Frequently Asked Questions About PEM Reliability

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Subject Outline

- Plastic (PEMs) vs. Hermetic (HSMs)
- Moisture Sensitivity/Al Corrosion
- Moisture Sensitivity/SMD Popcorning
- Temperature Cycle Stress
- Plastic Molding Compound
- PEM Temperature Range
- Manufacturing Controls for Reliability
- Conclusions

Plastic (PEMs) vs. Hermetic (HSMs)

Plastic (PEMs) Vs. Hermetic (HSMs)

Are PEMs as reliable as HSMs?

- PEMs will provide reliability equivalent to or better than HSMs if:
  - Application environment is understood relative to PEM capability.
  - Industry’s best practices are used by supplier and user.
  - Sufficient PEM data/experience exists for similar application environments

Plastic (PEMs) Vs. Hermetic (HSMs)

How does PEM failure rates compare to that of HSMs?

- Intersil data for same technologies and device types have shown comparable failure rates on High Temperature Operating Life tests conducted in same time frame.

Failure Rate at 55°C, 60% UCL		
Package	**Sample (1)**	**FITs (2)**
Hermetic (CERDIP	**117,991**	**7.9**
Plastic (PDIP)	**342,252**	**8.2**

1. **Combines data (1987-94) on CMOS and Bipolar IC's in 8 to 20-Ld packages.**
2. **Extrapolated from stress temperatures (^{3} 125C), FITs = Fails in 10^9 Device Hours, UCL = Upper Confidence Limit.**

Plastic (PEMs) Vs. Hermetic (HSMs)

What are the differences in failure modes and mechanisms?

- HSMs have as many failure modes and mechanisms as PEMs.
- HSMs more susceptible to mechanical stress.
- Molded PEM construction immune to mechanical stress.
- PEMs more susceptible to thermal and moisture stress.
- Comparative listing of modes/mechanisms shown in following chart.

Package Related Failure Modes/Mechanisms

Description	Stress/ Source	Response	Accelerating Test	Plastic	Hermetic
Cracked Die	Thermal	Electrical Short/Open	Temperature Cycle	X	X
	Mechanical	Electrical Short/Open	Impact Shock		X
Wire Breaks	Thermal	Electrical Open	Temperature Cycle	X	X
	Mechanical	Electrical Open	Vibration, Centrifuge		X
Wire Lifts	Thermal	Electrical Open	Temperature Cycle	X	X
	Mechanical	Electrical Open	Vibration, Centrifuge		X
Wire Lifts (Intermetallic)	Thermal	Electrical Open	High Temp Storage	X	X
Cracked Seals, external	Thermal	Loss of Hermeticity	Temperature Cycle		X
	Mechanical	Loss of Hermeticity	Impact Shock		X
Corroded Seals, external (Pin-to-Pin Shorts)	Moisture	Loss of Hermeticity	Humidity, Salt Atmosphere		X
Interface Delamination	Thermal	Reduced Moisture	Temperature Cycle	X	

Package Related Failure Modes/Mechanisms

(Continued)

Description	Stress/ Source	Response	Accelerating Test	Plastic	Hermetic
Internal Water Vapor	Package Assembly	Al Corrosion	Low Temperature Bias Life		X
Moisture Ingress	Moisture	Al Corrosion Autoclave, HAST	Temp/Humidity/Bias	X	
SMD Cracked Pkg. (Popcorn Effect)	Thermal	Reduced Moisture Resistance/Elect. Opens	Humidity/Solder Shock Sequence	X	
Metal Deformation Cracked Passivation	Thermal	Electrical Shorts/Open	Temperature Cycle	X	
Lifted Die	Thermal Mechanical	Electrical Shorts/Open Thermal Designation	Temperature Cycle Impact Shock, Centrifuge		X
Die Attach Voids	Package Assembly	Thermal Dissipation Low D/A Strength Cracked Die	Bias Life Temp Cycle, Centrifuge	X	X
Loose Die Attach	Package	Electrical Shorts	Vibration/Shock PIND		X

Moisture Sensitivity/Al Corrosion

Moisture Sensitivity/Al Corrosion

Since PEMs are nonhermetic, why don’t all parts corrode?

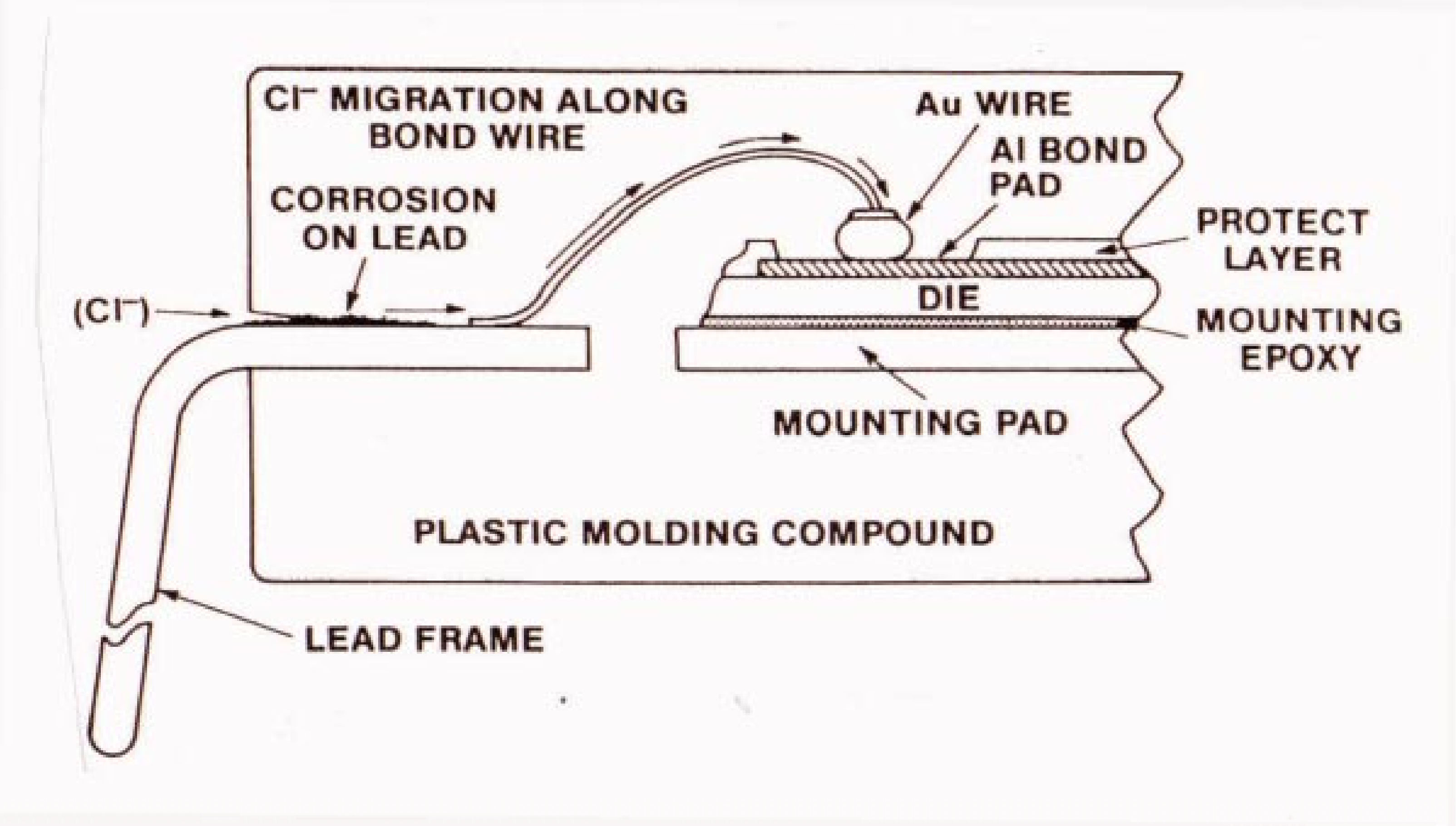
- ✓ Presence of moisture alone is not likely to cause corrosion.
- ✓ Corrosion is chemical reaction which requires the presence of an ionic species, such as chloride, which sets up an electrolytic cell with moisture.
- ✓ Rate of corrosion is function of combined effect of :
  - Bias Voltage
  - Moisture
  - Temperature
  - Conductivity of Electrolyte

Moisture Sensitivity/Al Corrosion

How does ionic contamination cause corrosion?

- ✓ Chloride is the most common ionic contaminant inducing corrosion.
  - Al oxide first dissolved by Cl ion: $Al(OH)_3 + Cl^- \rightarrow AL(OH)_2Cl + OH^-$
  - Exposed Al reacts with Cl ion: $Al + 4Cl^- \rightarrow [AlCl_4]^- + 3e^-$
  - Al anion reacts with water: $2[AlCl_4] + 6H_2O \rightarrow 2Al(OH)_3 + 6H^+ + 8Cl^-$
  - The corrosion product is aluminum hydroxide.
- ✓ Reaction frees up the Cl ion to continue the process as long as moisture is present.

