Performance Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Boards

Developed by the Plating Processes Subcommittee (4-14) of the Fabrication Processes Committee (4-10) of IPC

Supersedes:
IPC-4552 with Amendments 1 & 2 – December 2012
IPC-4552 – October 2002

Users of this publication are encouraged to participate in the development of future revisions.

Contact:
IPC
Table of Contents

1 SCOPE ................................................................. 1
1.1 Statement of Scope ............................................. 1
1.1.1 Feature Size for Thickness Measurement ............ 1
1.2 Description ....................................................... 1
1.2.1 Electroless Nickel Reducing Agents – Phosphorus Content ........................................... 1
1.3 Objective ............................................................. 1
1.3.1 Order of Precedence ........................................... 2
1.3.1.1 Appendices .................................................... 2

2 APPLICABLE DOCUMENTS ........................................ 2
2.1 IPC ...................................................................... 2
2.2 ASTM International (ASTM) .............................. 2
2.3 JEDEC ................................................................ 2
2.4 Defense Standardization Program ....................... 2
2.5 Telcordia Technologies, Inc. ............................... 3
2.6 International Organization for Standardization (ISO) ........................................... 3
2.7 Terms, Definitions and Acronyms ......................... 3
2.7.1 Metal Turnover (MTO) ....................................... 3
2.7.2 Hyperactive Corrosion Deposit ......................... 3
2.7.3 Selective Annular Ring Dewetting (SAD) ............ 3

3 REQUIREMENTS OF ENIG DEPOSIT ................... 4
3.1 Printed Board Fabrication Supplier Process Requirements ........................................... 5
3.1.1 General Plating Line Requirements .................... 5
3.1.1.1 ENIG Deposit Thickness Measurement ............ 5
3.1.1.2 Gauge Capability – Gauge R&R Type 1 Study ... 5
3.1.1.3 Collimator Size and Measurement Times ........ 10
3.1.1.4 Guard Bands and Lot Conformance Testing .............. 10
3.1.2 ENIG XRF Calibration Standards .................... 10
3.1.3 XRF Zero Offset Acceptability ......................... 10
3.1.4 Process Qualification Measurement Requirements ........................................... 11
3.1.5 Measuring Phosphorus Content in an ENIG Deposit ........................................... 12
3.1.5.1 Measurement of % Phosphorous (P) Content in Electroless Nickel (EN) Layers with Energy Dispersive X-Ray Spectroscopy (EDS) ......................... 12
3.1.5.2 Measurement of % Phosphorous (P) Content in Electroless Nickel (EN) Layers with Energy Dispersive X-Ray Fluorescence (EDXRF) .................... 13
3.1.5.2.1 Instrument Calibration for Phosphorus Content ........................................... 13
3.1.6 Gold Stripping of Plated Deposits for Evaluation of Hyper-Corrosion ......................... 13
3.1.6.1 Recognized Methods for Gold Stripping ............. 14
3.1.6.1.1 Chemical Stripping Solution Dwell Times and Process Steps ......................... 14
3.1.6.1.2 Evaluation Using SEM ................................... 14
3.1.6.1.3 Grain Boundary Enhancement vs. Hyper-Corrosion ................................... 14
3.1.6.1.4 Verification of Hyper-Corrosion ............... 14
3.1.6.1.5 Modifications to the Base Structure of the Deposits More Than the Minimum Thickness Limit ........................................... 20
3.1.6.1.6 Modifications to the Base Structure of the Deposits Less Than the Minimum Thickness Limit ........................................... 20
3.1.6.2 Deposits Less Than the Minimum Thickness Limit ........................................... 20
3.1.7.4 Electroless Nickel for Flexible Circuits ............ 20
3.1.7.5 Modifications to the Base Structure of the Electroless Nickel Deposits with Flexible Circuits ........................................... 20
3.1.7.14 Electroless Nickel for Flexible Circuits ............ 20
3.1.7.1.5 Modifications to the Base Structure of the Electroless Nickel Deposits with Flexible Circuits ........................................... 20
3.1.7.2 Immersion Gold Thickness ................................ 21
3.1.7.2.1 ENIG – Category B Coating Durability per IPC J-STD-003 ........................................... 21
3.1.7.3 Connectors ....................................................... 17
3.1.7.3.1 Soft Membrane Switches ............................ 17
3.1.7.3.2 Metallic Dome Contacts ............................... 17
3.1.7.4 EMI Shielding .................................................. 17
3.1.7.5 Conductive and/or Anisotropic Adhesive Interface (Replacement for Solder) .............. 17
3.1.7.6 Connectors ....................................................... 17
3.1.7.6.1 Press Fit Connectors .................................... 17
3.1.7.6.2 Edge Tab ..................................................... 17
3.1.7.6.3 Contact Surface .......................................... 17
3.1.7.7 Limitations of ENIG ........................................... 17
3.1.7.7.1 Creep Corrosion/Chemical Resistance .......... 17
3.1.7.7.2 High Frequency Signal Loss ......................... 18
3.1.7.8 Visual ............................................................. 18
3.1.7.9 Selective Annular Ring Dewetting (SAD) ............ 19
3.1.7.9.1 ENIG – Category B Coating Durability per IPC J-STD-003 ........................................... 21

