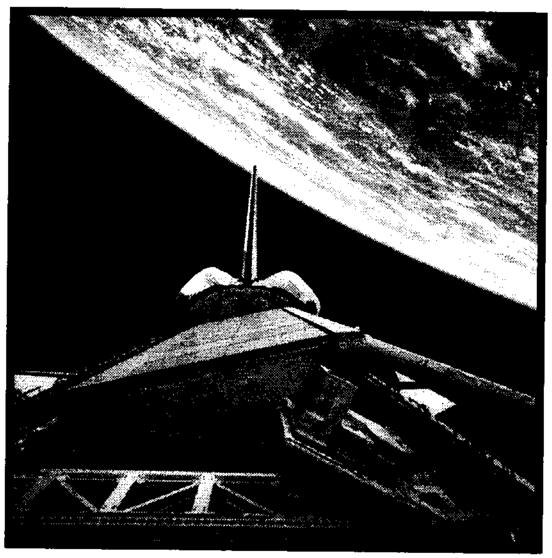
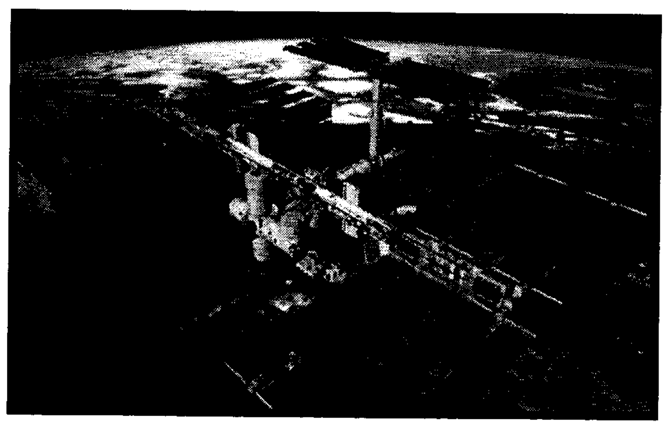
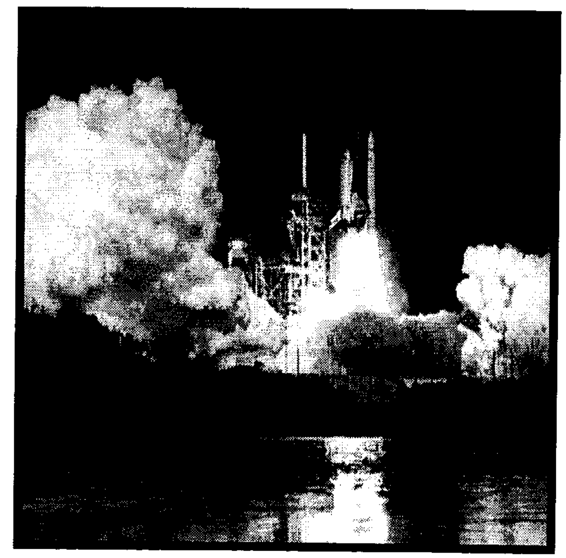
InterPACK '03

Reliability of Low Glass Transition Temperature PEMs

For Space Applications







July 6-11, 2003

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Agenda

- Introduction
- Glass Transition Temperature (Tg) Measurement Methods
- Definition of Glass Transition Temperature
- Coefficient of Thermal Expansion (CTE)
- Failure Modes of Exceeding Tg
- Tg Measurements Data
- PEMs Issues vs Tg
- Burn-In Investigations
- Advanced Reliability Data
- Observations/Summary

The work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration

Introduction

Many factors influence PEM component reliability.

Some of the factors that can affect PEM performance and reliability are the glass transition temperature (Tg) and the coefficient of thermal expansion (CTE) of the encapsulant or underfill.

JPL/NASA is investigating how the Tg and CTE for PEMs affect device reliability under different temperature and aging conditions. Other issues with Tg are also being investigated.

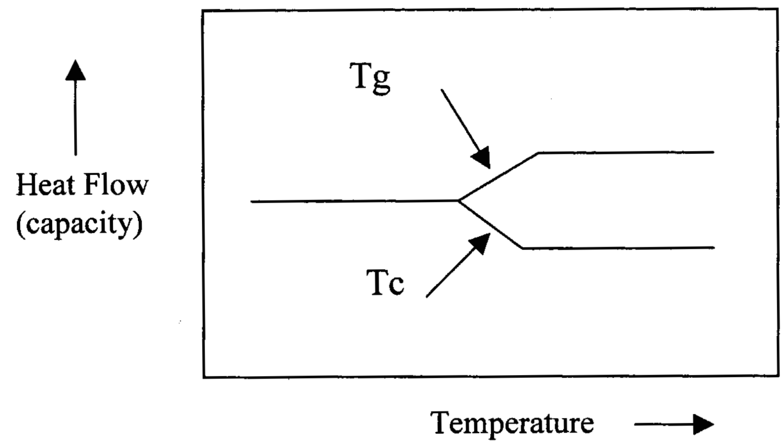
Data will be presented on glass transition temperature test results and reliability tests conducted at JPL.

