Robotics for Electronics Manufacturing

Understand the design, testing, and application of cleanroom robotics and automation with this practical guide. From the history and evolution of cleanroom robots to the latest applications and industry standards, this book provides the only complete overview of the topic available. Robotics for automating the most demanding cleanroom manufacturing process, the making of semiconductor devices, is used as an example throughout the book. The principles and applications also apply to related industries, including the flat panel display, solar panels, hard disk, nanotechnology, MEMS, and pharmaceutical industries.

With over 20 years of experience in robotics and cleanroom manufacturing, Dr. Karl Mathia covers the relevant subjects for the design and testing of clean robots that operate in both atmospheric and vacuum environments. He provides numerous real-world examples so the reader can learn from professional experience, maximize the design quality, and avoid expensive design pitfalls. The book also provides guidelines and hands-on tips for reducing development time and product cost. Compliance with industry standards for the design, assembly, and handling of cleanroom robots is stressed throughout, and detailed discussions of recommended materials for atmospheric and vacuum robots are included to help shorten product development cycles and avoid expensive material testing.

This book is the perfect practical reference for engineers working with robotics for electronics manufacturing in a range of industries that rely on cleanroom manufacturing.

Dr. Karl Mathia studied in Germany and the United States and holds advanced degrees in Electrical and Computer Engineering. He has over 20 years of experience in research and development, product development engineering, and also held management positions at leading robotic firms, including Brooks Automation and Newport Corporation. Dr. Mathia has published numerous articles in the area of automation, controls, and intelligent systems, and taught short courses in industry. He currently works as Chief Engineer at Zitech Engineering, LLC.

In my 16 years of serving the robotics industry, I have never come across a single book that explains the history, design, and use of cleanroom robotics for electronics manufacturing so thoroughly. The book provides an excellent description of the environment and challenges of this industry and gives valuable insight for designing robots and equipment to meet these challenges. This is a must read for anyone designing cleanroom equipment for electronics manufacturing!

Jeff Baird, Director of Engineering, Adept Technology, Inc.

A must read for anyone working on semiconductor or flat panel robotics. This book captures theory, applications and best practices. Chapters 2, 3, 4 and 7 are a concise reference for designing, specifying and implementing robots. Chapters 5 and 6 provide the technical background to both develop and control robotic systems.

Dr. Martin P. Aalund, Director NPI Engineering, KLA-Tencor Corp.

Karl has created the definitive reference for cleanroom robotics, as well as a practical guide for anyone who wishes to go beyond theory to the economic justifications and real world commercial requirements to deploy robot technology.

Dr. Rich Mahoney, Director of Robotics, Engineering & Systems Division, SRI International

This volume provides a comprehensive view of robot use as part of electronics manufacturing. The book gives a good overview of the different aspects to be considered in the design and deployment of robots for this sector. The text covers a sector overview, in-depth material for different applications areas and discusses also testing and deployment. It is a valuable reference both to engineers and technical managers in the field.

Dr. Henrik I. Christensen, KUKA Chair of Robotics, College of Computing, Georgia Institute of Technology

Robotics for Electronics Manufacturing is an important new reference work for anyone involved with manufacturing robots. The book provides design guidelines for robots in both air and vacuum environments, as well as a thorough overview of robot kinematics and dynamics. The chapter on testing and measuring robot performance is especially valuable as an accessible explanation of the many ISO, ANSI and RIA standards.

Dr. Trevor Blackwell, CEO and Founder, Anybots, Inc.

Robotics for Electronics Manufacturing is a fundamental and thorough reference for engineers practicing, or preparing to practice, automation design for the semiconductor and electronics equipment manufacturing industry. No other reference covers the disparate requirements and best practices for both atmospheric and vacuum robot design, as well as including test and characterization methods which are the key to the successful manufacturing of such products.

Dr. Jeffrey C. Hudgens, Director of Robotics, Applied Materials Inc.

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Principles and Applications in Cleanroom Automation

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To Maria

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Preface

This book is about the design and application of industrial cleanroom robots in electronics manufacturing. It is intended as a hands-on technical reference for engineers and factory managers involved in manufacturing electronic devices in cleanroom environments. The book provides insight into the principles and applications of industrial cleanroom robotics, in particular in semiconductor manufacturing, the most demanding process in terms of cleanliness requirements. Other examples are the hard disk, flat panel display, and solar industries, which also use high levels of cleanroom automation and robotics. In contrast to the complex manufacturing process, the typical robotic designs often utilize relatively simple robot kinematics in the highly structured environments of process and metrology tools. Some industries, for example the semiconductor front-end industry, are governed by technical standards and guidelines, which are generally helpful during the design process of robotic systems. On the other hand, robotic engineers in electronics manufacturing face challenges that are unknown in other markets, most importantly the cleanliness required in certain factories. Strict cleanliness requirements have resulted in two categories of cleanroom robots: 'atmospheric robots' for high-quality cleanliness at ambient atmospheric pressure, and 'vacuum robots' for extreme cleanliness in enclosures under various vacuum pressures. These two categories are the focus of this book.

The book is organized into seven chapters. Chapters 1 and 2 provide an overview of industrial robotics and industrial cleanroom robotics and are not prerequisites for the technical Chapters 3 to 7:

Chapter 1 provides an overview of the history and different types of industrial robots, and their socioeconomic impact.

Chapter 2 provides an overview of electronics manufacturing in cleanroom environments, cleanliness standards, and the emergence of cleanroom robots in semiconductor manufacturing.

Chapter 3 presents guidelines and best practices for the design of atmospheric robots, including the design example of a wafer-handling robot.

Chapter 4 presents guidelines and best practices for the design of vacuum robots, including the design example of a wafer-handling vacuum robot for automating a six-sided cluster tool.

Chapter 5 reviews common kinematic structures before discussing the kinematics of SCARA-type robots that are commonly used in electronics manufacturing. The forward kinematics model of a three-link robot arm is derived.

Chapter 6 discusses a general dynamic model for robot manipulators and derives the specific model for a three-link robot arm. A decentralized joint control strategy suitable for networked robot control is established.

Chapter 7 introduces several test and characterization methods and their underlying theory. Suitable test fixture designs are described.

A total of 29 examples throughout the book illustrate applications of the presented theory and concepts. All numerical examples were programmed in Matlab®. The International System of Units (SI units) is used whenever possible. For convenience some obsolete units that are still in use are also provided. SI base units, derived SI units, and unit conversion tables for non-SI units are listed in Appendix A. Applicable industry standards are listed at the end of each chapter. Contact information for the relevant publishing standards organizations are listed in Appendix B. Standard sets of conditions for temperature and pressure (STP) are listed in Appendix C. These are used to allow comparisons between different sets of experimental data and are relevant for applications in controlled vacuum and atmospheric environments.

Acknowledgments

This book would not have been possible without the advice and support of several engineers and scientists passionate about robotics. Special thanks go to Dr. Martin Aalund, Izya Kremerman, Ken Park, Jeff Thompson, and Enoch Wall. I also thank Andrew Ayre, Robert Bergner, Alan Campbell, Phil Danielson, Walter Henry, William Holtkamp, Dr. Jeff Hudgens, Peter Lundquist, Venu Menon, Frank Pavlik, Dr. John Tenney, and Dalton Victor. NxRev, Inc. kindly provided the Pro/ENGINEER software for creating robot drawings. The advice, guidance, and support from the editorial staff at Cambridge University Press is much appreciated. I am especially grateful to my wife Maria and our children Francisca and Dustin. Without their continuous encouragement and patience this book would have not been possible.