3.2 Performance Functions ........................................ 16
3.2.1 Shelf Life ......................................................... 16
3.2.1.1 Solderability .................................................... 16
3.2.1.2 Gold Embrittlement ......................................... 16
3.2.2 Aluminum and Copper Wire (Wedge) Bonding ........................................... 17
3.2.2.1 Gold Wire Bonding ......................................... 17
3.2.2.2 Contact Surface .............................................. 17
3.2.2.3 Soft Membrane Switches ............................... 17
3.2.2.4 Metallic Dome Contacts ................................. 17
3.2.5.4 EMI Shielding .................................................. 17
3.2.5 Conductive and/or Anisotropic Adhesive Interface (Replacement for Solder) .............. 17
3.2.5.6 Connectors ....................................................... 17
3.2.6 Electroless Nickel for Rigid Printed Boards ..................... 20
3.2.6.1 Deposits More Than the Upper Limit .............. 20
3.2.6.2 Deposits Less Than the Minimum Thickness Limit ........................................... 20
3.2.6.3 Electroless Nickel for Flexible Circuits ............ 20
3.2.6.4 Modifications to the Base Structure of the Electroless Nickel Deposits with Flexible Circuits ........................................... 20
3.2.6.5 Immersion Gold Thickness ................................ 21
3.2.6.6 ENIG – Category B Coating Durability per IPC J-STD-003 ........................................... 21

3.3 Shelf Life ............................................................. 16
3.3.1 Solderability ...................................................... 16
3.3.2 Gold Embrittlement ........................................... 16
3.3.3 Aluminum and Copper Wire (Wedge) Bonding ........................................... 17
3.3.4 Contact Surface ................................................. 17
3.3.5 Soft Membrane Switches .................................... 17
3.3.6 Metallic Dome Contacts ..................................... 17

3.4 Selective Annular Ring Dewetting (SAD) ............ 19
3.5 Electroless Nickel Thickness ................................... 20
3.5.1 Electroless Nickel for Rigid Printed Boards ..................... 20
3.5.1.1 Deposits More Than the Upper Limit .............. 20
3.5.1.2 Deposits Less Than the Minimum Thickness Limit ........................................... 20
3.5.1.3 Electroless Nickel for Flexible Circuits ............ 20
3.5.1.4 Modifications to the Base Structure of the Electroless Nickel Deposits with Flexible Circuits ........................................... 20
3.5.1.5 Immersion Gold Thickness ................................ 21
3.5.1.6 ENIG – Category B Coating Durability per IPC J-STD-003 ........................................... 21
4 QUALITY ASSURANCE PROVISIONS

4.1 General Quality Assurance Provisions

4.1.1 Qualification Recommendations

4.1.2 Sample Test Coupons

4.2 Quality Conformance Testing

4.2.1 Frequency of Thickness Measurements

4.2.2 Established Qualified Process

APPENDIX 1 Terms and Definitions Not Currently in IPC-T-50

APPENDIX 2 ENIG Process Sequence

APPENDIX 3 XRF Thickness Measurements of Thin Au (ENIG): Recommendations for Instrumentation (Detectors) and Their Limitations

APPENDIX 4 ENIG PWB Surface Finish Wetting Balance Testing

APPENDIX 5 IPC 4-14 SC ENIG Round Robin Solder Spread Testing

APPENDIX 6 Wire Bonding to ENIG

APPENDIX 7 Through Hole Solderability Testing

APPENDIX 8 Evaluation of Electroless Nickel Corrosion Due to Immersion Gold Plating, Using 3000X Magnification After Gold Stripping

