

Principles and Applications in Cleanroom Automation

KARL MATHIA

CAMBRIDGE

Contents

Preface

1	Industri	1	
	1.1 H	istory of industrial robotics	1
		ne global robotics industry	2
	1.3 A	pplications and operational stock by region	5
	1.4 Sc	ocioeconomic impact	6
	1.5 D	efinitions, standards, and terminology	7
	1.6 A	pplicable and related standards	11
2	Cleanro	12	
	2.1 M	lanufacturing in cleanroom environments	12
	2.2 Se	emiconductor manufacturing	14
	2.3 Fl	at panel display manufacturing	20
	2.4 St	abstrate-handling robots	23
	2.5 A	pplicable and related standards	28
3	Design	30	
	3.1 C	lean materials	30
	3.2 Pr	revention of electrostatic charge	37
	3.3 St	arface finishes for cleanroom robotics	43
	3.4 C	lean drive trains	48
	3.5 A	rm compliance	53
	3.6 E	nd-effectors	60
	3.7 R	obot assembly and handling	62
	3.8 A	pplicable and related standards	70
4	Design	73	
	4.1 R	obotics challenges in vacuum environments	73
	4.2 W	/hat is vacuum?	74
	4.3 S	tatic vacuum barrier	76
	4.4 D	ynamic vacuum barrier	79

page xi

x Contents

	4.5 Clear	n drive trains	92
	4.6 Exte	rnal and internal leaks	99
	4.7 Mate	rials and surface finishes	104
	4.8 Asse	mbly and installation of vacuum robots	115
	4.9 Appl	icable and related standards	120
5	Kinematics	124	
		space, operational space, and workspace	124
		matic robot structures	126
		nematical foundations	129
		vard kinematics	134
		rse kinematics	149
	5.6 Com	mercial substrate-handling robots	150
	5.7 Appl	icable and related standards	153
6	Dynamics	154	
	6.1 Man	ipulator dynamics	154
		ot motion control	162
		vorked, decentralized robot control	172
	6.4 Appl	icable and related standards	177
7	Test and c	179	
	7.1 Airb	orne particle contamination	179
		ace particle contamination	182
	7.3 Posit	cioning accuracy and repeatability	186
	7.4 Path	accuracy and repeatability	199
	7.5 Vibra	ation analysis	206
	7.6 Mec	hanical axis decoupling	212
	7.7 App	icable and related standards	218
	Appendix A SI units and conversion tables		220
	Appendix .	223	
	Appendix	225	
	References	226	
	Index	232	