

Contents

Preface xix

Acknowledgments xxi

PART ONE

INTRODUCTION TO SURFACE MOUNTING

Chapter 1	Introduction to Surface Mounting	3
1.0	Introduction	3
1.1	Types of Surface Mounting	7
1.2	Benefits of Surface Mounting	10
1.3	SMT Equipment Requiring Major Capital Investment	18
1.3.1	Pick-and-place equipment	19
1.3.2	Solder paste screen printer	20
1.3.3	Curing/baking oven	20
1.3.4	Reflow soldering equipment	21
1.3.5	Solvent cleaning	22
1.3.6	Wave soldering equipment	22
1.3.7	Repair and inspection equipment	22
1.4	When to Use Surface Mounting	23
1.5	Technical Issues in Surface Mounting	25
1.6	Trend in Surface Mounting	28
1.7	The Future	30
1.7.1	Chip-and-wire (chip-on-board) Technology	32
1.7.2	Tape-automated bonding (TAB)	34
1.7.3	Flip chip or controlled collapse bonding:	36
1.8	Summarv	38
Chapter 2	Implementing Surface Mount Technology	41
2.0	Introduction	41
2.1	Setting the Implementation Strategy	42

x Contents

2.2	Building the SMT Infrastructure	45
2.2.1	Developing internal SMT infrastructure	45
2.2.2	Influencing external SMT infrastructure	45
2.3	Setting In-House Manufacturing Strategy	50
2.4	Selecting an Outside SMT Assembly House	51
2.4.1	Evaluation and qualification of subcontractors	52
2.4.2	The various stages of subcontractor qualification	
2.4.3	Questionnaires for rating of subcontractors	54
2.4.3.1	Technology questions	54
2.4.3.2	Manufacturing questions	55
2.4.3.3	Business questions	56
2.4.3.4	Quality assurance questions	57
2.5	Managing the Risk: Pilot to Production	58
2.6	Summary	60

PART TWO

DESIGNING WITH SURFACE MOUNTING

Chapter 3	Surface Mount Components	65
3.0	Introduction	65
3.1	Surface Mount Component Characteristics	66
3.2	Passive Surface Mount Components	66
3.2.1	Surface mount discrete resistors	67
3.2.2	Surface mount resistor networks	70
3.2.3	Ceramic capacitors	71
3.2.4	Tantalum capacitors	75
3.2.5	Tubular passive components	79
3.3	Active Components: Ceramic Packages	80
3.3.1	Leadless ceramic chip carriers	82
3.3.2	Ceramic leaded chip carriers (preleaded and postleaded)	87
3.4	Active Components: Plastic Packages	88
3.4.1	Small outline transistors	89
3.4.2	Small outline integrated circuits	92
3.4.3	Plastic leaded chip carriers	95
3.4.4	Small outline J packages	98
3.4.5	Fine pitch packages	99
3.5	Miscellaneous Components	102
3.6	Future Components	103
3.7	Major Issues in Components	104
3.7.1	Lead coplanarity	104

3.7.2	Lead configuration	106
3.7.3	Standardization	109
3.8	Component Procurement Guidelines	10
3.9	Summary	111

Chapter 4 Substrates for Surface Mounting 113

4.0	Introduction	113
4.1	Glass Transition Temperature (T_g)	114
4.2	X, Y, and Z Coefficients of Thermal Expansion	116
4.3	Selection of Substrate Material	119
4.3.1	CTE compatibility considerations in substrate selection	127
4.3.2	Process considerations in substrate selection	129
4.4	Ceramic Substrates	131
4.4.1	Porcelainized steel substrates	132
4.5	Constraining Core Substrates	133
4.5.1	Copper-invar-copper constraining core substrates	134
4.5.2	Graphite epoxy constraining core substrates	134
4.6	Compliant Layer Substrate	136
4.7	Glass-Epoxy Substrates	138
4.7.1	Types of glass epoxy substrate	139
4.7.2	Operating temperatures for glass epoxy boards	142
4.7.3	Fabrication of glass epoxy substrates	143
4.8	Plating Processes	147
4.8.1	Copper plating	149
4.8.2	Gold plating	152
4.8.3	Nickel plating	153
4.8.4	Lead-tin solder plating	153
4.9	Solder Mask Selection	153
4.9.1	Wet versus dry film solder masks	155
4.9.2	Photoimageable solder masks	157
4.10	Via Hole Cracking Problems in Substrates	158
4.11	Summary	161

