

## **Microcircuit Failure Mechanisms and Anomalies**

This section describes failure mechanisms and anomalies of microcircuits. Use this section as a guide to design and select microcircuits.

### **Failure Mechanisms - General**

Microcircuit manufacturers have long since learned to control and reduce failures in their wafer fabrication and hermetic package processes. However, the plastic encapsulated microcircuit (PEM) processes are still maturing with some problems still not controlled as well as users would like. The military now allows the use of consumer, industrial and automotive microcircuits in applications. Since PEMs are fairly new to the military, their reliability and performance over time remain the subject of scrutiny by both the manufacturers and users.

Consumer-grade PEMs are the riskiest microcircuit products used by the military. The main areas of study regarding their use are their unique failure mechanisms. Until studies are complete, designers should continue to monitor these parts and not assume there is complete freedom to use any microcircuit in any environment without concern for reliability. The risk should be minimized and the parts should still be monitored. Both producers and users in the military marketplace should know the potential failure mechanisms and anomalies of each microcircuit they plan to use. Because of the newness and risk PEMs place on the military industry, this section describes them in more detail.

Figure 1 shows recent failure mechanism breakdown data for packaged die at microcircuit manufacturer facilities.

The Naval Surface Warfare Center, Crane Division has been periodically assessing PEMs for over 25 years. For an example, they recently assessed over 3,000 PEMs for Trident Fire Control, Trident Navigation, CEC, Army Tank Command (TACOM), and the NAVSEA Parts Reliability and Derating Manual Programs from 1997 through 1999. Figure 2 shows the number of failed, marginal, and passing PEMs during this assessment period. The more common failures and anomalies found during this assessment are (1) improper moisture-sensitivity-level of package, (2) contamination, (3) poor die-paddle construction, (4) poor wire-bonds, (5) voiding, and (6) delaminations. Having 30% of the total microcircuits either failing or being marginal enforces the obvious need for PEM assessments and monitoring.

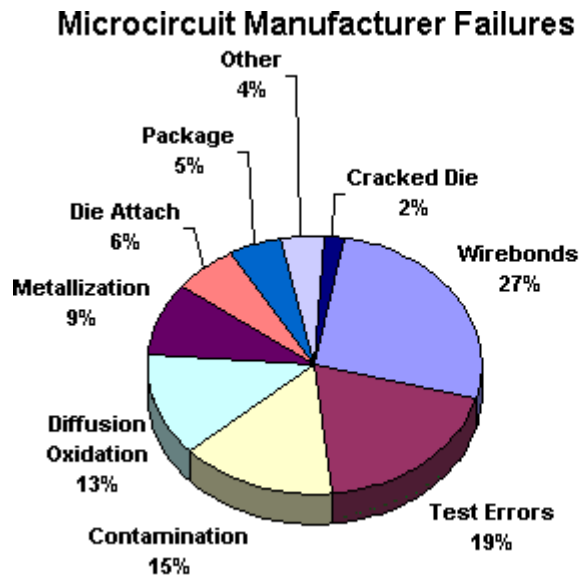


Figure 1. Microcircuit Manufacturer Failures  
 Source: ICE, "Roadmaps of Packaging Technology"

### PEM Assessment Results (1997-1999 data)

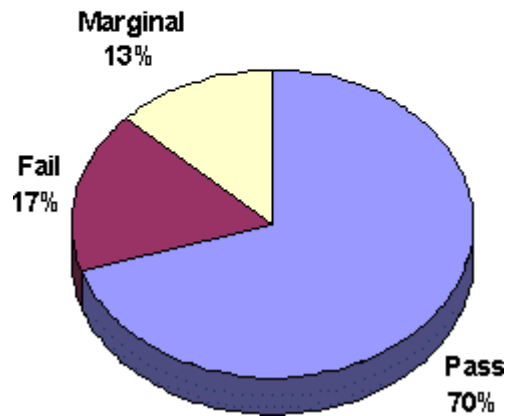


Figure 2. PEM Assessment Results  
 Source: NSWC-Crane Division

Table 1 and Table 2 cites some of the more common microcircuit failure mechanisms and anomalies with their probable causes.

Type	Example	Most Likely Cause	See Figure
Chemical	1. Corrosion	Moisture and Ionic.	12
	2. Contamination	Poor process control by MFR.	9
	3. Dendritic Growth	Moisture, Bias, and exposed metal.  Current density in Al metallization.	14
	4. Metal Migration	Inter-reaction of dissimilar metals E.G. Al-Au (Purple Plague).	13
	5. Intermetallics	Metal exposed to oxygen.	
	6. Oxides		
Physical	1. Open Circuit	Loss of bond/wire integrity, or cracked die from overstress by Thermal/Mechanical Shock, or Vibration, or weakened interconnects from Bond misplacement and from	6
	2. Short Circuit	Corrosion/Electro Migration. Loss/weakening of wire-bonds from sweep during injection of molding compounds.  Particle or interconnect wire, metallic migration, dendritic growth-poor process control.	
Function	1. Loss or Degrade	Electrical Overstress, ESD, Radiation, High Resistance Electrical Contact, High Temperature Exposure.	