Tg Measurement Methods Available

	Typical Time	Sample prep	Repeatability	Dependability	Comments
Differential Scanning Calorimetry	20 minutes	Easy	Good	Marginal	Many materials do not exhibit clear transitions
Thermo Mechanical Analysis	40 minutes	Medium	Fair	Good	Very dependant on sample preparation
Dynamic Mechanical Analysis	120 minutes	Difficult	Excellent	Excellent	Tg can be defined several different ways

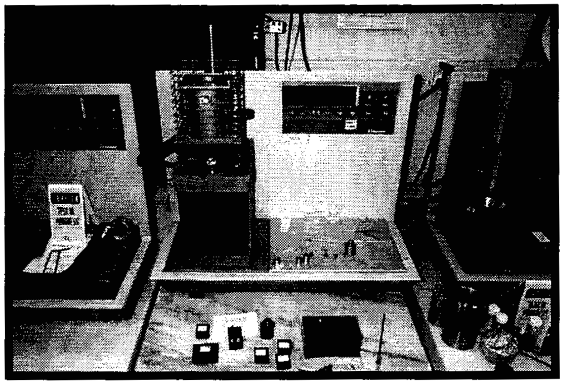
Differential Scanning Calorimetry (DSC)

- Quick and simple test
- No special preparation needed
- Method consists of heating the sample in a closely calibrated thermocel where the temperature of the sample is compared to the temperature of a blank reference point within the same cell
- The change in heat capacity at the Tg is seen as a shift in the baseline for the cured encapsulant

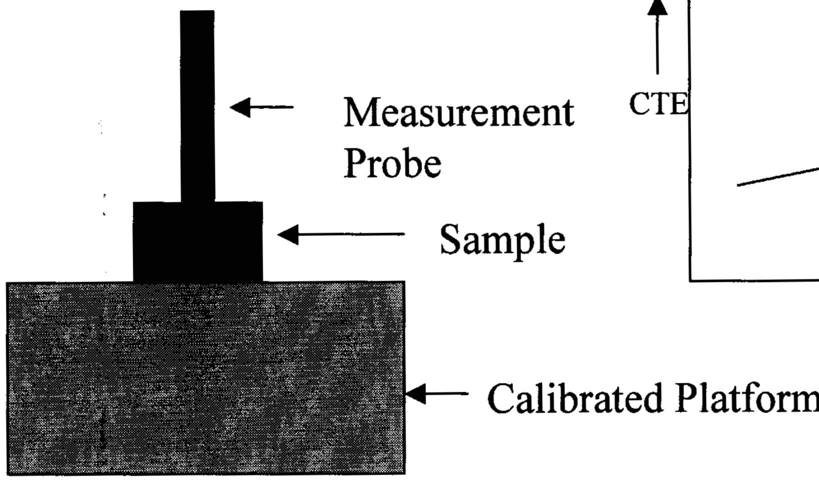


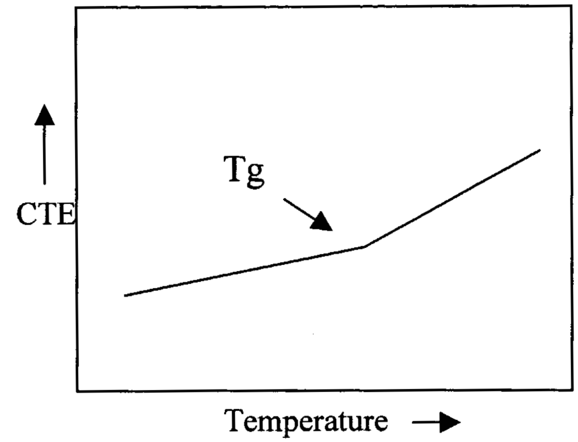
JPL DSC Tester

Thermal Mechanical Analysis (TMA)



JPL TMA Tester





The method consists of heating the sample upon a expansion-calibrated platform and measuring the dimensional change of the sample with an instrumented probe. Probe placement can alter reading.

- ISO 11359-1:1999
  Plastics -- Thermomechanical analysis (TMA) -- Part 1: General principles

- ISO 11359-2:1999
  Plastics -- Thermomechanical analysis (TMA) -- Part 2: Determination of coefficient of linear thermal expansion and glass transition temperature

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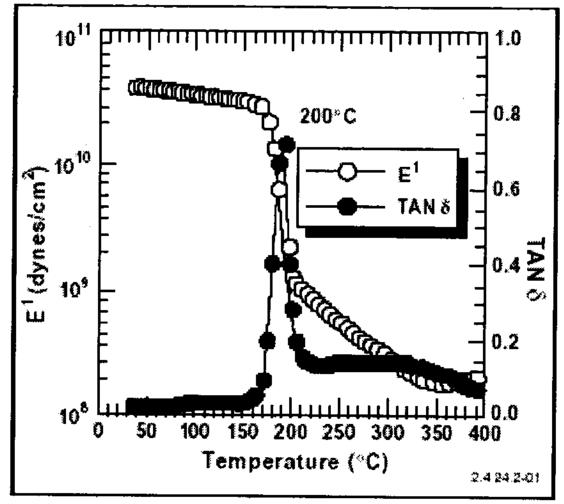
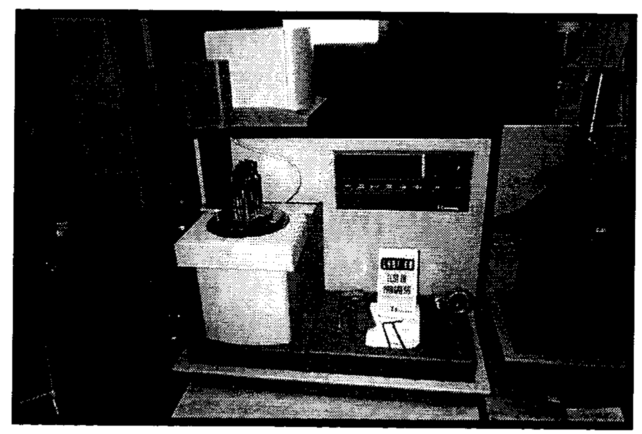
Dynamic Mechanical Analysis (DMA)

- Measures changes in dynamic characteristics of materials
- e.g. Modulus (stiffness)
- e.g. Damping (energy dissipation)
- e.g. Creep
- e.g. Stress Relaxation

