CMSE 2025 – Key-Note

Electronic Parts Standards: Past, Present and Future

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Executive Summary

- The management of PMP (Parts Material Process) activities at the government or the contractor level is a critical task that requires personnel with expertise in many areas
- PMP tasks establish the heart of the system reliability based upon part selection, procurement and testing
- The addition of new technology and the continual maintenance of current standards bring both unique challenges and the opportunity to reinvent parts engineering.
- We support a variety of space missions and programs. The success of each mission is critical to the future of space exploration.
- The space community needs to continue to evolve and we encourage the community to take advantage of the Parts Engineering School.
- For applications that do not require space quality products, alternate grade parts should be evaluated.
- A major part of PMP management is to understand the nuances of the classes and select the "best" part for the application and balance reliability, cost and schedule for the program

PMP management is critical to ensure long term system reliability

Specification History

- In the early 1960’s, the IC industry was developing, and IC failures were common. It was recognized that a series of standard screening tests could reduce or eliminate these “infant mortality” type failures
- The USAF Rome Air Development Center (RADC) was given the task and in 1968 developed MIL-STD-883
- 883 was intended for military hermetic parts
  - *In the context of microelectronics, it implies an airtight seal that will keep moisture and other harmful gases from penetrating the sealed package.*
  - *Metals, ceramics and glasses are the materials used to form the hermetic s, al and prevent water vapor from accumulating inside the package.*
  - *A properly made hermetic seal with a sufficiently low leak rate can keep a package dry and moisture free for many years*
- Concurrent with the development of MIL-STD-883, RADC established Mil-M-38510 procedures to specify the electrical and package outlines for standardization
- MIL-M-38510 set out the procedures to obtain a QPL listing for a given slash sheet and quality level
  - *This is the predecessor of the modern Mil-Prf-38534/5*
- This was a very effective system for the simpler part types and JAN slash sheets are still in use today.

Specification Today

- A result of the Perry Initiative of the mid 1990’s was to change the philosophy of rigid requirements in mil-specs and go to “performance specifications”
- The performance spec establishes the general requirements for the item (discrete semiconductor, monolithic integrated circuit or hybrid) and the verification requirements for ensuring that these devices meet the applicable performance as defined
- Performance Specs encourage and allow for alternate verification testing methods to meet performance requirements and foster ingenuity and growth within the supplier base – **“let the manufacturer who knows the most about his part, use his best commercial practices”**
- Performance Specifications
  - *General Hybrid Spec MIL-PRF-38534 FSC 5962*
  - *General Specification for Microcircuits MIL-PRF-38535 FSC 5962*
  - *General Specification for Semiconductor Devices MIL-PRF-19500 FSC 5961*
- Military Standards
  - *Standard Test Methods for Microcircuits MIL-STD-883*
  - *Standard Test Methods for Semiconductor Devices MIL-STD-750*

Quality Assurance Levels in MIL-SPECS

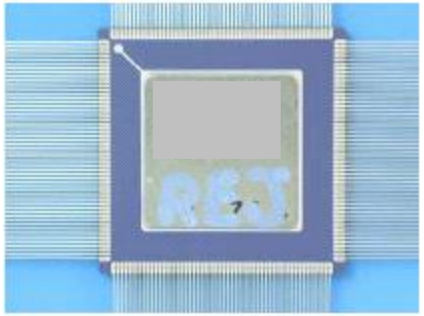
	Space Level Hermetic*	Space Level Non-Hermetic*	Avionics Level (launch vehicles, planes, tanks, etc) Hermetic*	Commercial Hermetic	Non-Hermetic Plastic
Integrated Circuits MIL-PRF-38535	Class V Extensive testing & documentation includes x-ray, tighter visual inspection, nondestruct bond pull, longer more stressful burn-in	Class Y/P Essentially the same testing reqts as Class V but no seal tests, no bond pulls, addtl visual reqts	Class Q Less testing and process controls than Class V/Y. No xray or non-destruct bond pull, less stringent visual inspection and shorter burn-in times	Class T Geared for commercial space. Reqts decreased from Class V to allow less costly parts but has increased risk due to less testing	Class N/P All requirements are determined by manufacturer and each manufacturer flow will be different.
Hybrids MIL-PRF-38534	Class K Reqts similar to Class V	Class L Reqts similar to Class Y	Class H Reqts similar to Class Q	Class D & E Reqts determined by manufacturer	Class F Reqts similar to Class H
Discrete Semiconductors MIL-PRF-19500	JAN S Requirements similar to Class V	N/A	JANTXV Non-critical JANTX Reqts similar to Class Q	JAN J or JAN Reqts similar to Class T	In Development

