High Reliability, Harsh Environment Electronics

ECTC 2017

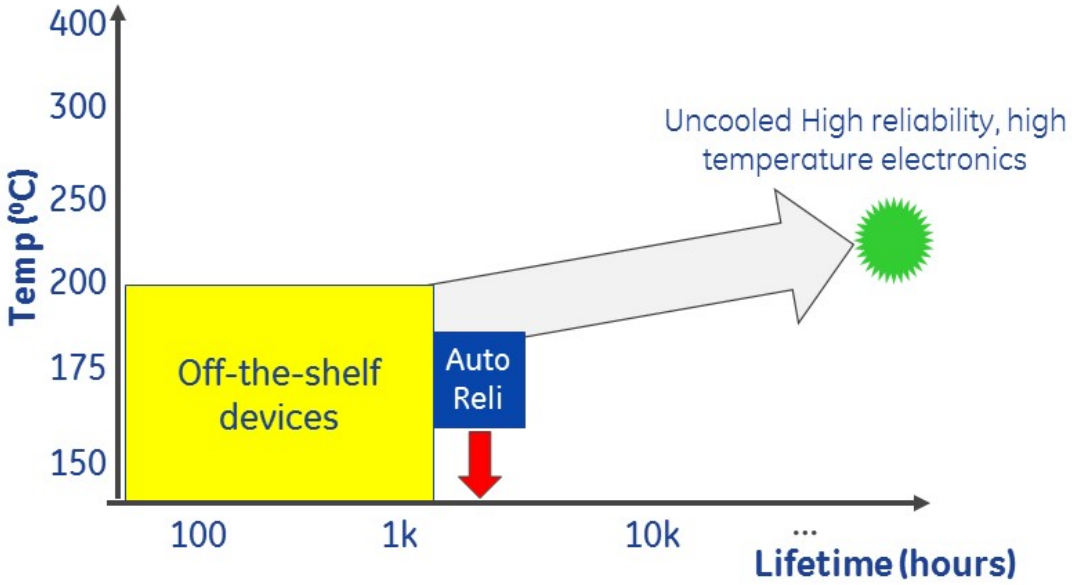
Emad Andarawis, David Shaddock, Liang Yin
Presenter: Nancy Stoffel

Imagination at work.

High Reliability Harsh Environment Electronics

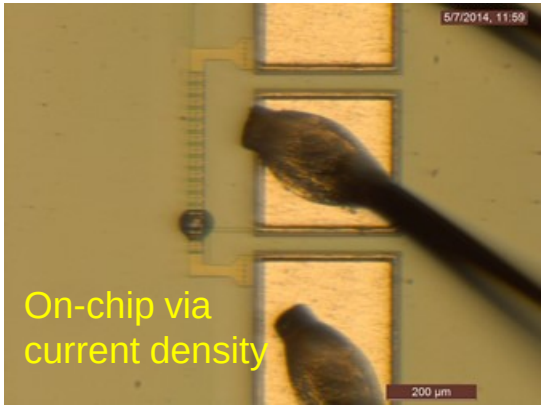
Reliability challenges at high temp:
- Industry driven by O&G: 1-2K hours of life at 210-225C
- Long Un-accelerated testing time (Years!)

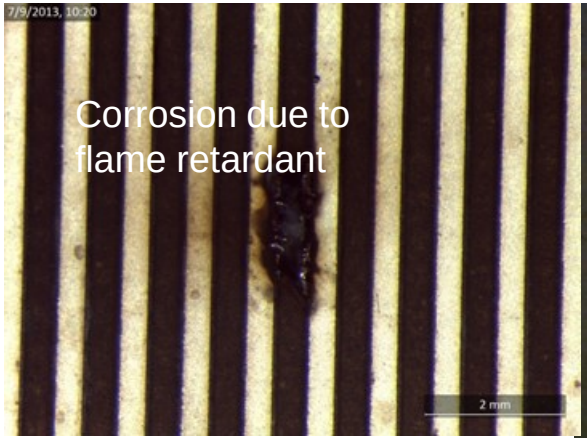
Performance challenges at high temp:
- Parameter shifts over temperature and time
- Integration potential

