ENGINEERING PRACTICES STUDY 1153

# TITLE: STUDY TO REVIEW PROPOSALS FOR STEP COVERAGE REQUIREMENTS IN MIL-PRF-19500.

26 August 2016

STUDY PROJECT

5961-2016-073

FINAL REPORT

Study Conducted by DLA LAND AND MARITIME

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I. OBJECTIVES: DLA Land and Maritime-VAC has conducted an EP study to review the step coverage requirements of MIL-PRF-19500 semiconductor die to determine if the existing requirements are sufficient to provide acceptable verification of step coverage and if equipment restrictions should be added for manufacturing specific die design types.

II. BACKGROUND: MIL-PRF-19500 tests for semiconductor die step coverage of JANS devices using test method 2077 of MIL-STD-750. One method of adding metallization to a die is an evaporation process. A potential byproduct of this process is a lack of metallization near the lower portion of the stepped areas on the die. This can be caused if the source material is at an angle to the step in the die creating a “shadow” that will become a void because of the lack of metallization distributed by the evaporation. Additionally if the source material is properly aligned with the steps of the die, shadowing still could be caused if the etch of the die is uneven and causes the more of the lower level to be etched away than near the top of the step. Rotation, heat, and other methods are used to overcome this potential voiding. Additionally, other methods such as sputtering are used to deposit metallization more evenly for some designs. MIL-PRF-19500 currently does not limit specific types of wafer manufacturing equipment for certain die designs.
A JANS device was recently found to have voiding in the aluminum metallization over a bond area oxide step that reduced the metal thickness to less than 50% in large areas around the bond pad edges. (In this instance, MIL-STD-750 Test Method 2077 allows a reduction in metal thickness of up to 50%.) The devices had passed all screening and conformance inspection testing required by MIL-PRF-19500. This flaw was found by a user that performed an alternate cross section SEM inspection in accordance with test method 2077 that would normally not have been performed. This method is only required for certain design types, and where the angled view (normally used) is not adequate. A change in wafer processing causing uneven etching, and an undercut in the passivation near the edge of the bond pad was determined to be the cause of the voiding. The undercut area did not allow for adequate metal evaporation deposition. The manufacturer has already taken steps to eliminate the uneven passivation layer etch and has replaced the evaporation process with a sputtering process.
**Initial Proposals:** The proposals listed below were evaluated in this EP study to determine which proposal, if any, is needed to help find escapes similar to those listed above and to ensure adequate step coverage for MIL-PRF-19500 devices. These proposals are applicable for designs that utilize wafer passivation, etching, and metal deposition techniques using evaporators for depositing current carrying metallization over oxide steps where there is a potential for voiding to occur. A third proposal restricts evaporators for this design entirely. Please review the proposals below and provide feedback if additional testing or restrictions are needed in MIL-PRF-19500.

1. Require manufacturers to evaluate if their evaporator is adequate by comparing the results against a sputtered wafer. Manufacturers could also propose additional stress testing that could detect this flaw when present.

2. Implement a cross-sectional SEM inspection per TM2077 for qualification and die process change.
(By adding it to these two locations it could potentially find any anomalies that the standard angled view does not find, although escapes could still happen if the location on the die is poorly chosen.)

3. Replace the evaporation process with sputtering. Example: "Due to inherent process limitations, evaporation shall not be used to deposit current carrying conductor metallization over steps in the device topography, where present in the design, such as contact windows, oxide/passivation steps, etc."

Because the step is difficult to cover in an evaporation process, it was suggested that we should prohibit it in MIL-PRF-19500 instead of trying to test to detect it, especially because SEM is not a TX/TXV requirement, so poor step coverage would typically not even be discovered on these devices using the second proposal if no additional testing was added for the TX/TXV product. Evaporation would still be applicable for flat surface designs (such as back metal, diodes, flat conductors, etc,) that do not include steps.

III. RESULTS: The comments received by DLA Land and Maritime have been reviewed and are listed in **Attachment 1**.

IV. CONCLUSIONS: Based on the comments received, the second proposal listed above requiring a cross sectional SEM for qualification and die process change will be proposed to add to MIL-PRF-19500. In addition, the proposal received for updating TM2077 will be submitted for consideration during the next specification action of MIL-STD-750.

V. RECOMMENDATIONS: DLA Land and Maritime recommends that the proposed changes of this EP Study be submitted as comments to the MIL-PRF-19500P Amendment4.

Attachment 1

**Commenter 1:**
Rather than eliminate technologies that are still in use we just need to assure the performance of the technology. This can be accomplished rather simply by changing the last sentence of paragraph 3.4 (TM2077)

From: " When an aerial view does not provide adequate detail for determining step coverage, the specimen shall be cross sectioned."

To: " When a metallization step is in the current carrying direction the specimen shall be cross sectioned."

**Commenter 2:**
The anomaly reported by NWSC should be addressed. It remains unclear that replacement of metal evaporation with sputtering would resolve the issue of a shadowing related defects. The introduction of sectioning as a tool for locating metallization defects is very questionable; sectioning is time consuming, expensive, as well as requiring highly skilled technician. In addition, the location of the transistor on a wafer to be sectioned may add uncertainty to the effectiveness as a tool for identifying metallization deficiencies. Sectioning and the use of Focused Ion Beam inspection are useful laboratory tools but not an alternative to robust design screening and qualification of devices. Discussions with Navy and the applicable manufacturer support the following conclusions the anomaly resulted from a design deficiency which is being corrected. It is recommended that all future qualification or design changes require a Scanning Electron Microscope (SEM) documentation as defined in MIL-PRF-19500Paragraph E.3.1.2.1, including SEM photos of the device surface as well as photos of a sectioned device.

**Commenter 3:**
1. Evaluation of step metal coverage certainly is important. However, sputtering and evaporation have their own characteristics. The two methods <u>should not be required to be compared</u>, because doing so will be comparing the quality of each process, not whether or not it is adequate. This would place an extra burden on the manufacturer, and perhaps increase cost.
No matter what process is used, the manufacturer should evaluate step coverage to a standard (not another process) to verify adequate coverage and evaluate the quality of their process.

2. YES! Using a cross-section SEM analysis is the best solution to both prove out a design or process change in the fab. Step metal can be properly evaluated (top to bottom) using a cross-section. This is how we found our step coverage issue in the first place. The Cross-section can be done by whatever means a lab has (mechanical / FIB, etc.) By requiring this, the manufacturer will prove to DLA and the customer that step coverage is adequate, especially in underling layers (where defects might occur, and be obscured from aerial SEM). Since this would be required only on qualification or requalification, there will both minimal impact to the manufacturer and great benefit to the customer. Although cross-sectioning looks at a particular slice, and therefore may hide defects in a different plane along the same step edge, this method will still give a view of the entire step and potentially uncover any sub-surface step defects that may be hidden via the top layer. To summarize: Require Cross-sectioning for qualification and requalification. Require either aerial or cross-section for standard JANS group B tests.

3. Although sputtering has proven it can provide better metal coverage than evaporation, using evaporation for a device that has been proven to have adequate step coverage will still have proper performance. Manufactures should be encouraged to use sputtering but not required to if they can produce acceptable MIL STD performance using evaporation.

Testing for step metal defects: We feel that the best way to test for the type of defects of step metal we have seen is via cross-section samples. Electrical data would only show degradation in very severe step-metal failures. In our experience, we did not see any shift in electrical performance parameters in devices that had large reduction (greater than 80%) in the step metal. Thus we do not think an electrical test would “screen” out low step coverage parts