IPC-4552B

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-4552A – August 2017
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 Purpose ... 1
1.2 Description ... 1
1.3 Classification ... 1
1.4 Measurement Units ... 1
1.5 Definition of Requirements ... 1
1.6 Process Control Requirements ... 2
1.7 Order of Precedence ... 2
1.7.1 Conflict ... 2
1.7.2 Clause References ... 2
1.7.3 Appendices ... 2
1.8 Use of "Lead" ... 3
1.9 Abbreviations and Acronyms ... 3
1.10 Terms and Definitions ... 3
1.10.1 Electroless Process ... 3
1.10.2 Hyperactive Corrosion Deposit ... 3
1.10.3 Immersion Process ... 3
1.10.4 Metal Turnover (MTO) ... 3
1.10.5 Reduction Assisted Immersion Gold Also known as: Mixed Reaction Immersion Gold ... 3
1.10.6 Selective Annular Ring Dewetting (SAD) ... 4
2 APPLICABLE DOCUMENTS ... 4
2.1 IPC ... 4
2.2 Joint Standards ... 5
2.3 ASTM International (ASTM) ... 5
2.4 JEDEC ... 5
2.5 Defense Standardization Program ... 5
2.6 Telcordia Technologies, Inc. ... 5
2.7 International Electrotechnical Commission (IEC) ... 5
2.8 International Organization for Standardization (ISO) ... 5
3 REQUIREMENTS of ENIG DEPOSIT ... 6
3.1 Printed Board Fabrication Supplier Process Requirements ... 7
3.1.1 General Plating Line Requirements ... 7
3.1.2 ENIG XRF Calibration Standards ... 12
3.1.3 XRF Zero Offset Acceptability ... 12
3.1.4 Process Qualification Measurement Requirements ... 13
3.1.5 Electroless Nickel Reducing Agents – Phosphorus Content ... 14
3.1.6 Gold Stripping of Plated Deposits for Evaluation of Corrosion Level ... 16
3.2 Performance Functions ... 16
3.2.1 Shelf Life ... 16
3.2.2 Humidity Indicator Card (HIC) ... 19
3.2.3 Aluminum and Copper Wire (Wedge) Bonding ... 19
3.2.4 Contact Surface ... 19
3.2.5 EMI Shielding ... 19
3.2.6 Conductive and/or Anisotropic Adhesive Interface (Replacement for Solder) ... 20
3.2.7 Connectors ... 20
3.2.8 Limitations of ENIG ... 20
3.3 Visual ... 20
3.4 Selective Annular Ring Dewetting (SAD) ... 21
3.5 Finish Thickness ... 22
3.5.1 Electroless Nickel Thickness ... 22
3.5.2 Immersion Gold Thickness ... 24
3.5.3 Exceptions to the Required Thickness Ranges ... 25
3.6 Nickel Corrosion ... 27
3.6.1 Morphologies of Features at Electroless Nickel – Immersion Gold Interfaces ... 28
3.6.2 Corrosion Level Definition ... 30
3.6.3 Corrosion Level Evaluation of an As-Plated ENIG Deposit by Cross Section ... 32
3.6.4 ENIG Baselining ... 38
3.6.5 ENIG Corrosion Performance Monitoring ... 38
3.6.6 Optional Testing to Determine IMC Formation on Boards Showing Product Rating 2 ... 39
3.7 Porosity ... 40
3.8 Adhesion ... 40
3.9 Solderability ... 41
3.9.1 Stressing of the Deposit Prior to Solderability Testing ... 41
3.9.2 Force Measurement Testing (Wetting Balance Testing) ... 41
3.10 Cleanliness ... 42
3.11 Electrolytic Corrosion ... 42
3.12 Chemical Resistance ... 42
4 QUALITY ASSURANCE PROVISIONS ... 42
4.1 General Quality Assurance Provisions ... 42
4.1.1 Qualification Recommendations ... 42
4.1.2 Sample Test Coupons ... 42
4.2 Quality Conformance Testing ... 44
4.2.1 Thickness ... 44
4.2.2 Qualified Process ... 44

APPENDIX 1 **Abbreviations and Acronyms** 45

APPENDIX 2 **ENIG Process Sequence** 47

APPENDIX 3 **XRF Thickness Measurements of Thin Au (ENIG): Recommendations for Instrumentation (Detectors) and Their Limitations** 48