*Hermetic has the quality of being airtight. In common usage, the term implies not letting the ingress or egress of gasses, moisture, contaminants and is defined by a leak rate.

Different quality levels define the requirements for design, construction, reliability and testing for the intended application

Part Identification

- Devices are identified either with the military part number, contractor part number, or commercial part number
  - *Examples*
    - 5962-10101VXA – Integrated Circuit
    - M38510/10101SXA – Integrated Circuit
    - JANS2N2222A – Transistor
    - 3M114ABC – Contractor Integrated Circuit
    - 74HC74 – Commercial Integrated Circuit



- Devices are manufactured and identified with a lot date code that allows traceability to a specific manufacturing lot
  - *Lot date code represents the specific date when the device package was sealed or encapsulated*

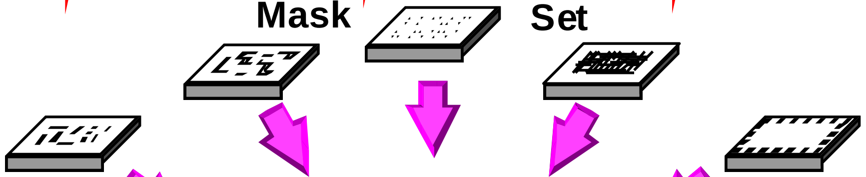
Part number and traceability are important – allows for trending and reachback of problems

Fabrication flow of an Active Device

Wafer Fab → Wafer Test → Packaging → Package Test

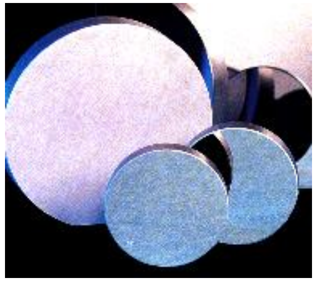
Issues Observed
- Incorrect/errors on masks
- Immature process
- Bad/dropped wafers
- Furnace errors

Mask Set



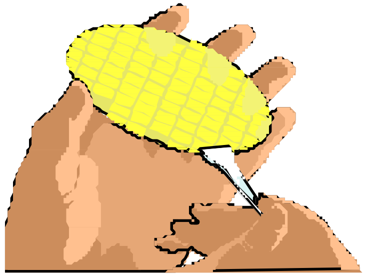
A topology of transistors, interconnects, & insulators defined by a "mask set" is built up layer by layer on the blank wafers

A layer by layer build up of patterns created on the blank wafer to define the designed function & performance desired. The patterns are made by the use of masks & etching processes which create the final device layout.