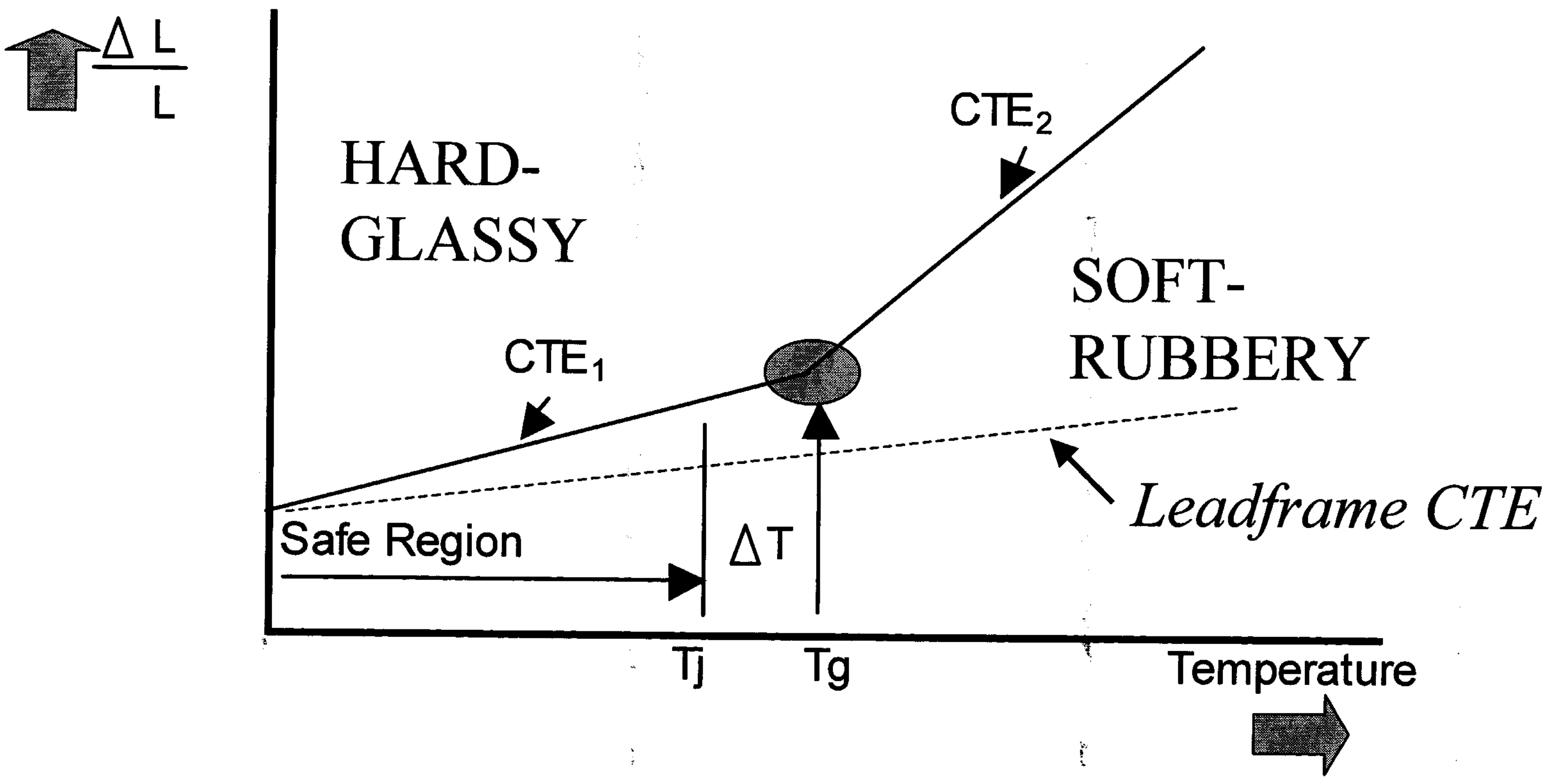




JPL DMA Tester

Glass Transition Temperature (Tg) - Amorphous Polymer

PEM Tg is calculated as the midpoint of the temperature range at which a dramatic change in CTE occurs.



Coefficient of Thermal Expansion (CTE)

CTE is a measure of the fractional change in dimension (usually thickness) per degree rise in temperature. For microelectronics encapsulants, it is often quoted in "ppm/°C" (value x 10-6/°C).

CTE is highly dependent on the chemistry composition, filler loading, and cure cycles of the encapsulant.

It is desirable to have both a high Tg and a low CTE that closely matches the package assembly components (which include the die, wires, and leadframe).

Failure Modes Reported When Tg is Exceeded

- CTE of epoxy encapsulant will permanently change (breakdown of chemical cross-linking of polymers); this could cause displacement of wire bonds resulting in a premature wear-out and breakage of wires
- Premature aging (e.g. storage)
- Induced stresses between materials internal/external) because of CTE mismatch; reduces temp. cycling capability
- Adhesion degradation
- Corrosion and lifted bonds due to release of Bromine, Red Phosphorous (flame retardants) and or other ionics
- Device performance degradation

