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**INTEGRATED CIRCUIT PACKAGING,  
ASSEMBLY AND INTERCONNECTIONS**

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ASSEMBLY AND INTERCONNECTIONS**

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 Springer

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# **DEDICATION**

**To my family,**

**my wife Joan**

**and**

**our children, their spouses and grandchildren**

**Karen – Christopher, Ryan, Kevin**

**Billy and Cathy – Alli, Jeff, Shauna**

**Joni and Fred – Danny, Kerri, Traci Jo**

**Jimmy and Colleen – Maggie, Molly, Katie, Claire**

**Ronny and Meryl – RJ, Connor**

**Steven**

**Kenny**

# Table of Contents

<b>List of Figures .....</b>	<b>xiii</b>
<b>List of Tables.....</b>	<b>xxi</b>
<b>Preface .....</b>	<b>xxiii</b>
<b>Acknowledgements .....</b>	<b>xxv</b>
<b>About the Author.....</b>	<b>xxvii</b>
<b>1 Electronic Manufacturing and the Integrated Circuit.....</b>	<b>1</b>
<b>1 — MICROELECTRONICS AND THE TRANSISTOR.....</b>	<b>1</b>
1.1 — The Integrated Circuit and Moore’s Law (2-5).....	1
1.2 — Electronics Manufacturing and the Technology Drivers.....	3
1.3 — A Technology Driver—The Integrated Circuit.....	8
1.4 — The International Roadmap for Semiconductors (ITRS) .....	10
<b>2 Integrated Circuit Manufacturing: A Technology Resource... </b>	<b>15</b>
<b>2 — IC MANUFACTURING TECHNOLOGIES .....</b>	<b>15</b>
2.1 — Overview of the IC Manufacturing Processes.....	15
2.2 — The Manufacturing Environment .....	17
2.3 — The Photolithographic Process.....	20
2.4 — IC Methodologies and Packaging, Assembly, Interconnections .....	28
<b>3 Packaging the IC—Single Chip Packaging .....</b>	<b>31</b>
<b>3 — THE IC PACKAGE.....</b>	<b>31</b>
3.1 — Trends in IC Packaging.....	32
3.2 — Area Array Packages—PGA, BGA .....	36
3.3 — BGA Surface Mount Assembly.....	41
3.4 — BGA Attributes .....	42
3.5 — BGA Concerns .....	42
3.6 — The Future .....	43
3.7 — Lead-Free Manufacturing.....	43

<b>4</b>	<b>The Chip Scale Package .....</b>	<b>47</b>
<b>4</b>	<b>— THE CHIP SCALE PACKAGE, CSP .....</b>	<b>47</b>
4.1	— Chip Scale Package Manufacturing Technologies .....	48
4.2	— The $\mu$ BGA <sup>TM</sup> .....	52
4.3	— Wafer Level Packaging—The WLP .....	55
4.4	— Reliability Concerns .....	57
4.5	— Summary .....	58
<b>5</b>	<b>Multichip Packaging.....</b>	<b>61</b>
<b>5</b>	<b>— MULTICHIP PACKAGING (MCP).....</b>	<b>61</b>
5.1	— MCP Substrate/Package Technologies .....	62
5.2	— The Hybrid Circuit .....	62
5.3	— The Multichip Module (MCM) .....	65
5.4	— 3-D Packaging .....	67
5.5	— 3-D Packaging and the Flex Circuit .....	71
5.6	— Die Stacking Using Silicon Thru-Vias .....	75
5.7	— System in Package (SiP)/System on Package (SoP) .....	77
5.8	— Summary—Benefits of Multichip Packaging .....	79
<b>6</b>	<b>Known Good Die (KGD) .....</b>	<b>81</b>
<b>6</b>	<b>— THE KGD STORY .....</b>	<b>81</b>
6.1	— The Semiconductor Assembly/Packaging/Test Process.....	81
6.2	— The Bare Die Problem.....	83
6.3	— Addressing the Bare Die Problem—Wafer Lot Acceptance Testing .....	86
6.4	— Known Good Die (KGD).....	86
6.5	— Wafer Level Burn-in and Test (WLBT).....	90
6.6	— Industry Responsiveness .....	92
<b>7</b>	<b>Packaging Options—Chip on Board.....</b>	<b>93</b>
<b>7</b>	<b>— DIRECT CHIP ATTACH (DCA) AND CHIP ON BOARD (COB).....</b>	<b>93</b>
7.1	— The COB Process .....	94
7.2	— Flip Chip On Board (FCOB).....	98
7.3	— Summary .....	101
<b>8</b>	<b>Chip &amp; Wire Assembly.....</b>	<b>103</b>
<b>8</b>	<b>— CHIP &amp; WIRE ASSEMBLY .....</b>	<b>103</b>
8.1	— Die/Wire Bonding and Bonder Equipment Development.....	103
8.2	— Impact of the IC on Bonding and Bonder Development .....	105
8.3	— The Chip and Wire Assembly Process .....	105

8.4 — Bonding Wire: Au, Al, and Cu.....	106
8.5 — Bonding Methods.....	108
8.6 — Types of Bonds .....	110
8.7 — The Ball Bonding Process.....	110
8.8 — Wedge Bonding.....	111
8.9 — Obstacles to Quality and Reliable Wire Bonding.....	112
8.10 — Metallurgical Concerns and Surface Finishes.....	114
8.11 — Handling and Storage.....	118
8.12 — Verifying Wire Bonding Quality.....	118
8.13 — Responding to the IC and End Product .....	120
8.14 — Wire Bonding on Organic Substrates, The PBGA and PWB.....	125
8.15 — Summary .....	127