APPENDIX 9-A Cyanide Gold Stripping for ENIG

APPENDIX 9-B Test Method for Potassium Iodide/Iodine (Non-Cyanide) ENIG Gold Stripping Procedure

APPENDIX 9-C Method for Stripping Gold Plating from ENIG Finished PCBs by Broad Beam Argon Ion Milling

APPENDIX 10 Determination of Thickness and Phosphorus Content In Electroless Nickel (EN) Layers X-Ray Fluorescence (XRF) Spectrometry [IPC-TM-650, Method 2.3.44]

APPENDIX 11 Phosphorus Content Measurement in ENIG Using Electron Dispersive Spectroscopy EDS – Initial Testing

APPENDIX 12 Standard Developments Efforts of Electroless Nickel Immersion Gold

APPENDIX 13 Using Guard Bands or a Gauge Correction Factor to Accommodate Type 1 Gauge Study Measurement Uncertainty

Figures

Figure A Example of Repeat Measurement Data from Three Different XRF Tools

Figure B Graphical and Statistical Evaluation of Data from XRF Tool # 1

Figure C Graphical and Statistical Evaluation of Data from XRF Tool # 2

Figure D Graphical and Statistical Evaluation of Data from XRF Tool # 3

Figure 3-1 Potassium Iodide/Iodine (K_I / I_2) at 15 sec. dwell (left) vs. 60 sec. dwell (right)
Figure 3-2  Cyanide-Based Stripping at 15 sec. dwell (left) vs. 60 sec. dwell (right) .......................... 15
Figure 3-3  Cyanide Stripping (left) vs. KI/I₂ Stripping (right) Using Focused Ion Beam (FIB) ........ 15
Figure 3-4  25,000X FIB Images – Cyanide (left) vs. KI / I₂ (right) – Same Dwell Time ................. 15
Figure 3-5  Ion Mill Stripping of Defect-Free Nickel (left) vs. Hyper-Corroded Nickel (right) .......... 16
Figure 3-6  Uniform Plating ........................................... 18
Figure 3-7  Extraneous Plating or Nickel Foot .............. 18
Figure 3-8  Skip Plating (No Ni plating) ....................... 18
Figure 3-9  Edge Pull Back .............................................. 19
Figure 3-10 Example of SAD (Selective Annular ring Dewetting) .................................................. 20
Figure 3-11 Another Example of the SAD Defect .......... 20
Figure 3-12 Selective Annular Ring Dewetting Defect .... 20
Figure 3-13 Grain Structure of Conventional Nickel Deposit ......................................................... 21
Figure 3-14 Grain Structure of Nickel Deposit Modified for Dynamic Flex Applications .................. 21
Figure 3-15 Example of Fracture in Conventional Nickel Deposit ................................................. 21
Figure 3-16 Modified Nickel Deposit of Cycles Showing No Fracture with Same Number ............... 21
Figure 3-17 Defect Free ENIG Deposit – Knee of Hole ... 25
Figure 3-18 Defect Free ENIG Deposit – SMT Feature ... 25
Figure 3-19 Level 1 Hyper-Corrosion – SMT Feature .... 25
Figure 3-20 Level 1 Hyper-Corrosion – Knee of Hole .... 25
Figure 3-21 Level 2 Hyper-Corrosion – Knee of Hole ..... 25
Figure 3-22 Level 2 Hyper-Corrosion – SMT Feature .... 25
Figure 3-23 Level 3 Hyper-Corrosion – Knee of Hole ..... 26
Figure 3-24 Level 3 Hyper-Corrosion – SMT Feature ..... 26
Figure 3-25 Example of a Crack in the Nickel Deposit ... 26
Figure 3-26 Decision Tree to Assist in Setting Rating Level of Hyper-Corrosion .......................... 27
Figure 3-27 Example of an Acceptable Contiguous IMC Layer 1000X ........................................... 28
Figure 3-28 Example of a Rejectable Non-Contiguous IMC Layer 1000X ....................................... 28
Figure 3-29 Example – Rejectable with Little-to-No IMC Formation 1000X .................................... 28
Figure 3-30 Example – Rejectable with Little-to-No IMC Formation 1000X .................................... 28
Figure 3-31 Standard IPC Force Measurement Coupon . 29
Figure A4-1 Example of the Wetting Balance Coupon Used for the Testing of ENIG ...................... 38
Figure A4-2 Box Plot of the 1 µin Samples From All Suppliers ...................................................... 39
Figure A4-3 Box Plot of the 1.5 µin Samples From All Suppliers ..................................................... 39
Figure A4-4 Box Plot of the 2.0 µin Samples From All Suppliers ..................................................... 40
Figure A4-5 The Metronolec ST88 Wetting Balance Used for the Testing ................................. 40
Figure A4-6 Example of Excellent and Consistent Wetting From Sample Group # 4 Tested as Received with SAC305 and Test Flux # 2 (this is a 1.6 µm at - 4 cm Au thickness sample) .............. 41
Figure A4-7 Wetting Curves From Sample # 8 Tested as Received Showing Again Excellent Wetting Consistency Intra Group (this is one of the control thickness samples) ...................... 41
Figure A4-8 Example of Some Very Inconsistent Wetting Seen with Sample Group 11, Again Tested As Received with No Stressing (this group was later identified to have had a plating issue and was withdrawn from further consideration for this specification revision effort) ........................................... 42
Figure A4-9 Post 2X Reflows Using a SnPb Profile and SnPb Solder for Testing (good robustness) ...... 42
Figure A4-10 Post 2X Reflows Using a Hotter Pb-Free Profile but Testing with SnPb Solder (FAIL) ........................................................................................................................................ 43