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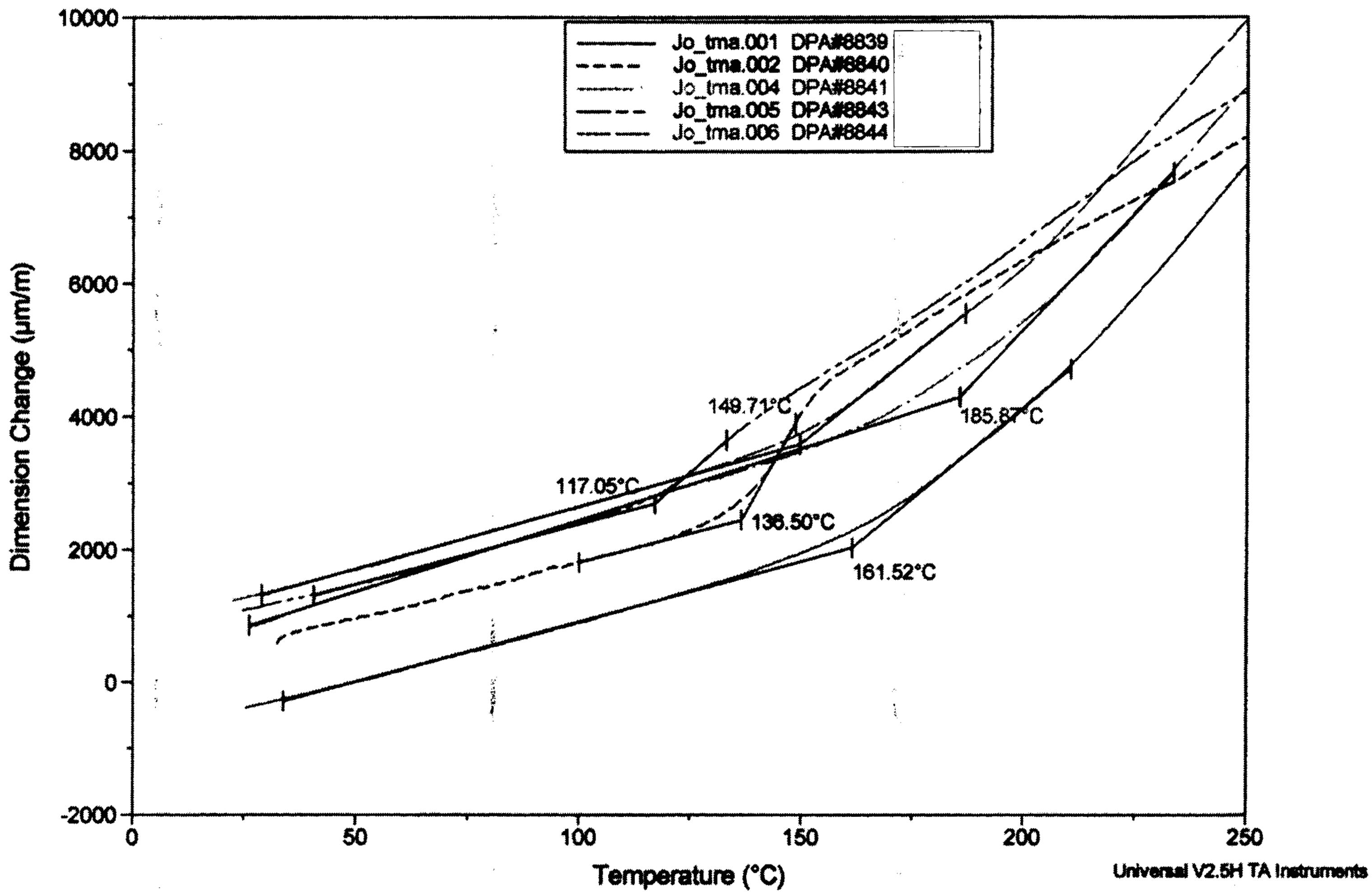
Other PEMs Issues Relative to Tg

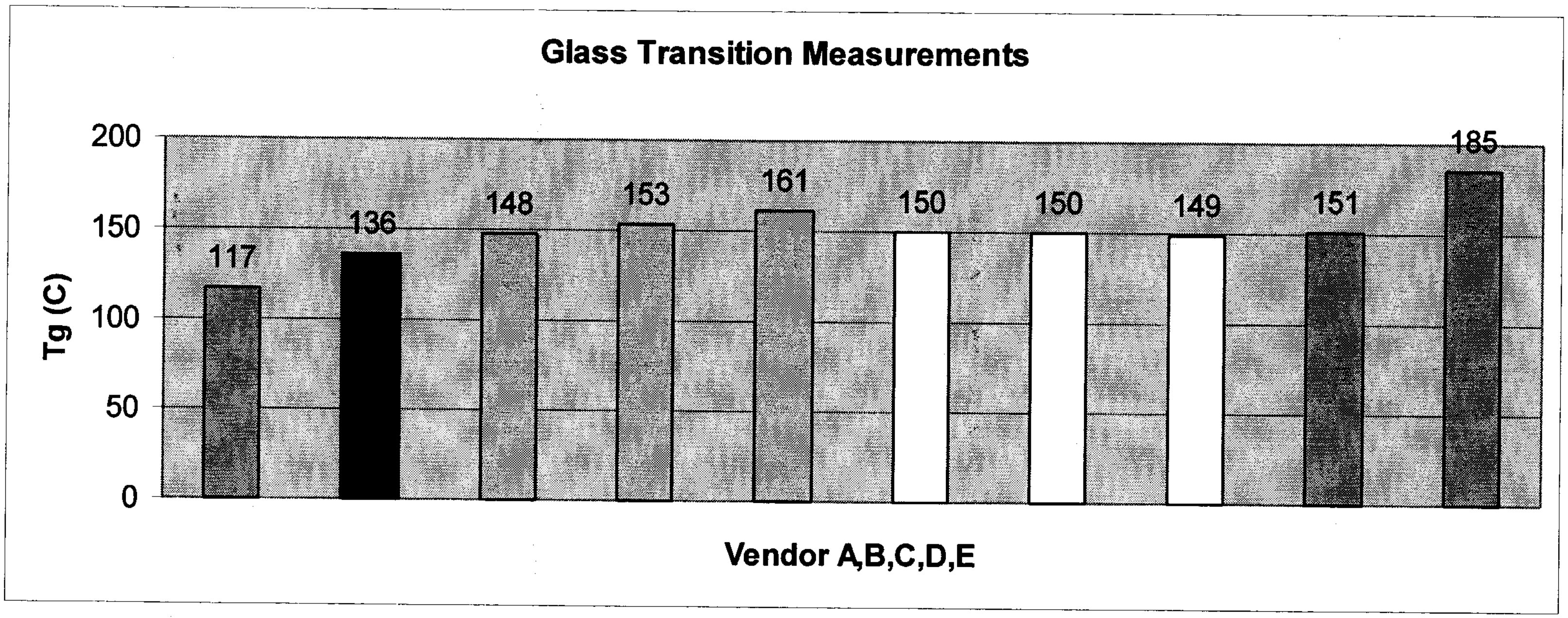
- **Maximum allowable burn-in temperatures vs Tg (now under investigation)**
- Derating required vs Tg (future)
- Reliability vs low and high Tg (future)
- Review of ASTM E595-93 methodology (future) (performing outgassing) when Tg <125°C
- Lead free solders (require higher soldering temperatures)