**9 Tape Automated Bonding—TAB..... 129**

<b>9 — BACKGROUND—MINIMOD.....</b>	<b>129</b>
9.1 —Tape Automated Bonding .....	129
9.2 — The TAB Tape .....	129
9.3 — TAB Assembly.....	134
9.4 — Reliability Concerns.....	138
9.5 — Areas of Applications.....	139
9.6 — Summary .....	140

**10 Flip Chip—The Bumping Processes..... 143**

<b>10 — BACKGROUND .....</b>	<b>143</b>
10.1 — IBM’s Flip Chip Transistor.....	143
10.2 — Wafer Bumping.....	147
10.3 — Bump Deposition Processes.....	150
10.4 — Comparing Flip Chip Solder Bumping Processes.....	160
10.5 — Polymer/Bumps.....	161
10.6 — Stud/Ball Bumping.....	163
10.7 — Trends in Bumping Technology.....	165

**11 Flip Chip Assembly..... 169**

<b>11 — BASIC FLIP CHIP ASSEMBLY .....</b>	<b>169</b>
11.1 — Flip Chip Bonding Processes .....	170
11.2 — The Solder Reflow Process .....	171
11.3 — Flip Chip Solder Joint Reliability.....	173
11.4 — Reliability and Lead-Free Solders.....	182
11.5 — Solder Reflow Attach: Comments, Concerns.....	183
11.6 — Alternative Flip Chip Bonding Methods .....	183
11.7 — Adhesive Flip Chip Attachment.....	184

11.8 — Adhesive Bumps .....	188
11.9 — Summary: Advantages of Flip Chip as a First Level Interconnect....	189
<b>12 HDI Substrate Manufacturing Technologies: Thin Film Technology.....</b>	<b>193</b>
<b>12 — HIGH DENSITY PACKAGE/SUBSTRATE MANUFACTURING TECHNOLOGIES.....</b>	<b>193</b>
12.1 — Thin Film Technology.....	193
12.2 — The Patterning Process.....	195
12.3 — Processing an HDI Substrate Interconnect .....	200
12.4 — Thin Film Materials.....	202
12.5 — Alternative Thin Film Processes for MCP Applications .....	212
12.6 — High Density Interconnects—Cost and Yield Considerations .....	218
<b>13 HDI Substrate Manufacturing Technologies: Thick Film Technology.....</b>	<b>221</b>
<b>13 — THICK FILM TECHNOLOGY.....</b>	<b>221</b>
13.1 — The Thick Film Process .....	221
13.2 — The Patterning Process.....	222
13.3 — Thick Film Screen Printing and MCM-C/HDI.....	227
13.4 — Advanced Thick Film Patterning Processes .....	229
<b>14 HDI Substrate Manufacturing Technologies: Cofired Ceramic.....</b>	<b>233</b>
<b>14 — THE COFIRED CERAMIC TAPE TECHNOLOGY.....</b>	<b>233</b>
14.1 — IBM's Multilayer Interconnect (MLI) Packaging Program .....	234
14.2 — The Co-fired Ceramic Technology .....	236
14.3 — The Cofired Ceramic Tape Process.....	237
14.4 — High Temperature Cofired Ceramic HTCC .....	237
14.5 — Low Temperature Co-fired Ceramic LTCC .....	238
14.6 — Comparing Thick Film, HTCC and LTCC .....	239
14.7 — Advanced LTCC Processes.....	241
14.8 — Summary Co-fired Ceramic Process Technologies.....	243
<b>15 Substrate Manufacturing Technologies: Organic Packages and Interconnect Substrate.....</b>	<b>245</b>
<b>15 — THE LEVEL 2.0 PRINTED WIRING BOARD.....</b>	<b>245</b>
15.1 — Overview of Conventional MLB Processing .....	247
15.2 —The PBGA and the MCM-L.....	248



15.3 — Impact of the IC on Packaging and Interconnect Technology .....	249
15.4 — Vias and HDI .....	251
15.5 — IBM’s SLC and HDI PWB Build Up Technology (BUT) .....	253
15.6 — Current Status Microvia HDI PWBs.....	256
15.7 — Enhancing HDI PWBs—Embedded Passives .....	257
15.8 —Technology Status.....	259
<b>Acronymns and Definitions .....</b>	<b>261</b>
<b>Microelectronics Glossary.....</b>	<b>265</b>
<b>Index .....</b>	<b>289</b>