Figure A4-11 Post 8 Hours Exposure to 72 °C/85% R.H. (excellent robustness) ......................... 43
Figure A4-12 Post 2X Exposures to a SnPb Profile Then Tested With SnPb (excellent robustness) .... 44
Figure A4-13 Post 2X Exposures to a Pb-Free Profile and Tested with SnPb (shows some increased spread in the data but overall, very good robustness compared to the failures seen in Figure A4-7) ............................................................................... 44
Figure A4-14 Post 8 hours @ 72 °C/85% R.H. (excellent robustness) ........................................... 45
Figure A4-15 Another Sample Group Post 2X Exposures to a SnPb Profile Then Tested with SnPb (excellent robustness) .... 44
Figure A4-16 Post 2X Pb-Free Reflow Profile Exposure (good robustness) ...................................... 46
Figure A4-17 Post 8 hours @ 72 °C/85% R.H. (excellent robustness) ........................................... 46
Figure A4-18 Post 2X SnPb Profile Exposure (good wetting times, increased spread in the data) .......... 47
Figure A4-19 Post 2X Pb-Free Profile Exposure (increasing spread in the data and some failures) ........ 47
Figure A4-20 Post 8 Hours @ 72 °C/85% R.H. (excellent robustness) ........................................... 48
Figure A4-21 Post 2X SnPb Reflow Exposures (excellent robustness) ............................................ 48
Figure A4-22 Post 2X Pb-Free Reflow Exposures (one outlier but overall, excellent robustness) ..... 49
Figure A4-23 Post 8 Hours @ 72 °C/85% R.H. (excellent robustness) ........................................... 49
Figure A4-24 Post 2X SnPb Reflow Exposures From Another Supplier (excellent robustness) ........ 50
Figure A4-25 Post 2X Pb-Free Reflow Exposures From Another Supplier (excellent robustness) .... 50
Figure A7-5 Hole Fill Evaluation of the Non-Stressed Samples Tested Using Eutectic SnPb Solder .................................................. 65
Figure A7-6 The Impact of 2X Reflows on Samples Tested Subsequently with Eutectic SnPb Solder ............................................. 66
Figure A7-7 Impact on Hole Fill Defects When Samples Experience 2X Reflows + 8 Hours of 72 °C 85% R.H. ........................................ 67
Figure A7-8 Example of Complete Hole Fill and the Level of Inner Layer Interconnects from One Row of 5PCB a Single Test Coupon from a Sample Tested with No Stressing with SnPb Solder ........................................................................... 68
Figure A7-9 Example of the Impact of Stressing on the Hole Fill Using 2X SnPb Reflows and Tested With SnPb Solder, the I Au Thickness was 1.71 µm” .......................................................... 69
Figure A7-10 Example of the Impact of Stressing on the Hole Fill Using 2X SnPb Reflows + 8 Hours of 72 °C 85% R.H. and Tested with SnPb Solder, the I Au Thickness was 2.96 µm” .... 70
Figure A7-11 The Hole Fill Defects Seen with SAC305 Solder on Non-Stressed Samples .................................................. 71
Figure A7-12 The Impact of 2X Reflow Stressing on Samples Subsequently Soldered with SAC305 Solder .................................................. 72
Figure A7-13 The Impact on Hole Fill Defects When the Samples Experience 2X Reflows + 8 Hours of 72 °C 85% R.H. .......................... 73
Figure A7-14 Example of the Impact of Stressing on the Hole Fill Using 2X Pb-Free Reflows and Tested with SAC305 Solder; the I Au Thickness was 1.77 µm” ................................. 74
Figure A7-15 Example of the Impact of Stressing on the Hole Fill Using 2X Pb-Free Reflows + 8 Hours of 72 °C / 85% R.H. and Tested with SAC305 Solder; the I Au Thickness was 2.37 µm” ........................................ 75
Figure A7-16 Summary Graph on Hole Fill Defects as a Function of Stressing Pre-Testing ................................................. 76
Figure A8-1 SEM/EDS/FIB Equipment Photo ........................................ 77
Figure A8-2 Sample VI (3000X) .................................................. 78
Figure A8-3 Potassium Iodide/Iodine Gold Stripped EDAX Spectrum .............................................................................. 78
Figure A8-4 FIB-SEM Cross Section 10,000X .................................. 79
Figure A8-5 Sample VI, 3000X .................................................. 79
Figure A8-6 Cyanide Gold Stripped EDAX Spectrum ................. 79
Figure A8-7 Cyanide Gold Stripped EDAX Spectrum .................. 80
Figure A8-8 FIB-SEM Cross Section (10,000X) ......................... 80
Figure A8-9 Sample VI, 10,000X .............................................. 80
Figure A8-10 Sample VI, 10,000X ............................................... 81
Figure A9-C-A Broad Beam Argon Ion Mill ..................................... 85
Figure A9-C-1 SEM Micrograph (BEI) of As-Finished ENIG Surface Prior to Broad Beam Ion Milling. ........................................ 89
Figure A9-C-2 SEM Micrograph (BEI) of ENIG Surface After 30 Seconds of Ion Milling. Some Residual Gold Still Evident Indicating the Sample is Under-Milled. ........................................ 89