Chapter 5 Surface Mount Design Considerations 163

5.0	Introduction	163
5.1	System Design Considerations	164
5.2	Form, Fit, and Function	165
5.3	Real Estate Considerations	165
5.4	Manufacturing Considerations	170

xii Contents

5.5	Cost Considerations	171
5.5.1	Printed circuit board cost	173
5.5.2	Component cost	176
5.5.3	Assembly cost	177
5.6	Thermal Considerations	178
5.7	Package Reliability Considerations	182
5.7.1	Package cracking mechanism	183
5.7.2	Solutions to package cracking	189
5.7.3	Reliability tests for package cracking	193
5.8	Solder Joint Reliability Considerations	194
5.8.1	Solder joint reliability tests	197
5.9	Interconnect Considerations	202
5.10	CAD Layout Considerations	204
5.11	Summary	205
Chapter 6 Surface Mount Land Pattern Design		209
6.0	Introduction	209
6.1	General Considerations for Land Pattern Design	210
6.2	Land Patterns for Passive Components	211
6.2.1	Land pattern design for rectangular passive components	213
6.2.2	Land pattern design for tantalum capacitors	214
6.3	Land Patterns for Cylindrical Passive (MELF) Devices	217
6.4	Land Patterns for Transistors	219
6.5	Land Patterns for Plastic Leaded Chip Carriers	220
6.6	Land Patterns for Leadless Ceramic Chip Carriers	226
6.7	Land Patterns for Small Outline Integrated Circuits and R-Packs	226
6.8	Land Patterns for SOJ (Memory) Packages	228
6.9	Land Patterns for DIP (Butt Mount) Packages	230
6.10	Land Patterns for Fine Pitch, Gull Wing Packages	230
6.11	Land Patterns for Solder Paste and Solder Mask Screens	230
6.12	Summary	232
Chapter 7 Design for Manufacturability, Testing, and Repair		235
7.0	Introduction	235
7.1	Design Guidelines, Rules, the Role of the Designer	236
7.2	Standard Form Factor Considerations	237
7.3	Component Selection Considerations for Manufacturability	238

7.4	Soldering Considerations	241
7.5	Component Orientation Consideration	246
7.6	Interpackage Spacing Considerations	250
7.6.1	Assumptions in interpackaging spacing requirements	250
7.6.2	Interpackage spacing requirements	251
7.7	Via Hole Considerations	257
7.8	Solder Mask Considerations	259
7.9	Repairability Considerations	260
7.10	Cleanliness Considerations	261
7.11	Testability Considerations	262
7.11.1	Guidelines for ATE testing	263
7.12	Summary	265

PART THREE

MANUFACTURING WITH SURFACE MOUNTING

Chapter 8 Adhesive and Its Application 269

8.0	Introduction	269
8.1	Ideal Adhesive for Surface Mounting	269
8.1.1	Precure properties	270
8.1.2	Cure properties	271
8.1.3	Postcure properties	271
8.2	General Classification of Adhesives	273
8.3	Adhesives for Surface Mounting	274
8.3.1	Epoxy adhesives	274
8.3.2	Acrylic adhesives	275
8.3.3	Other adhesives for surface mounting	275
8.4	Conductive Adhesives for Surface Mounting	276
8.5	Adhesive Application Methods	279
8.5.1	Screening	281
8.5.2	Pin transfer	281
8.5.3	Syringing	282
8.6	Curing of Adhesives	287
8.6.1	Thermal cure	287
8.6.1.1	Thermal cure profile and bond strength	288
8.6.1.2	Adhesive cure profile and flux entrapment	292
8.6.2	UV/Thermal cure	294
8.7	Evaluation of Adhesives with Differential Scanning Calorimetry	296
8.7.1	Basic principles of DSC analysis	297
8.7.2	DSC characterization of an epoxy adhesive	299