APPENDIX 4 **ENIG PWB Surface Finish Wetting Balance Testing** 50

APPENDIX 5 **IPC 4-14 SC ENIG Round Robin Solder Spread Testing** 68

APPENDIX 6 **Wire Bonding to ENIG** 74

APPENDIX 7 **Through Hole Solderability Testing** 75

APPENDIX 8 **Evaluation of Electroless Nickel Corrosion Due to Immersion Gold Plating, Using 3000X Magnification After Gold Stripping** 90

APPENDIX 9-A **Cyanide Gold Stripping for ENIG** 95

APPENDIX 9-B **Test Method for Potassium Iodide/ Iodine (Non-Cyanide) ENIG Gold Stripping Procedure** 96

APPENDIX 9-C **Method for Stripping Gold Plating from ENIG Finished PCBs by Broad Beam Argon Ion Milling** 98

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]** 103

APPENDIX 11 **Phosphorus Content Measurement in ENIG Using Electron Dispersive Spectroscopy EDS** 110

APPENDIX 12 **Standard Developments Efforts of Electroless Nickel Immersion Gold** 115

APPENDIX 13 **Using Guard Bands or a Gauge Correction Factor to Accommodate Type 1 Gauge Study Measurement Uncertainty** 134

APPENDIX 14 **Worked Examples of Hyper-Corrosion Evaluations** 139

Figures

Figure 3-1a Example of Repeat Measurement Data from Three Different XRF Tools 8

Figure 3-1b Graphical and Statistical Evaluation of Data from XRF Tool # 1 9

Figure 3-1c Graphical and Statistical Evaluation of Data from XRF Tool # 2 10

Figure 3-1d Graphical and Statistical Evaluation of Data from XRF Tool # 3 11

Figure 3-2 Potassium Iodide/Iodine (KI / I_2) at 15 sec. dwell (left) vs. 60 sec. dwell (right) 17

Figure 3-3 Cyanide-Based Stripping at 15 sec. dwell (left) vs. 60 sec. dwell (right) 17

Figure 3-4 Cyanide Stripping (left) vs. KI/I_2 Stripping (right) Using Focused Ion Beam (FIB) 17

Figure 3-5 25,000X FIB Images – Cyanide (left) vs. KI / I_2 (right) – Same Dwell Time 18

Figure 3-6 Ion Mill Stripping of Defect-Free Nickel (left) vs. Hyper-Corroded Nickel (right) 18

Figure 3-7 Humidity Indicator Card (HIC) Example 19

Figure 3-8 Uniform Plating 20

Figure 3-9 Extraneous Plating or Nickel Foot 21

Figure 3-10 Skip Plating (No Ni plating) 21

Figure 3-11 Edge Pull Back 21

Figure 3-12 Example of SAD (Selective Annular Ring Dewetting) 22

Figure 3-13 Another Example of the SAD Defect 22

Figure 3-14 Selective Annular Ring Dewetting Defect 22

Figure 3-15 Grain Structure of Conventional Nickel Deposit 23

Figure 3-16 Grain Structure of Nickel Deposit Modified for Dynamic Flex Applications 23

Figure 3-17 Example of Fracture in Conventional Nickel Deposit 23

Figure 3-18 Modified Nickel Deposit Showing No Fracture with Same Number of Cycles 23

Figure 3-19 Example of Multiple Spike Defects on the Knee of a Hole at 1000X 28

Figure 3-20 Example of an Isolated Spreader Defect at 1000X (Rate as Level 1, if < 40%) 29

Figure 3-21 Example of Multiple Spreader Defects on the Knee of a Hole at 1000X 29

Figure 3-22 Example of Black Band Defect (Jagged in Nature) with Varying Depth of Penetration Type of Corrosion at 1000X 29

Figure 3-23 Example of Black Band That Would be Rejectable if It Met the Minimum 30% Coverage of the Field of View at 1000X 29

