REQUIREMENT 16

DETAILED REQUIREMENTS FOR MICROCIRCUITS (MONOLITHIC, HYBRID, OPTOCOUPLER, AND MULTICHIP MODULE)

16. General. This section describes detailed requirements for a DPA of commonly used microcircuits. These requirements supplement the general requirements in section 4. When applicable, specification numbers or types are referenced to assist in identification. Pre-DPA tests such as functional tests and solderability tests are assumed to have been satisfied by normal inspection and testing and are therefore not addressed.

16.1 Microcircuits, hermetic (MIL-PRF-38534 and MIL-PRF-38535, monolithic, multichip, and hybrids). Configuration photographs and drawings or diagrams as supplied by the manufacturer.

16.1.1 Method. DPA examination shall be performed in accordance with method 5009 of MIL-STD-883, as modified.

16.1.1.1 External visual examination. Perform this examination in accordance with method 2009 of MIL-STD-883, on all samples.

16.1.1.2 Hermeticity testing. Perform both fine and gross leak testing in accordance with method 1014 of MIL-STD-883.

16.1.1.3 Radiographic examination. Perform radiographic examination on all samples in accordance with method 2012 of MIL-STD-883.

16.1.1.4 Particle impact noise detection (PIND). Perform PIND testing on all samples in accordance with method 2020 of MIL-STD-883, condition A.

16.1.1.5 Internal water vapor testing/residual gas analysis (RGA). Perform internal water vapor /RGA testing in accordance with method 1018 of MIL-STD-883. The sample size for this testing will be one for QPL/QML devices and three for non-QPL devices with zero failures or five devices with a maximum of one failure (3/0, 5/1). It is preferred that additional devices over and above the DPA sample lot be provided for this test to allow for processing in parallel to the DPA once hermeticity testing has been completed. If this cannot be done due to cost or availability issues, care should be taken to ensure that a minimal amount of damage results to the internal structures of the device during this test. Any damage caused by the intrusion of the puncturing tool into the cavity(s) of the device(s) shall be noted as such.

16.1.1.6 Internal visual examination. This examination shall be performed on all samples in accordance with method 2010 of MIL-STD-883, condition as applicable, for monolithic devices. Methods 2017 and 2032 of MIL-STD-883 are applicable for hybrid microcircuits. Care should be taken during the delidding process to ensure minimal damage is introduced to the device bond wires or die surfaces. Any damage to the device induced during delidding or subsequent handling shall be noted. All anomalous conditions shall have an image(s) recorded, which clearly detail the condition(s) noted.

16.1.1.7 Bond pull testing. This testing shall be performed on two samples minimum in accordance with method 2011 of MIL-STD-883, condition D. In the event an anomalous condition is noted during bond pull testing, SEM shall be utilized to examine the failed interface(s) and appropriate images recorded.

16.1.1.8 SEM. SEM examination shall be performed to verify metallization step coverage in addition to documenting anomalous conditions noted in the previous portion of the DPA. The step coverage evaluation will be performed on two monolithic devices or one for hybrid devices. All expanded metallization discrete semiconductor dice within a hybrid shall be inspected. The evaluation will be performed in accordance with method 2018 of MIL-STD-883, except for the following clarifications that take precedence:

a. The scope of the evaluation will be focused on verifying the step coverage of the primary conducting layers of metallization only. Barrier layer(s), if present, shall count towards the requirement for metallization coverage for the particular metal layer under examination unless otherwise specified by the customer. A separate evaluation of the barrier layer step coverage or contact coverage will not be required during the course of the DPA.

b. The glassivation removal process of multilayer metal devices may be accomplished in a single step if no damage will occur to the metallization, which would alter the validity of the examination (i.e. corrosion of the metal). Otherwise, successive deglassivation procedures/steps shall be performed to allow for examination of each metal layer independently. Care must be taken to ensure that all glassivation has been removed from via or contact structures to prevent obscuring the step coverage inspection.

c. In the event a metal layer completely obscures an underlying metal layer such that metallization inspection of at least 10 percent of the lower layer metal can not be performed, the obscuring layer of metallization shall be removed chemically following its inspection.

16.1.1.9 Die shear testing for Monolithics. Die shear strength testing of all semiconductor dice will be performed on 50 percent (round down) or a minimum of two for monolithic microcircuits, whichever is greater, of the DPA samples in accordance with method 2019 of MIL-STD-883. All samples exhibiting anomalous conditions shall have images recorded of the die attachment remains at the shear location. The sample size shall be two (2) for monolithic microcircuits, one for hybrids and MCMs with all the active elements inside hybrids/MCMs to be examined.