Examples of Tg Measurement Results for PEMs with No Preconditioning (as procured)

TMA 5°C/min in Helium
Gary Plett / Analytical Chemistry Lab / JPL



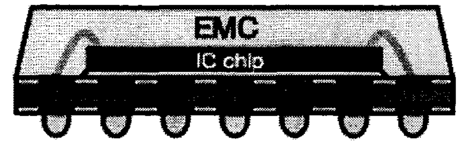
PEMs Tg Measurement Results with No Preconditioning (as procured)



Measurement Error = ± 2°

Tg varies among different vendors and date codes from the same vendor.

Example of Semiconductor Vendor's Epoxy Molding Compound Properties Specified



General Properties					
Item	Unit	Condition	Newly Developed		Conventional
			CEL-300*	CEL-310*	CEL9200*
Spiral Flow	cm	EMMI-1-66	100	90	90
Gelation Time	sec	175°C	40	30	28
Tg	°C	TMA	120	110	120
CTE(a1)	ppm/°C	TMA	7	8	8
Flexural Modulus	GPa	JIS-K-6911	28.0	26.0	26.0
Water Absorption	wt%	PCT 20h	0.28	0.31	0.30
Flammability	-	UL-94	V-0	V-0	V-0

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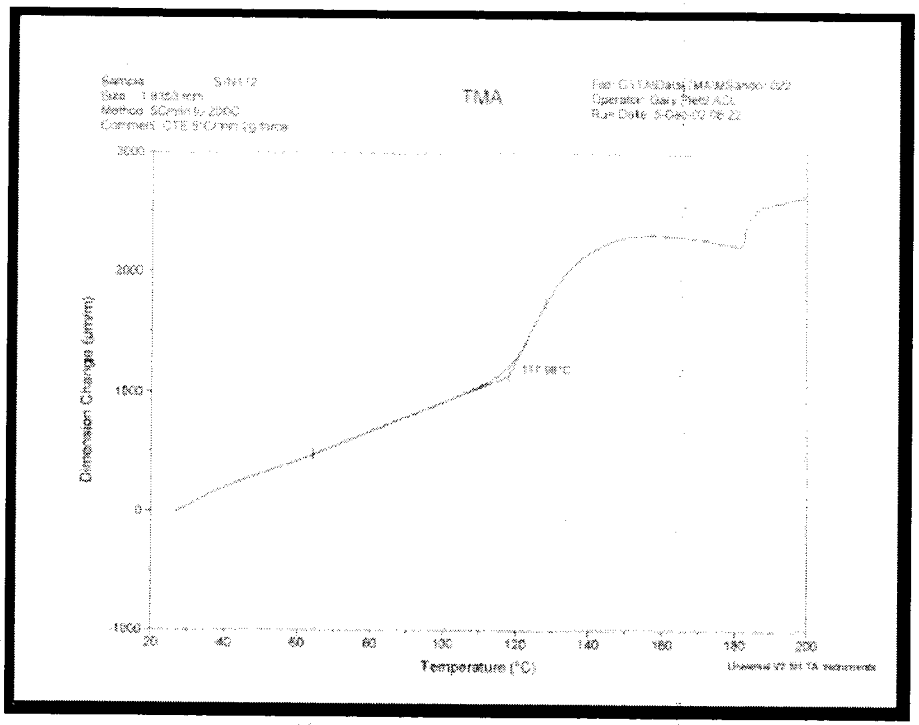
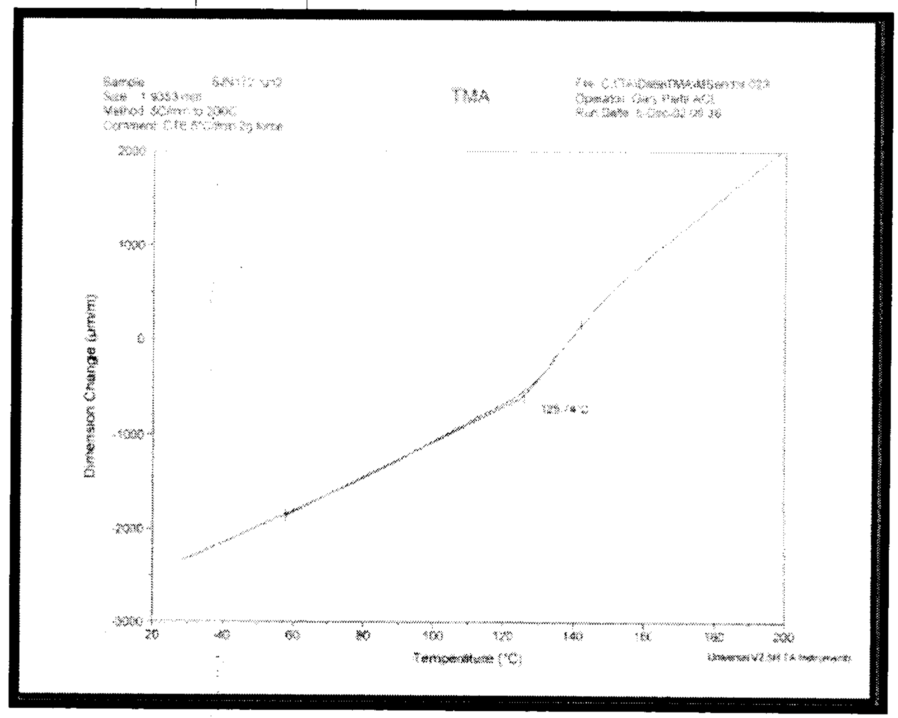
Examples of post BI