Table 1. Failure Mechanisms: Die/Interconnects

## Chemical Failure Mechanisms

Historic chemical failure mechanism concerns with hermetic seal microcircuits also apply to PEMs; for example corrosion, contamination, dendritic growth, metal migration, oxides and intermetallics. PEMs are even more likely to develop "Purple Plague" because of the wide use of Aluminum (Al) and Gold (Au) in their wire bond fabrication. Although PEM manufacturers now use greatly improved encapsulant, additives such as bromide (fire retardant) can introduce halogens which produce corrosion when combined with moisture - all plastic encapsulates absorb moisture. PEM manufacturers now use encapsulants with additives such as bromide (a fire retardant) which can introduce halogens that produce corrosion when combined with moisture. All plastic encapsulants absorb moisture and improperly cured encapsulants can result in excessive porosity and moisture absorption.

Improperly cured encapsulant can result in excessive porosity and moisture absorption.

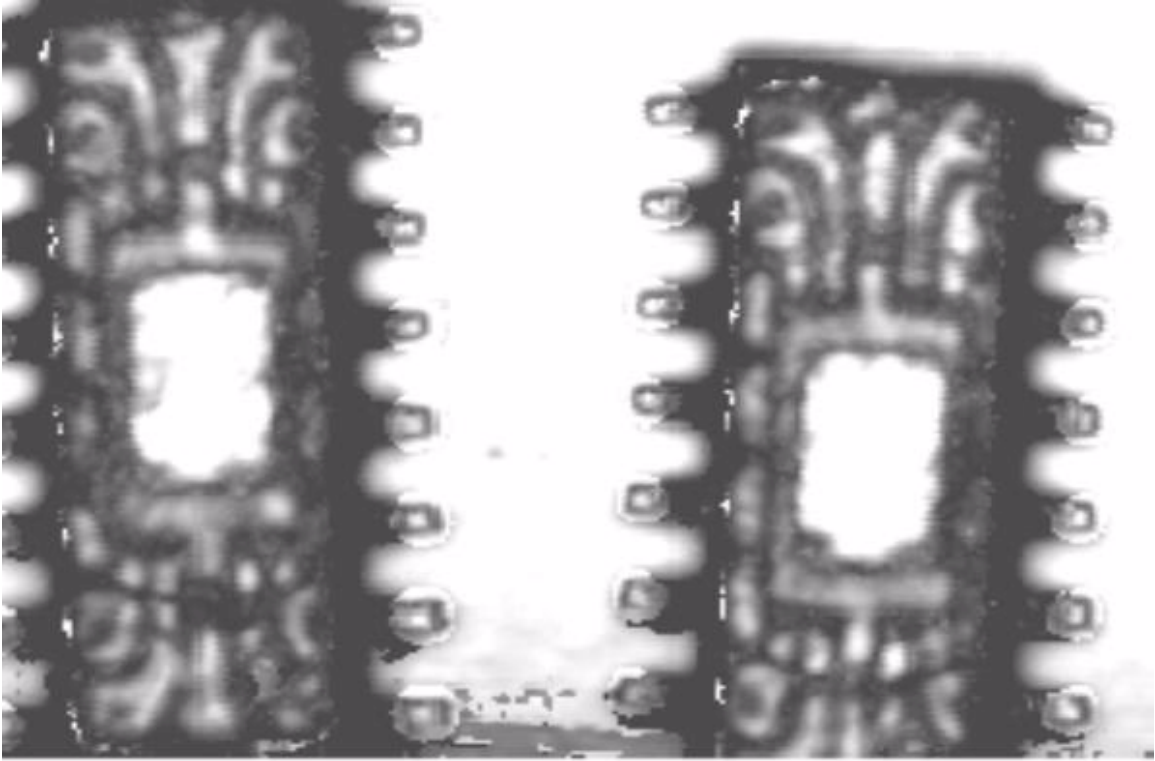
Type	Example	Most Likely Cause	See Figure
Chemical	1. Corrosion	Salt or Harsh Atmosphere.	10, 11
	2. Porosity/Pin Holes	Poor cure of Encapsulant by MFR. (Encapsulated IC); Inferior grade of metal (Hermetic IC).	1, 15,
	3. Solderability	Poor finish by MFR. or Harsh Atmosphere.	16
	4. Marking	High Temperature Exposure, Harsh Atmosphere or Cleaning Agent.	
Physical	1. Leaks	Poor weld or braze by Mfr., Fatigue by Thermal/ Mechanical Shock or Vibration (Hermitic seal IC).	2, 3,
	2. Rupture - "Pop Corning" Delaminations	Absorbed moisture expands during solder operation (Encapsulated Packages) poor	4, 5,

