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Handbook of Critical Dimension Metrology
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Introduction

The purpose of this review is to provide an authoritative reference volume for semiconductor process engineers engaged in metrology and process control. After more than eight years of experience at the SPIE Microlithography Symposium in San Jose, we believe that IC metrologists are ready for their own handbook. The San Jose metrology conference is strong in presenting short papers of topical interest, but it is not an appropriate forum for papers which provide more depth and breadth, historical references, mathematical background, and compilation of the best work of multiple authors spanning a period of years. Furthermore, prior to this work, there was no single volume that addressed these needs.

The scope of the review volume has been reduced slightly relative to that of the San Jose conference in order to make the task manageable and to give the reviews a consistent critical dimension and overlay theme. It begins modestly with definitions of terms and procedures. The authors were asked to include sufficient mathematical background to make the papers self-contained and accessible to someone with a bachelor of engineering background. Where possible, process control applications were used as examples to maintain a strong focus on utility. To assure the handbook's long-term value as a reference, we encouraged examples of leading-edge submicrometer technology, along with liberal use of equations, graphs, profiles, and image data.

The topics were specifically selected to highlight common problems and to answer frequently asked questions. For example:

What is critical dimension metrology and how can it be used for process control? How are line width, pitch, and aspect ratio defined? What is meant by precision, accuracy, error, uncertainty and linearity? Which procedures are used to determine these parameters?

Which measurement technologies are available and how do they work? How are bright field, confocal, coherence, and correlation optical microscopes different? How do source brightness, current and energy affect measurement in a scanning electron microscope? What influence does tip geometry have on surface reconstruction by an atomic force microscope? How can electrical current flowing through a conductor be used to measure linewidth and overlay? How can film thickness be measured?

How can I evaluate measurement system performance in a rigorous manner? What is the difference between repeatability, reproducibility, and stability? What are the recommended standards and procedures for tool calibration? How does tool capability affect product risk analysis? What are MTBF, MTBA and MTTS and how do they affect cost-of-ownership models? What are SECS, GEM, and MESC and how do they affect communication, control and automation of equipment?

What are the major applications of CD measurement equipment? In stepper setup applications, why is linewidth generally a parabolic function of stepper focus and a hyperbolic function of resist exposure? What are the most successful mathematical models for grid and intrafield registration? How do WIS and TIS impact overlay measurements? Why are lens distortions and stage errors important in matching lithographic tools? What is meant by across-field, across-wafer, and across-lot process uniformity?

Which mathematical tools do I need for data analysis? How can a classical variance components analysis be used to separate static, dynamic, and long-term precision? What is the most efficient experiment design to fit a second-order response in linewidth? What is the general linear model and how can it be used to generate response surfaces? What are the most robust techniques for sampling and tracking process data over time?

While not all of these questions are answered in this volume, the discerning reader will note that we have largely succeeded in covering the field. As with most handbooks, we expect to make improvements in successive editions, adding fresh material as the semiconductor industry progresses inexorably toward smaller dimensions. Those with opinions regarding the direction and content of the next offering are encouraged to write to the Editor.