16.1.1.10 Passive element shear sampling plan. All passive elements (non-semiconductor dice) within 50 percent (round down) of the devices (large magnetic and stacked capacitor elements excluded) will be shear tested in accordance with method 2019 of MIL-STD-883, except as noted below.

a. The acceptance criteria will be that found in method 2019.

b. The shear force will be applied as stated in method 2019, in a plane perpendicular to the longest axis of the passive element. The attachment area will be defined by measuring the actual possible area of attachment to a device as practical for its design, for example: a ceramic chip capacitor is typically attached by its end metallization areas. The attachment area would be determined by measuring one of those two end metal areas optically from an incident angle. This value would then be multiplied by two to obtain the attachment area prior to testing. Non-conductive staking material beneath the capacitor body will not be measured as it is commonly used to ensure adequate mechanical support but is not typically required for electrical attachment purposes. If any element has been intentionally attached by its bottom surface area, then that area will be considered the attachment area for the purposes of this evaluation.

c. The elements will be sheared to separation as practical from the substrate in order to provide more quantitative results useful in further evaluations and assessments of the device.

d. Care shall be taken to ensure that all previously noted anomalous conditions have been resolved prior to shear testing and destruction of the evidence.

16.2 Optocouplers.

16.2.1 Method. Optocouplers shall be tested as a hybrid in accordance with 16.1 herein. Care shall be taken during any surface coating removal process to prevent damage to the dice, bond wires, or die attachment.

16.3 Crystal oscillators.

16.3.1 Method. Crystal oscillators shall be tested as a hybrid in accordance with 16.1 herein. The quartz crystal and its mounting will be evaluated using the criteria of requirement 12 herein. Removal of the crystal is required for a thorough inspection of the package interior.

16.4 Multichip modules.

16.4.1. Method. Multichip modules shall be tested as hybrids in accordance with 16.1 herein. This inspection must be performed in two stages. Delid, internal visual, bond pull, SEM, and die shear must be performed on the discrete leadless chip carrier (LCC) components on one side of the assembly prior to delid and inspection of the LCC on the other side of the substrate if present. Subsequent DPA inspection is then performed on the second side of the device. This ensures that no damage will occur to the internal members of the LCC on the side not under test.

The sampling requirement for SEM inspection may be reduced to one assembly (all dice) if traceability (same part number/lot date code) for the subassembly LCC exists from the device to device.

16.5 Plastic encapsulated microcircuits.

16.5.1 Method.

16.5.1.1 External visual examination. Inspect each sample at 3X to 10X magnification. One photograph of one typical device showing all marking shall be taken. Failure criteria of method 2009 of MIL-STD-883, "external visual", are applicable except:

a. General criteria for presence of any secondary coating material that obscures a seal area.

b. Foreign/displaced material requirement for braze material flow, or other foreign material.

c. Construction defects.

d. Package body/lid finish.

e. Lead requirement for misalignment to the braze pad.

f. Lead requirement for braze material that increases the lead dimensions.

g. Package body/lid - leaded devices requirement for any chipout dimensions.

h. Package body/lid - leadless devices.

i. Glass seals.

16.5.1.1.1 Additional criteria. Additionally, look for:

a. Package non-planarity, warping, or bowing.

b. Foreign inclusions in the package, voids and cracks in the plastic encapsulant.

c. Deformed leads.

16.5.1.2 Radiographic examination. Radiographs shall be taken of each device in two views 90 degrees apart (top and side views), in accordance with method 2012 of MIL-STD-883. The purpose of this examination is to find the die and wire placement for future de-capsulation and to detect internal defects of the package. Look for the following defects:

a. Foreign objects, voids, and filler conglomerates in the encapsulant.

b. Voids in the die attach material.

c. Misaligned leads.

d. Burrs on lead frame (inside the package).

e. Poor wire bond geometry (wires that deviate from a straight line from bond to external lead or have no arc and make a straight line run from die bonding pad to lead).

f. Swept or broken wires.

g. Improper die placement.

16.5.1.3 Acoustic microscopy. All samples shall be subjected to the acoustic micro imaging analysis. The purpose of this examination is to nondestructively detect the following defects:

a. De-lamination of the molding compound from the lead frame, die, or paddle.

b. Voids and cracks in molding compound.

c. Unbonded regions and voids in the die-attach material (if possible).

