

Table of Contents

- Preface p. xi
- 1 Industrial robotics p. 1
 - 1.1 History of industrial robotics p. 1
 - 1.3 Applications and operational stock by region p. 5
- 2 Cleanroom robotics p. 12
 - 2.2 Semiconductor manufacturing p. 14
 - 2.4 Substrate-handling, robots p. 23
- 3 Design of atmospheric robots p. 30
 - 3.3 Surface finishes for cleanroom robotics p. 43
 - 3.5 Arm compliance p. 53
- 4 Design of vacuum robots p. 73
 - 4.2 What is vacuum? p. 74
 - 1.2 The global robotics industry p. 2
 - 3.6 End-effectors p. 60
 - 1.4 Socioeconomic impact p. 6
 - 2.1 Manufacturing in cleanroom environments p. 12
 - 2.5 Applicable and related standards p. 28
 - 3.1 Clean materials p. 30
 - 1.5 Definitions, standards, and terminology p. 7
 - 1.6 Applicable and related standards p. 11
 - 3.7 Robot assembly and handling p. 62
 - 2.3 Flat panel display manufacturing p. 20
 - 3.4 Clean drive trains p. 48
 - 3.8 Applicable and related standards p. 70
 - 3.2 Prevention of electrostatic charge p. 37
 - 4.1 Robotics challenges in vacuum environments p. 73
 - 4.3 Static vacuum barrier p. 76
 - 4.4 Dynamic vacuum barrier p. 79
 - 4.5 Clean drive trains p. 92
 - 4.6 External and internal leaks p. 99
 - 4.7 Materials and surface finishes p. 104
 - 4.8 Assembly and installation of vacuum robots p. 115
 - 4.9 Applicable and related standards p. 120
- 5 Kinematics p. 124
 - 5.1 Joint space, operational space, and workspace p. 124
 - 5.2 Kinematic robot structures p. 126
 - 5.3 Mathematical foundations p. 129
 - 5.4 Forward kinematics p. 134
 - 5.5 Inverse kinematics p. 149
 - 5.6 Commercial substrate-handling robots p. 150
 - 5.7 Applicable and related standards p. 153
- 6 Dynamics and control p. 154
 - 6.1 Manipulator dynamics p. 154
 - 6.2 Robot motion control p. 162

- 6.3 Networked, decentralized robot control p. 172
- 6.4 Applicable and related standards p. 177
- References p. 226
- 7 Test and characterization p. 179
- 7.4 Path accuracy and repeatability p. 199
- 7.1 Airborne particle contamination p. 179
- Appendix A SI units and conversion tables p. 220
- Appendix C Standard temperature and pressure (STP) p. 225
- Index p. 232
- 7.2 Surface particle contamination p. 182
- 7.5 Vibration analysis p. 206
- 7.3 Positioning accuracy and repeatability p. 186
- 7.6 Mechanical axis decoupling p. 212
- Appendix B Standards organizations p. 223
- 7.7 Applicable and related standards p. 218