Contents

- 8.7.3 DSC characterization of an acrylic adhesive 302
- 8.8 Summary 308

Chapter 9 Solder Paste and Its Application 311

- 9.0 Introduction 311
- 9.1 Solder Paste Properties 311
 - 9.1.1 Metal composition 313
 - 9.1.2 Metal content 313
 - 9.1.3 Particle size and shape 316
 - 9.1.4 Flux activators and wetting action 316
 - 9.1.5 Solvent and void formation 318
 - 9.1.6 Rheological properties 318
 - 9.1.6.1 Viscosity 318
 - 9.1.6.2 Slump 320
 - 9.1.6.3 Working life and tackiness 320
 - 9.1.7 Solder balls 322
 - 9.1.8 Printability 323
- 9.2 Solder Paste Printing Equipment 325
- 9.3 Solder Paste Printing Processes 328
 - 9.3.1 Screen printing 336
 - 9.3.2 Stencil printing 337
 - 9.3.3 Screen printing versus stencil printing 338
 - 9.3.4 Dispensing 341
- 9.4 Paste Printing Defects 342
- 9.5 Paste Printing Variables 343
 - 9.5.1 Solder paste viscosity 343
 - 9.5.2 Print thickness 344
 - 9.5.3 Squeegee wear, pressure, and hardness 344
 - 9.5.4 Print speed 345
 - 9.5.5 Mesh tension 345
 - 9.5.6 Board warpage 345
- 9.6 Summary 345

Chapter 10 Metallurgy of Soldering and Solderability 349

- 10.0 Introduction 349
- 10.1 Phase Diagrams 350
- 10.2 Metallization Leaching in Passive Surface Mount Components 356
- 10.3 Solder Alloys and Their Properties 359
- 10.4 Solderability 364
 - 10.4.1 Wetting 365

10.4.2	Nonwetting	367
10.4.3	Dewetting	368
10.5	Various Approaches for Ensuring Solderability	368
10.6	Solderability Test Methods and Requirements	372
10.7	Recommendations for Solderability Test Methods and Requirements	377
10.8	Effect of Substrate Surface Finish on Solderability	380
10.9	Effect of Component Lead or Termination Finish on Solderability	381
10.10	Summary	384
Chapter 11	Component Placement	387
11.0	Component Placement	387
11.1	Manual Placement of Parts	388
11.2	Automated Placement of Parts	390
11.3	Selection Criteria for Placement Equipment	392
11.3.1	Maximum substrate size handling capacity	393
11.3.2	Maximum feeder input or slot capacity	394
11.3.3	Placement rate and flexibility	396
11.3.4	Placement accuracy/repeatability	397
11.3.5	Vision capability	398
11.3.6	Adhesive dispensing capability	399
11.3.7	Other important selection criteria	400
11.4	Selection of Feeders for Placement Equipment	403
11.4.1	Tape and reel feeders	403
11.4.2	Bulk feeders:	407
11.4.3	Tube or stick feeders	408
11.4.4	Waffle packs	411
11.5	Available Placement Equipment	411
11.5.1	Equipment with low flexibility and high throughput	412
11.5.2	Equipment with high flexibility and low throughput	415
11.5.3	Equipment with medium flexibility and throughput	416
11.5.4	Equipment with low cost and throughput but high flexibility	417
11.6	Summary	418
Chapter 12	Soldering of Surface Mounted Components	423
12.0	Introduction	423
12.1	Wave Soldering	424
12.1.1	Design and process variables in wave soldering	425
12.1.2	Process and equipment variables in wave soldering	429