Path of Ingress of Ions and Moisture

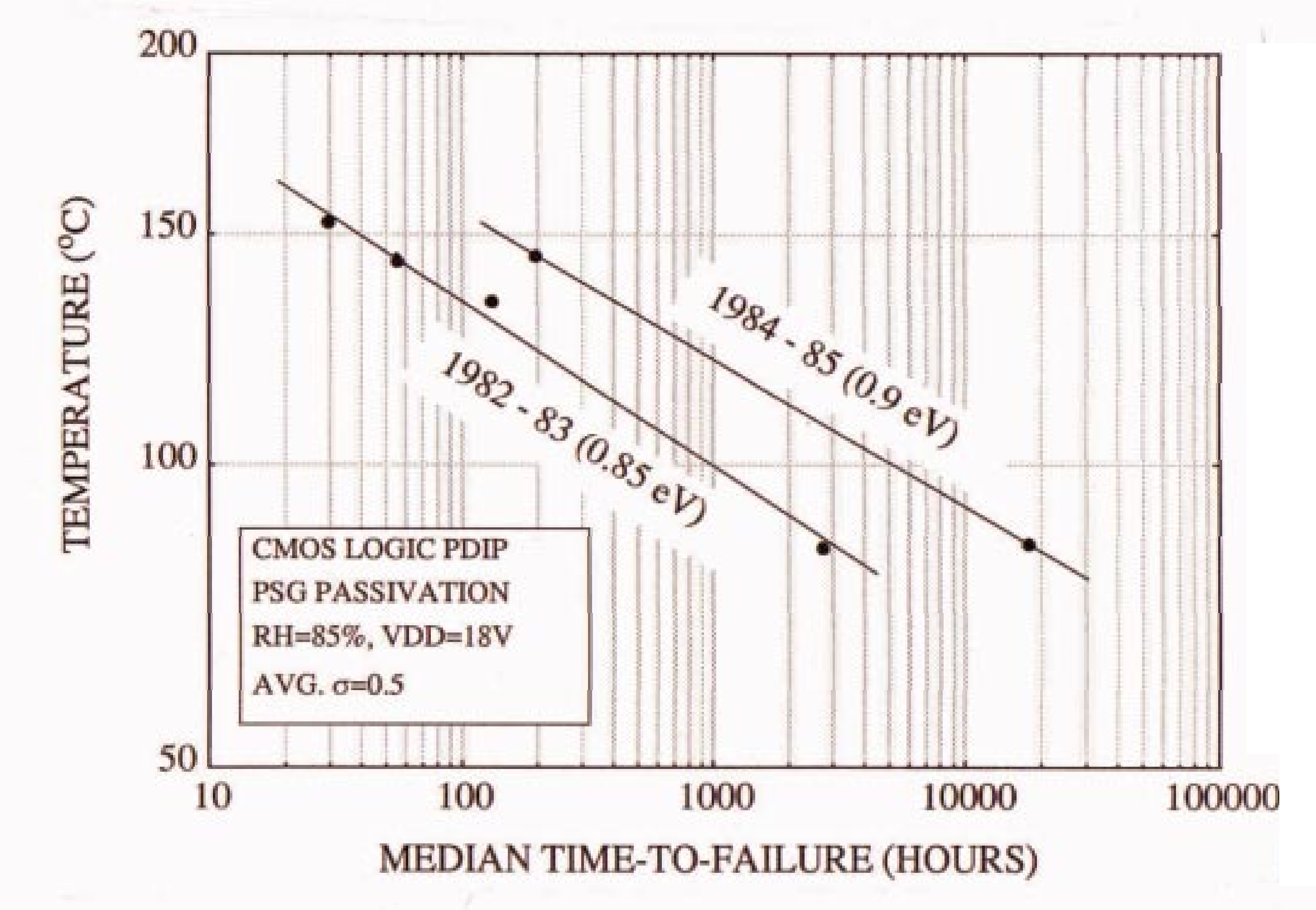


Moisture Sensitivity/Al Corrosion

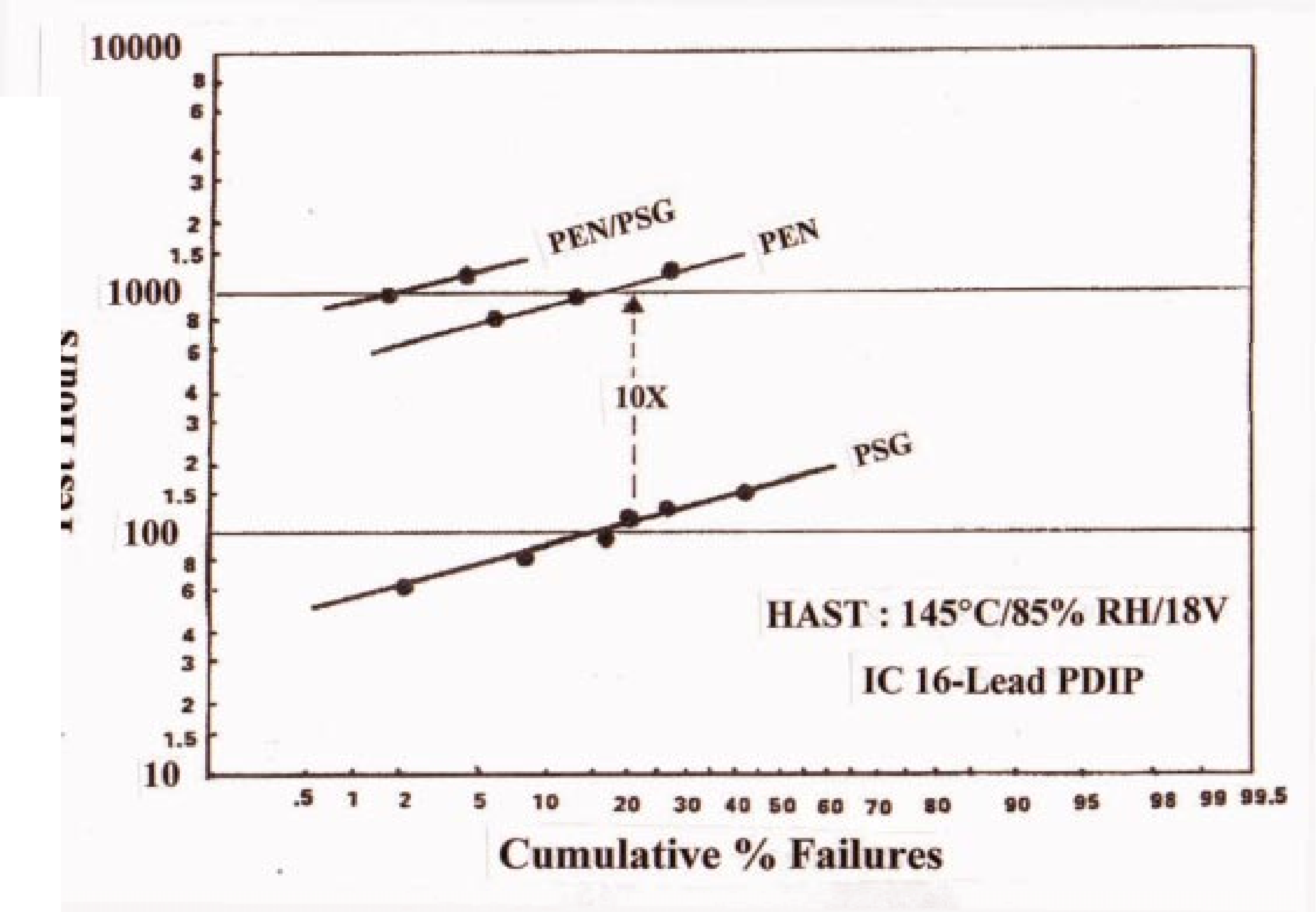
Is moisture induced corrosion a concern today?

- ✓ Main deterrent in use of PEMs by Military dating to 1970's.
- ✓ Survivability has significantly increased in last 15 years:
  - – Improved mold compound purity and adherence
  - – Improved purity of die attach materials
  - – Improved glass passivation and deposition tools
  - – Improved leadframe construction and design
  - – Cleaner and more automated manufacturing processes
  - – Elimination of halide fluxes and other sources of halides
  - – Education of the user relative to board assembly of PEMs
- ✓ Corrosion is rarely the cause of failure today (PEMs used in billions/year).

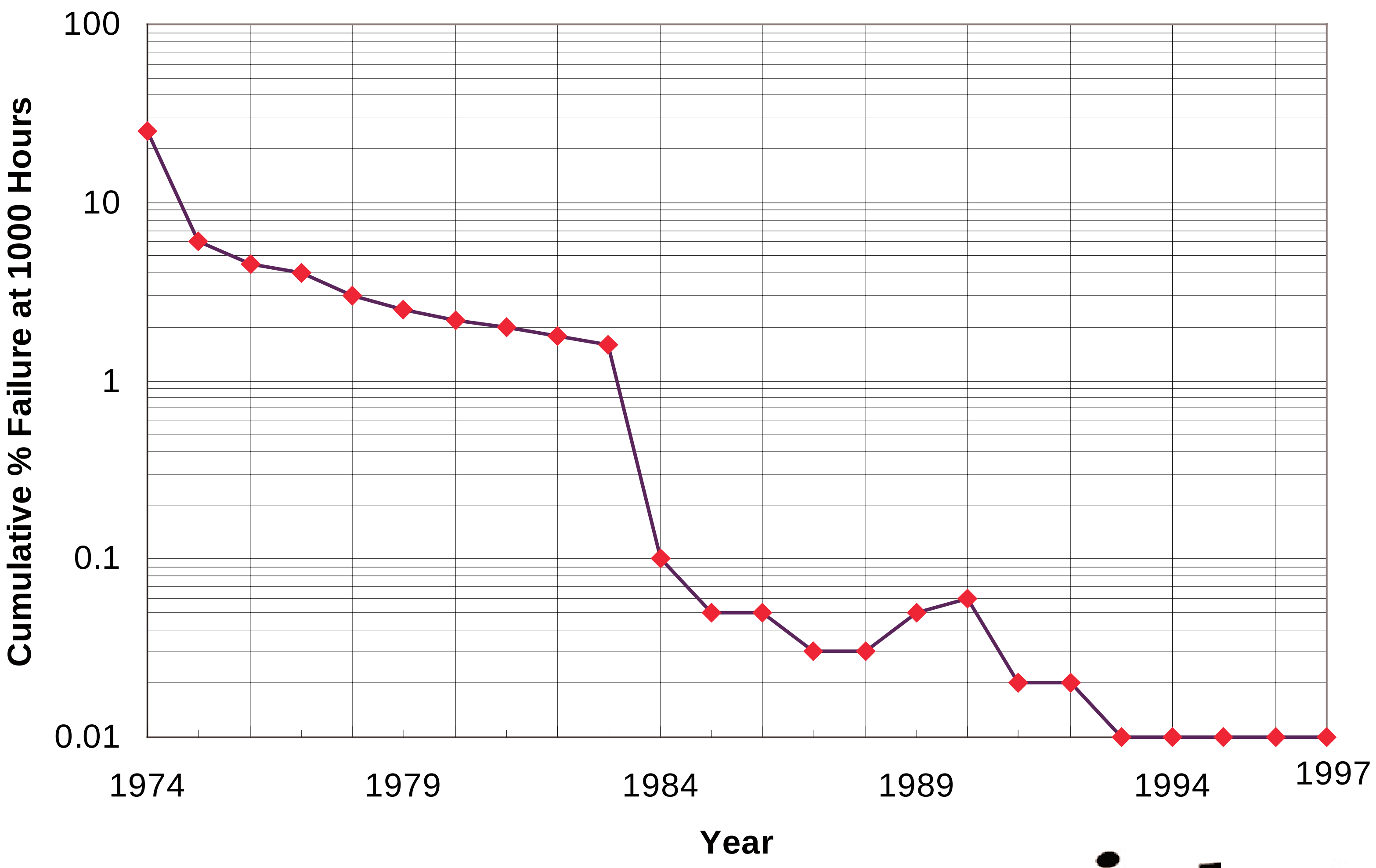
Al Corrosion Wearout Characterization at 85% RH Demonstrates Up To A 6X Increase in MTF Due to Improvements In Mold Compound, Lead Frame Construction, and Cleaner Processing



Comparison of Plasma Enhanced Nitride (PEN) and Phosphosilicate Glass (PSG) Passivation for Al Corrosion



THB 85C/85% RH, CMOS Logic IC's in PDIP



Moisture Sensitivity/Al Corrosion

What acceleration factor models are used for corrosion?