# List of Figures

<b>Figure 1-1.</b> Moore's Law .....	2
<b>Figure 1-2.</b> The Electronic Manufacturing Process .....	4
<b>Figure 1-3(a).</b> Single Chip Packaging .....	5
<b>Figure 1-3(b).</b> Multichip Packaging .....	5
<b>Figure 1-3(c).</b> Chip On Board.....	6
<b>Figure 1-4(a).</b> Chip & Wire .....	6
<b>Figure 1-4(b).</b> TAB.....	6
<b>Figure 1-4(c).</b> Flip Chip.....	7
<b>Figure 1-5.</b> Printed Circuit Board (PCB) or Printed Wiring Board Assembly (PWBA).....	7
<b>Figure 1-6.</b> IC circa 1970, Single Level Al Metallization $\approx$ 20 Micrometers Minimum Line Width.....	8
<b>Figure 1-7(a).</b> IC circa 2000, Multilevel Metallization.....	9
<b>Figure 1-7(b).</b> SEM Photomicrograph Multilevel Copper Interconnect, Minimum Line Width $\approx$ 2 micrometers.....	9
<b>Figure 1-8(a).</b> Peripheral and Area Array I/O formats .....	12
<b>Figure 1-8(b).</b> I/O Capabilities: Peripheral Format vs. Area Array .....	13
<b>Figure 1-9.</b> Area Array Packages—BGAs .....	14
<b>Figure 2-1.</b> A 300 mm (12") and 200 mm (8") Diameter Silicon Wafer .....	16
<b>Figure 2-2.</b> Schematic Cross-Section of a Si Integrated Circuit .....	17
<b>Figure 2-3.</b> A Class 1 Cluster Cell within a Class 10 Cleanroom.....	19
<b>Figure 2-4.</b> Robotic Wafer Handling .....	19
<b>Figure 2-5.</b> Si Wafer Fab, The Front End Processes.....	20
<b>Figure 2-6.</b> The Basic Pattern Transfer Process.....	21
<b>Figure 2-7(a).</b> An Array Photomask .....	22
<b>Figure 2-7(b).</b> A Reticle.....	23
<b>Figure 2-8.</b> Deposition of Liquid Photoresist by Spinning .....	24
<b>Figure 2-9.</b> Positive and Negative Acting Photoresist .....	25
<b>Figure 2-10.</b> The Basic Exposure System.....	26
<b>Figure 2-11.</b> (a) Contact Printer; (b) Proximity Printer.....	26
<b>Figure 2-12.</b> Projection Printer .....	27
<b>Figure 2-13.</b> The Wafer Stepper Projection System .....	28
<b>Figure 2-14.</b> The Step and Scan Projection System.....	28
<b>Figure 3-1.</b> Transistor and an Early IC Package (TO-5 Outline).....	31
<b>Figure 3-2.</b> IC Package History and Trends.....	32
<b>Figure 3-3(a).</b> Ceramic and Plastic Dual Inline Packages .....	33
<b>Figure 3-3(b).</b> PCB with Through-Hole Solder Attached DIPs.....	33
<b>Figure 3-4(a).</b> Small Outline IC Packages (SOIC) .....	34
<b>Figure 3-4(b).</b> PCB with Surface Mounted Components.....	35

<b>Figure 3-5.</b> Plastic Quad Flat Pack, PQFP .....	35
<b>Figure 3-6.</b> Peripheral leaded Package vs. Area Array Package .....	36
<b>Figure 3-7.</b> The Pin Grid Array Package (PGA) .....	36
<b>Figure 3-8(a).</b> BGA Package .....	37
<b>Figure 3-8(b).</b> BGA—Typical Bump Diameters And Pitch .....	37
<b>Figure 3-9.</b> Ceramic BGA Configurations .....	38
<b>Figure 3-10.</b> Ceramic BGA, Ceramic Column BGA, Pad BGA .....	38
<b>Figure 3-11.</b> Intel’s Pentium 4 in Plastic BGA .....	39
<b>Figure 3-12.</b> PBGA Configurations with Rigid Laminate .....	39
<b>Figure 3-13.</b> Schematic Flip Chip in Package (FCIP) PBGA .....	40
<b>Figure 3-14.</b> Tape BGA Configurations .....	41
<b>Figure 3-15.</b> CBGA, PBGA, TBGA .....	41
<b>Figure 4-1.</b> BGA vs. CSP .....	47
<b>Figure 4-2.</b> CSP Packages .....	48
<b>Figure 4-3(a).</b> Lead Frame Based CSP (Small Outline No-Leads, SON) .....	49
<b>Figure 4-3(b).</b> Laminate-Based CSP .....	49
<b>Figure 4-3(c).</b> Tape Based CSP .....	50
<b>Figure 4-4.</b> The CSP Loop .....	50
<b>Figure 4-5.</b> Schematic of CSP on Rigid Organic Substrate .....	51
<b>Figure 4-6(a).</b> Embedded CSP .....	51
<b>Figure 4-6(b).</b> Metallurgical Cross-Section Embedded CSP .....	52
<b>Figure 4-7(a).</b> Chip & Wire Bonded $\mu$ BGA™ (Face-Up) .....	52
<b>Figure 4-7(b).</b> The $\mu$ BGA™ Tape Lead Bonded Face-Down .....	53
<b>Figure 4-8.</b> $\mu$ BGA™ “Interposer” Tape Format and a Singulated CSP .....	53
<b>Figure 4-9.</b> $\mu$ BGA™ Lead Bonding Assembly Process .....	54
<b>Figure 4-10.</b> $\mu$ BGA™ Lead Bonding Die Attach .....	54
<b>Figure 4-11.</b> $\mu$ BGA™ Structured Compliancy .....	55
<b>Figure 4-12.</b> The UltraCSP® Process .....	56
<b>Figure 4-13.</b> WL-CSP .....	56
<b>Figure 4-14.</b> The ShellCase CSP .....	57
<b>Figure 4-15.</b> Flip Chip International’s <i>UltraCSP</i> ® with Polymer Collar .....	58
<b>Figure 5-1.</b> Multichip vs. Single Chip Packaging .....	61
<b>Figure 5-2.</b> Hybrid Circuit with Transistors and Diodes (Circa 1960s) .....	63
<b>Figure 5-3.</b> Multiple ICs on Multilevel Thick Film Conductor Pattern (Circa early 1980s) .....	64
<b>Figure 5-4.</b> RF/Microwave Hybrid Circuit .....	64
<b>Figure 5-5(a).</b> MCM-D (mounted on PWB) .....	65
<b>Figure 5-5(b).</b> MCM-C Coffered Ceramic Package .....	66
<b>Figure 5-5(c).</b> Laminate MCM-L in Molded BGA Package. Top—Molded Package; Left—Wire Bonded ICs; Right—Bottom of Package .....	66
<b>Figure 5-6.</b> Earliest 3-D Packaging: The RCA Micromodule .....	67
<b>Figure 5-7.</b> 3-D IC Stacking Options .....	68
<b>Figure 5-8.</b> Stacked TSOPs .....	68
<b>Figure 5-9.</b> (a) Schematic 3-D Memory Cube; (b) TI’s 3-D Memory Cube .....	69
<b>Figure 5-10(a).</b> Wire Bonded Stacked Die .....	69