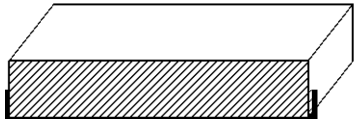


"Blank" Wafer

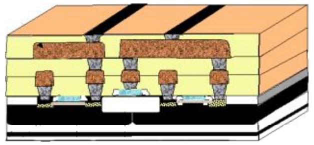
Integrated Circuit (IC) Factory



Finished IC "Die" on Wafer



Cross-section



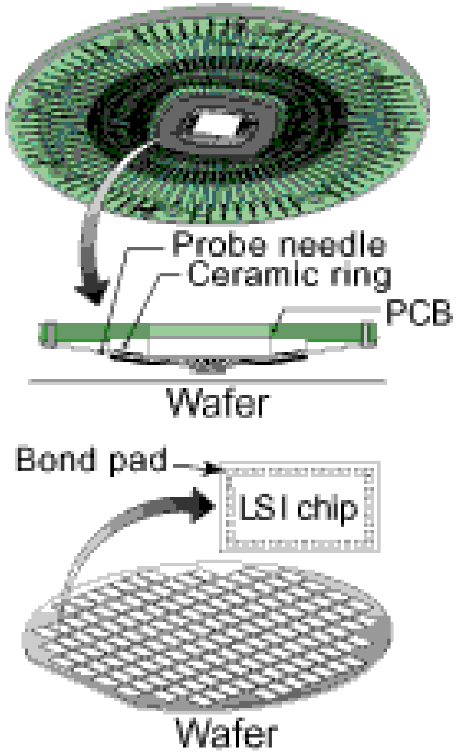
Cross-section

Pictorials developed by Aerospace from various sources

Wafer Test

- Wafer die automatically "probe tested"
  - *First point of evaluating electrical characteristics after fabrication*
- Purpose to "screen out" defective die prior to the expensive packaging step
- DC tests & slow speed dynamic tests
- Early look at Proof Of Development (POD) functionality
- Room & high temperature tests
- Die destined for multi-chip packaging require more stringent screening
- Issues Observed
  - *Bad/Wrong test program or fixture*
  - *Overstressed/ESD causing yield problems*

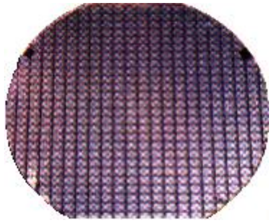
Wafer-level tests screen defective parts before proceeding to higher levels of assembly



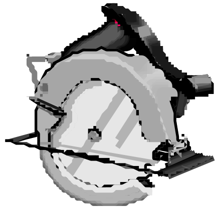
Pictorials Courtesy of Unknown Origin on Internet

Packaging (Assembly)

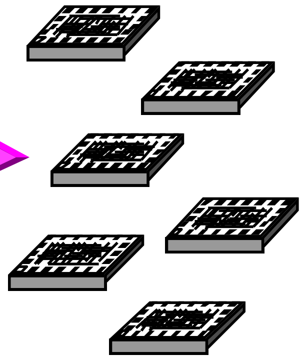
ICs that pass preliminary wafer test (probe) are then marked, cut into die and packaged



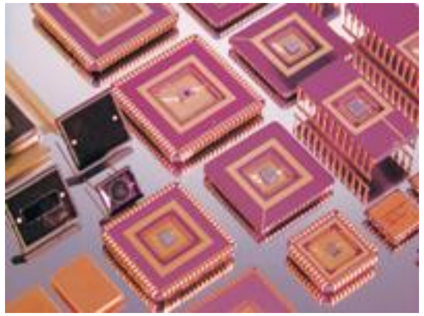
Finished Wafer

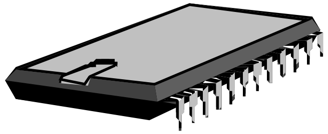


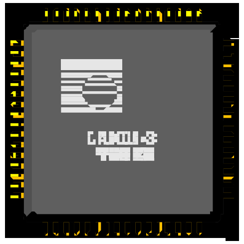
Wafer "Dicing"



Integrated Circuit Die or "Chips"







