicing high technology strategist so innovators designers entrepreneurs product managers investors and executives may properly prepare their companies to succeed

Physical Design and Mask Synthesis for Directed Self-Assembly Lithography Seongbo Shim, Youngsoo Shin, 2018-03-21 This book discusses physical design and mask synthesis of directed self assembly lithography DSAL It covers the basic

background of DSAL technology physical design optimizations such as placement and redundant via insertion and DSAL mask synthesis as well as its verification Directed self assembly lithography DSAL is a highly promising patterning solution in sub 7nm technology      **Nano-CMOS Design for Manufacturability** Ban P. Wong,Anurag Mittal,Greg W. Starr,Franz

Zach,Victor Moroz,Andrew Kahng,2008-12-29 Discover innovative tools that pave the way from circuit and physical design to fabrication processing Nano CMOS Design for Manufacturability examines the challenges that design engineers face in the nano scaled era such as exacerbated effects and the proven design for manufacturability DFM methodology in the midst of increasing variability and design process interactions In addition to discussing the difficulties brought on by the continued dimensional scaling in conformance with Moore s law the authors also tackle complex issues in the design process to overcome the difficulties including the use of a functional first silicon to support a predictable product ramp Moreover they introduce several emerging concepts including stress proximity effects contour based extraction and design process interactions This book is the sequel to Nano CMOS Circuit and Physical Design taking design to technology nodes beyond 65nm geometries It is divided into three parts Part One Newly Exacerbated Effects introduces the newly exacerbated effects that require designers attention beginning with a discussion of the lithography aspects of DFM followed by the impact of layout on transistor performance Part Two Design Solutions examines how to mitigate the impact of process effects discussing the methodology needed to make sub wavelength patterning technology work in manufacturing as well as design solutions to deal with signal power integrity WELL stress proximity effects and process variability Part Three The Road to DFM describes new tools needed to support DFM efforts including an auto correction tool capable of fixing the layout of cells with multiple optimization goals followed by a look ahead into the future of DFM Throughout the book real world examples simplify complex concepts helping readers see how they can successfully handle projects on Nano CMOS nodes It provides a bridge that allows engineers to go from physical and circuit design to fabrication processing and in short make designs that are not only functional but that also meet power and performance goals within the design schedule      **Directed**

**Self-assembly of Block Co-polymers for Nano-manufacturing** Roel Gronheid,Paul Nealey,2015-07-17 The directed self assembly DSA method of patterning for microelectronics uses polymer phase separation to generate features of less than 20nm with the positions of self assembling materials externally guided into the desired pattern Directed self assembly of Block Co polymers for Nano manufacturing reviews the design production applications and future developments needed to facilitate the widescale adoption of this promising technology Beginning with a solid overview of the physics and chemistry of block copolymer BCP materials Part 1 covers the synthesis of new materials and new processing methods for DSA Part 2 then goes on to outline the key modelling and characterization principles of DSA reviewing templates and patterning using topographical and chemically modified surfaces line edge roughness and dimensional control x ray scattering for characterization and nanoscale driven assembly Finally Part 3 discusses application areas and related issues for DSA in nano

manufacturing including for basic logic circuit design the inverse DSA problem design decomposition and the modelling and analysis of large scale template self assembly manufacturing techniques Authoritative outlining of theoretical principles and modeling techniques to give a thorough introduction to the topic Discusses a broad range of practical applications for directed self assembly in nano manufacturing Highlights the importance of this technology to both the present and future of nano manufacturing by exploring its potential use in a range of fields      *Extending Moore's Law through Advanced*

*Semiconductor Design and Processing Techniques* Wynand Lambrechts,Saurabh Sinha,Jassem Ahmed Abdallah,Jaco Prinsloo,2018-09-13 This book provides a methodological understanding of the theoretical and technical limitations to the longevity of Moore s law The book presents research on factors that have significant impact on the future of Moore s law and those factors believed to sustain the trend of the last five decades Research findings show that boundaries of Moore s law primarily include physical restrictions of scaling electronic components to levels beyond that of ordinary manufacturing principles and approaching the bounds of physics The research presented in this book provides essential background and knowledge to grasp the following principles Traditional and modern photolithography the primary limiting factor of Moore s law Innovations in semiconductor manufacturing that makes current generation CMOS processing possible Multi disciplinary technologies that could drive Moore s law forward significantly Design principles for microelectronic circuits and components that take advantage of technology miniaturization The semiconductor industry economic market trends and technical driving factors The complexity and cost associated with technology scaling have compelled researchers in the disciplines of engineering and physics to optimize previous generation nodes to improve system on chip performance This is especially relevant to participate in the increased attractiveness of the Internet of Things IoT This book additionally provides scholarly and practical examples of principles in microelectronic circuit design and layout to mitigate technology limits of previous generation nodes Readers are encouraged to intellectually apply the knowledge derived from this book to further research and innovation in prolonging Moore s law and associated principles      VLSI and Chip Design Dr. M.