<b>Figure 5-10(b).</b> 2 Die Stack Flip Chip/Wire Bonded.....	70
<b>Figure 5-11.</b> A 2 Die Stacking/Package Process Flow .....	70
<b>Figure 5-12.</b> 3 Die Stack .....	71
<b>Figure 5-13.</b> SEM of a 4 Stacked Die Assembly with 2 Spacers.....	71
<b>Figure 5-14.</b> Various Stacked Die Configurations.....	72
<b>Figure 5-15.</b> Folded Flex: Hearing Aid Application.....	72
<b>Figure 5-16.</b> Folded Flex Stacked Packages.....	73
<b>Figure 5-17(a).</b> Flex inner layers with Packaged and Unpackaged Components .....	73
<b>Figure 5-17(b).</b> Finished Cube Showing Inner Layer Interconnections .....	73
<b>Figure 5-18.</b> (a) Single Chip Neo-Stack™ inner layer; (b) Multichip Inner Layer.....	74
<b>Figure 5-18(c).</b> 19-Layer Smart Flash Stack including Two Neo-Stack™ Layers .....	74
<b>Figure 5-19(a).</b> Vertical Integration Silicon Through-Via Die-to-Die Stacking Process.....	76
<b>Figure 5-19(b).</b> Cu filled Silicon Through Vias .....	76
<b>Figure 5-20.</b> Schematic Cross-Section of Vertically Interconnected Stacked Die .....	77
<b>Figure 5-21.</b> MCM vs. SiP vs. SoP.....	78
<b>Figure 5-22.</b> Cost/Benefits SiP/SoP vs. SoC.....	79
<b>Figure 6-1.</b> (a) IC Wafer on Film Frame; (b) Wafer Sawing.....	82
<b>Figure 6-2.</b> Waffle Pack, Gel-Pak®, Tape, Film Frame .....	82
<b>Figure 6-3.</b> IC Plastic Encapsulated Package Process .....	83
<b>Figure 6-4.</b> MCP Assembly/Test Process Flow .....	84
<b>Figure 6-5.</b> Multichip Assembly/Electrical Yield vs. Electrical Yield of Die .....	85
<b>Figure 6-6.</b> The DiePak Die Carrier.....	87
<b>Figure 6-7.</b> Die Flow for Package Device and KGD Die in Temporary Carrier.....	88
<b>Figure 6-8.</b> KGD Testing—Options 2, 3, 4.....	89
<b>Figure 6-9.</b> Cost/Reliability Tradeoffs .....	90
<b>Figure 6-10.</b> Wafer Level Burn-in and Test.....	91
<b>Figure 7-1.</b> (left) Chip on Board Assembly; (right) MCM-L.....	93
<b>Figure 7-2.</b> SMT/COB Assembly .....	94
<b>Figure 7-3(a).</b> COB Assembly: Die Attach, Wire Bonding, Encapsulation (Glob Top).....	95
<b>Figure 7-3.</b> (b) Wedge Bonding on PWB; (c) Ball Bonding on PWB.....	95
<b>Figure 7-4.</b> Assemblies Before and After Glob Top Encapsulation.....	96
<b>Figure 7-5.</b> SMT/COB Process Flow.....	98
<b>Figure 7-6.</b> Flip Chip/SMT Assembly Process .....	99
<b>Figure 7-7.</b> SMT/Flip Chip On Board, FCOB .....	99
<b>Figure 7-8.</b> Comparing QFP, TAB, COB, Flip Chip Footprint on PWB.....	100
<b>Figure 8-1.</b> Classic Wedge Wire Bond .....	103
<b>Figure 8-2.</b> Classic Wire Ball Bond.....	105
<b>Figure 8-3.</b> IC Assembly Process for PEMs .....	106
<b>Figure 8-4.</b> Al Wire Bonding on Power Hybrid.....	108

<b>Figure 8-5.</b> Metallurgical Cross Sections of Au and Cu Ball Bonds on Al with Data on Growth Rates at Elevated Temperatures .....	109
<b>Figure 8-6.</b> Bonding Tools—Capillary and Wedge Bonding Tools .....	110
<b>Figure 8-7.</b> SEM Au Ball Bond and Al Wedge Bond .....	111
<b>Figure 8-8.</b> The Ball Bonding Process .....	112
<b>Figure 8-9.</b> The Wedge Bonding Process .....	113
<b>Figure 8-10.</b> SEM—Thick Film and EDAX Analysis .....	116
<b>Figure 8-11.</b> Wire Bonding on Screen Printed Thick Film .....	116
<b>Figure 8-12.</b> Schematic Ball Shear (left) and Wire Pull Testing (right) .....	118
<b>Figure 8-13.</b> Wire Bonding Failure Modes/Sites .....	120
<b>Figure 8-14(a).</b> Two and Three Staggered Row I/O Pad Configurations .....	121
<b>Figure 8-14(b).</b> 3 Staggered Rows of Bond Pads .....	122
<b>Figure 8-15.</b> Capillary Re-Design for Fine Pitch Applications .....	122
<b>Figure 8-16.</b> Fine Pitch Ball Bonding .....	123
<b>Figure 8-17.</b> PBGA Showing Fan Out of Package Pads and Long Loop Wire Bonds .....	123
<b>Figure 8-18.</b> No Sweep Encapsulant .....	124
<b>Figure 8-19.</b> High Density Fine Pitch Wire Bonding with Insulated Wires .....	124
<b>Figure 8-20.</b> Wire Bonding Responding to Changing Packaging Technologies .....	125
<b>Figure 8-21.</b> Bond Pad “Cupping” on “Soft” Substrate .....	127
<b>Figure 9-1.</b> Schematic of a Single Frame TAB Assembly .....	130
<b>Figure 9-2.</b> Microprocessor IC TAB Tape—35mm Tape .....	131
<b>Figure 9-3.</b> Close-up of TAB Tape (70 mm) for Very High I/O Count IC .....	131
<b>Figure 9-4.</b> Types of TAB Tapes .....	132
<b>Figure 9-5.</b> Tape Layout with Annular Ring .....	133
<b>Figure 9-6.</b> Excised TAB Assembly in Carrier for Testing .....	133
<b>Figure 9-7(a).</b> Schematic Bumped Die TAB .....	134
<b>Figure 9-7(b).</b> Bumped Tape TAB .....	135
<b>Figure 9-7(c).</b> TAB Lead on Al Pad .....	135
<b>Figure 9-8.</b> TAB Inner Lead Bonding Process .....	136
<b>Figure 9-9.</b> TAB Package/Substrate Attachment Options .....	137
<b>Figure 9-10.</b> Face Up and Flip TAB Bonding .....	137
<b>Figure 9-11.</b> TAB Failure Sites .....	138
<b>Figure 9-12.</b> Microprocessor Module (~5"x5") with all TAB Device Assembly ...	140
<b>Figure 10-1.</b> (a) IBM’s Flip Chip Transistor; (b) Multichip Transistor Assembly .....	144
<b>Figure 10-2.</b> IC with Bumps Directly on Bond Pads .....	144
<b>Figure 10-3.</b> IC I/O Pad Formats: (L to R) Dual Row Peripheral, Peripheral + Partial, Area Array .....	145
<b>Figure 10-4(a).</b> Direct Bump on Pad .....	145
<b>Figure 10-4(b).</b> Schematic Redistribution Layer (RDL) .....	146
<b>Figure 10-4(c).</b> Schematic of Relocated Pad and Bump .....	146
<b>Figure 10-4(d).</b> SDRAM Flip Chip with Redistributed Bond Pads .....	146
<b>Figure 10-5(a).</b> Al Pad as Received .....	150