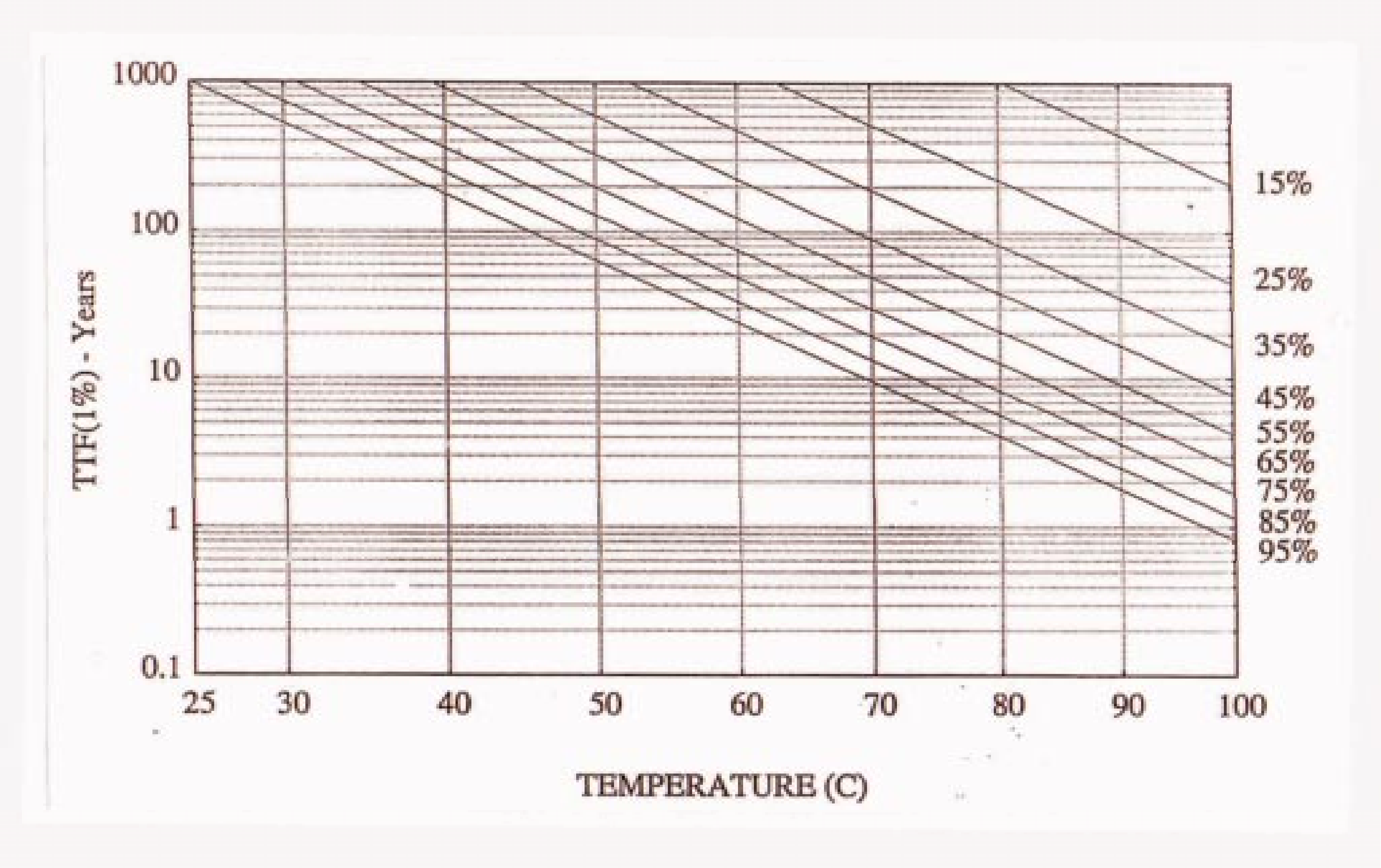
- ✓ Intersil wearout data showed good fit to Peck's model.

$$AF = \exp\left[Ea/k\left(1/T_U - 1/T_S\right)\right]\left(RH_S/RH_U\right)^a\left(V_S/V_U\right)^b$$

where AF = Acceleration Factor
T = Temperature at Use and Stress (°C + 273)
RH = Relative Humidity at Use and Stress Conditions
V = Voltage at Use and Stress Conditions
Ea = Activation Energy (0.9 eV) from Intersil Data
k = Boltzman's Constant (8.62 E-5 eV/°K)
a = 2.66 Based on Peck [1]
b = 1.4 from Intersil Data

[1] Peck and Hallberg, Quality and Reliability Engineering International, (1991).

CMOS Logic Plastic Dual-In-Line Package (PDIP) Life Prediction To 1% Failure For Aluminum Corrosion As A Function Of Temperature and % Relative Humidity at 5 Volts Continuous Bias



Moisture Sensitivity/Al Corrosion

What are the results of moisture-related tests used to monitor PEMs?

- ✓ Data obtained during 1997 on 14 - 28 lead PDIPs and SOICs:

Test & Conditions	Hours	Failures/Samples PDIP	Failures/Samples SOIC
Temp/Humidity/Bias 85C/85% RH/Rated V_{DD}	1000	0/3858	0/1459
HAST 135°C/85% RH/Rated V_{DD}	48	0/4410	0/2385
Autoclave 121°C/100% RH/15 psig	96 192	0/7290 0/9122	0/2385 0/7199

Long Term 85°C/85% RH Test Data

Test	Package	Hours	Sample	Failures
Storage (No bias)	PDIP	7,000	40	0
	PDIP	10,000	120	0
	PDIP	11,000	40	0
Temperature/Humidity/Bias (6V bias)	PDIP	3,000	180	0
	SO*	3,000	290	0
	PDIP	5,000	50	0
	SO*	5,000	50	0
	PDIP	7,000	40	0
	PDIP	13,000	40	0
	PDIP	14,000	40	0
	PDIP	17,000	40	0
Temperature/Humidity/Bias (18V bias)	PDIP	5,000	40	0
	PDIP	7,200	40	1 @ 7.2k
	PDIP	8,000	120	0
	PDIP	9,000	160	1 @ 6k 1 @ 9k

* Data combines Digital Logic (CMOS Metal Gate, CMOS Silicon Gate) and Bipolar ICs. Combines parts subjected to various conditions of reflow solder pre-conditioning.

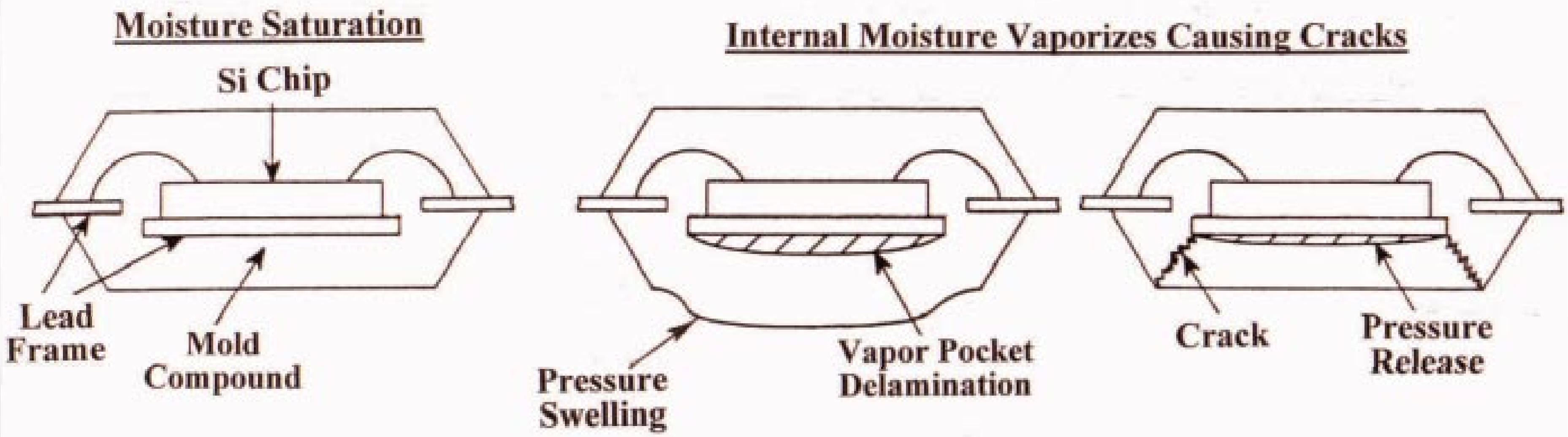
Moisture Sensitivity/SMD Popcorning

Moisture Sensitivity/SMD Popcorning

What is “popcorn cracking”?

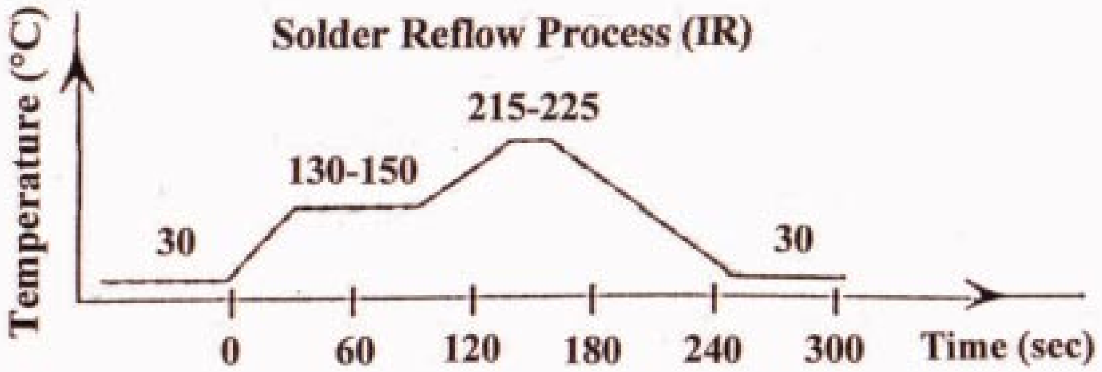
- ✓ SMDs subjected to solder reflow temperatures are susceptible to cracking and delamination of mold compound.
- ✓ Temperatures create sudden vaporization of absorbed moisture
  - – Absorbed moisture > 0.2% of package weight critical
  - – Larger/thinner packages more susceptible
- ✓ Cracking creates paths for ingress of moisture/contaminants.
- ✓ Phenomenon is industry wide materials problem.
- ✓ Current solution is dry-packing and floor life control of sensitive SMDs.