	Delaminations 3. Lead Seal	operation (Encapsulated Packages), poor process control, Thermal Shock (Encapsulated Packages).  Poor process control of Lead/Package seal by MFR., Mechanical Fatigue from Vibration to Temperature Cycling. (Both Package Technologies).	7, 8
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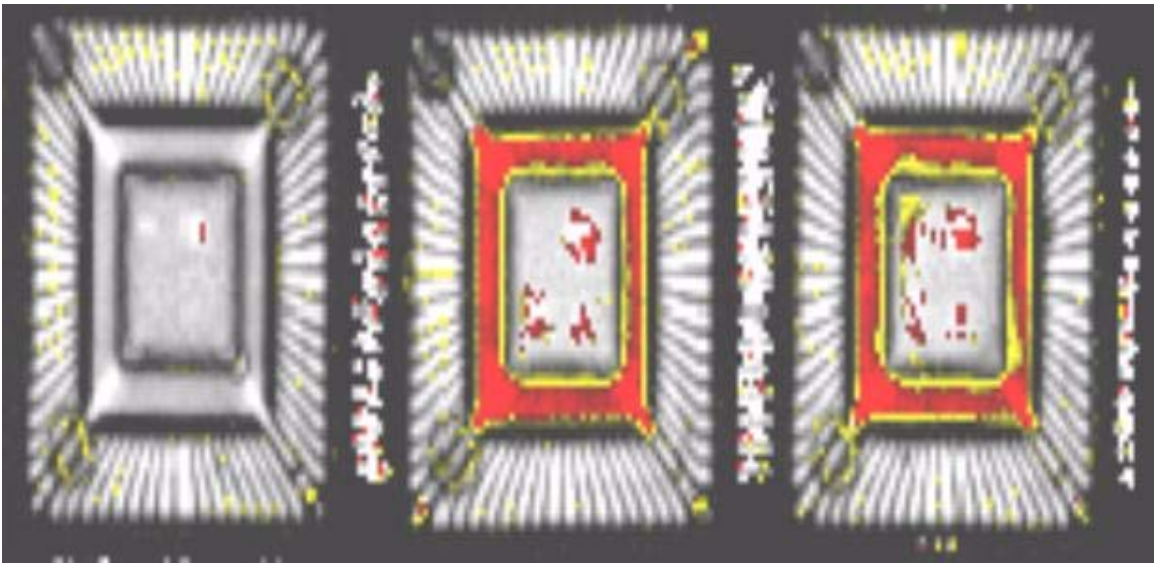
Table 2. Failure Mechanisms: Packages/Leads

Physical anomalies occur from other additives used to tailor package characteristics, e.g. hardness, temperature coefficients of expansion, and heat dissipation. When these additives are segregated from inadequate mixing, they can produce cracking, crazing, pinholes, delaminations and voiding, which again is conducive to excessive moisture absorption. Probably the most common problem encountered by users is the phenomena known as "pop corning". It is caused by the rapid expansion of moisture within the encapsulant during soldering. The moisture absorbed during storage and handling quickly turns to steam producing sufficient pressures to literally blow the package apart.

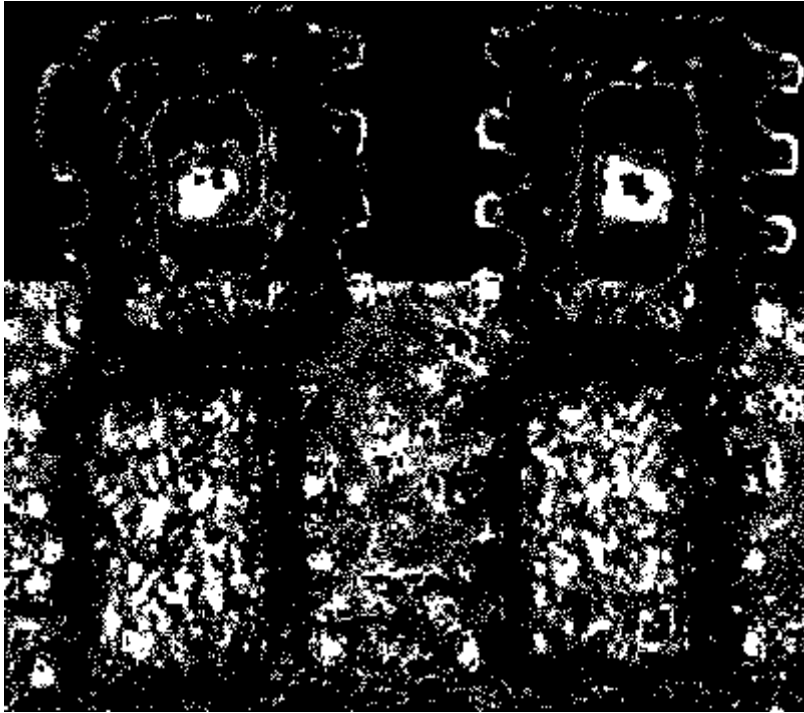
Typical examples of defects and anomalies are shown in Figures 3 through 18.



**Figure 3**  
C-SAM image of PEM with die-attach delaminations (white area) and poor material porosity causing fuzzy image.