Vendor A - CTE residual stress using TMA

TMA1



TMA2



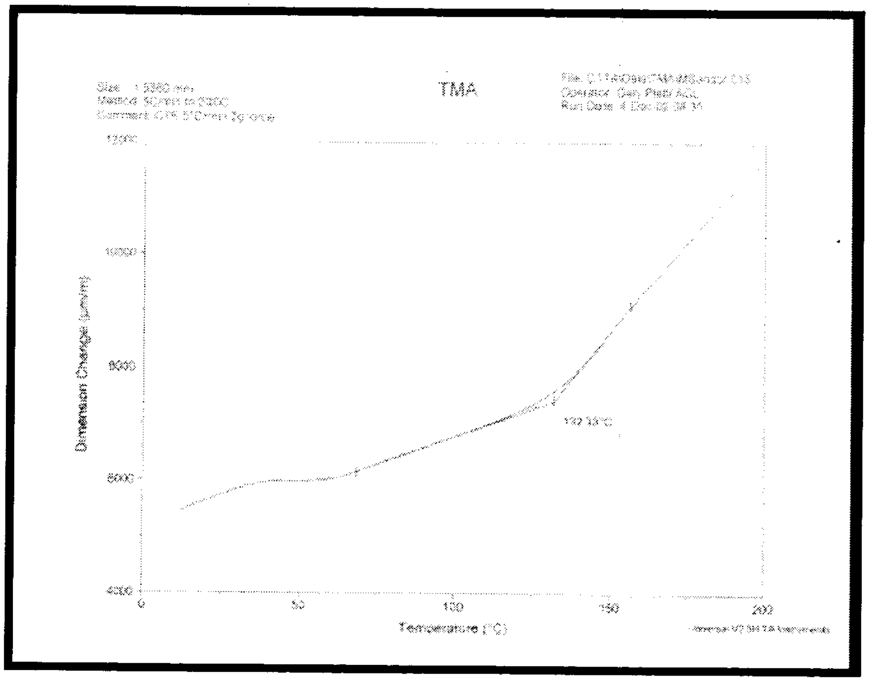
Note: 1) TMA1 and TMA2 are done consecutively

2) Vendor A has typically more CTE stress above Tg and some examples of extreme CTE stress below Tg

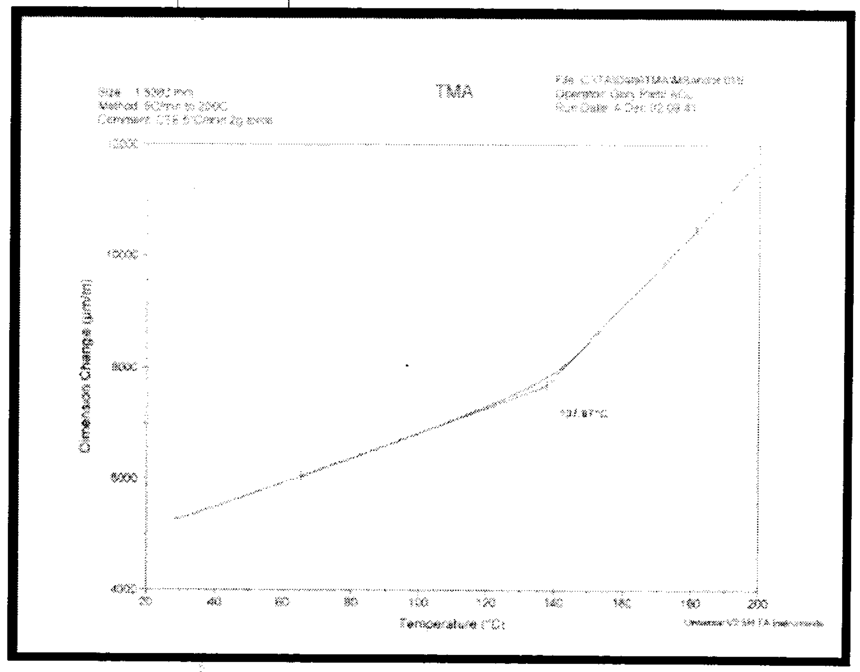
Examples of post BI

Vendor B - CTE residual stress using TMA

TMA1



TMA2



Note: 1) TMA1 and TMA2 are done consecutively

2) Vendor B typically has little CTE stress below Tg and none above Tg

PEMs Tg Measurement Comparison Post Burn-in

Note: Two consecutive TMA runs were performed only if 1st run indicated mechanical stress above or below the Tg.

Vendor B product has less residual mechanical stresses with BI and a more stable Tg with added thermal stress.

Vendor A				
BI=85C				
1st Run	117.98	117.86	116.59	
2nd Run	**125.74**	**122.9**	**122.92**	
BI=115C				
1st Run	120.25	119.2	120.56	
2nd Run	**126.05**	**124.34**	120.92	
BI=145C				
1st Run	124.96	129.11	119.18	129.68
2nd Run	**127.96**	129.83	**130.92**	***127.4***
Vendor B				
BI=85C				
1st Run	132.39	132.08	131.98	131.22
2nd Run	132.47	NA	NA	NA
BI=130C				
1st Run	133.90	133.10	133.26	133.44
2nd Run	133.21	NA	NA	NA
BI=150C				
1st Run	132.33	134.06	131.57	132.92
2nd Run	**137.97**	NA	NA	NA

Allowable Burn-In/Reliability Investigations

Objective: Determine if device electrical behavior changes when the BI temperature is at or above the part Tg as measured.