<b>Figure 10-5(b).</b> Al Pad after Electroless Ni/Immersion Au Plating (5 microns thick).....	150
<b>Figure 10-6.</b> Ball Placement by Vacuum Process.....	151
<b>Figure 10-7(a).</b> The Evaporation Bumping Process (C-4).....	152
<b>Figure 10-7(b).</b> Schematic of C-4 Evaporated Bump Before and After Reflow.....	153
<b>Figure 10-7(c).</b> Solder Dammed Substrate Pad (C-4).....	153
<b>Figure 10-8.</b> The Electroplated Solder Bumping Process.....	154
<b>Figure 10-9.</b> Schematic Cross-section of Bump Site Pre-Plating and AS-Plated Bump.....	155
<b>Figure 10-10.</b> SEM Electroplated Cu Bumps.....	155
<b>Figure 10-11.</b> Electroplated Au Bumps.....	156
<b>Figure 10-12(a).</b> Wafer Bumping Process Using Stencil Printing.....	157
<b>Figure 10-12(b).</b> Bumping by Stencil Printing.....	157
<b>Figure 10-13(a).</b> C4NP Mold with Cavities Corresponding to Bump Locations....	158
<b>Figure 10-13(b).</b> Molten Solder Filling of Mold Cavities.....	158
<b>Figure 10-13(c).</b> Molten Solder Bump Transfer to Wafer.....	158
<b>Figure 10-14.</b> Continuous Mode Solder Jet Technology.....	159
<b>Figure 10-15.</b> (a) Schematic Cross-section of NiAu Bump; (b) 20 $\mu$ m Ni-Au Bump.....	160
<b>Figure 10-16.</b> Stencil Printed Conductive Epoxy Bump (75 $\mu$ m).....	162
<b>Figure 10-17.</b> Elastomeric Bumps.....	163
<b>Figure 10-18.</b> Au Stud Bumps as Bonded and After Coining.....	164
<b>Figure 10-19.</b> Coined Stud Bumps As Bonded.....	164
<b>Figure 10-20.</b> Stacked and Area Array Stud Bumps.....	165
<b>Figure 11-1.</b> (right) Manual Flip Chip Aligner Bonder; (left) Schematic of Bi-directional Viewing of Die and Package/Substrate Footprint.....	169
<b>Figure 11-2.</b> Solder Reflow Options.....	171
<b>Figure 11-3.</b> Flip Chip Solder Reflow Process.....	172
<b>Figure 11-4.</b> Solder Reflow and Self-Alignment.....	172
<b>Figure 11-5.</b> SMT/Flip Chip Assembly.....	173
<b>Figure 11-6(a).</b> Schematic of a FCOB Solder Joint Fatigue Failure.....	174
<b>Figure 11-6(b).</b> Metallurgical Cross-Section of Solder Fatigue Cracking in Eutectic SnPb.....	175
<b>Figure 11-7.</b> CTE Values for Various Microelectronic Packaging Materials.....	175
<b>Figure 11-8.</b> Flip Chip Assembly on Organic Substrate (FCOB).....	176
<b>Figure 11-9.</b> Fatigue Life vs. Substrate CTE; TC/ 0–100°C.....	177
<b>Figure 11-10.</b> Flip Chip with Underfill.....	178
<b>Figure 11-11.</b> (a) Distance From Neutral Point (DNP); (b) Von-Mises Strain at Each Bump Location with/without Underfill (IBM).....	178
<b>Figure 11-12.</b> Micro Moire Pattern Analysis of FCOB With/Without Underfill....	179
<b>Figure 11-13.</b> (a) Underfill Dispensing and Capillary Flow; (b) No Flow Underfill; (c) Wafer Level Underfill Process.....	180
<b>Figure 11-14.</b> Flip Chip Isotropic Adhesive Attachment.....	185
<b>Figure 11-15.</b> (a) Stencil Printed Epoxy; (b) Epoxy Dipped Stud Bump; (c) Cross-section Isotropic Epoxy Attached.....	186
<b>Figure 11-16.</b> Anisotropic Conductive Adhesive Attach.....	186