Popcorn Cracking

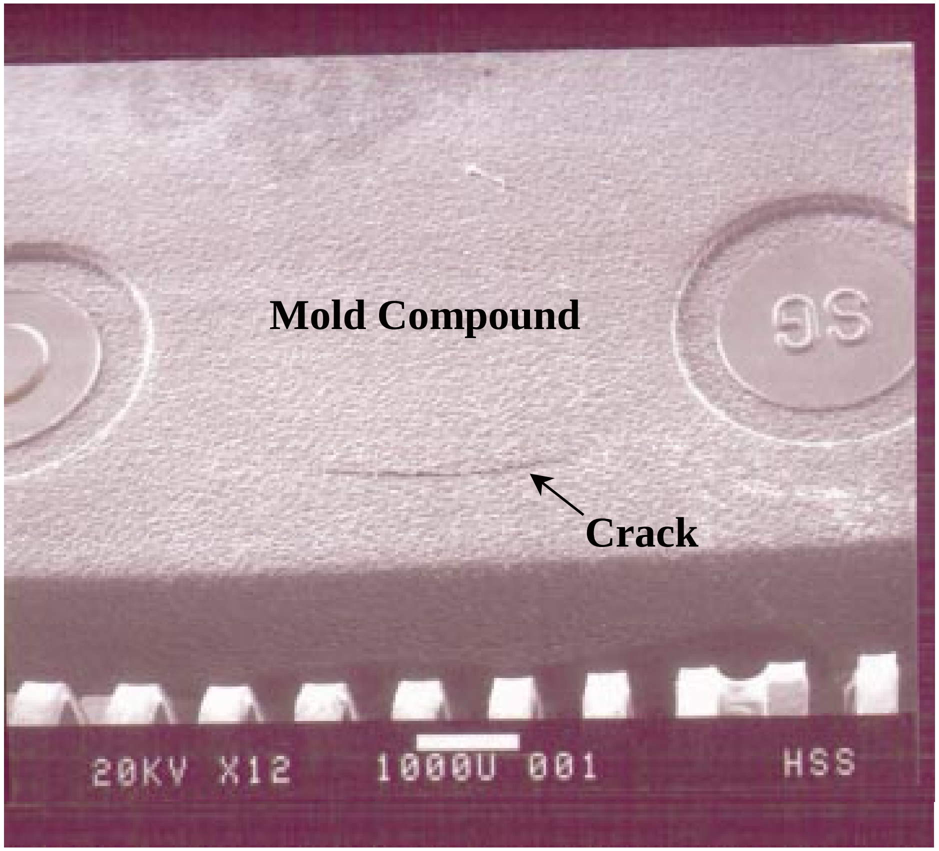


Level of saturation depends on storage conditions:

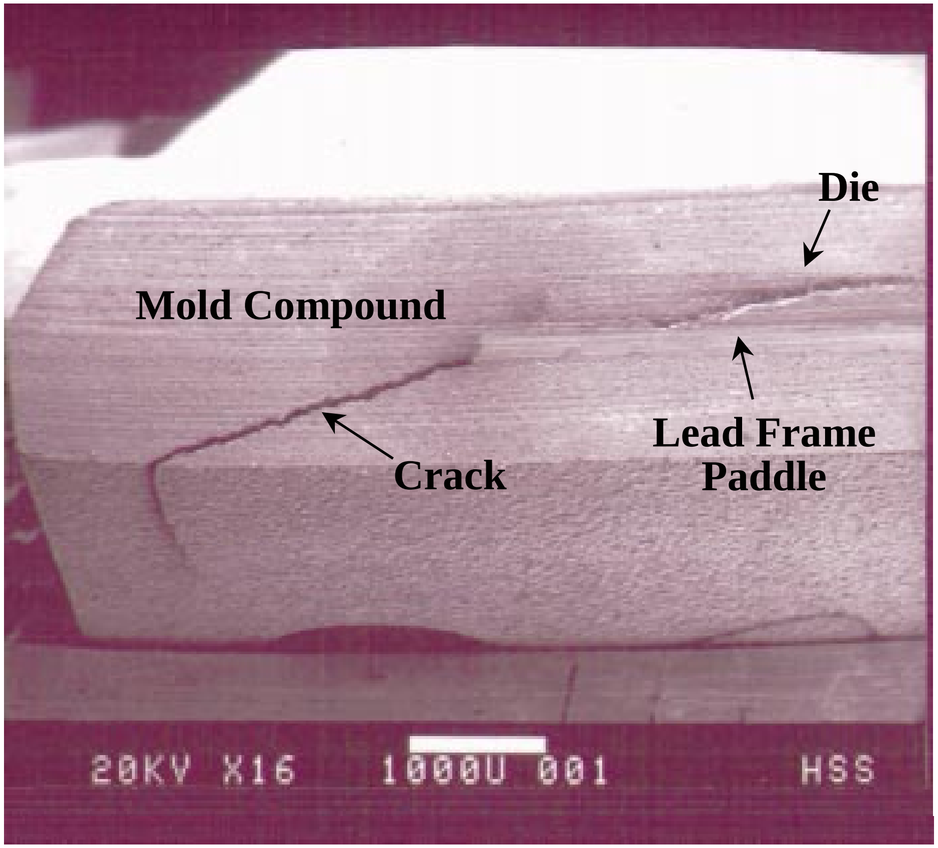
- Humidity
- Temperature
- Time



SEM Photos of Popcorn Cracking
MQFP Package



Crack on External Package Surface



Cross-Section of Crack Propagation

Fick’s Law of Diffusion

1. $$\frac{M_{t1}}{M_S} = 4 \checkmark \left(\frac{D_f \checkmark tl}{1^2 \checkmark p} \right)^{\frac{1}{2}}$$

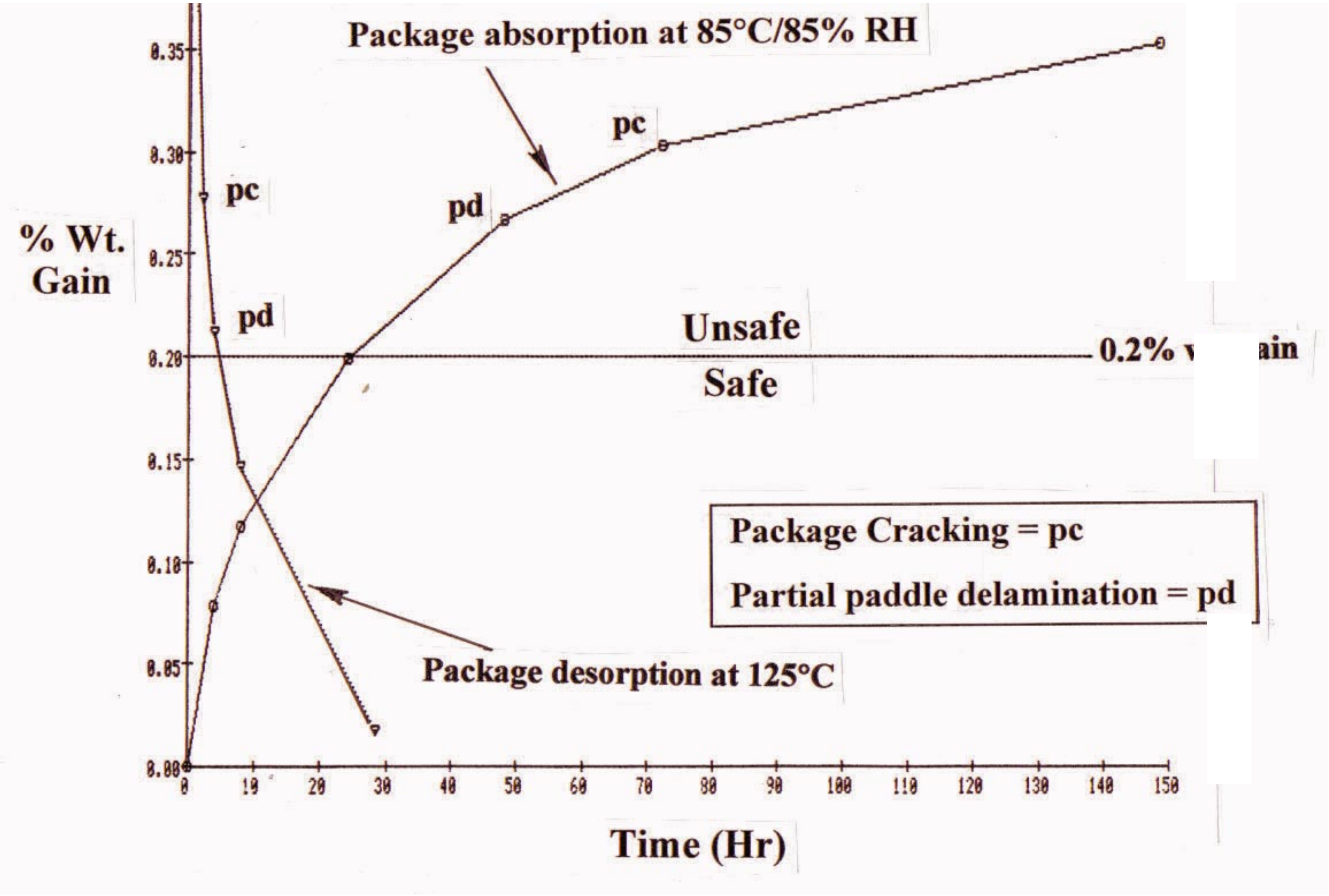
2. $$1n \left(\frac{M_S - M_{t2}}{M_S} \right) = 1n \left(\frac{8}{p\ 2} \right) - \frac{p^{2} \checkmark D_f \checkmark t2^{2}}{1^2}$$

3. $$M_{(x,\, t)} = M_S \checkmark \left(\frac{4}{p}\ å \left(\frac{1}{2k+1} \checkmark exp \left(\frac{-(2k+1)^{2} \checkmark p^{2} \checkmark D_f \checkmark t)}{1^2} \right) \checkmark sin \left(\frac{(2k+1) \checkmark p^{2} \checkmark x}{1} \right) \right) \right)$$