Figure A9-C-3 SEM Micrograph (BEI) of ENIG Surface After 1 Minute of Ion Milling. The Nodular Morphology is Intact and No Residual Gold is Evident Indicating That the Sample is Properly Milled. ........................................ 89

Figure A9-C-4 SEM Micrograph (BEI) of ENIG Surface After 15 Minutes of Ion Milling. No Residual Gold is Evident, but the Enhanced Grain Structure and Some Ditching Indicate the Sample is Over-Milled. ........................................ 89

Figure A9-C-5 SEM Micrograph (BEI) of ENIG Surface After 15 Minutes of Ion Milling. Hyper-Corrosion is Still Evident, but not Significantly Exaggerated. ........................................ 89

Figure A10-1 XRF Instrument Layout ........................................ 91

Figure A10-2 Sample Placement with Respect to Detector ........................................ 93

Figure A10-3 Positioning of a 1 mm φ Collimator on a 1.5 mm x 1.5 mm [0.060 in x 0.060 in] Pad ........................................ 93

Figure A10-4 Scheme of Interaction ........................................ 94

Figure A10-5 Spectrum of an EN layer on Cu (PCB), Showing IP-k and I_{KX-K}. ........................................ 95

Figure A10-6 Spectra of Samples NiP12/Cu/PCB (blue) and 50 nm Au/96 nm Pd/3.2 µm NiP9.3/Cu/PCB (yellow), Showing Peak Overlap of P-K and Au-M Energy Lines ........................................ 96

Figure A11-1 Reported Phosphorus Content From Seven Test Sites for Sample A. The range in reported content is from a low of 3.85 wt.% to a high of 48.09 wt.%. Generally the higher reported values were from the lower kV values which is typically recommended by the EDS suppliers for evaluating Phosphorus. ... 98

Figure A11-2 Reported Phosphorus Content From Eight Test Sites for Sample B. The range in reported content is from a low of 3.36 wt.% to a high of 58.09 wt.%. It is noted that the same test site did not produce these extreme values or was the same location for the data reported for Sample A. ........... 99