- #1) Device Type A/D, Tg = 117C (30 parts split into three groups)

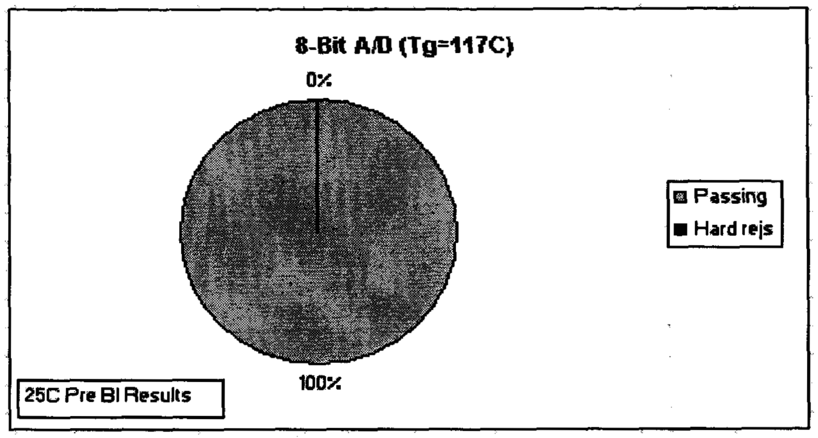
  Pre & Post Performance testing over temperature with +85C/+115C/+145C Burn-In for 240 hours

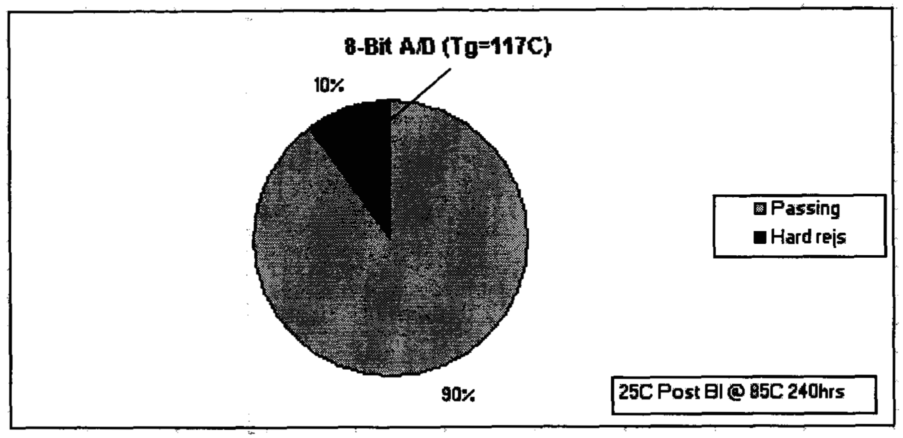
- #2) Device Type Op Amp, Tg = 136C (30 parts split into three groups)

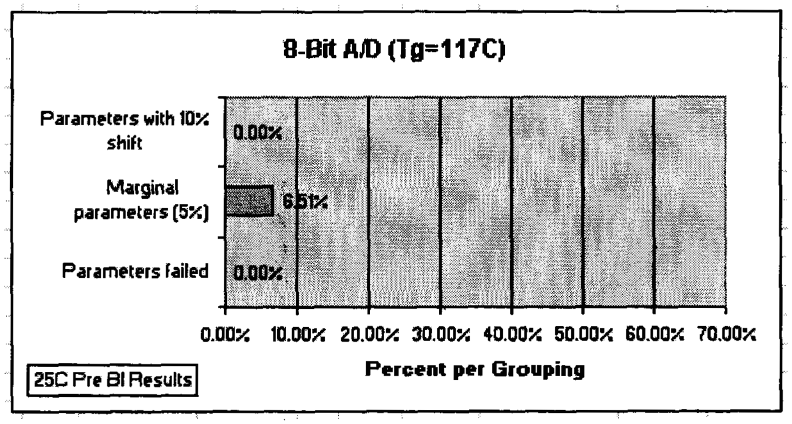
  Pre & Post Performance testing over temperature with +85C/+130C/+150C Burn-In for 240 hours

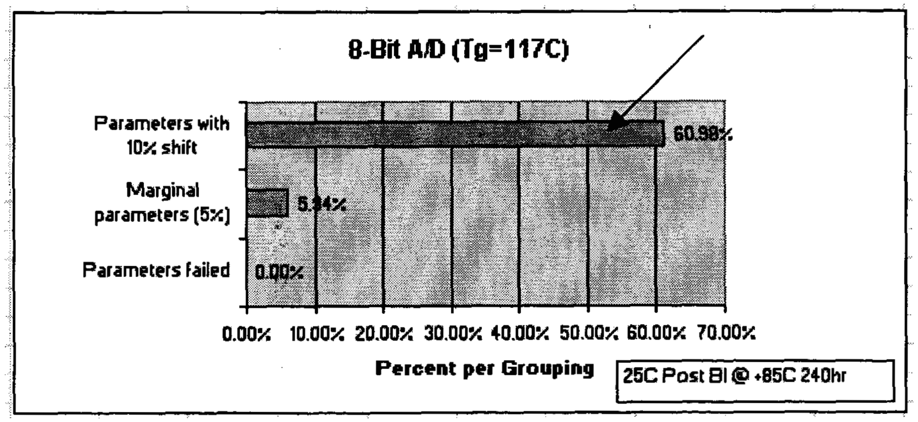
Vendor A - COTS A/D Reliability Data Set 1A