Die can be Mounted in a Variety of Package Types

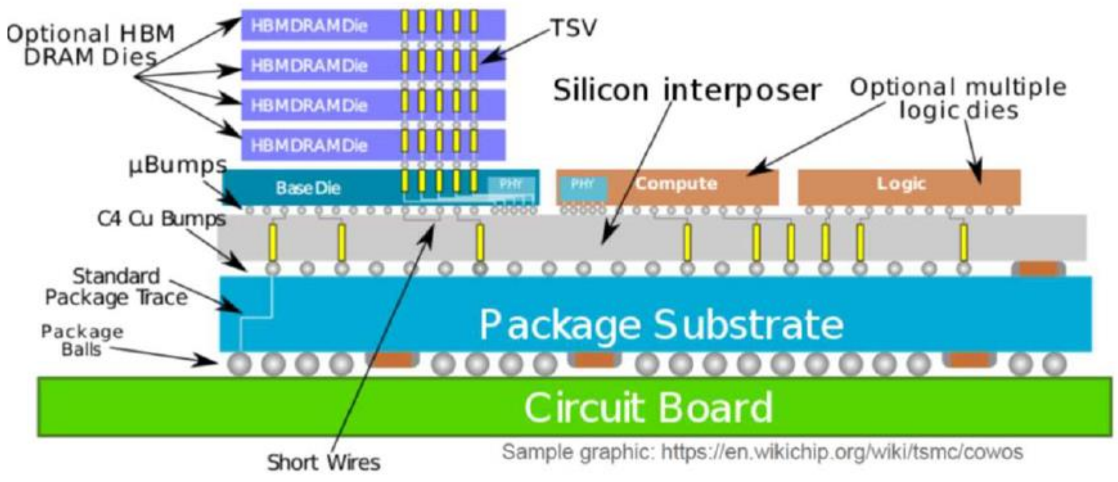
<u>Issues Observed</u>

- Chipped/scratched die
- Bad die attach
- Bad wire bonds
- Poor lid seal
- Cracked seals

Pictorials Courtesy of Unknown Origin on Internet

Advanced Packaging

- Manufacturers using advanced packaging techniques for enhanced performance
  - *Flip-chip die attachment*
  - *Column Grid Arrays*
  - *Non-hermetic*
  - *External capacitors for bypass and filtering*



Pictorial courtesy of Xilinx Corporation

Package Level Testing

- Purpose to "screen out" defective or marginal devices not meeting performance requirements
- All parts are tested for DC, AC and functional performance
- Room, cold & high temperature tests are performed
- Issues Observed
  - *Bad/Wrong test program or fixture*
  - *Overstressed/ESD causing yield problems*

Pictorials Courtesy of
Unknown Origin on Internet

First complete evaluation of electrical performance

MIL-PRF-19500, MIL-PRF-38534 and MIL-PRF-38535

- These specifications are performance specifications with the purpose of establishing the general requirements for the item (monolithic integrated circuit. Hybrid or discrete semiconductor) and the verification requirements for ensuring the devices meet the applicable performance as defined.
- The documents cover the following:
  - *Design and Construction*
  - *Packaging*
  - *Traceability*
  - *Quality Assurance*
  - *Performance*
  - *Verification*
  - *Screening*
  - *Qualification*
  - *Quality/Technology Conformance Inspection*
  - *Test Optimization*
  - *Non-conformances*
  - *Audits*
  - *New Technology Insertion*

11

MIL-STD-883 and MIL-STD-750

- A collection of destruct and non-destruct test methods used as screening and qualification tests to verify microelectronic (monolithic and hybrids) performance requirements and to assess the reliability of devices
- 1000 series TMs… Environmental Tests
- 2000 series TMs… Mechanical Tests
- 3000 series TMs… Electrical Tests (Digital)
- 4000 series TMs… Electrical Tests (Linear)
- 5000 series are Test Procedures e.g. TM 5011, TM 5008
- When testing to 883 one MUST further specify the test condition, quality level and other details contained in the individual test method.
- MIL-STD-750 test methods are used for discrete devices and mirror test methods for the integrated circuits and hybrid devices

MIL-PRF-ATM Purpose and goals

- MIL-PRF-ATM (Advanced Technology Microcircuit) intended to bring heterogeneous integrated (HI) components into the military specification (QML) arena
- HI parts procured as COTS, SCD, or MFG specific flows have been and continue to be used by various USG programs. ATM intends to standardize test and documentation expectations.

