X Ray Metrology In Semiconductor Manufacturing

X-Ray Metrology in Semiconductor ManufacturingHandbook of Silicon Semiconductor MetrologyNational Semiconductor Metrology ProgramDevelopment of Virtual Metrology in Semiconductor ManufacturingNational Semiconductor Metrology ProgramSemiconductor FabricationScanning Probe Metrology of Semiconductor Line Edge RoughnessIntroduction to Metrology Applications in IC ManufacturingRisk Minimization Through Metrology in Semiconductor ManufacturingIntroduction to Metrology Applications in IC ManufacturingSemiconductor Strain MetrologyHandbook of Semiconductor Manufacturing TechnologyStatistical Methods for Enhanced Metrology in Semiconductor/Photovoltaic ManufacturingMetrology for the Semiconductor IndustrySemiconductor FabricationMethods of Measurement for Semiconductor Materials, Process Control, and DevicesOptical Metrology Roadmap for the Semiconductor, Optical, and Data Storage Industries IISemiconductor Measurement TechnologyCharacterization and Metrology for ULSI Technology: 2003Semiconductor Measurement Technology D. Keith Bowen Alain C. Diebold National Semiconductor Metrology Program (U.S.) Bhalinder Singh Gill National Semiconductor Metrology Program (U.S.) Dinesh C. Gupta Ndubuisi George Orji Bo Su Juan Alejandro Sendon Perez Su Bo Terence K. S. Wong Yoshio Nishi Dekong Zeng Robert I. Scace Dinesh C. Gupta United States. National Bureau of Standards Angela Duparré United States. National Bureau of Standards David G. Seiler W. Murray Bullis

the scales involved in modern semiconductor manufacturing and microelectronics continue to plunge downward effective and accurate characterization of materials with thicknesses below a few nanometers can be achieved using x rays while many books are available on the theory behind x ray metrology xrm x ray

metrology in semiconductor manufacturing is the first book to focus on the practical aspects of the technology and its application in device fabrication and solving new materials problems following a general overview of the field the first section of the book is organized by application and outlines the techniques that are best suited to each the next section delves into the techniques and theory behind the applications such as specular x ray reflectivity diffraction imaging and defect mapping finally the third section provides technological details of each technique answering questions commonly encountered in practice the authors supply real examples from the semiconductor and magnetic recording industries as well as more than 150 clearly drawn figures to illustrate the discussion they also summarize the principles and key information about each method with inset boxes found throughout the text written by world leaders in the field x ray metrology in semiconductor manufacturing provides real solutions with a focus on accuracy repeatability and throughput

containing more than 300 equations and nearly 500 drawings photographs and micrographs this reference surveys key areas such as optical measurements and in line calibration methods it describes cleanroom based measurement technology used during the manufacture of silicon integrated circuits and covers model based critical dimension overlay

virtual metrology vm predicts end of batch properties metrology data from measurable input data composed of pre process metrology and fault detection and classi cation fdc system outputs this dissertation aims at moving a step closer to the realization of vm in semiconductor manufacturing by providing solutions to the challenges that present vm technology faces first various vm methods are introduced and compared in terms of prediction accuracy using four industrial datasets collected from a plasma etch system at texas instruments inc kalman lter estimation is employed in a novel way to serve as a vm model for predicting outputs of a static process recursive pls regression r plsr and kalman filter show the best prediction results as they update the model whenever new measurements are available next two pls variants pls with ewma mean update and recursive pls are proposed as robust vm algorithms that can predict process outputs fairly accurately in the presence of unexpected process drifts and noise the obtained results reinforce vm technology by suggesting appropriate prediction methods when unexpected process changes occur for a successful implementation of vm the data entering the vm model needs to be free from faults fault free reconstructed data are obtained by performing fault detection fault identi cation and fault reconstruction a novel fault detection method based on statistics pattern analysis spa is presented the spa method provides better fault detection performance for diff erent types of faults as compared to the mpca based methods next three well known fault identi cation methods present in literature are implemented an equation that relates the rbc with the svi is derived the contribution plot method identi es a smaller number of faults correctly as compared to the rbc and the svi methods fairly good estimates of the fault magnitude are obtained when the faults are identi ed correctly an approach that combines physical measurements with the vm estimates to develop a more robust approach than using vm alone is presented ewma r2r control is implemented using three well known sampling methods in order to demonstrate the superior performance of two novel control schemes b ewma r2r control and vm assisted ewma r2r control a new reliance index which is attractive from a mathematical and practical point of view is proposed the vm assisted ewma r2r control yields the best control results among the control schemes employed in this study the simulation results demonstrate that vm has the potential to reduce measurement costs signi cantly while promising better process control

over the years the size of components that make up microelectronics integrated circuits ic has steadily decreased a key measure of the size of features used to fabricate ic components is the width of patterned lines the relative uncertainty associated with determining the width of these lines has increased as the width itself decreases a major source of this uncertainty is the deviation of the line edge from a straight line otherwise known as line edge roughness ler ler has been linked to current leakage in devices and is becoming an important contributor to the lithography error budget the tools currently used to measure ler have limitations and may not be able to meet the ler measurement needs of the semiconductor industry this is because semiconductor lines are complex three dimensional structures with vertical surfaces and the available instruments are not optimized for such measurement hence there is a need for robust ler metrology techniques we explore the use of the atomic force microscope afm for measuring ler there are several implementations of the afm and it is not clear if all of them measure ler in the same way the goal of this study is to explore how different implementations of the afm measure ler and what improvements are needed to achieve increased resolution results of measurement comparisons using different afms are presented and requirements for afm based ler metrology are outlined