Figure A11-3 Reported Phosphorus Content From Eight Test Sites for Sample C. The range in reported content is from a low of 3.92 wt.% to a high of 61.24 wt.%. The same two locations that produced the extreme values for Sample B also produced them for Sample C. It is further noted that the low wt.% was produced at the highest accelerating voltage for test site # 2 and the lowest accelerating voltage for test site 8 ....... 99

Figure A11-4 The Most Consistent Wt.% Reported Regardless of Accelerating Voltage Being Used for Sample A Foil Group ........... 100

Figure A11-5 The Most Consistent Wt.% Reported Regardless of Accelerating Voltage Being Used for Sample B Foil Group ........... 100

Figure A11-6 The Most Consistent Wt.% Reported Regardless of Accelerating Voltage Being Used for Sample C Foil Group. The Same Two Test Sites Produced the Most Consistent Results for Sample B as Well. .... 101

Figure A12-1 Results from Gold Thickness Survey ........... 103

Figure A12-2 Results from Nickel Thickness Survey ........... 104

Figure A12-3 Comparison of Gold Thickness Values by XRF Machine Type ........................................ 106

Figure A12-4 Comparison of Gold Plating Thickness Variation by Vendor for Similar Bath Life Conditions ........................................ 108

Figure A12-5 Comparison of Nickel Plating Thickness Variation by Vendor for Similar Bath Life Conditions ........................................ 109

Figure A12-6 Wetting Times as a Function of Plating Dwell Times for Vendor D, 90 Days Old .......... 110

Figure A12-7 Wetting Times as a Function of Plating Dwell Times for Vendor D, 90 Days Old .......... 111

Figure A12-8 Test Board for Wetting Balance Measurements ........................................ 112

Figure A12-9 Wetting Balance Data for Vendor D Post 18 Hours 85/85 Conditioning ........................................ 113

Figure A12-10 Comparison of One Micronich Gold Deposit Tested at 8 Months Shelf Life vs as Received and 85/85 ........... 114

Figure A12-11 Comparison of One Micronich Gold Deposit after Various Storage Times/Conditions .......... 115

Figure A12-12 Contact Resistance Data for Vendor D for Interlocking Square Contacts ........... 117

Figure A12-13 Contact Resistance Data for Vendor C for Interlocking Square Contacts ........... 118

Figure A12-14 Comparison of Gold Thickness by Vendor for the Interlocking Square Contact Test .......... 119

Figure A12-15 Interlocking Square Contact Test Coupon .. 120

Figure A13-1a Part Misclassifications ........... 121

Figure A13-1b Part Misclassifications ........... 121

Figure A13-2 Guard Bands ........... 122

Figure A13-3 Type 1 Gauge Study Results ........... 123

Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3-1</td>
<td>Requirements of Electroless Nickel/Immersion Gold Plating</td>
</tr>
<tr>
<td>Table 3-2</td>
<td>Twelve (12) Repeat Au Measurements and the Mean Value</td>
</tr>
<tr>
<td>Table 3-3</td>
<td>Three Examples of XRF Data Sets [=µin]</td>
</tr>
<tr>
<td>Table 3-4</td>
<td>One More Example of XRF Data [=µin]</td>
</tr>
<tr>
<td>Table 3-5</td>
<td>Three Levels of Hyper-Corrosion Observed Using Optical Microscopy</td>
</tr>
<tr>
<td>Table 4-1</td>
<td>Suggested Fabricator Qualification Plan</td>
</tr>
<tr>
<td>Table 4-2</td>
<td>C=0 Sampling Plan (Sample Size for Specific Index Value)</td>
</tr>
<tr>
<td>Table A3-1</td>
<td>XRF Detectors and Their Limitations at Typical Count Rates</td>
</tr>
<tr>
<td>Table A4-1</td>
<td>1.0 µin Minimum at -4 φ From the Mean Sample (all suppliers are below the target)</td>
</tr>
</tbody>
</table>
Table A4-2  1.5 µin Minimum at -4 σ From the Mean Sample (only one supplier met the goal) ...... 38
Table A4-3  2.0 µin Minimum at -4 σ From the Mean (Control Sample) (only one supplier met goal) ............................................................... 38
Table A5-1  Au Thicknesses Measured by XRF for the PCBs Used for Solder Spread Testing From Appendix G3 .............................................................. 55
Table A5-2  Description of Test Matrix for Solder Spread Evaluation .............................................................. 55
Table A5-3  Average Solder Spread Result for Each Combination of Solder Paste, Au Thickness and PCB Conditioning .............................................................. 57
Table A6-1  Average Thicknesses of Immersion Gold ...... 61
Table A6-2  Pull Values for 1 mil Aluminum Wire Bonds .............................................................. 61
Table A6-3  Pull Values for 10 mil Aluminum Wire Bonds .............................................................. 61
Table A6-4  Pull Values for 1 mil Copper Wire Bonds ...... 61
Table A10-1  Typical Achievable Results for NiP/Cu/PCB Samples (1mm Collimator; Measuring Time 120 s) .............................................................. 92
Table A10-2  Evaluation of 5 Readings (Repeatability Conditions) of the Sample in Figure A10-6 .... 93
Table A13-1  Guard Band Sigma Recommendation ........ 121
Table A13-2  Guard Band Sigma Recommendation ........ 124
Performance Specification for Electroless Nickel/Immersion Gold (ENIG) Plating for Printed Boards