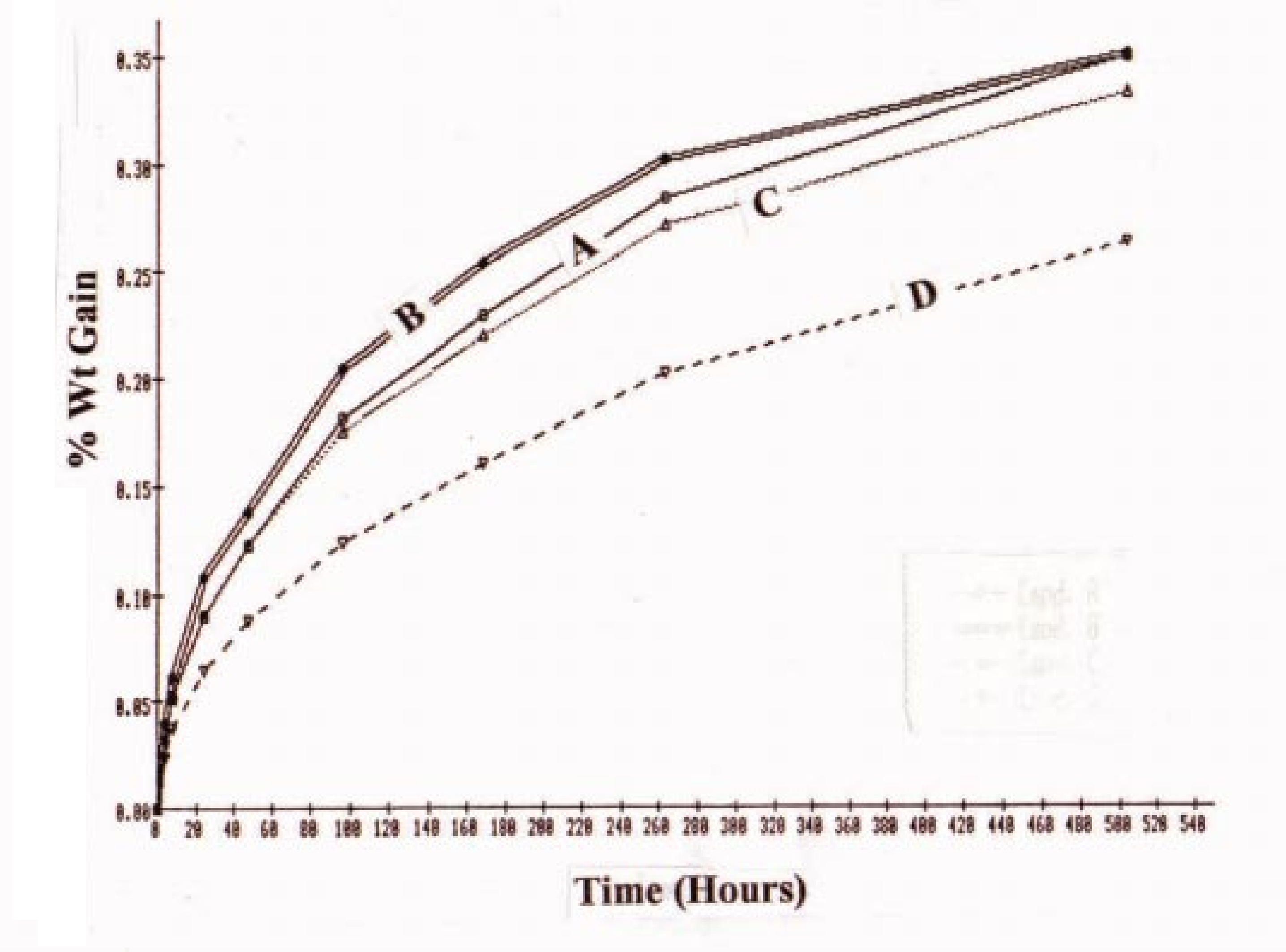
M_{tl}, M_{t2} = water absorption ratio at time t1 and t2
M_S = saturated moisture absorption ratio
1 = thickness of package

D_f = moisture diffusion coefficient
x = distance from package edge to paddle surface
t = moisture absorption time

PLCC 68-Lead Moisture Absorption/Desorption



Different Mold Compounds Moisture Absorption 45°C/85% RH



Moisture Sensitivity/SMD Popcorning

How is SMD moisture sensitivity determined?

- ✓ JESD22 - A112/A113 specifies standards for pre-conditioning, characterizing and rating moisture sensitivity levels of SMDs.

JESD22 - A112 Moisture Sensitivity Levels

Level	Dry Pack Req'd	Floor Life*
1	No	Unlimited @£30°C/90% RH
2	Yes	1 Year @ £ 30°C/60%RH
3	Yes	168 Hours @ £ 30°C/60%RH
4	Yes	72 Hours @ £ 30°C/60%RH
5	Yes	24 Hours @ £ 30°C/60%RH
6	Yes	6 Hours @ £ 30°C/60%RH

*** Conditions apply after removal from dry pack container.**

Temperature Cycle Stress

Temperature Cycle Stress

What effect does temperature cycle have on PEMs?

- ✓ Temperature cycle works the CTE (coefficient of thermal expansion) of each material in contact with another.

PEM Material	CTE (ppm/°C)
Chip Silicon	3.5
Chip Oxide	8 - 10
Chip Aluminum	23.8
Leadframe (Alloy 42)	5.0
Leadframe (Copper)	16.9
Gold Wire	14.3
Die Attach Material	40 - 70
Mold Compounds	7.5 - 28

Temperature Cycle Stress

What effect does temperature cycle have on PEMs ? (continued …)

- ✓There should be no detrimental effects within the specified temperature cycle range.
- ✓Under excessive temperature cycle stress, differences in material CTE can lead to:
  - Delamination of mold compound to internal surfaces (die, leadframe)
  - Cracked passivation and interlevel oxide at die corners (large die)
  - Deformation of chip metallization at die corners (large die)
  - Bond wire lifts/breaks at die corners (large die)

Temperature Cycle Stress

What practices are used to prevent temperature cycle failure mechanisms?

- ✓ Best practices involve:
  - Lower stress mold compounds (larger die/packages)
  - Design rules for metal layout and bond placement
  - Passivation stress characterization
  - Planarized die surfaces
  - Adherence to temperature cycle ratings by user
  - Stress-relief die coatings (ultra sensitive devices)

Temperature Cycle Stress

What are the temperature cycle acceleration factors?

✓Stress is modeled by the Coffin-Manson relationship:

$AF = (\Delta T_S / \Delta T_U)^n$

where, AF = Acceleration Factor

ΔT = Temperature excursion at stress and use

n = Exponent based on failure mechanism

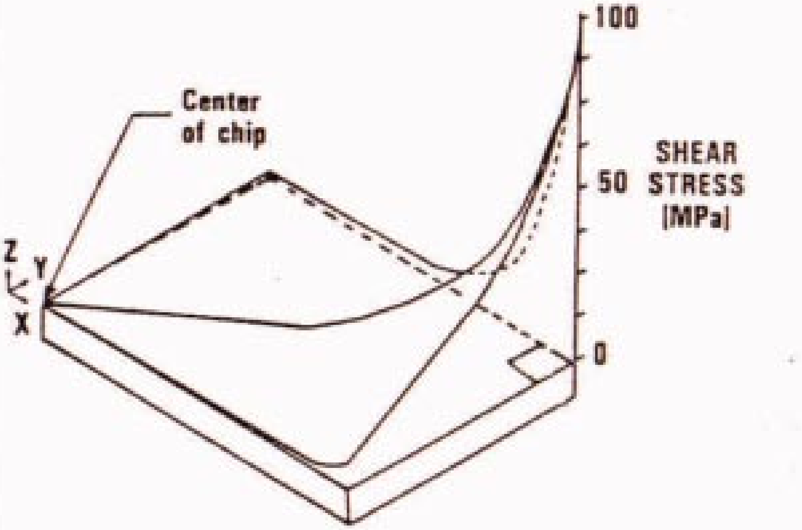
✓Values of n reported: n = 4 for bond wire fatigue