Maheswaran,Mandadupu Anusha,Bandam Narendar,Modugu Rambabu,2024-05-23 VLSI and Chip Design exploration of Very Large Scale Integration VLSI technology and the intricacies of modern chip design It fundamental principles advanced methodologies and the latest innovations in circuit design fabrication and testing With a focus on digital and analog systems this integrates theoretical concepts with practical applications catering to both beginners and professionals It emphasizes design optimization power efficiency and scalability making it an essential resource for engineers researchers and students aspiring to excel in semiconductor technology and integrated circuit design      **Handbook of Emerging Materials for Semiconductor Industry** Young Suh Song,Laxman Raju Thoutam,Shubam Tayal,Shiromani Balmukund Rahi,T. S. Arun Samuel,2024-05-31 The proposed book will be a one stop place for all the young material researchers to understand the recent and reliable material making process characterization and reliability test tools The proposed book is designed to

provide basic knowledge to understand and analyse structure property relationship for reliable emerging material systems for next generation of semiconductor technologies The book is suggested to engineers and scientists across the world working on various new and novel materials for reliable semiconductor device applications The book is expected to serve as a reference guide for young scientists and engineers in the field of material science and electronic engineers to acquire latest state of art experimental and computational tools to encourage their research activities Since the scope of the book is generic the book can be referred by all the students of science and engineering students to create a common awareness about the latest material systems and state of art characterization tools that have been broadly utilized to study the physical and chemical properties of different material systems It introduces the readers to a wide variety of new emerging materials systems including their synthesis fabrication measurement reliability test modelling and simulations with in depth analysis of selective applications This book contains the state of art research updates in the various fields of semiconductor artificial intelligence AI bio sensor biotechnology with respect to reliable material research Therefore various students who are eager to get a job in semiconductor AI Autonomous car biotechnology are strongly recommended to read this book and learn about related state of art knowledge

**Advanced Communication Systems and Next-Gen Circuit Design: Intelligent Integration of Electronics, Wireless Infrastructure, and Smart Computing Systems** Goutham Kumar

Sheelam,2025-06-10 The rapid convergence of electronics wireless communication and intelligent computing is reshaping the technological landscape demanding new approaches to circuit design and communication infrastructure Advanced Communication Systems and Next Gen Circuit Design Intelligent Integration of Electronics Wireless Infrastructure and Smart Computing Systems addresses this transformative era by exploring the fusion of cutting edge hardware design adaptive software systems and intelligent networking technologies This book aims to bridge the gap between foundational principles and emerging innovations offering readers a comprehensive view of how advanced communication systems are built and optimized for future needs From low power high performance integrated circuits to intelligent wireless protocols and machine learning assisted design methodologies we highlight the interconnected evolution of technologies that define the next generation of systems Whether you are a researcher engineer or graduate student this book is structured to guide you through both theoretical insights and practical implementations Each chapter provides in depth discussions real world case studies and future oriented perspectives designed to inspire innovation and deeper inquiry In a world increasingly driven by autonomous systems smart environments and ubiquitous connectivity mastering the synergy between hardware and software is no longer optional it is essential We hope this book serves as both a foundational reference and a forward looking guide for those committed to designing and deploying the intelligent systems that will power the future Design for Manufacturability Through Design-process Integration Alfred Kwok-Kit Wong,Vivek K. Singh,2007 Proceedings of SPIE present the original research papers presented at SPIE conferences and other high quality conferences in the broad ranging