- ATM intended to be technology and MFG approach agnostic
  - Some technologies not addressed (integrated photonics, some III-IV items, etc.)
  - Fan out method agnostic
- Primary drivers from MIL-PRF-38535/34 to ATM are TSVs, chiplet use, >2D configuration

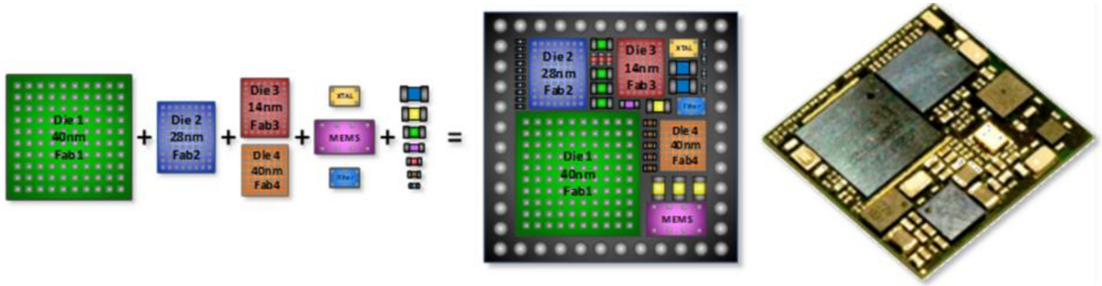


Figure 6. Heterogeneous Integration and System in Package (SiP). Source: ASE

Ref: Heterogeneous Integration Roadmap - IEEE Electronics Packaging Society

Difference of ATM product vs. MIL-PRF-38534/38535 legacy

- Each ATM product will have a SMD, Qualification plan, and Production plan
  - *Production plan is similar to legacy 38535 Appendix A material but may also address "test optimization" as part of initial production*
    - Intent is to provide OEM flexibility to optimize test flows aligned with product capabilities vs. arbitrary recipe applied to all products
  - *Qualification plan incorporates multiple documents including radiation plan (RPP), Package integrity plan (PIDTP), and other elements to address qualification*
    - ATM product typically have already undergone qualification and technology verification at OEM
    - Qualification differences addressed vs. failure mechanisms needing to be address for military / space needs
  - *Intent of SMD is to provide opportunity for OEMs to capture and make available to the community additional information not currently within SMD scope*
- Each ATM product is expected to have a specification written by the manufacturer that is not approved by the qualifying activity
- ATM products tend to be OEM specific with multiple levels of IP integrated
  - *Availability of information to purchaser may require NDA*
- Intent of documentation change is to simplify and streamline where possible and ensure content is aligned with HI products vs legacy monolithic or hybrid products

Status of MIL-PRF-ATM

- Using MIL-PRF-38535 as basis, pulling in 38534 material and modifying to make applicable to HI production, test flows, radiation capabilities, etc.
- OEMs provided flexibility to identify best method to validate product capabilities vs. failure mode
- Integrating NASA and Aerospace industry activities as applicable

Source	Section	Main body text	Main body tables	Appendix A	Appendix B	Appendix C	Appendix D	Appendix E	Appendix F	Appendix G	Appendix H	Appendix J
38535	Used	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
	Title	Specification	Specification	Quality	Space requirements	Radiation	Sampling	Qualification of offshore processes	Tape bonded items	QML program	Cert, Val, Qual	TCI and screening
	ATM use	Baseline for main body text	Baseline for main body tables	Baseline for Appendix A	Integrate into main body	Redlines and incorporate	TBD	Keep letter for potential future use	Keep letter for potential future use	Incorporate as needed into other sections	Baseline for PIDTP	Incorporate as needed into other sections
38534	Used	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No
	Title	Specification	Specification	Quality	Don't use	Hermetic element	Non-hermetic element	Design and construction criteria	Sampling	RHA	Don't use	Don't use
	ATM use	Incorporate elements as needed	Incorporate elements as needed	Don't use	Don't use	Integrate into main body tables as needed	Integrate into main body tables as baseline	Integrate into Appendix A, H as needed	Merge with Appendix D as appropriate	Baseline for Appendix C	Don't use	Don't use
ATM	Used	Yes	Yes	Yes	No	Yes	TBD	No	No	No	Yes	No
	Title	Specification	Specification	Quality	Don't use	Radiation	Sampling	Don't use	Don't use	Don't use	Cert, Val, Qual	Don't use
	Rationale	See applicable file DRAFTED	See applicable file IN WORK	See applicable file DRAFTED	Integrated into main body text and tables	See applicable file IN WORK	Is the sampling rationale applicable to ATM devices? Merge 35/34 sampling appendixes into 1?		Tape not expected to be applicable to ATM devices	Integrate into main body and Appendix A	PIDTP material ON DECK	May integrate into Appendix H and other locations