metrology has grown significantly especially in semiconductor manufacturing and such growth necessitates increased expertise until now this field has never had book written from the perspective of an engineer in a modern ic manufacturing and development environment the topics in this tutorial text range from metrology at its most basic level to future predictions and challenges including measurement methods industrial applications fundamentals of traditional measurement system characterization and calibration measurement system characterization and calibration semiconductor specific applications optical metrology measurement techniques charged particle measurement techniques x ray and in situ metrology hybrid metrology and mask making includes example spreadsheets of measurement uncertainty analysis specifically precision matching and relative accuracy

this thesis consists in analyzing the different properties of metrology workshops proposing novel approaches to optimize sampling rates and developing new dynamic strategies for risk reduction in semiconductor manufacturing a thorough analysis of metrology workshops in the site of rousset of stmicroelectronics has been carried out their physical properties and also their characteristics such as measure qualification lot sampling and dispatching strategy and risk levels are considered also a new procedure is developed that helps to determine which sampling strategy fits better according to the metrology workshop characteristics and risk values new approaches are then proposed to optimize the sampling rates for different types of metrology tools respecting the metrology capacity and taking into account parameters such as throughput rates of process machines and metrology tools and the failure probabilities of process machines the numerical experiments show that the metrology capacity is better used and process machines are efficiently controlled depending on their characteristics paying more attention the critical machines in the final part of the thesis simulation models of several metrology workshops are developed these models reproduce the behaviour of the workshops to better understand them and to evaluate the impact of proposed improvements

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this book surveys the major and newly developed techniques for semiconductor strain metrology semiconductor strain metrology has emerged in recent years as a topic of great interest to researchers involved in thin film and nanoscale device characterizati

retaining the comprehensive and in depth approach that cemented the bestselling first edition s place as a standard reference in the field the handbook of semiconductor manufacturing technology second edition features new and updated material that keeps it at the vanguard of today s most dynamic and rapidly growing field iconic experts robert doering and yoshio nishi have again assembled a team of the world s leading specialists in every area of semiconductor manufacturing to provide the most reliable authoritative and industry leading information available stay current with the latest technologies in addition to updates to nearly every existing chapter this edition features five entirely new contributions on silicon on insulator soi materials and devices supercritical co2 in semiconductor cleaning low κ dielectrics atomic layer deposition damascene copper electroplating effects of terrestrial radiation on integrated circuits ics reflecting rapid progress in many areas several chapters were heavily revised and updated and in some cases rewritten to reflect rapid advances in such areas as interconnect technologies gate dielectrics photomask fabrication ic packaging and 300 mm wafer fabrication while no book can be up to the minute with the advances in the semiconductor field the handbook of semiconductor manufacturing technology keeps the most important data methods tools and techniques close at hand

as semiconductor technology is aggressively scaling to finer feature sizes manufacturing complexity increases dramatically this drives the need for extensive control on processing equipment and on the efficiency of the associated metrology similarly in the field of photovoltaic pv manufacturing processing technology is driven by cost reduction while increasing output power per cell in either case the variability impact on the final performance is critical in this thesis we focus on the application of statistical methods for enhanced metrology in both semiconductor and pv manufacturing the work falls into three main topics wafer to wafer w2w virtual metrology vm via predictive modeling site to site s2s metrology modeling for fault detection and classification fdc and predictive variability modeling for solar pv the first topic is on creating predictive vm models for w2w control in plasma etching one of the bottlenecked processes for technology node scaling the idea is to utilize equipment sensor data to predict the wafer processing results so that actual wafer measurements can be reduced or eliminated vm comprises four main steps data extraction outlier removal variable selection and model creation they aim to deal with the special characteristics of equipment sensor data which are high dimensional collinear and non stationary vm models are trained and tested with approximately one production year worth of wafer data collected from a single plasma etching tool the best model result is obtained by a hybrid model that utilizes step wsie parameter selection and neural network nn based

prediction which achieved a testing r2 of 0 75 the second topic aims to develop fdc schemes for wafer level s2s metrology we first focus on utilizing spatial and multivariate statistics for detecting outlier wafers spatial and multivariate methods are preferred given the temporal and spatial varying nature of wafer level metrology data we then focus on selecting the optimal measurement sites for process monitoring various site selection schemes are evaluated within the fdc application showing than more than 70 metrology savings with no discernable reduction in performance is possible the third topic addresses modeling the variability of solar cells the impact of environmental and manufacturing variability is simulated and discussed a predictive model for manufacturing variability induced mismatch power loss is proposed and evaluated with various pv array configurations finally spatial statistics are used to model the non uniformities of solar cell properties a spice based distributive solar cell simulator is constructed to estimate electrical performance for various defect distribution patterns finally a statistical model is created in order to correlate the spatial characteristics of defect patterns with the corresponding electrical performance

the worldwide semiconductor community faces increasingly difficult challenges as it moves into the manufacturing of chips with feature sizes approaching 100 nm 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 topics include integrated circuit history challenges and overviews front end lithography interconnect and back end and critical analytical techniques 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 continue 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 editors believe that this book of collected papers provides a concise and effective portrayal of industry characterization needs and the way they are being addressed by industry academia and government to continue the dramatic progress in semiconductor technology hopefully it will also provide a basis for stimulating advances in metrology and new ideas for research and development

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