The apparatus and materials for this test shall include: 1) An ultrasonic imaging equipment based on reflection (pulse echo) technology in which a single focused acoustic lens mechanically scans a tiny dot of ultrasound through the sample. A reflection is generated at each interface and returned to the sending transducer for processing and image generating. Signal processing shall allow information to be gathered from multiple levels within the sample. A C-Mode Scanning Acoustic Microscope (C-SAM) can be used for this purpose; 2) De-ionized water shall be used as a medium fluid to provide acoustic coupling between the sample and the transducer.

16.5.1.3.1 Examination sites. Examination of the package for voids, cracks, and de-laminations shall be performed on each sample at six areas:

a. Interface between the die and molding compound.

b. Interface between the lead frame and molding compound (top view).

c. Interface between the paddle periphery and molding compound (top view).

d. Die-to-paddle attachment interface (if not possible). This can be evaluated using through-transmission scanning.

e. Interface between the paddle and molding compound (back view).

f. Interface between the lead frame and molding compound (back view).

NOTE:· Combined C-mode scans can be performed to investigate more than one area during one scanning run. Die-attach inspection shall be performed in accordance with method 2030 of MIL-STD 883, “ultrasonic inspection of die attach” for the parts with the die mounted onto a substrate or heat sink. This standard can also be applicable for other package types provided the resolution is adequate to detect voids in the attachment material.

16.5.1.3.2 Evaluation criteria. In the device examination, the following aspects shall be considered as unacceptable and devices which exhibit any of the following defects shall be rejected:

a. Cracks in plastic package intersecting bond wires.

b. Internal cracks extending from any lead finger to any other internal feature (lead finger, chip, die attach paddle) if crack length is more than a half of the corresponding distance.

c. Any crack in the package breaking the surface.

d. Any void in molding compound crossing wire bond.

e. Any measurable amount of de-lamination between plastic and die.

f. De-lamination of more than half of the backside of the die paddle/plastic interface.

g. Complete lead-finger de-lamination from the plastic (either top or backside).

h. Delamination of the lead-finger that includes the wirebound area.

i. Delamination of the top tie bar area for more than half of its length.

NOTE: If rejectable internal cracks or de-laminations are suspected, a polished cross section may be required to verify the suspected site.

16.5.1.4 Cross-sectioning test. Cross-sectioning will be performed on one intact device for the purpose of inspecting typical die and post bond interfaces as well as die attach quality. If acoustic microscopy has revealed discrepancies/de-laminations in the die attach, plastic to die interface, or other significant interfaces, this sample should be utilized for sectioning. An attempt should be made to section into the discrepant area as a means of providing additional verification and information concerning the defect. Precision metallographic techniques shall be utilized which will result in high quality results without the introduction of damage to the device. The data to be obtained from this inspection will be qualitative in nature and is intended to determine general bonding quality. Excessive/inadequate intermetallic bond formation shall be identified and reviewed for acceptability.

16.5.1.5 De-capsulation. The purpose of this section is to provide guidelines for possible de-capsulation methods for failure analysis (FA) and DPA of plastic encapsulated semiconductor devices. It is also intended to characterize advantages and disadvantages and indicate possible pitfalls.

16.5.1.5.1 Preliminary steps. X-ray analysis should be performed before de-capsulation to learn die shape, placement and size; and to determine the height of the bond wires. This information will assist in choosing the correct mask or gasket and/or depth of the trench to be milled in the package surface. The samples may be baked before wet de-capsulation.
This step is intended to remove all moisture from the package so that damage will not occur due to acidic corrosion of the metallization.

CAUTIONS:· 1) Results of subsequent examinations depend heavily on de-capsulation quality. Detailed records about de-capsulation process irregularities and possible artifacts should be maintained. 2)· Do not expose wire bonds at the lead frame when using wet etching techniques. These bonds are frequently made to silver plated areas and chemical etchants will quickly degrade them.

16.5.1.5.2 Milling. This step is not necessary but is often useful for manual wet etching and plasma etching. Milling prevents the leads from breaking off by ensuring that the chip surface is exposed before the lead frame, and reduces the time required for etching. Any suitable milling machine is acceptable; use of a dental drill to create a small impression is possible but not preferable because a flat surface would not result. The procedure is as follows;

a. Using X-ray data, calculate the depth of the trench to be milled.

b. Install the part into the fixture of a milling machine. The surface being worked should be parallel with the milling plane.

c. Start milling, moving the mill tip down to the calculated depth. Mill the trench slightly longer and wider than the die.