- Shifting format from legacy MIL-STDs to focus on failure modes, mechanisms and intent behind tests
- Core issue with HI product is that legacy approaches to quality and reliability verification may not be applicable due to application dependencies resulting in need to identify alternative community acceptable approaches for “standard” quality and reliability validation products

Where Do We Go From Here?

- We know military/space parts are generations behind the commercial parts industry
- Can the government continue to build high reliability systems with old technology?
  - *Yes but technologies become obsolete and the supply base continues to shrink*
  - *No – need to learn how to best use commercial technologies*
- Need to develop guidelines and practices for use of commercial technologies
- Use the best part that is available and meets the mission and application requirements
- Various government and industry teams working to develop information as to how to best use commercial technologies
- Aerospace has been leading an industry Mission Success Improvement Workshop (MSIW) developing guidance documents for the use of commercial technologies
- JEDEC has been in the forefront of integrating commercial requirements into military specifications
- The use of new technologies enhances system capabilities but data and testing must accompany the implementation to ensure long term mission success
- Checklists for new technology insertion must be adhered to

New Technology

- New technology/devices that are to be utilized for space applications and have no space heritage, must be characterized and qualified to ensure they will meet space mission requirements
- Military level grade parts do receive same level characterization as space level
- Characterization – all aspects of the device technology must be evaluated to ensure all failure mechanisms are known and understood, the process is well controlled, the long-term reliability of the product is established, radiation characteristics are identified, and overall parametric performance is well defined in terms of margins and areas of concern
  - *Wafer Level Reliability (i.e., Electromigration, TDDB, Antifuse, etc.)*
  - *Failure Modes Effects Analysis – evaluation of all potential failure modes and the impacts*
  - *Physics of Failure approach*
  - *Process variability analysis*
  - *Wafer Lot Acceptance*
  - *Long Term Reliability Testing*
- Qualification
  - *Standard mil-spec tests*

New technology must be completely evaluated for space utilization

Plastic Encapsulated Microcircuits (PEMs) and Plastic Encapsulated Devices (PEDs)

- As described earlier, the mil-specs were developed for the use of hermetic packages, but most new complex devices are manufactured in plastic encapsulated packages
- Various organizations are generating requirements for military/space systems to utilize plastic devices
- The utilization for plastic parts in military and space applications have to ensure the parts are rugged and will meet the mission requirements
  - *Temperature*
  - *Mechanical*
  - *Radiation*
  - *Reliability*
- SAE with industry, and government support developed documents for utilization of commercial, COTs and other types of parts
  - *AS6294/1 space and AS694/2 for terrestrial*
  - *AS6294/3 space discrete semiconductors and AS6294/4 discrete terrestrial*
  - *Task groups assigned to implement requirements in applicable mil-specs*
  - *Supplier buy-in mandatory*
- JEDEC has various task groups assigned to implement these SAE documents into the mil-spec system to ensure a standardized flow for customers

Summary and Conclusions

- The management of PMP (Parts Material Process) activities at the government or the contractor level is a critical task that requires personnel with expertise in many areas
- PMP tasks establish the heart of the system reliability based upon part selection, procurement and testing
- The addition of new technology and the continual maintenance of current standards bring both unique challenges and the opportunity to reinvent parts engineering.
- We support a variety of space missions and programs. The success of each mission is critical to the future of space exploration.
- Military standards still have a definitive role in todays' highly complex systems BUT so does commercial technologies
- For applications that do not require space quality products, alternate grade parts should be evaluated.
- A major part of PMP management is to understand the nuances of the classes and select the "best" part for the application and balance reliability, cost and schedule for the program

PMP management is critical to ensure long term system reliability