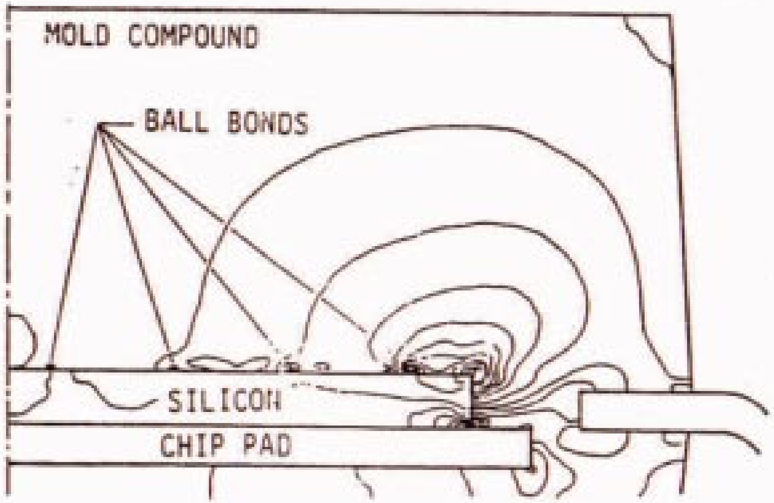
n = 7 for bond/silicon fracture

n = 11 for thin film cracking

Modeling Stress: Stress Maximum at Chip Corner

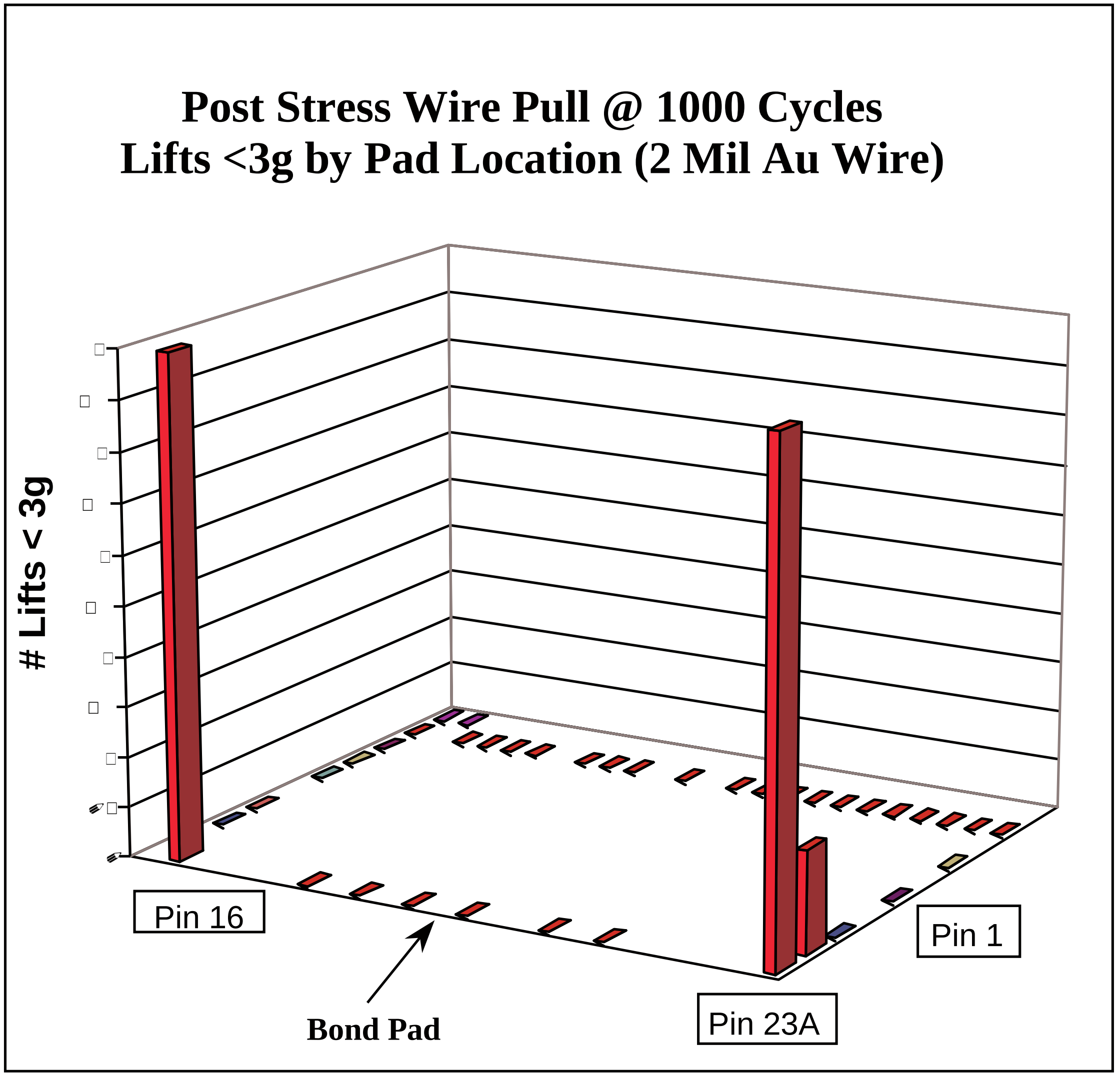
MODELING STRESS: STRESS MAXIMUM AT CHIP CORNER





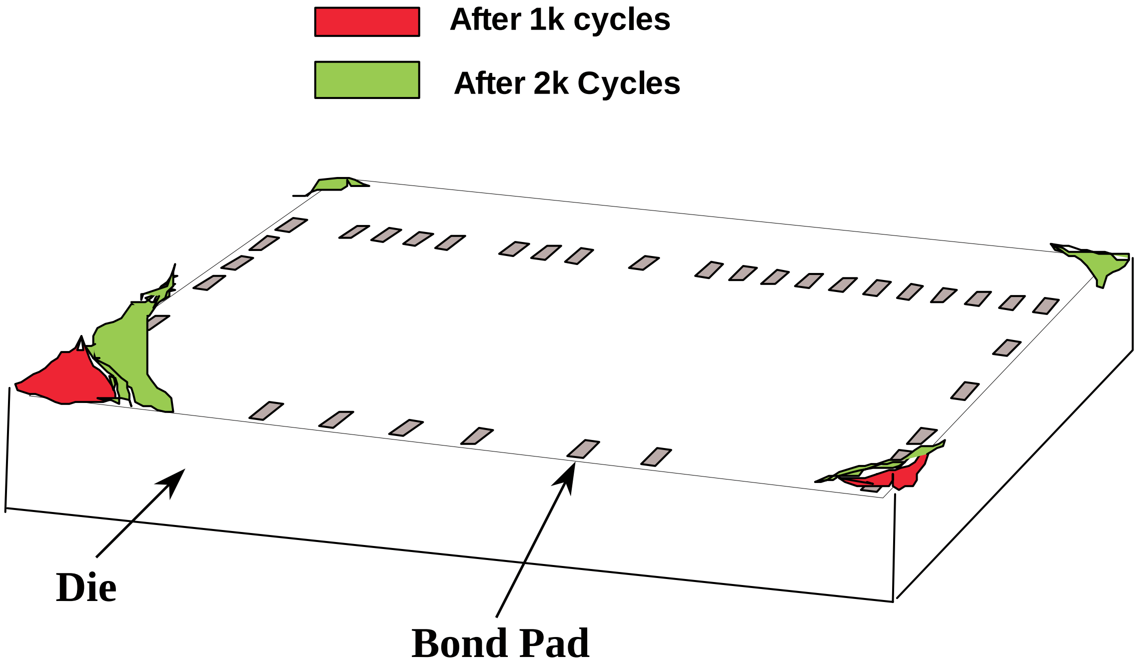
Shear Stress Effects Near Ball Bonds

Power Slug SOIC -65°C to +150°C Temperature Cycle

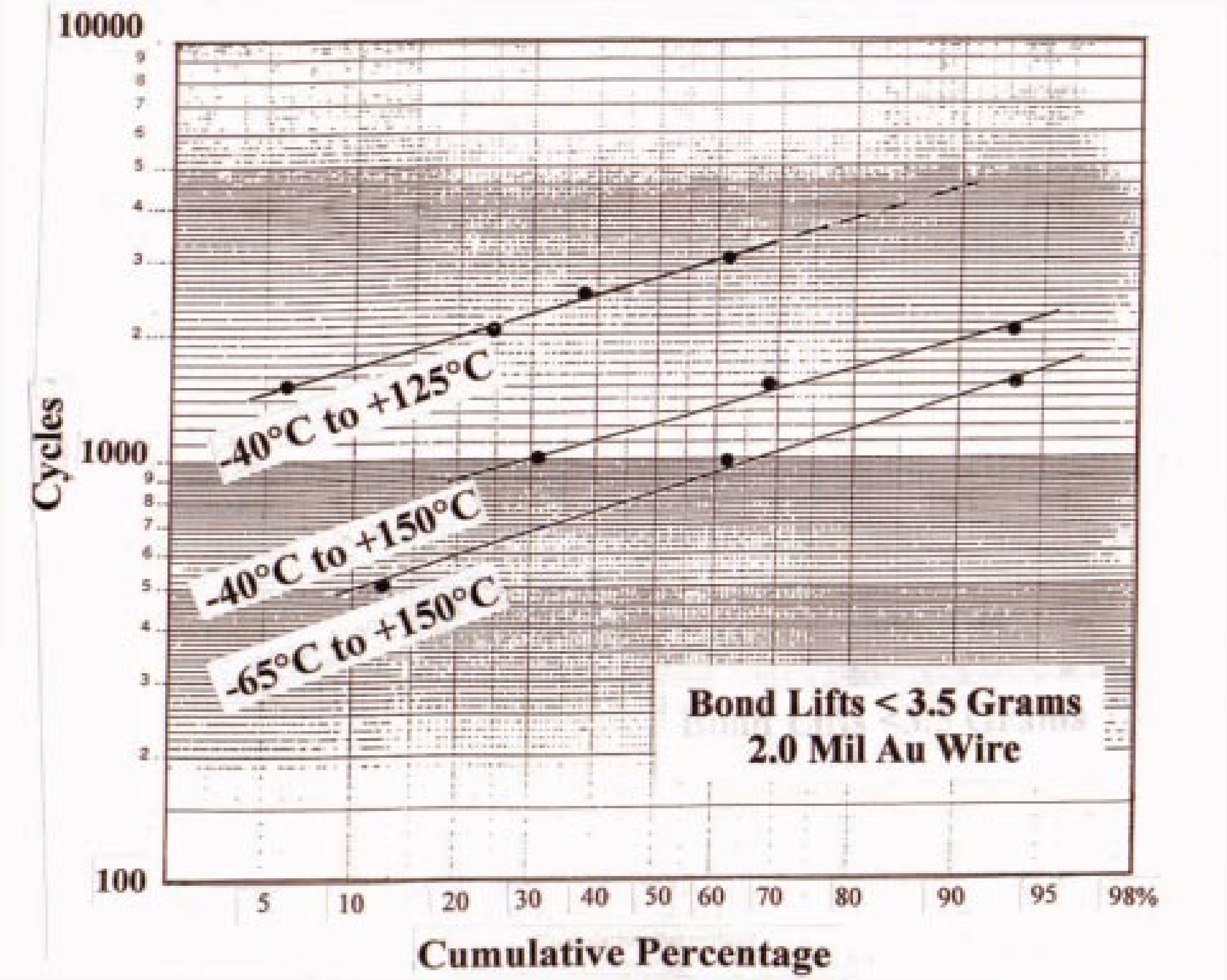


Post Stress Wire Pull @ 1000 Cycles
Lifts <3g by Pad Location (2 Mil Au Wire)

Power Slug SOIC
Temperature Cycle -65°C to +150°C
Delamination Progression at Die Corners
(From C-SAM Analysis)



Power Slug SOIC Temperature Cycle Wearout For Corner Bonds



Power Slug SOIC Temperature Cycle Wearout For Corner Bonds

Condition	DT (°C)	t_{50} (Cycles)	Sigma (s)
-40°C to +125°C	165	2700	.378
-40°C to +150°C	190	1200	.344
-65°C to +150°C	215	840	.405

1) Log-normal median-time-to-failure (t_{50}) is computed for corner bond lifts <3.5.
2) Average of the log-normal s values = .375.