**Figure 4**  
C-SAM images of PEM with delaminations (Red area)

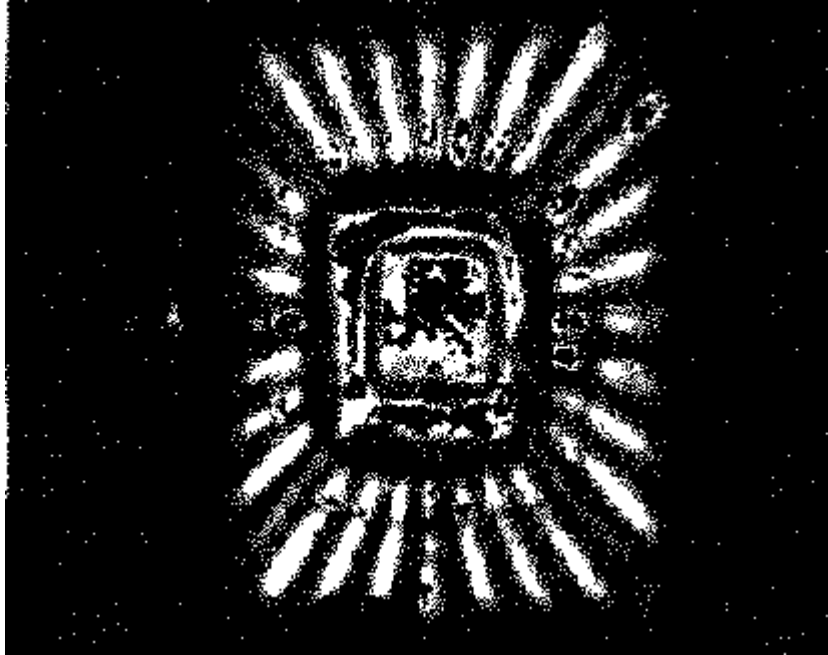


**Figure 5**

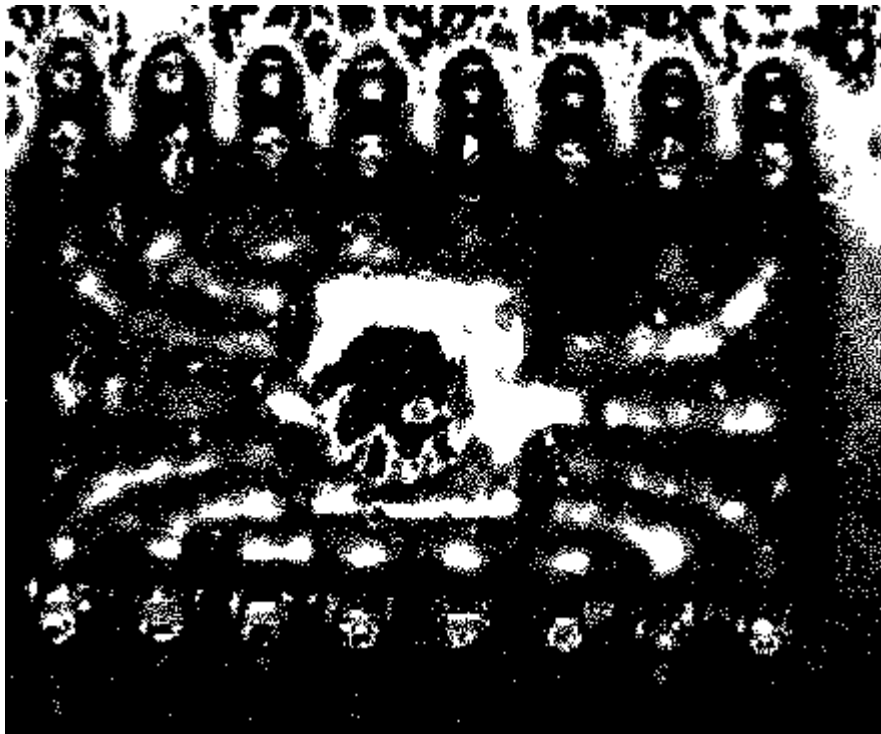
C-SAM images of PEMs.

Top images show delaminations (Red area).

Bottom images show porosity in-texture appearance is mottled.



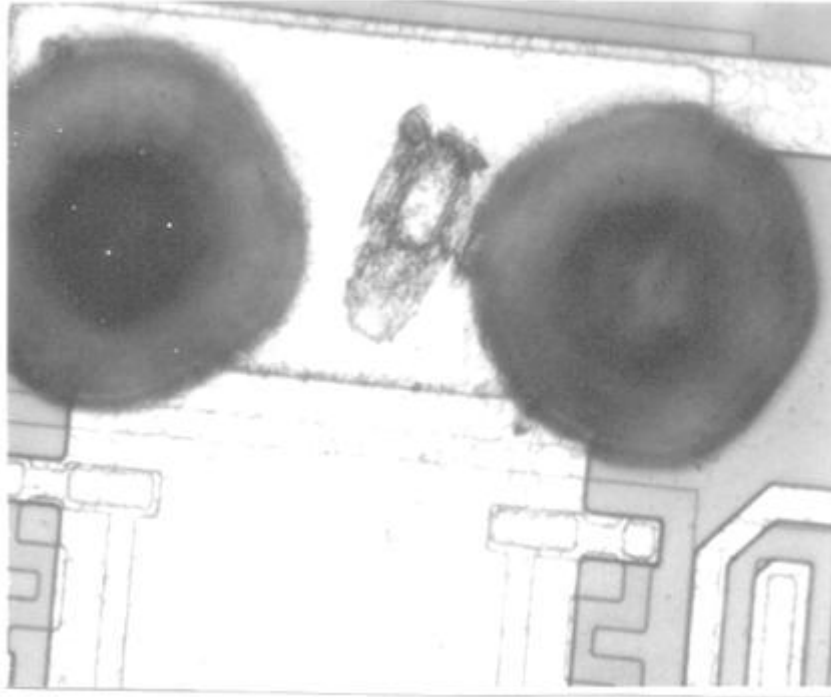
**Figure 6**  
C-SAM image of PEM with poor die-attach (Red area)  
and delaminations (Yellow/Red area)