SS=10







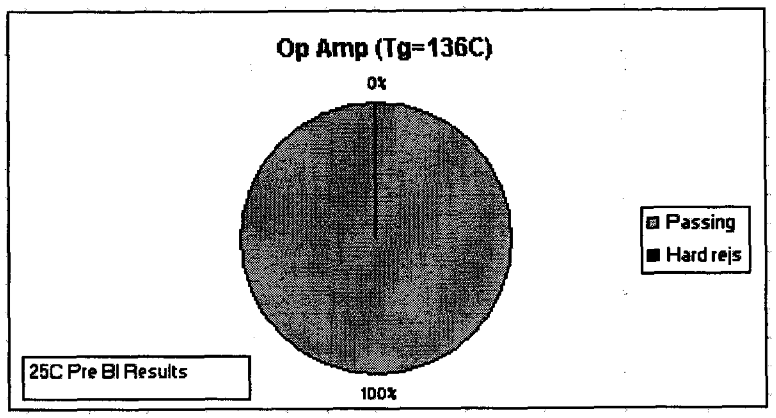


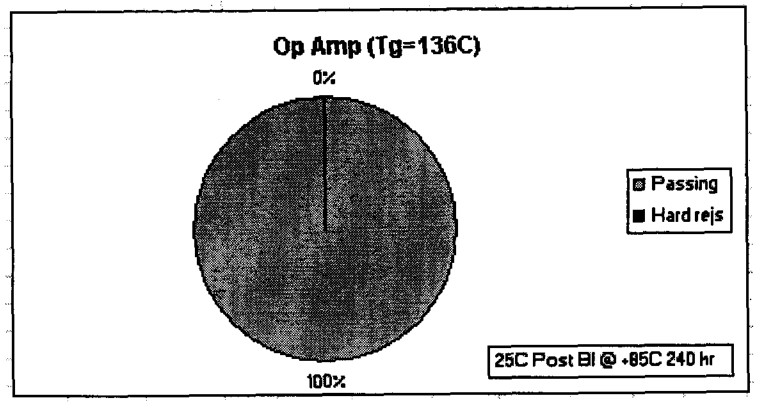
Note: 1) Hard rejects include opens, shorts, and failing data sheet parametric limit.

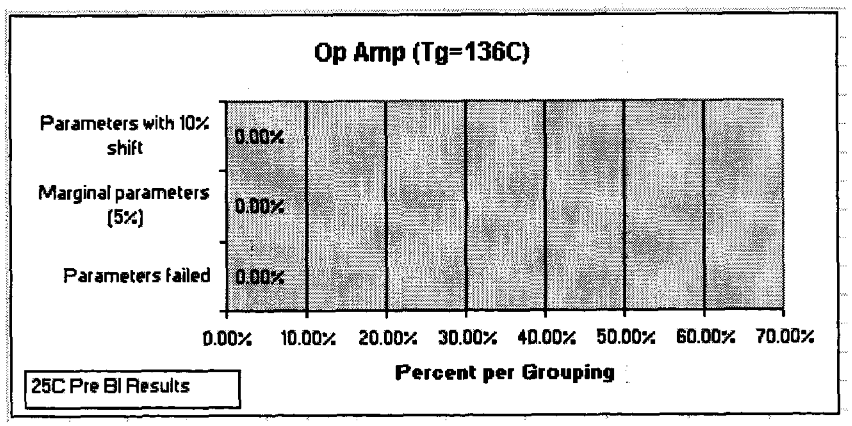
2) Substantial electrical behavioral changes seen with burn-in.

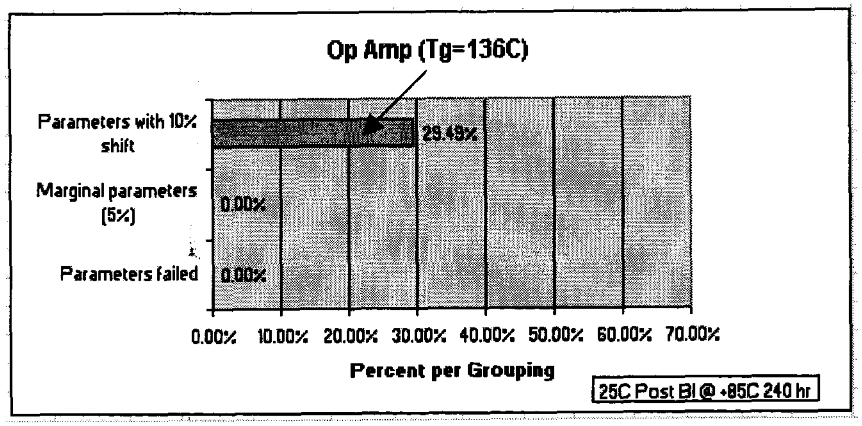
Vendor B - COTS Op Amp Reliability Data Set 1A

SS=10









Note: 1) Hard rejects include opens, shorts, and failing data sheet parametric limit.

2) Less electrical behavioral change seen with burn-in.

Observations/Summary

- Based on post Burn-in TMA analysis, vendor A has residual mechanical stresses in the plastic. This is evident from TMA plots taken above and below the Tg. Repeating the TMA removes the residual stress while in most cases also increasing the Tg indicating an unstable (uncured) Tg. The electrical behavior of the product also shows more change with a 85C burn-in possibly indicating a correlation to the Tg instability.

- Vendor B product appears to have much more consistent mechanical stress profiles when thermal stress is applied and device behavior is more stable with burn-in stress applied. The differences between the two vendors may be attributed to different process controls and materials.

- Differences observed such as lower Tg, residual mechanical stresses, and changes in electrical behaviors can have implications to device reliability for Space applications. This is the first study of its kind where Tg is being studied as a function of burn-in. JPL's position remains unchanged i.e. to keep the Burn-in temperature well below the measured Tg.

- Further work is underway to determine the significant risk factors and methodologies to mitigate them with using screening and or qualification.

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Follow-up Work

- Analysis of cold and high temperature electrical read & record data
- Perform failure analysis
- Perform post burn-in measurements for any ionics extracted
- Perform wire bond pull tests to detect any degradation