Power Law Regression Line Fit:

$$t_{50} = 1.8\,(DT)^{4.4},\ \ N = 4.4,\ \ R^2 = 0.97$$

Power Law Acceleration Factor Model:

$$AF = t_{50\,(T)} / t_{50\,(U)} = (DT_T / DT_U)^N$$

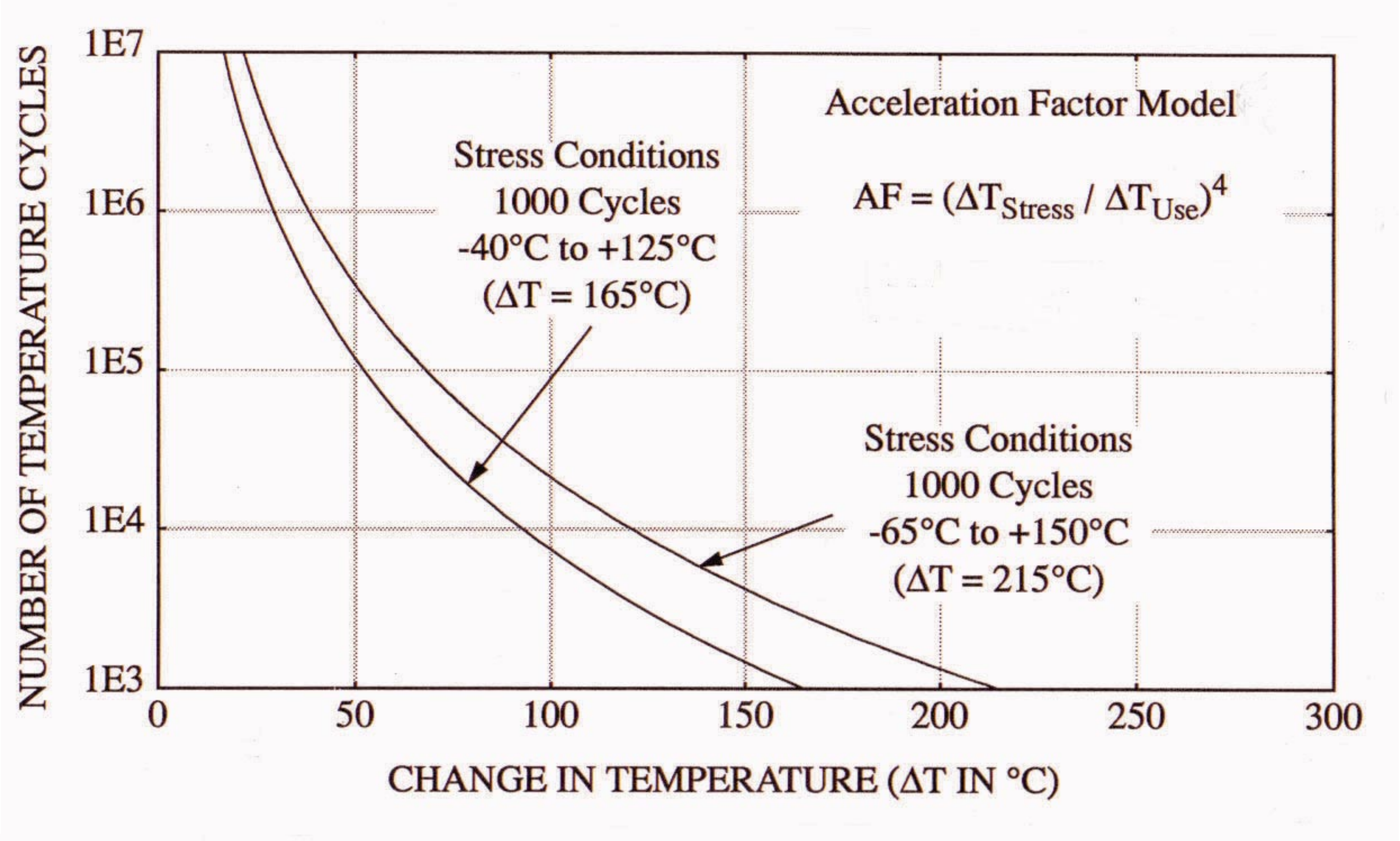
Where, AF = acceleration factor

DT_T = temperature excursion at test conditions

T_U = temperature excursion at use conditions

N = 4.4 (from data)

Number of Temperature Cycles Equivalent to Qualification Stress Conditions



Plastic Molding Compound

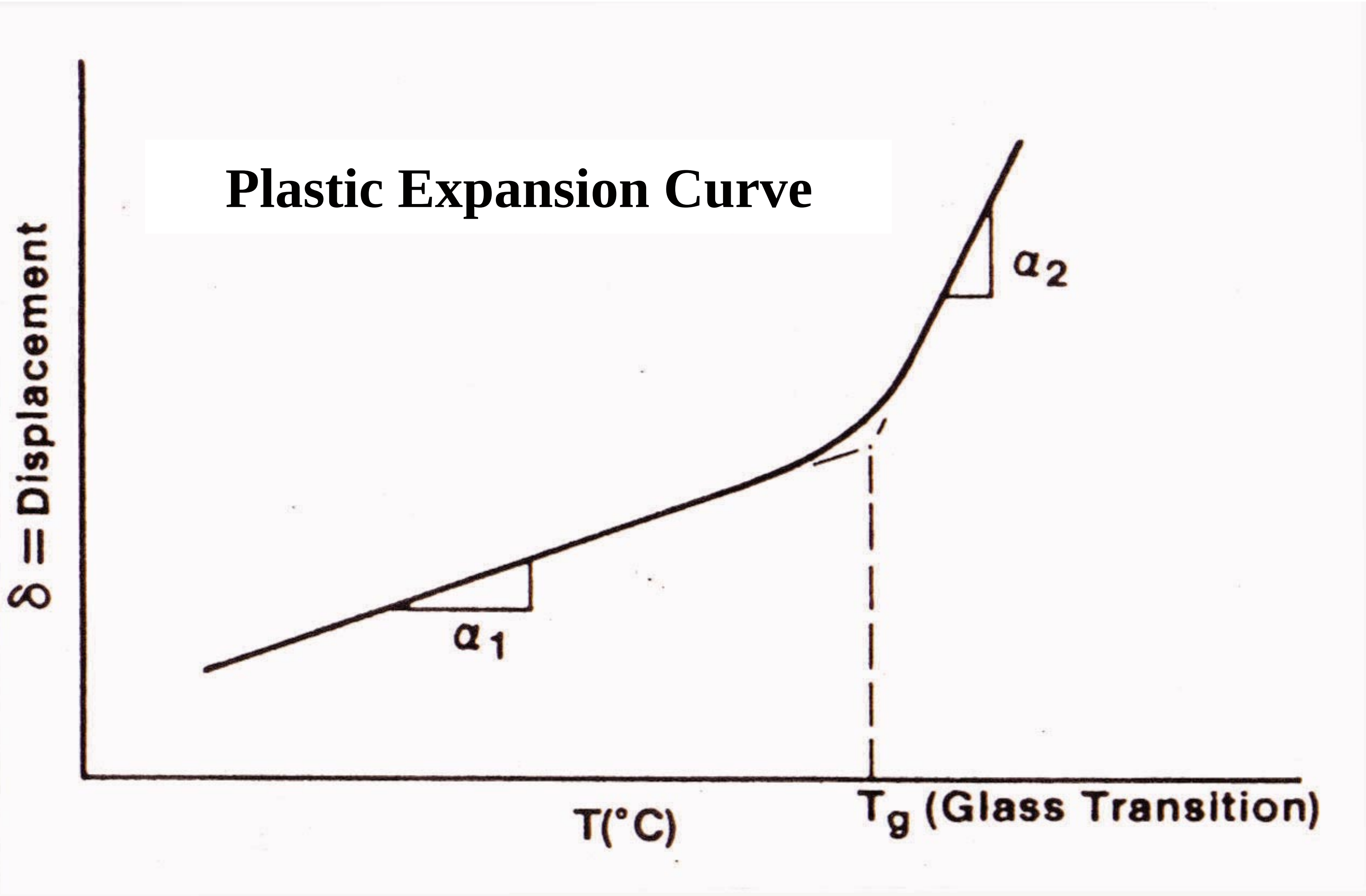
Plastic Molding Compound

What is mold compound glass transition temperature (Tg)?

✓Tg is the temperature corresponding to the glass-to-liquid transition:

- Below Tg: CTE is relatively low and increases slightly over temp.
- Above Tg: CTE is high and increases substantially over temp.

Plastic Expansion Curve



Plastic Molding Compound

How does exceeding the Tg affect PEM reliability?

- ✓ Tg’s of mold compounds commonly in use range from 150°C to 165°C.
- ✓ Exceeding the Tg over time can:
  - Breakdown chemical cross-linking of polymers
  - Release previously bound up flame retardants and ionics
  - Cause corrosion, device instability or lift bonds due to release of ionics
  - Reduce temperature cycle capability (due to high CTE)
  - Reduce adherence causing delamination
- ✓ Newer compounds currently under evaluation by Intersil have a Tg of 200°C. Potential tradeoffs have to be assessed.

Plastic Molding Compound

How consistent is the molding compound material from lot-to-lot?

- ✓ Intersil has extensively measured key parameters over several years using SPC charts.

SPC of Mold Compound Parameters

Parameter	#Lots	%Lots <LCL	% Lots >UCL
Glass Transition Temp (Tg)	464	1.0	1.3
Coeff. Therm. Expansion (CTEa_1)	464	1.7	0.8
Coeff. Therm. Expansion (CTEa_2)	442	0.0	0.2
Filler Material (% Weight)	442	0.4	0.4
Moisture Uptake (% Weight)	328	1.2	1.2

Note: CTEa_1 (40-100°C), CTEa_2 (180-220°C)

Plastic Mold Compound

How are impurity levels controlled?

	Max.	Typical Levels Observed
Hydrolyzable chloride, ppm	150	50-130
Moisture Uptake, %	0.5	0.2 - 0.4
Water Extractable Species [3]		
Water Extract Conductivity, mmho/cm	150	30-70
Water Extract pH	3.0 - 6.0	3.5 - 6.5
Sodium, ppm	5	0.5 - 3.0
Potassium, ppm	5	<0.5 - 3.0
Chloride, ppm	5	1.0 - 5.0
Bromide, ppm	20	5.0 - 20.0
Total Halides, ppm	50	<30

	Max.	Typical Levels Observed
Trace Metals		
Zinc, ppm	100	<100
Iron, ppm	300	<100-500
Calcium, ppm	300	1 - 50
Aluminum, ppm	- - -	100 - 1000
Chromium, ppm		1 - 50
Copper, ppm		1 - 50
Magnesium, ppm		1 - 20
Manganese, ppm		1 - 10
Nickel, ppm		1 - 50
Silver, ppm		1 - 5
Titanium, ppm		1 - 100

PEM Temperature Range

PEM Temperature Range

Can PEMs meet the Military operating temperature range (-55°C to +125°C)?

- ✓ Most PEMs designed for following ambient temperature ranges (Max Tj = 150C):

  Commercial: 0°C to +70°C

  Industrial: -40°C to +85°C

  Automotive: -40°C to +125°C

- ✓ Some PEMs are rated in the Military temperature range (e.g., Intersil Logic Families).
- ✓ Not all PEMs are upgradeable to -55°C to +125°C, but do all Military applications require this temperature range?