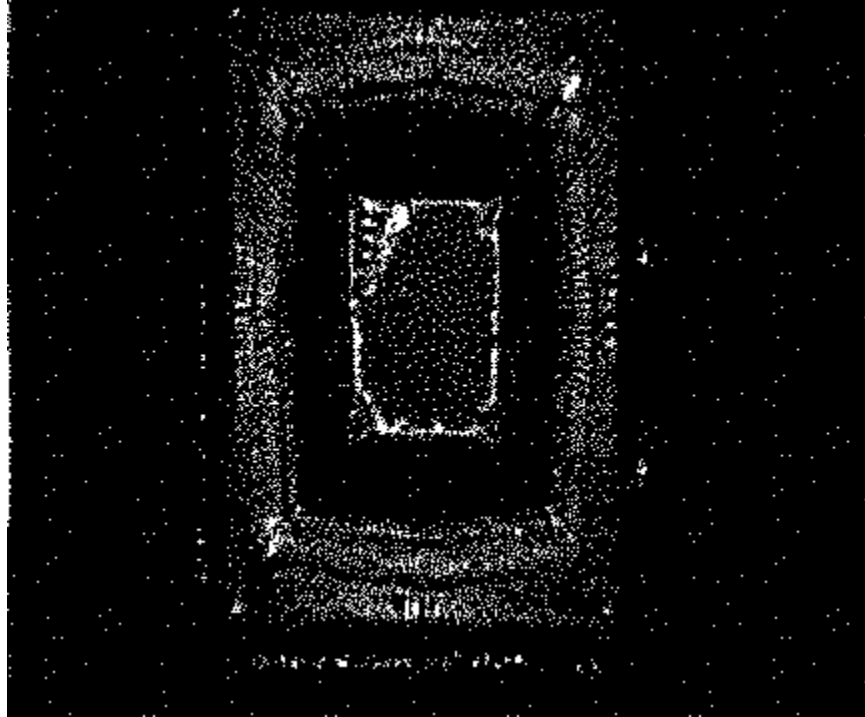
**Figure 7**

C-SAM image of PEM with poor die-attach.  
Appears voided (Red area) and material has excessive porosity causing fuzzy image.

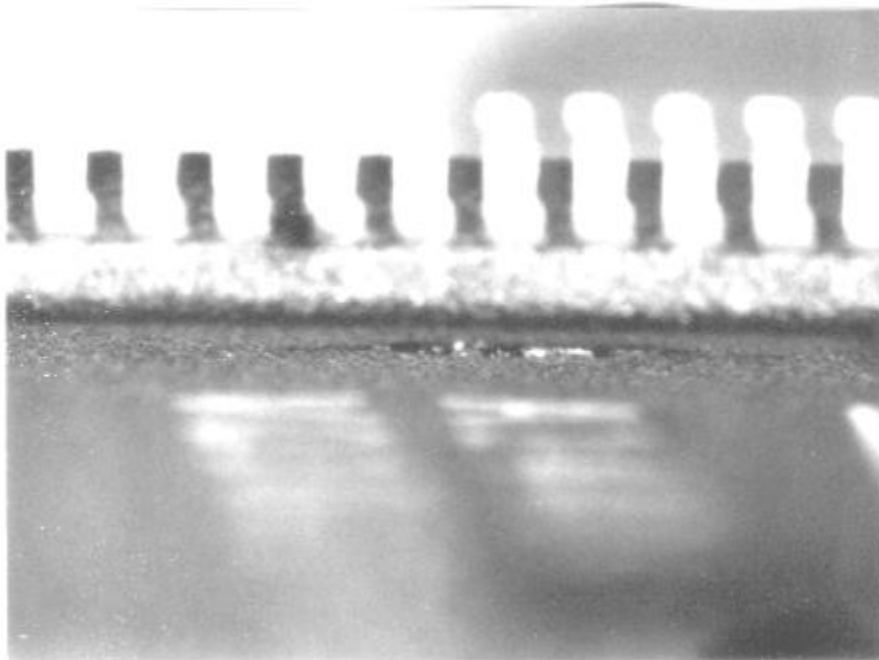


**Figure 8**

Construction analysis photo of PEM.  
Wire-bond displacement weakening bond causing latent dis-bond failure.



**Figure 9**  
C-SAM image of PEM. “Pop-corning” effect  
caused damaged corner from vapor phase solder re-flow overheating.