fields of optics and photonics These books provide prompt access to the latest innovations in research and technology in their respective fields Proceedings of SPIE are among the most cited references in patent literature [Microlithography](#) Bruce W. Smith, Kazuaki Suzuki, 2020-05-01 The completely revised Third Edition to the bestselling Microlithography Science and Technology provides a balanced treatment of theoretical and operational considerations from fundamental principles to advanced topics of nanoscale lithography The book is divided into chapters covering all important aspects related to the imaging materials and processes that have been necessary to drive semiconductor lithography toward nanometer scale generations Renowned experts from the world's leading academic and industrial organizations have provided in depth coverage of the technologies involved in optical deep ultraviolet DUV immersion multiple patterning extreme ultraviolet EUV maskless nanoimprint and directed self assembly lithography together with comprehensive descriptions of the advanced materials and processes involved New in the Third Edition In addition to the full revision of existing chapters this new Third Edition features coverage of the technologies that have emerged over the past several years including multiple patterning lithography design for manufacturing design process technology co optimization maskless lithography and directed self assembly New advances in lithography modeling are covered as well as fully updated information detailing the new technologies systems materials and processes for optical UV DUV immersion and EUV lithography The Third Edition of Microlithography Science and Technology authoritatively covers the science and engineering involved in the latest generations of microlithography and looks ahead to the 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 technology this book is the most comprehensive and reliable source for anyone from student to seasoned professional looking to better understand the complex world of microlithography science and technology

**Design and Analysis of Integrated Manufacturing Systems** W. Dale Compton, 1988-02-01 Design and Analysis of Integrated Manufacturing Systems is a fresh look at manufacturing from a systems point of view This collection of papers from a symposium sponsored by the National Academy of Engineering explores the need for new technologies the more effective use of new tools of analysis and the improved integration of all elements of manufacturing operations including machines information and humans It is one of the few volumes to include detailed proposals for research that match the needs of industry [Plunkett's InfoTech Industry Almanac](#) Jack W. Plunkett, 2008-02 Plunkett's InfoTech Industry Almanac presents a complete analysis of the technology business including the convergence of hardware software entertainment and telecommunications This market research tool includes our analysis of the major trends affecting the industry from the rebound of the global PC and server market to consumer and enterprise software to super computers open systems such as Linux web services and network equipment In addition we provide major statistical tables covering the industry from computer sector revenues to broadband subscribers to semiconductor industry production No other source provides this book's easy to understand comparisons of growth



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**Plunkett's Infotech Industry Almanac 2009: Infotech Industry Market Research, Statistics, Trends & Leading Companies** Plunkett Research Ltd, 2009-02 Market research guide to the infotech industry a tool for strategic planning competitive intelligence employment searches or financial research Contains trends statistical tables and an industry glossary Includes one page profiles of infotech industry firms which provides data such as addresses phone numbers executive names

Variation-Aware Advanced CMOS Devices and SRAM Changhwan Shin, 2016-06-06 This book provides a comprehensive overview of contemporary issues in complementary metal oxide semiconductor CMOS device design describing how to overcome process induced random variations such as line edge roughness random dopant fluctuation and work function variation and the applications of novel CMOS devices to cache memory or Static Random Access Memory SRAM The author places emphasis on the physical understanding of process induced random variation as well as the introduction of novel CMOS device structures and their application to SRAM The book outlines the technical predicament facing state of the art CMOS technology development due to the effect of ever increasing process induced random intrinsic variation in transistor performance at the sub 30 nm technology nodes Therefore the physical understanding of process induced random intrinsic variations and the technical solutions to address these issues plays a key role in new CMOS technology development This book aims to provide the reader with a deep understanding of the major random variation sources and the characterization of each random variation source Furthermore the book presents various CMOS device designs to surmount the random variation in future CMOS technology emphasizing the applications to SRAM

*Stereolithography* Paulo Jorge Bártolo, 2011-03-18 Stereolithography Materials Processes and Applications will focus on recent advances in stereolithography covering aspects related to the most recent advances in the field in terms of fabrication processes two photon polymerization micro stereolithography infrared stereolithography and stereo thermal lithography materials novel resins hydrogels for medical applications and highly reinforced resins with ceramics and metals computer simulation and applications

*Characterization and Metrology for ULSI Technology 2005* David G. Seiler, 2005-09-29 The worldwide semiconductor community faces increasingly difficult challenges in the era of silicon nanotechnology and beyond The magnitude of these challenges demands special attention

from the metrology and analytical measurements community New paradigms must be found Adequate research and development for new metrology concepts are urgently needed Characterization and metrology are key enablers for developing new semiconductor technology and in improving manufacturing This book summarizes major issues and gives critical reviews of important measurement techniques that are crucial to continuing the advances in semiconductor technology It covers major aspects of process technology and most characterization techniques for silicon research including development manufacturing and diagnostics The book also covers emerging nano devices and the corresponding metrology challenges that arise

## Whispering the Secrets of Language: An Psychological Quest through **Design For Manufacturability With Advanced Lithography**

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