To ensure that the bond wires remain intact during milling, it is recommended that approximately 0.2 mm (.008 inch) of plastic be allowed to remain covering them.

16.5.1.5.3 Suggested techniques.

16.5.1.5.3.1 Manual wet etching. Advantage: A quick result is possible with readily available equipment. Disadvantage: Removal of contamination from the surface of the die preventing chemical analysis; the method requires very careful attention to safety.

a. Apparatus and materials:

    (1) A heating plate, metal block, beaker, aluminum weighing dish, and disposable dropper.

    (2) Red fuming nitric or sulfuric acid can be used as etchants. Acetone, isopropanol, or methanol can be used for rinsing.

b. Notices:

    (1) Red fuming nitric acid can be used in most cases. Sulfuric acid can be used as a solvent specific to anhydride epoxies.

    (2) Red fuming nitric acid has little effect on plastic at room temperature, but elevating the temperature to approximately 100°C will cause it to de-capsulate a device in few minutes. Higher temperatures will only decompose the acid. When heated in an open beaker, the acid will evaporate NO2 and absorb moisture with time, thus becoming diluted and converted into yellow nitric acid. Dilute (yellow) nitric acid is not suitable for de-capsulation purposes because it reacts with the metal in the devices.

    (3) To have an effect on epoxy, sulfuric acid must be heated to about 150°C. Use de-ionized water for rinsing.

c. Procedure:

    (1) Mill a trench or create a small impression, according to section 16.5.1.5.2.

    (2) Make a mask using aluminum foil adhesive tape shielding the specific areas not to be etched.

    (3) Install the part on a metal (copper or aluminum) block to provide heat directly to the bottom of the device. Then place it in an aluminum weighing dish on a plate heated to approximately 90°C and wait several minutes to allow the package to heat up.

    (4) Pour a small quantity of red fuming nitric acid into a beaker and apply several drops to the device with the dropper.

(5) Cleanup: Rinse with cold nitric acid for a few seconds, rinse in a spray of acetone, then in isopropanol or ultrasonically clean in methanol. Blow with dry air.

(6) Repeat above steps 3 through 5 until the die is exposed.

(7) If necessary, perform a plasma cleanup with a 10:1 mixture of 02:CF4 in a barrel plasma (50W, 30-60 minutes).

d. Cautions:

(1) It is very important to keep the part hot and the exposure time very short for reaction with acid.

(2) There are safety hazards with this process. All safety procedures should be invoked.

16.5.1.5.3.2 Wet chemical jet etching. This method eliminates some safety problems inherent to manual wet etching and provides quick, clean, and localized removal of encapsulant in the die area, usually with no damage to the part.

a. Apparatus and materials:

(1) Jet etcher (e.g., B&G de-capsulator, model 250).

(2) Red fuming nitric or sulfuric acid, acetone, isopropanol.

b. Notices:

(1) Red fuming nitric acid can be used in most cases. Sulfuric acid can be used as a solvent specific to anhydride epoxies.

(2) Red fuming nitric acid has little effect on plastic at room temperature, but elevating the temperature to approximately 100°C will cause it to de-capsulate a device in few minutes. Higher temperatures will only decompose the acid. When heated in an open beaker, the acid will evaporate NO2 and absorb moisture with time, thus becoming diluted and converted into yellow nitric acid. Dilute (yellow) nitric acid is not suitable for de-capsulation purposes because it reacts with the metal in the devices.

(3) To have an effect on epoxy, sulfuric acid must be heated to about 150°C. Use de-ionized water for rinsing.

(4) De-capsulation of the first part may require from 3 to 6 steps followed by low power optical examination. After the process regimen is readjusted, de-capsulation can be done in one - two steps (three to five minutes).

c. Procedure:

(1) Choose a gasket according to the die size, calculated by X-ray data.

(2) Adjust the part and the gasket onto the fixture.

(3) Set parameters of the process (etching temperature, etching time, and volume of etching acid) using manufacturer’s data and experience and perform de-capsulation.

(4) Rinse the part in acetone and then in isopropanol after each step of etching. Blow with dry air.

(5) If necessary, perform a plasma cleanup with a 10:1 mixture of 02:CF4 in a barrel plasma (50W, 30 to60 minutes).

d. Caution: De-capsulation of thick packages with relatively small surface areas (like DIP-8) may result in a cavity wall depression that halts the etching process. To avoid this, use gaskets of a lesser size.