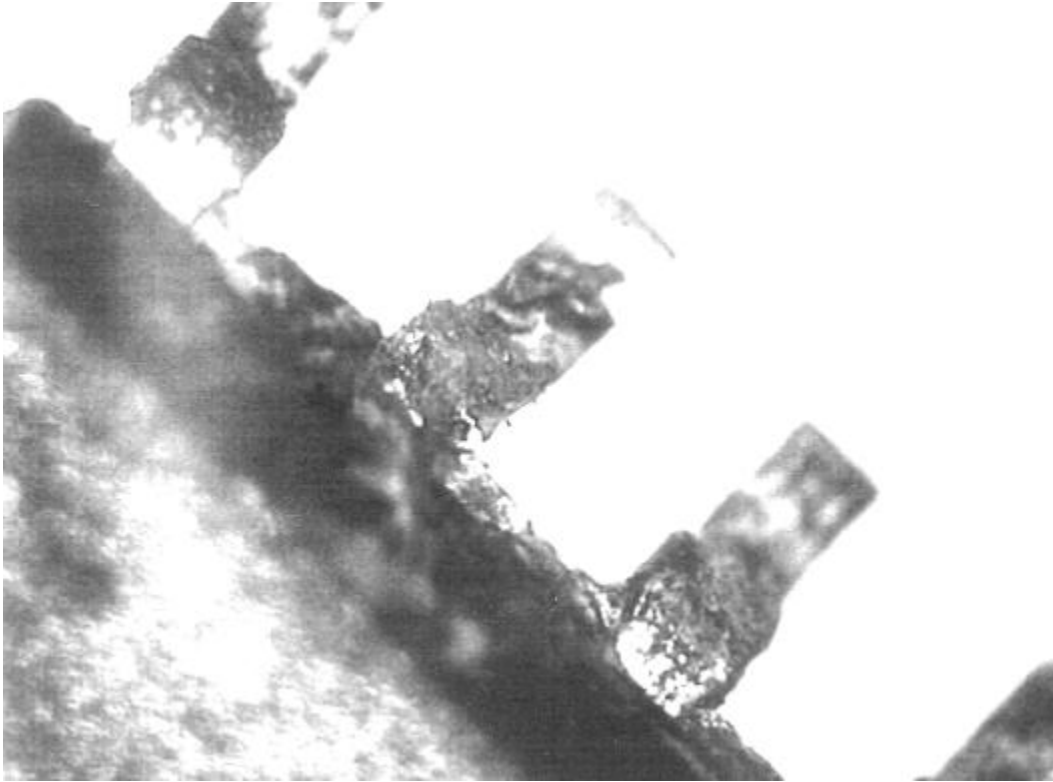
**Figure 10**

Construction analysis Photo of PEM. “Pop-Corning” effect caused crack in plastic from vapor phase solder re-flow overheating.

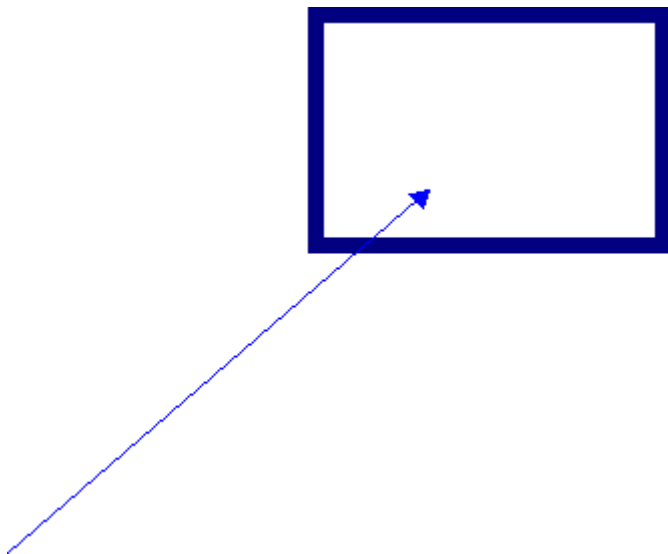


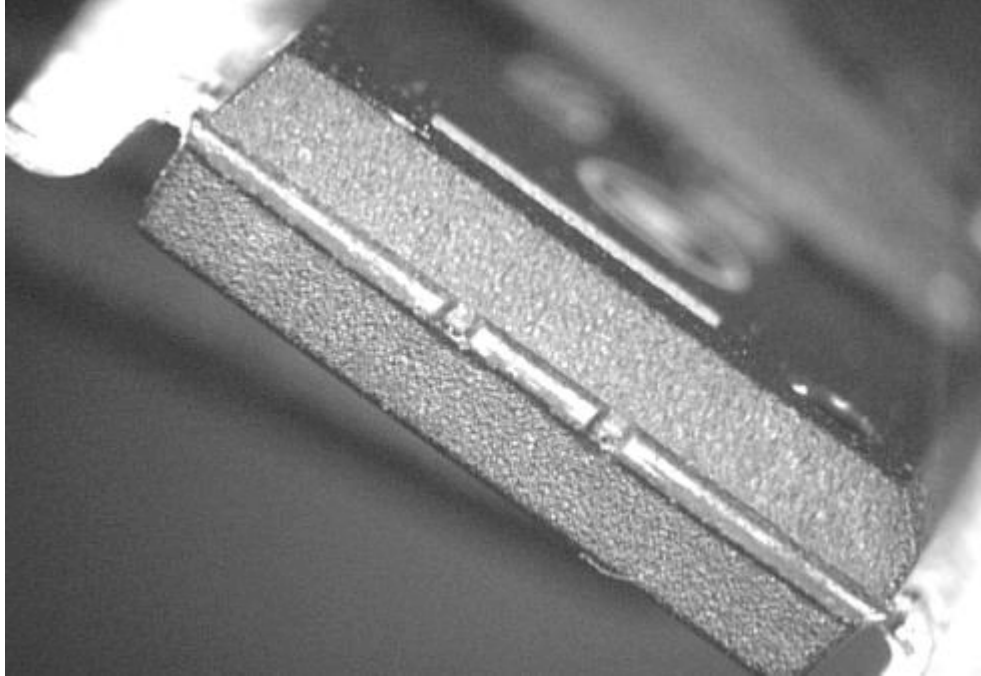
**Figure 11**

SEM photo of PEM. Contamination - Residue from halogen presence in package. Cause latent defect by accelerating corrosion and weakening bond.