<b>Figure 11-17.</b> Non-conductive Adhesive FC Bonding Contact Resistance vs. Applied Force .....	187
<b>Figure 11-18.</b> Conductive Polymer Bumps and Attachment .....	189
<b>Figure 12-1.</b> Thin Film Cleanroom.....	194
<b>Figure 12-2.</b> Subtractive Etch and Selective Plate Up Patterning Processes .....	195
<b>Figure 12-3.</b> Thin Film Process for WL-CSP (Ultra CSP®) .....	196
<b>Figure 12-4.</b> Dry Film Lamination and Patterning.....	198
<b>Figure 12-5.</b> (Left) Dry Film Applied Over Previously Patterned Structure; (Right) Substrate Vias or Holes.....	198
<b>Figure 12-6.</b> Electrodeposited Resist: Patterned for Selective Plate-up of 25um Lines Over Previously Patterned 45um Thick 100um Wide Feature .....	199
<b>Figure 12-7.</b> Subtractive Etch Process; The “Etch Factor” .....	202
<b>Figure 12-8.</b> Planarization of a Deposited Dielectric .....	205
<b>Figure 12-9.</b> Photodefiable vs. Photosensitive (+/-) Via Patterning .....	206
<b>Figure 12-10.</b> Achievable Via Diameters Using Laser and Photo-Patterning .....	207
<b>Figure 12-11.</b> Metallurgical Cross-Section Thin Film Multilayer Interconnect on Ceramic Substrate.....	208
<b>Figure 12-12.</b> Thin Film Interconnects on Co-fired Ceramic Substrate.....	209
<b>Figure 12-13.</b> Thin Film Multilayer Interconnect on PWB (MCM-L/D) .....	209
<b>Figure 12-14.</b> Si Substrate Supporting Multilevel Thin Film Interconnect for MCM .....	210
<b>Figure 12-15.</b> Schematic Cross-Section of a Si Substrate with Embedded Active and Passive Devices.....	211
<b>Figure 12-16.</b> DRAM Chips Flip Chip Assembled on Electrically Tested ASICs .....	211
<b>Figure 12-17.</b> GE HDI “Chips First” MCM .....	212
<b>Figure 12-18.</b> The “Chips First” (GE HDI) MCM Process Flow .....	213
<b>Figure 12-19.</b> GE HDI MCM and SMT Printed Circuit Board Assembly.....	213
<b>Figure 12-20.</b> The Low Cost GE HDI or Embedded Chip Build Up (ECBU) Process.....	214
<b>Figure 12-21(a).</b> An ECBU MCM with Embedded Active and Passives.....	215
<b>Figure 12-21(b).</b> An ECBU MCM with Embedded Actives and Passives and Package Devices and Discrete Passives Mounted on Top Layer.....	215
<b>Figure 12-22.</b> The Intel BBUL Process for Microprocessors .....	216
<b>Figure 12-23.</b> Intel’s Current Microprocessor Package and the BBUL .....	217
<b>Figure 12-24.</b> Intel’s Multichip BBUL .....	217
<b>Figure 12-25.</b> Substrate Size/Yield and Defect Density .....	219
<b>Figure 13-1.</b> The Multilayer Thick Film Process Sequence.....	222
<b>Figure 13-2(a).</b> Photo-Patterned Emulsion (2 mils l/s) on 360 SS Mesh.....	224
<b>Figure 13-2(b).</b> Fully Patterned Screen .....	225
<b>Figure 13-3.</b> Screen Printing Process.....	225
<b>Figure 13-4.</b> Manual Screen Printer.....	226
<b>Figure 13-5.</b> Thick Film Printing Variables Requiring Monitoring.....	226
<b>Figure 13-6.</b> Automatic Thick Film Screen Printer .....	227
<b>Figure 13-7.</b> Screen Printed Thick Film Au Conductor trace .....	228