16.5.1.5.3.3 Plasma etching. Plasma etching has very high selectivity (the technique minimizes etching of the die metals and lead frame). Safety and contamination problems of wet chemical processes are avoided. Plasma treatment is a gentle process compared to wet etching and sometimes makes it possible to expose bonds at both ends of the wires. The disadvantage is that significantly more time is required.

a. Apparatus and materials: A non-reactive ion etching mode plasma system should be used, for example, Plasma GIGA-ETCH 100-E system (Technics Plasma GmbH). In this system, the plastic molding compound is removed from the device automatically and up to 12 devices can be treated simultaneously. The filler material (quartz powder) is automatically blown from the surface with brief blasts of compressed air in time intervals of several minutes. De-processing is performed at approximately 0.5 - 1 mbar pressure of the gas mixture O2:CF4 (80:20).

b. Notice: The process time varies typically between 5 and 15 hours depending upon the type of the device and the trench depth.

c. Procedure:

    (1) Mill a trench according to section 16.5.1.5.2.

    (2) If necessary, cover the package with an aluminum foil mask so only the area to be etched is exposed to the plasma.

    (3) Adjust and secure samples under the blow nozzles and start the process.

d. Caution: Oxygen/freon plasma (mostly used for de-processing) does not affect Al and Au, but can attack other metals and glassivation (especially Si3N4).

16.5.1.6 Internal visual inspection. All de-capsulated samples shall be subjected to this examination. The purpose of this test is to verify that the quality of the performed de-capsulation is adequate for further analysis, to examine de-capsulated device for visual defects, and to identify those damaged by de-capsulation. The device shall be examined microscopically first at a low power (30X to 60X) magnification and then at a high power magnification (75X to 200X) to determine the existence of defects as described in 16.5.1.6.1 and 16.5.1.6.2. All failures from 16.5.1.3.2 should be analyzed to confirm that the failure mechanism occurrence is not due to the de-capsulation technique.

16.5.1.6.1 Verification of the de-capsulation quality.

a. Confirm acceptance of the specimen for further bonding examination. At least 25 percent, or three wire bonds, whichever is greater, should meet the following criteria: Be clean, have no damage, and be exposed more than approximately two-thirds of their length.

b. Confirm acceptance of the specimen for further glassivation integrity and SEM examinations. At least 75 percent of the die area should be clean and have no damage caused by de-processing.

c. Record any artifacts, which may have affected the DPA results.

16.5.1.6.2 Criteria. Evaluation criteria in accordance with method 2010 of MIL-STD-883, and method 2013 of MIL-STD-883, “internal visual inspection for DPA" are applicable. Additionally, no device shall be acceptable that exhibits the following defects:

a. Foreign intrusions in exposed plastic material.

b. Glassivation pinholes, peeling or cracks (in particular those specific to filler particle-induced damage).

c. Metallization voids, corrosion, peeling, or lifting.

16.5.1.7 Glassivation layer integrity. One sample, or 20 percent of the lot, whichever is greater, which met the requirements in accordance with 16.5.1.6.1.b shall be subjected to a glassivation layer integrity test. This examination shall be performed in accordance with method 2021 of MIL-STD-883, “glassivation layer integrity".

16.5.1.8 Bond pull test. At the discretion of the user, each sample that met the requirements in accordance with 16.5.1.6.1.a shall be subjected to a destructive bond pull test. The wire bonds shall be pulled to destruction according to method 2011 of MIL-STD-883, condition D, “bond strength (destructive bond pull test)”. The results shall be used for engineering insight only and should be recorded for information only, not as a part of the record reflecting conformance or non-conformance to the requirements of this standard.

16.5.1.9 SEM examination. Two samples minimum, except those that were subjected to glassivation integrity examination, that meet the requirements in accordance with 16.5.1.6.1.b shall be subjected to this test. The purpose of this examination is to evaluate quality of the die interconnect metallization. The two samples shall undergo SEM inspection for metallization step coverage. The subsequent examination shall be performed in accordance with method 2018 of MIL-STD-883, and 16.1.1.8 herein. It is important to remove all polymer residues from the die if cross sectioning is found to be necessary. Otherwise, the acid absorbed in the polymer remnants would mix with de-ionized water (during polishing) and cause corrosion of the aluminum metallization.