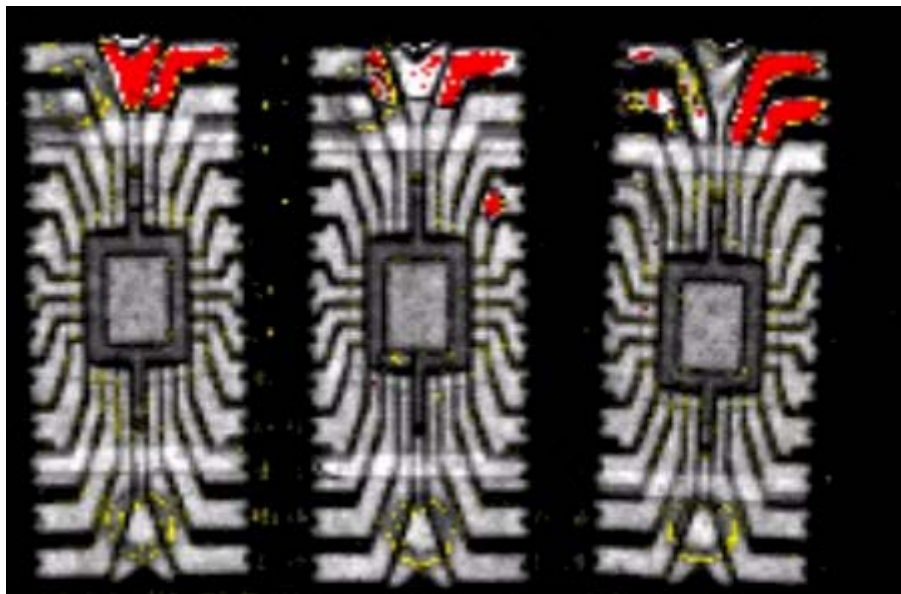
**Figure 12**  
Photo of PEM following Salt Spray test. Failures from excessive lead damage.  
Caused by Salt Spray.





**Figure 13**

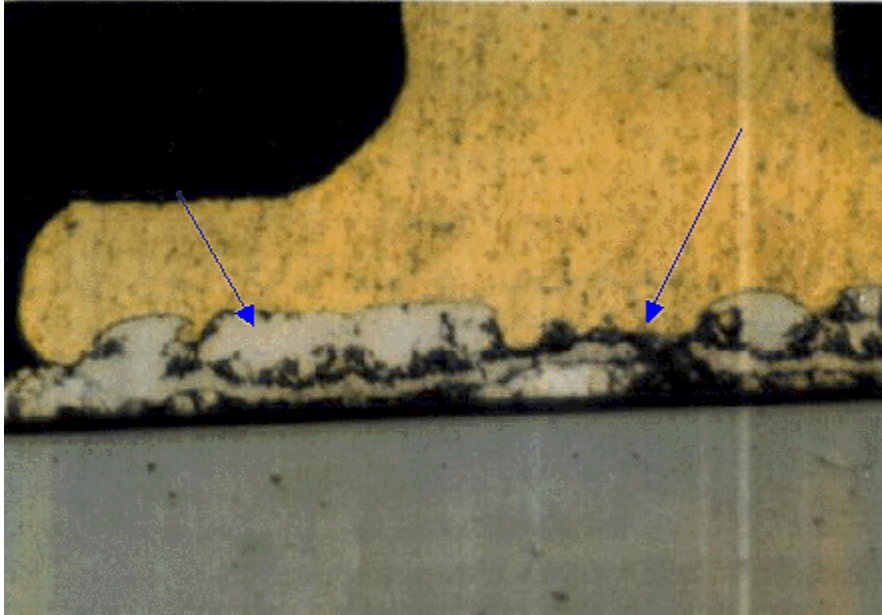
Photo of PEM. Loss of seal integrity at leadframe tabs of PEM.  
Allowed moisture/salt ingress during salt spray  
Test. Accelerated corrosion latent defect.



**Figure 14**

C-SAM image of PEMs.