<b>Figure 13-8(a).</b> Thick Film Multilayer Interconnect Board (MIB).....	228
<b>Figure 13-8(b).</b> Cofired Ceramic MIBs Populated with Ceramic Chip Carrier Packages .....	229
<b>Figure 13-9.</b> Diffusion Patterning™ Process .....	230
<b>Figure 13-10.</b> Dupont Fodel® Photosensitive Thick Film Paste Processing .....	231
<b>Figure 13-11(a).</b> Photo-Patterned 50 um Via in Thick Film Dielectric .....	231
<b>Figure 13-11(b).</b> Photo-Patterned Thick Film Au Conductor Traces; Left: 28 um lines, 22 um spaces; Right: 50 um lines, 4.5 um thick .....	232
<b>Figure 14-1.</b> Patent on Cofired Ceramic Manufacture Issued to Harold W. Stetson, RCA .....	233
<b>Figure 14-2(a).</b> IBM Thermal Conduction Module (TCM).....	234
<b>Figure 14-2(b).</b> Cross-Section of TCM Ceramic Substrate Interconnect .....	235
<b>Figure 14-3(a).</b> Next Generation TCM .....	235
<b>Figure 14-3(b).</b> A Cofired Ceramic Package with Thin Film Signal Layers and Top Layer Metallization .....	236
<b>Figure 14-4.</b> Unfired (“Green”) Ceramic Tape .....	236
<b>Figure 14-5.</b> Cofired Ceramic Optional Instruction Features (LTCC).....	237
<b>Figure 14-6.</b> The Cofired Ceramic Tape Process.....	238
<b>Figure 14-7(a).</b> HTCC Hermetic Single and Multichip Packages .....	239
<b>Figure 14-7(b).</b> HTCC Multilayer Interconnect Board with Select Areas for Hermetic Sealing .....	239
<b>Figure 14-8.</b> LTCC Multichip Packages .....	240
<b>Figure 14-9.</b> LTCC-M, A Constrained Cofired Ceramic Tape Process.....	242
<b>Figure 14-10.</b> Large Area Panel (7"x 11") Using Heralock™ Self-Constrained LTCC Tape.....	243
<b>Figure 15-1(a).</b> Multilayer PWB with Plated-Through Holes .....	246
<b>Figure 15-1(b).</b> Plated Through-Hole Via .....	246
<b>Figure 15-2.</b> Inner Layer Patterning Process Sequence .....	248
<b>Figure 15-3(a).</b> Schematic Plastic BGA .....	249
<b>Figure 15-3(b).</b> PBGAs in Strip Format and After Epoxy Molding/Singulation... ..	249
<b>Figure 15-4(a).</b> Unpopulated MCM-L Substrate .....	250
<b>Figure 15-4(b).</b> MCM-L—Multichip Module with Laminate Substrate .....	250
<b>Figure 15-5.</b> Through-Hole, Blind, and Buried Vias .....	252
<b>Figure 15-6.</b> Effect of Via Type on Board Size .....	252
<b>Figure 15-7.</b> Methods of Via Generation .....	253
<b>Figure 15-8(a).</b> Schematic IBM’s Surface Laminar Circuit-SLC BGA .....	254
<b>Figure 15-8(b).</b> Cross-section SLC Flip Chip Package .....	254
<b>Figure 15-9.</b> Single Chip SLC/BUT PBGA.....	254
<b>Figure 15-10.</b> Key Feature Dimensions for the HDI PWB.....	255
<b>Figure 15-11.</b> The HDBU and Super HDBU .....	256
<b>Figure 15-12.</b> Cross-section Super-HDBU 2–3–2 PWB.....	256
<b>Figure 15-13.</b> Multilayer and Microvia PWB Projections .....	257
<b>Figure 15-14.</b> Cell Phone Key Features and Component Count .....	257
<b>Figure 15-15.</b> Embedded Discrete Capacitor .....	258
<b>Figure 15-16.</b> Discrete vs. Embedded Planar Decoupling Capacitor.....	259



# List of Tables

<b>Table 1-1.</b> Overall IC Characteristics (ITRS Technology Roadmap (ITRS 2005)) .....	11
<b>Table 1-2.</b> Single Chip Pin Count (ITRS 2005) .....	11
<b>Table 2-1.</b> Cleanroom Classifications [US FED STD 209E Cleanroom Standards] .....	18
<b>Table 2-2.</b> Comparison of Positive and Negative Resists .....	25
<b>Table 5-1.</b> Comparing DIP, SMT, MCP at System Level ( <i>Courtesy Hughes Aircraft</i> ) .....	62
<b>Table 5-2.</b> Advantages of System on Package vs. System On Chip .....	78
<b>Table 7-1.</b> Encapsulants for COB .....	97
<b>Table 7-2.</b> COB vs. FCOB/WLP .....	100
<b>Table 8-1.</b> Eutectic vs. Adhesive Bonding .....	107
<b>Table 8-2.</b> Material Properties of Al, Cu, and Au Wire .....	107
<b>Table 8-3(a).</b> Advantages/Disadvantages of Thermocompression Bonding .....	109
<b>Table 8-3(b).</b> Advantages/Disadvantages of Ultrasonic Bonding .....	109
<b>Table 8-3(c).</b> Advantages/Disadvantages of Thermosonic Bonding .....	110
<b>Table 8-4.</b> Sources of Contamination that Lead to Poor Quality Bonds .....	114
<b>Table 8-5.</b> Metallurgical Compatibility of Wire bonding Materials. ....	115
<b>Table 8-6(a).</b> Au Wire Destructive Pull Test Criteria .....	119
<b>Table 8-6(b).</b> Al Wire Destructive Pull Test Criteria .....	119
<b>Table 9-1.</b> Key Elements of a TAB Assembly .....	130
<b>Table 9-2.</b> Comparing Tape Options .....	133
<b>Table 9-3.</b> Comparison TAB Inner Lead Bonding Techniques .....	138
<b>Table 10-1.</b> Reflow Temperatures for Common Solder Bump Materials .....	147
<b>Table 10-2.</b> Typical Bump Materials and Favored UBM .....	149
<b>Table 10-3.</b> Comparing Wafer Bumping Processes .....	161
<b>Table 11-1.</b> Materials Properties of Some Organic Substrates .....	176
<b>Table 11-2.</b> Lead and Lead-Free Solders Performance on HTS and HTOL Reliability Screening .....	183
<b>Table 11-3.</b> Reliability Screening Tests for Solder Bumped FC/WLP .....	184
<b>Table 12-1.</b> Thin Film Process Capability .....	194
<b>Table 12-2.</b> Typical Properties of Spin on Liquid Resist .....	197
<b>Table 12-3.</b> Dry Film Photoresist Properties .....	197

<b>Table 12-4.</b> Electrodeposited Photoresist Properties.....	199
<b>Table 12-5.</b> Mask Aligner vs. 1X Stepper.....	200
<b>Table 12-6.</b> Conductor Metals .....	203
<b>Table 12-7.</b> Metals and Their Function ( <i>Courtesy Advanced Technical Ceramics</i> ) .....	204
<b>Table 12-8.</b> Material Properties for Polyimide and BCB .....	205
<b>Table 12-9.</b> Thermal Properties of Select Inorganic Materials .....	208
<b>Table 12-10.</b> Patterning Requirements for Various Package/Substrate Interconnects .....	219
<b>Table 13-1.</b> Most Common Thick Film Formulations .....	223
<b>Table 14-1.</b> Cofired Ceramic Materials and Properties.....	240
<b>Table 14-2.</b> Advantages/Disadvantages Thick Film, HTCC, LTCC.....	241
<b>Table 15-1.</b> Typical Electrical Properties of Some Laminate Materials .....	247
<b>Table 15-2.</b> Typical Thermal Properties of Some Laminate Materials .....	247

# Preface

The integrated circuit with each new generation has been characterized by increasing functionality. In the 1980's Very Large Scale Integrated Circuits (VLSIC) began to emerge with transistor counts approaching one million plus per chip! The IC package quickly became more than a "chip carrier". Now the packaging had to address the electrical, mechanical and thermal requirements of the IC, and had to do so cost-effectively. A package costing more than the chip was not an option. In addition, the demands of the marketplace for product that was "smaller, better and cheaper" came into play.

