

Lithography Process Control

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Harry J. Levinson

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INTRODUCTION TO THE SERIES

The Tutorial Texts series was begun in response to requests for copies of SPIE short course notes by those who were not able to attend a course. By policy the notes are the property of the instructors and are not available for sale. Since short course notes are intended only to guide the discussion, supplement the presentation, and relieve the lecturer of generating complicated graphics on the spot, they cannot substitute for a text. As one who has evaluated many sets of course notes for possible use in this series, I have found that material unsupported by the lecture is not very useful. The notes provide more frustration than illumination.

What the Tutorial Texts series does is to fill in the gaps, establish the continuity, and clarify the arguments that can only be glimpsed in the notes. When topics are evaluated for this series, the paramount concern in determining whether to proceed with the project is whether it effectively addresses the basic concepts of the topic. Each manuscript is reviewed at the initial state when the material is in the form of notes and then later at the final draft. Always, the text is evaluated to ensure that it presents sufficient theory to build a basic understanding and then uses this understanding to give the reader a practical working knowledge of the topic. References are included as an essential part of each text for the reader requiring more in-depth study.

One advantage of the Tutorial Texts series is our ability to cover new fields as they are developing. In fields such as sensor fusion, morphological image processing, and digital compression techniques, the textbooks on these topics were limited or unavailable. Since 1989 the Tutorial Texts have provided an introduction to those seeking to understand these and other equally exciting technologies. We have expanded the series beyond topics covered by the short course program to encompass contributions from experts in their field who can write with authority and clarity at an introductory level. The emphasis is always on the tutorial nature of the text. It is my hope that over the next few years there will be as many additional titles with the quality and breadth of the first ten years.

Donald C. O'Shea
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PREFACE

In the mid-1980s the semiconductor industry underwent a fundamental change. With superior yields, reliability, and efficiency, Japanese manufacturers of integrated circuits surpassed their American competitors in terms of market share. The American semiconductor industry responded with significant quality improvement and regained the leadership market position by 1993. Today the integrated circuit business is highly competitive and global.

During the transition years I found that I was frequently consulted by lithography engineers who were attempting to apply quality improvement methods, such as statistical process control (SPC), to which they had been recently introduced. Through discussions with these engineers it became clear that there were subtle reasons why SPC could not be applied in a straightforward way to many situations which occurred in lithography. My explanations to the engineers evolved into a set of class notes, and now this Tutorial Text.

Many of the quality problems that we were trying to solve arose in conventional manufacturing situations, while others involved development pilot lines. Methods for addressing the problems that occur in the context of process development are rarely addressed in texts on process control. Another objective of this Tutorial Text is to present control methodologies applicable to development pilot lines.

To understand this text there are some prerequisites. A basic foundation in lithography science is assumed. The SPIE Handbook on *Microlithography, Micromachining and Microfabrication. Volume 1: Microlithography*¹ provides a suitable introduction. It is also assumed that the reader has had some introduction to basic statistical concepts and statistical process control. It is my intention that this text be a self-contained tutorial on lithography process control for readers familiar with the prerequisite lithography science and basic statistical process control, although some subjects may involve a higher level of mathematical sophistication than others. The text covers the subject of lithography process control at several levels. Discussions of some very basic elements of statistical process control and lithography science are included, because, when trying to control a lithography process, a number of subtle problems arise that are related to fundamental issues. To most readers, the information presented on the foundations of statistical process control should be familiar. Nevertheless, it is useful to review the foundations of statistical process control, in order to clearly identify those circumstances in which the method may be applied, and where it needs to be applied with particular care. This inclusion of basic topics also allows the text to serve as an introduction to process control for the novice lithography engineer and as a reference for experienced engineers. More advanced topics are also included to varying

levels of detail. Some of these topics, such as complex processes and feedback, are discussed in considerable detail, because there is no comparable presentation available. Other topics are only introduced briefly, and the reader is referred to other texts that cover the subject quite well.

The text also contains numerous references to the extensive literature on the subject of this book. These references are intended as a guide for further study by the interested reader and are also meant to serve as an acknowledgment to the many people who have contributed over the years to improving our understanding of the lithography process and how better to control it.

A few special acknowledgments are in order. First, I want to thank my wife, Laurie Lauchlan, who tolerated the many hours I spent in the study writing this book, and who shared many of her insights on metrology. Dr. David C. Joy helpfully provided information on recent developments in the understanding of charging in low voltage SEMs. I also want to express my gratitude to Chuck DeHont, who first allowed many of these ideas first to be implemented. Finally, I want to thank the many people with whom I have worked at Advanced Micro Devices, Sierra Semiconductor, and IBM, through whose efforts the world has been improved.

Harry J. Levinson
January 1999

¹ *Handbook of Microlithography, Micromachining, and Microfabrication. Volume 1: Microlithography*, P. Rai-Choudhury, Ed., SPIE Press, Bellingham (1997).