xvi Contents

12.2	Types of Wave Soldering for Surface Mounting	432
12.2.1	Dual-wave soldering	432
12.2.2	Vibrating wave soldering	434
12.2.3	Modified wave soldering	437
12.3	Wave Versus Reflow Soldering	439
12.4	Single-Step Soldering of Mixed Assemblies	439
12.5	Single-Step Soldering of Double-Sided SMT Assemblies	440
12.6	Vapor Phase Soldering	441
12.6.1	The Heat transfer mechanism in vapor phase soldering	444
12.7	Infrared Reflow Soldering	446
12.7.1	The Heat transfer mechanism in infrared soldering	447
12.7.2	Convection/IR versus near IR	448
12.8	Vapor Phase Versus Infrared Reflow Soldering	449
12.8.1	Cost and flexibility	451
12.8.2	Solder profile development	451
12.8.2.1	Heating rate	452
12.8.2.2	Peak temperature in preheat zone	453
12.8.2.3	Time above solder melting point	453
12.8.2.4	Peak reflow temperature	454
12.8.2.5	Cooling rate and duration above glass transition temperature	454
12.8.3	Solder defects	455
12.8.4	Solder opens (wicking)	456
12.8.5	Tombstoning and part movement	459
12.8.6	Thermal shock on components	460
12.8.7	Solder mask discoloration	460
12.9	Laser Reflow Soldering	461
12.10	Miscellaneous Reflow Soldering Methods	465
12.11	Selecting The Appropriate Soldering Method	466
12.12	Summary	468

Chapter 13 Flux and Cleaning 471

13.0	Introduction	471
13.1	Concerns in Surface Mount Cleaning	471
13.2	The Function of Flux	473
13.3	Considerations in Flux Selection	474
13.4	Flux Classification	475
13.4.1	Inorganic fluxes	476
13.4.2	Organic acid fluxes	477
13.4.3	Superactivated fluxes (SRA and SA)	478

13.4.4	Rosin fluxes	478	
13.5	Contaminants and Their Effects	479	
13.5.1	Particulate contaminants	480	
13.5.2	Nonpolar contaminants	480	
13.5.3	Polar contaminants	481	
13.6	Major Considerations in Solvent Selection	482	
13.7	Commonly Used Solvent Types	488	
13.8	Solvent Cleaning Equipment	489	
13.8.1	Batch solvent cleaning equipment	489	
13.8.2	In-line solvent cleaning equipment	491	
13.8.3	Ultrasonic cleaning equipment	494	
13.9	Aqueous Cleaning	494	
13.9.1	Aqueous cleaning equipment	496	
13.10	Cleanliness Test Methods and Requirements	497	
13.10.1	Visual examination	497	
13.10.2	Solvent extraction	500	
13.10.3	Surface Insulation Resistance (SIR)	500	
	13.10.3.1 SIR measurement test conditions		501
	13.10.3.2 Application of the SIR test		506
13.11	Designing for Cleaning	509	
13.12	Summary	511	

Chapter 14 Quality Control, Repair, and Testing 515

14.0	Introduction	515	
14.1	Statistical Quality Control	515	
14.2	Application of SQC: A Case History	518	
14.2.1	Implementing statistical process control	519	
14.3	Defects Related to Materials and Process Defects	522	
14.3.1	Substrate-related defects	523	
14.3.2	Component-related defects	524	
14.3.3	Adhesive-related defects	527	
14.3.4	Defects related to solder paste	527	
14.3.5	Process-related defects	528	
14.4	Solder Joint Quality Requirements	529	
14.5	Solder Joint Inspection	539	
14.6	Repair Equipment and Processes	543	
14.6.1	Repair requirements	547	
14.6.2	Soldering irons for surface mount repair	550	
14.6.3	Hot air systems for surface mount repair	551	
14.6.4	Rework profiles	553	

Contents

14.7	Assembly Testing	555
14.7.1	Fixtures for ATE testing	557
14.7.2	Issues in ATE testing	561
14.8	Summary	562

APPENDIX A		
SURFACE MOUNT STANDARDS		565

APPENDIX B		
DETAILED QUESTIONNAIRE FOR EVALUATING PICK-AND-PLACE EQUIPMENT FOR SURFACE MOUNTING		575

APPENDIX C		
GLOSSARY		583

INDEX		593
--------------	--	------------