Figure 3-24 Example of a Crack in the Nickel Deposit at 1000X 30

Figure 3-25 Example of Level 0 Corrosion – Knee of Hole at 1000X 31

Figure 3-26 Example of Level 0 Corrosion – SMT Feature at 1000X 31

Figure 3-27 Level 1 Corrosion – SMT Feature at 1000X 31

Figure 3-28 Level 1 Corrosion – Knee of Hole at 1000X 31

Figure 3-29 Level 2 Corrosion – Knee of Hole at 1000X 32

Figure 3-30 Level 2 Corrosion – SMT Feature at 1000X 32

Figure 3-31 Level 3 Hyperactive Corrosion – Knee of Hole at 1000X 32
Figure 3-32 Level 3 Hyperactive Corrosion – SMT Feature at 1000X 32
Figure 3-33 Etched Defined PTH 33
Figure 3-34 Solder Mask Defined Features 33
Figure 3-35 Solder Mask Defined SMT Pad 33
Figure 3-36 Etched Defined SMT Pad (non-supported PTH are treated as SMT Pad) 33
Figure 3-37 Blank Product Rating Spread Sheet 34
Figure 3-38 Example Product Rating for 5 Different Panels 35
Figure 3-39 Decision Tree Based on Product Rating Evaluation 35
Figure 3-40 Through Holes to be Evaluated for Corrosion at 25X 36
Figure 3-41 Location 1 Worked Example – Rating Is a Level 2 at 1000X 36
Figure 3-42 Location 2 Worked Example – Rating Is a Level 1 at 1000X 36
Figure 3-43 Location 3 Worked Example – Rating Is a Level 2 at 1000X 36
Figure 3-44 Location 4 Worked Example – Rating Is a Level 0 at 1000X 36
Figure 3-45 Location 5 Worked Example – Rating Is a Level 2 at 1000X 36
Figure 3-46 Location 6 Worked Example – Rating Is a Level 0 at 1000X 37
Figure 3-47 Location 7 Worked Example – Rating Is a Level 0 at 1000X 37
Figure 3-48 Product Rating for the Worked Example 37
Figure 3-49 Example of Run Chart Created for Recording Product Rating 38
Figure 3-50 Example of an Acceptable Contiguous IMC Layer at 1000X 40
Figure 3-51 Example of a Rejectable Non-Contiguous IMC Layer at 1000X 40
Figure 3-52 Example – Rejectable with Little-to-No IMC Formation at 1000X 40
Figure 3-53 Example – Rejectable with Little-to-No IMC Formation at Annular Ring for Through Hole with Level 2 Corrosion Level at 1000X 41
Figure 3-54 Standard IPC Force Measurement Coupon 41

Tables

Table 3-1 Requirements of Electroless Nickel/ Immersion Gold Plating 6
Table 3-2 Twelve (12) Repeat Au Measurements and the Mean Value 13
Table 3-3 Example of Phosphorus Content Analysis Over a 4-Quarter Period 15
Table 3-4 Three Examples of XRF Data Sets (µm [µin]) 24
Table 3-5 One More Example of XRF Data (µm [µin]) 25
Table 3-6 Identification of Corrosion Level of a Location 30
Table 3-7 Product Rating based on Corrosion Investigation 34
Table 4-1 Suggested Fabricator Qualification Plan 43
Table 4-2 C=0 Sampling Plan per Lot Size 44

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

1 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 series (IPC-6012, IPC-6013 and IPC-6018) of standards. 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 Purpose This specification sets the requirements specific to ENIG as a surface finish (see Table 3-1 for a summary of these requirements).

1.2 Description ENIG is an electroless nickel layer capped with a thin layer of immersion gold (IAu). 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 B735 and IPC-TM-650, Methods 2.3.24, 2.3.24.1 and 2.3.24.2.

1.3 Classification IPC standards recognize that electrical and electronic assemblies are subject to classifications by intended end-item use. Three general end-product classes have been established to reflect differences in manufacturability, complexity, functional performance requirements, and verification (inspection/test) frequency. It should be recognized that there may be overlaps of equipment between classes.

CLASS 1 General Electronic Products
Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 Dedicated Service Electronic Products
Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.

CLASS 3 High Performance/Harsh Environment Electronic Products
Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

1.4 Measurement Units All dimensions and tolerances in this specification are expressed in hard SI (metric) units and bracketed soft imperial [inch] units. Users of this specification are expected to use metric dimensions. All dimensions ≥ 1 mm [0.0394 in] will be expressed in millimeters and inches. All dimensions < 1 mm [0.0394 in] will be expressed in micrometers and microinches.

1.5 Definition of Requirements The words **shall** or **shall not** are used in the text of this document wherever there is a requirement for materials, preparation, process control or acceptance.