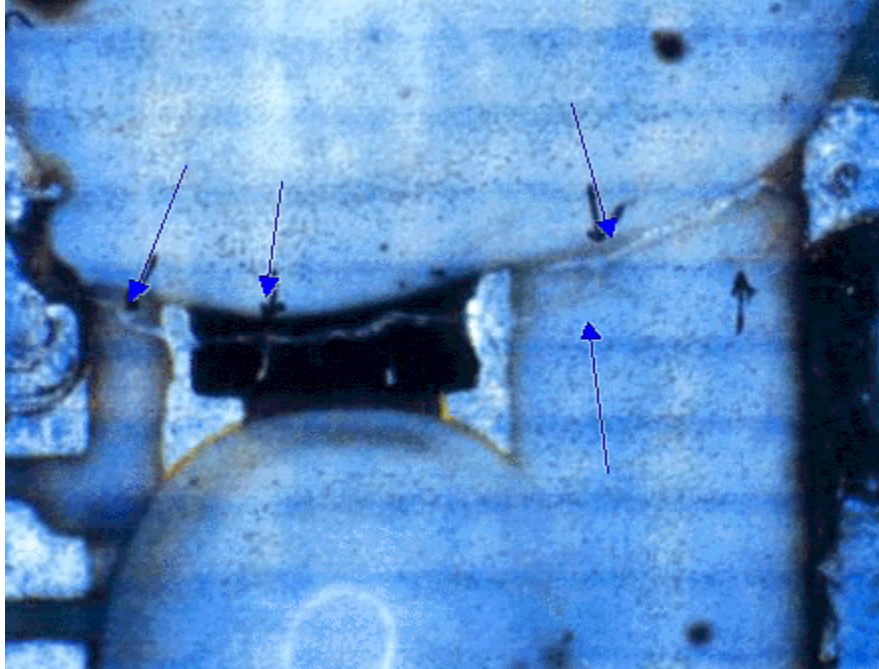
Salt ingress into PEM following Salt Spray test. Cause latent corrosion defect.  
Same PEM as Figure 11.



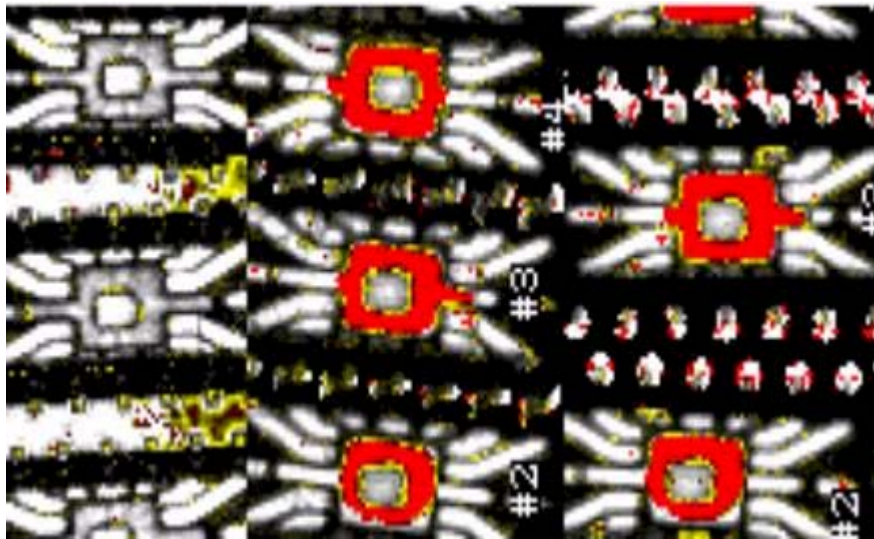
**Figure 15**

SEM photo of PEM with Kirkendall Voiding (Purple Plague)

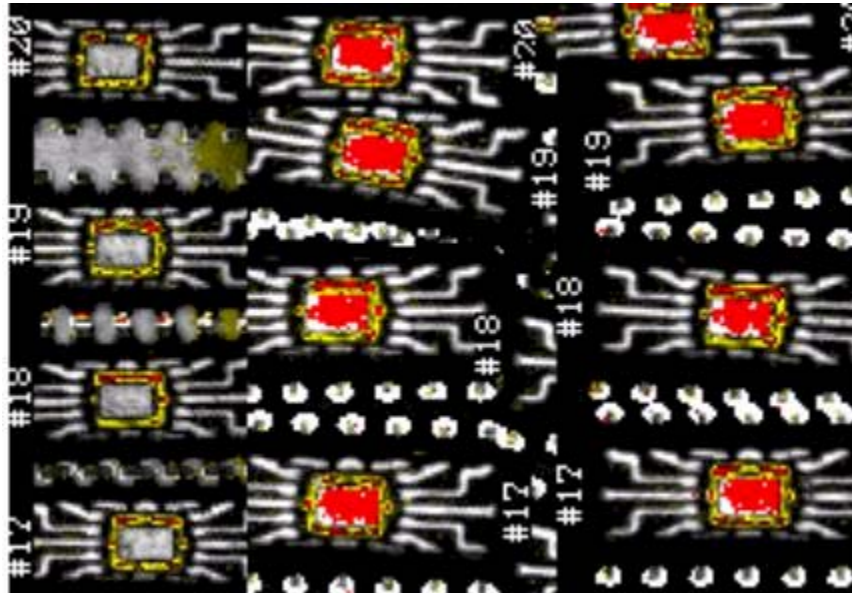




**Figure 16**  
SEM photo of PEM with internal dendritic growth



**Figure 17**  
C-SAM images of PEMs with poor die-paddle attachment.  
Left images are initial scans.  
Center images are following pre-conditioning.  
Right images are following 50 hours of HAST.



**Figure 18**

C-SAM images of PEMs with poor Die-Attach.  
Left images are initial scans.  
Center images are following pre-conditioning.  
Right images are following 50 hours of HAST.