1 SCOPE

1.1 Statement of Scope This performance specification sets requirements for Electroless Nickel/Immersion Gold (ENIG) deposit thicknesses for applications including soldering, wire bonding and as a contact finish. It is intended for use by chemical suppliers, printed board manufacturers, electronics manufacturing services (EMS) and original equipment manufacturers (OEM). This standard may be used to specify acceptance criteria to meet performance requirements in addition to those found in the IPC-6010-FAM: Printed Board Performance Specifications. The ENIG deposit specified by using this document will meet the highest coating durability rating as specified in the J-STD-003 printed board solderability specification.

This specification is based on three critical factors:
1. The ENIG plating process is in control producing a normal distribution for nickel and gold deposit thickness.
2. That the tool used to measure the deposit and therefore control the process is accurate and reproducible for the thickness range specified.
3. That the ENIG plating process results in uniform deposit characteristics.

If any of these three critical factors are not met, then the deposit produced will not meet the performance criteria defined herein.

1.1.1 Feature Size for Thickness Measurement This performance specification has been generated based on a deposit thickness measured ONLY on feature sizes of 1.5 mm x 1.5 mm [0.060 in x 0.060 in] or equivalent area (± 10%). Measurement of non-standard feature sizes and/or a combination of different feature sizes will prevent compliance to the statistical requirements of this specification. Requirements to measure non-standard sized features is AABUS and the supplier of the printed board is not responsible for the performance of the deposit as specified in this document.

1.2 Description ENIG is an electroless nickel layer capped with a thin layer of immersion gold. It is a multifunctional surface finish, applicable to soldering, aluminum and copper wedge wire bonding, press fit connections, and as a contact surface. The immersion gold layer protects the underlying nickel from oxidation/passivation over its intended life. However, this layer is not impervious and it will not pass the requirements of a “classic” porosity test as defined in ASTM B 735 & IPC-TM-650, Methods 2.3.24, 2.3.24.1 and 2.3.24.2).

1.2.1 Electroless Nickel Reducing Agents – Phosphorus Content Phosphorus-containing, reducing agents are used for the reduction of the electroless nickel during the deposition process and phosphorus is incorporated in the nickel deposit. Currently there are two levels of phosphorus found in electroless nickel deposits used for ENIG:
1. A mid-phosphorus nickel with phosphorus levels ranging from 5 wt. % to 10 wt. %
2. A high phosphorus nickel with phosphorus levels greater than 10.0 wt. %.

The level of this co-deposited element should be controlled within the supplier’s specified process limits. Variation of phosphorus levels outside the specified process limits may have adverse effects on the performance of the finish and/or potentially increase the occurrence and/or severity of hyper-corrosion.

The phosphorus content within the interfacial region between the electroless nickel and immersion gold layers is higher than that found in the bulk deposit. After soldering, the phosphorus levels at the interface between solder and the electroless nickel will always be higher than that found on a non-soldered pad, as the tin in the solder preferentially reacts with the nickel, leaving a phosphorus-rich layer behind. This is a NORMAL and expected occurrence.

1.3 Objective This specification sets the requirements specific to ENIG as a surface finish (see Table 3-1 for a summary of these requirements). As other finishes require specifications, they will be addressed by the IPC Plating Processes Subcommittee as part of the IPC-455X specification family. As this and other applicable specifications are under continuous review, the subcommittee will add appropriate amendments and make necessary revisions to these documents. The 4-14