Manufacturing Controls for Reliability

Manufacturing Controls for Reliability

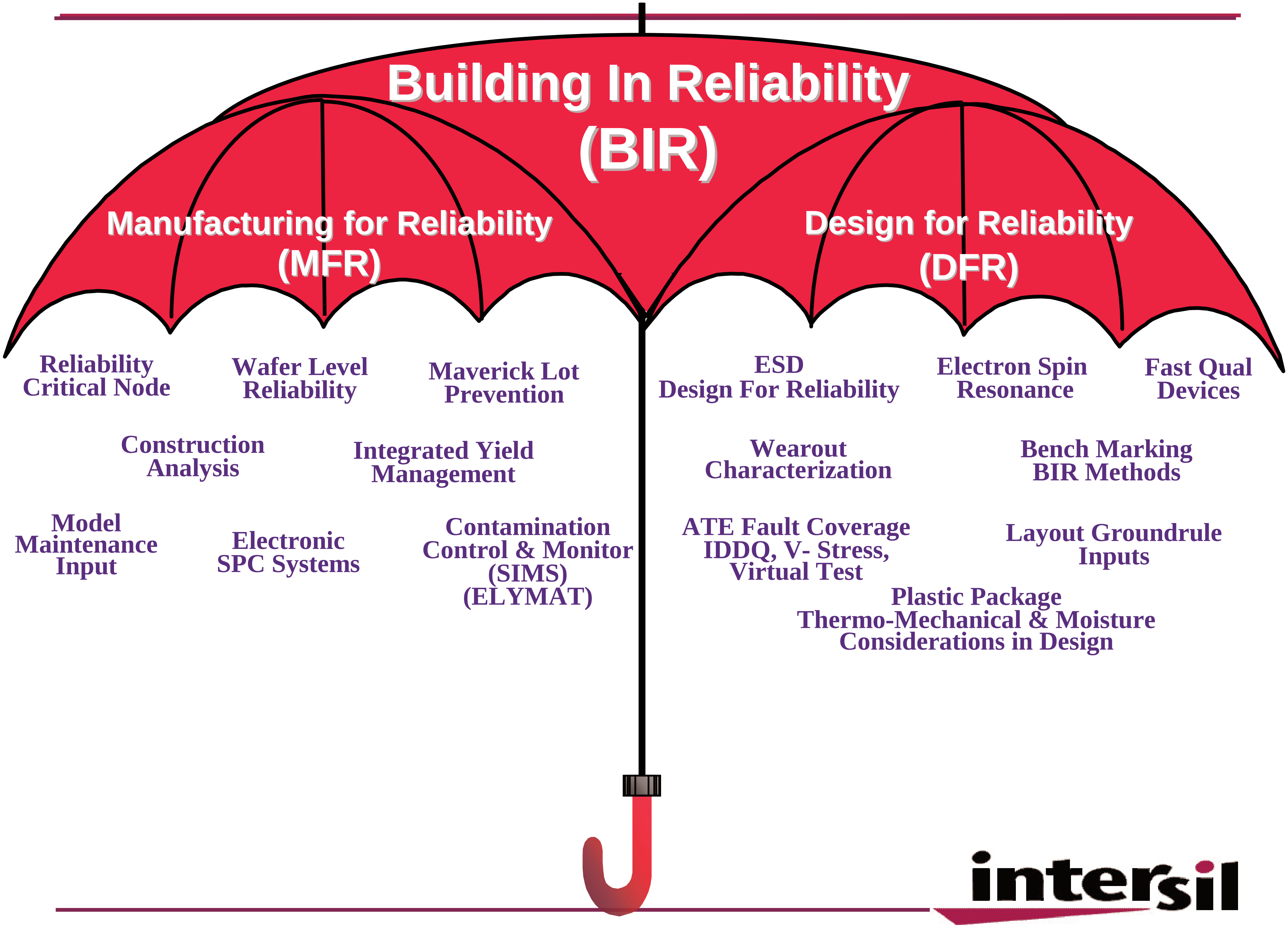
How does the production flow differ between Military and Commercial products?

Wafer fab:

- Both Military and Commercial product share the same flows, which employ SPC and reliability critical node controls (see attached chart).

Assembly:

- Assembly flows for hermetic and plastic parts differ due to the nature of the packaging.
- Both flows employ SPC and critical node controls (see attached chart for PEMs).



Building In Reliability (BIR)

Manufacturing for Reliability (MFR)

Reliability Critical Node

Wafer Level Reliability

Maverick Lot Prevention

Construction Analysis

Integrated Yield Management

Model Maintenance Input

Electronic SPC Systems

Contamination Control & Monitor (SIMS) (ELYMAT)

Design for Reliability (DFR)

ESD Design For Reliability

Electron Spin Resonance

Fast Qual Devices

Wearout Characterization

Bench Marking BIR Methods

ATE Fault Coverage IDDQ, V- Stress, Virtual Test

Layout Groundrule Inputs

Plastic Package Thermo-Mechanical & Moisture Considerations in Design

Building-In Reliability

- Process Wearout characterization early in development cycle leads to the following:
  - ✓ Reliability input to the Design/Layout groundrules
  - ✓ Specification of reliability critical node parameters (Wafer Fab & Assembly)
  - ✓ Statistical Process Control, Variance Reduction Methods (SPC) and Problem Solving Methods:
  - ✓ The absence of Wearout Failure Mechanisms in the useful life of product.

Critical Nodes

- SPC control parameters related to reliability failure mechanisms.
- Cpk's have a minimum goal of 1.33 to reliability limits; screening limits may be used to improve Cpk levels.
- Yearly capability studies are required; capability data can come from WAT when correlation is shown with in-line SPC.
- Reliability and Manufacturing coordinate the assignment and implementation of nodes at all Fab sites.
- Data from Critical Nodes is available to customers.

Generic List of Reliability Critical Nodes

Base Reliability Issue	Related Failure Mechanism	Critical Node	Characterization Node
MOS Active Area	Hot Carrier	✓	
Final Gox Thickness	Gox Breakdown	✓	✓✓
MOS Gate Length	Hot Carrier, Gox Breakdown	✓	
Final Conductor-Si Dielectric Thickness	Dielectric Breakdown	✓	
Final Poly-M1 Dielectric Thickness	Poly-M1 Dielectric Breakdown Stress Induced Voids	✓	
Poly-M1 Dielectric Film Stress	Stress Induced Voids		✓
Final M1-M2 Dielectric Thickness	M1-M2 Dielectric Breakdown, Stress Induced Voids	✓	
M1-M2 Dielectric Film Stress	Stress Induced Voids		✓
Final M1, M2, etc. Thickness	Electromigration, Stress Induced Voids	✓	
Metal Cross-Sectional Area in and around Aperture & Via	Electromigration, Stress Induced Voids		✓
Final M1, M2, etc., Line Width	Electromigration, Stress Induced Voids	✓	
Metal Film Quality	Electromigration, Stress Induced Voids	✓	
Passivation Integrity	Corrosion, Electromigration, Stress Induced Voids	✓ Thickness/ Doping	✓✓ PIT
Passivation Film Stress	Stress Induced Voids		✓

Plastic Package Critical Node List (PDIP)

Process Flow Step	Critical Node Parameter	Type of Control
Saw	Kerf Width, DI Resistivity	X Bar - R Monitor
Die Visual	Visual Quality	AQL
Die Attach	Visual Quality	NP - Chart
Die Attach Cure	Oven Temperature Die Shear	X Bar - R Z - Chart
Wire Bond	Pull Strength Visual Temperature Force Ball Shear	X Bar - R NP - Chart X Bar - R X Bar - R X Bar - R
Mold	Visual Q Acoustic Microscopy	NP - Chart Monitor
Chemical Deflash	Visual Q	NP - Chart
Mold Cure	Oven Temperature	X Bar - R
Trim/Form	Visual Q	NP - Chart
Solder Dip	Visual Q Solder Thickness	AQL X Bar - R
Brand	Visual Q	NP - Chart

Reliability Monitors
Comparison of Military Hermetic and Intersil Plastic

Hermetic Military (MIL-STD-883) Quality Conformance Inspection (QCI)			Plastic Commercial Matrix Monitor		
Description	**Sample/ Acc. No.**	**Frequency**	**Descriptions**	**Sample Acc. No.**	**Frequency**
Group B			**Matrix I**		
Resistance to Solvents	3/0	Each lot	HTOL (125°C or 175°C, 48 Hours)	45/0	2X/Month
Bond Strength	22/0	Each lot	HAST (135°C/85% RH, 48 Hours)	45/0	2X/Month
Solderability (8 Hrs. Steam Age)	10/0	Each lot	Autoclave (96 Hours)	45/0	2X/Month
			Thermal Shock (200 Cycles)	45/0	2X/Month
Group C			**Matrix II**		
HTOL (125°C, 1k Hours)	45/0	1X/12 Months	HTOL (125°C, 1k Hours)	45/0	1X/Month
			THB (85/85, 1k Hours)	45/0	1X/Month
			Autoclave (192 Hours)	45/0	1X/2 Months
			Storage Life (150°C, 1k Hours)	45/0	1X/2 Months
			Temp Cycle (1k Cycles)	45/0	1X/2 Months
Group D			**Matrix III**		
1. Physical Dimensions	15/0	1X/6 Months	Solderability (8 Hrs. Steam Age)	22/0	2X/Months
2. Lead Integrity	15/0	1X/6 Months	Brand Adherence	15/0	1X/Month
3. Thermal Shock (15 cycles)	15/0	1X/6 Months	Lead Integrity	15/0	1X/Month
Temp Cycle (100 cycles)			Physical Dimensions	11/0	1X/Month
Moisture Resist (10 cycles)			Flammability UL-94	5/0	1X/Quarter
4. Shock					
Vib. Var. Freq.	15/0	1X/6 Months			
Acceleration			SPC Monitored (Eqv. to Hermetic)		
5. Salt Atm. (24-240 HPS)			Bond Strength	SPC	1X/Shift
6. Internal Wafer Vapor	15/0	1X/6 Months	Die Shear	SPC-Z	1X/Oven/Cycle
7. Adhesion of Lead Finish	3/0	1X/6 Months		Chart	
8. Lid Torque	15/0	1X/6 Months	Solderability >4 Hours Steam Age	Recording	1X/Shift
	5/0	1X/6 Months	>8 Hours Steam Age	Recording	1X/Week

Note: Mil-Std-883 requires assembly locations to have an additional monitor program to Mil-Std-976 (i.e., Bond Strength/Die Shear, etc.) which has not been covered by this table.

intersil

Conclusions

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- PEMs will provide the desired reliability if:
  - PEM capability matched to application conditions.
  - Industry’s best manufacturing practices used.
- System designer must become familiar with:
  - PEM use envelope and system environment
  - Potential failure mechanisms
  - Supplier’s reliability data
  - Supplier’s quality systems
  - Best practices for using PEMs

Conclusions - continued

- PEM use envelope is ever expanding.
- PEM reliability has been successfully demonstrated in many applications.
- Important to consider qualified suppliers experienced in Military HSMs and Commercial PEMs.

The End