As a result the late '80s saw paradigm shifts in IC packages and packaging options. Area array packages, in particular, the Ball Grid Array (BGA) began to emerge that more effectively addressed increasing chip I/O count. Ceramic packaging for high performance circuits (microprocessors digital signal processors) gave way to organic based packages, the plastic BGA (PBGA), offering a more favorable solution to package cost. And the hybrid circuit suddenly became a multichip module!

Over the past 15 years the author has developed and presented professional development courses at various technical symposia as well as on-site at semiconductor, component and equipment manufacturers and materials suppliers facilities. The courses have covered topics that make up the electronic manufacturing arena focusing on packaging and assembly of the integrated circuit.

This book evolved from these courses and discusses the many changes that have taken place not only with the physical package itself but also the currently available packaging options and assembly technologies. It is intended to serve as an *introduction* to IC packaging and assembly providing sufficient coverage to afford a working knowledge of the basic concepts and technologies. The book is intended for personnel new to the industry and, those indirectly involved in electronics manufacturing such as upper management, quality assurance, procurement, marketing and sales, and equipment manufacturers and material suppliers. For those directly involved the book can serve as a useful *overview* of new and emerging technologies.

The First Chapter is discussion of electronic manufacturing that basically describes the packaging and assembly of the integrated circuit. It identifies the various levels of microelectronic assembly, i.e., Level 1.0 interconnects – chip to package and Level 2.0 – chip or package to a substrate board and the packaging options, – single chip, multichip and chip on board.

The Second Chapter briefly reviews the integrated circuit manufacturing process and the *applicability* of much of the procedures and practices to IC packaging and assembly. It highlights the significance of a cleanroom operating environment and the photolithographic process in particular, as a model for implementing a proven high yield cost effective manufacturing technology.

Subsequent Chapters 3 and 4, discuss the trends in the IC package, the Chip Scale Package, and Wafer Level Packaging. Chapter 5 covers Multichip Packaging and the various sub-classifications – the hybrid circuit, the multichip module, System

in Package, System on Packaging and the rapidly developing 3-D Packaging that includes stacking of both multiple die and packages.

Working with bare die as opposed to package devices is discussed in Chapter 6 and covers the subject of Known Good Die or KGD. It presents the concerns associated with bare die and multichip applications and the problem related to the lack of sufficient electrical testing of unpackaged die to insure the device meeting full electrical specifications. Various approaches to resolving this problem and providing for Known Good Die are discussed.

The assembly of a bare die onto an organic board, Chip on Board (COB) is covered in Chapter 7. Implementation and incorporation into Surface Mount Assembly lines and concerns are included. A “packageless packaging” approach makes it a viable packaging option offering both increased component density and an enhanced reliability at the Level 2.0 printed circuit board (PCB) assembly.

The Level 1.0 interconnect technologies are covered in subsequent chapters, C&W Assembly in Chapter 8, TAB in Chapter 9, and Flip Chip Bumping and Assembly, Chapter 10 and 11 respectively.

The last four chapters, 12 through 15, cover the manufacturing technologies, namely Thin Film, Thick Film, Cofired Ceramic and the Organic Laminate Technology, for packages – SCP and MCP, and High Density Interconnect (HDI) substrates. The Thin Film process technology is highlighted as the leading technology in meeting the challenges that arise with the packaging and assembly of current and future integrated circuits. It basically emulates the IC manufacturing and therefore has the inherent capability for achieving very fine line conductor circuitry and the high wiring density required for high density interconnects supporting Levels 1.0 and 2.0. The application of the Thin Film Technology to Thick Film, Cofired and Laminate, to further enhance the overall advantages of each is also discussed. Chapter 15 presents a discussion of a combined Thin Film and Laminate process (Build Up Technology, BUT) as a key enabler for Level 2.0 interconnect substrates that adequately accommodates all current and future IC packaging and assembly technologies.

# Acknowledgements

I was fortunate in having spent my early years in the electronics industry at RCA working on materials and process development supporting the early manufacture of both the transistor and the integrated circuit that followed. I am indebted to my mentor during those early years, the late Arnold Rose, who guided me and provided me the opportunity to become deeply involved in the many process technologies that are still part of IC manufacturing.

Over the years that followed there were many individuals who help expand my areas of expertise and made it possible for me to write this book. There were and are many and to attempt to recognize everyone would be nearly impossible and would add many pages to this book. And I am certain I would be missing many as well. They come from all areas of industry and include: component manufacturers, equipment manufacturers and material suppliers, manufacturer reps and of course, my colleagues in consulting.

There are several however that I must acknowledge since they were particularly helpful in bring this book to fruition. In particular I am extremely thankful to Richard Brown, an industry consultant, author, instructor of professional development courses who provided invaluable insight. I am most grateful for the many discussions, his suggestions and critiques he provided that were so helpful.

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## About the Author

A graduate of Fordham University with a BS in Physics Bill has had extensive experience in Microelectronics covering semiconductor processing and assembly, hybrid circuits, and PWB fabrication and assembly. He began his career with RCA Semiconductor Division and subsequently worked for General Electric and Lockheed Electronics. While at RCA he was awarded six U.S. patents covering wafer processing and semiconductor assembly. At General Electric he was a staff engineer and consultant for hybrid circuits and PWB manufacturing.

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