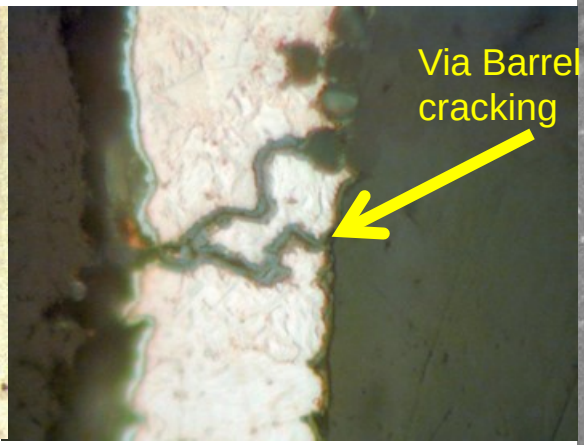


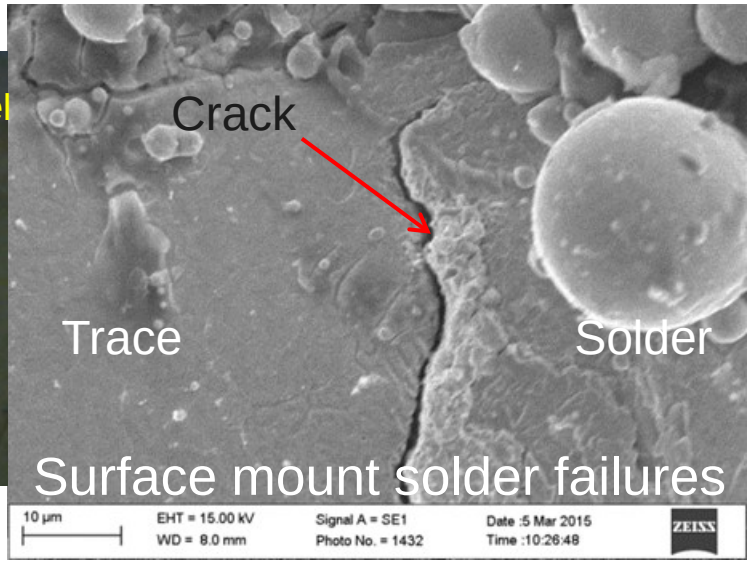
Reliability and performance go down with temperature, so does our ability to assess them!

High temp reliability and challenges









Reliability assessment approach and test capabilities

Screening → Accelerated life testing → Model parameter extraction → Life Prediction → Validation

Accelerated life testing → Failure Analysis → Model parameter extraction

HTS to 260 ˚ C

HTS to 704˚C

Thermal shock chambers
-70 to 350 & 370˚C

High Temp Vibration to 300˚C

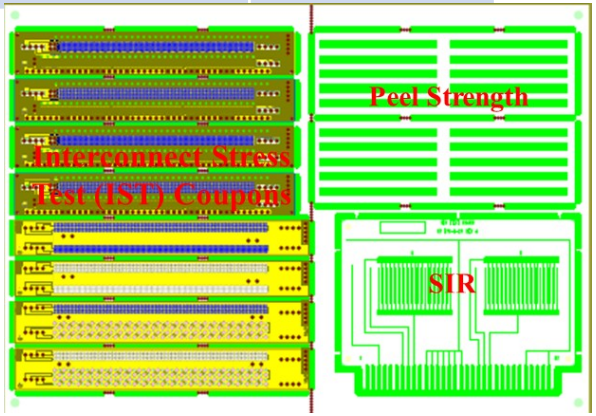
High Temperature Circuit Substrates

	Cost	Feature size	Lifetime above 200C	CTE to Semiconductor	Circuit Density	Second level assembly	Thermal conductivity
Circuit board laminates (FR-4)	🟢	🟡	🔴	🔴	🟢	🟢	🟡
Thick film/Al_2O_3	🟡	🔴	🟢	🟡	🔴	🟡	🟡
Thin film/AlN	🟡	🟢	🟢	🟢	🟡	🟡	🟢
LTCC	🔴	🟡	🟢	🟢	🟡	🟡	🔴
HTCC	🟡	🟡	🟢	🟡	🟡	🟡	🟡

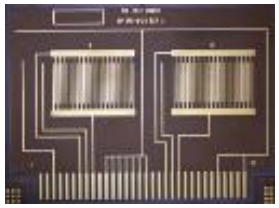
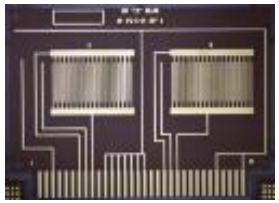
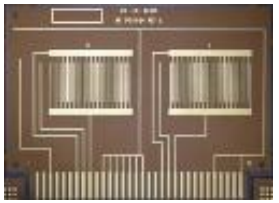
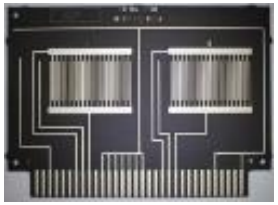
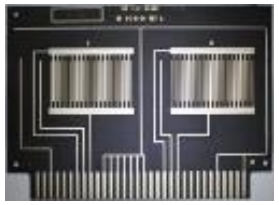
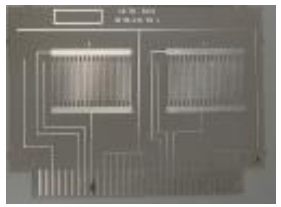
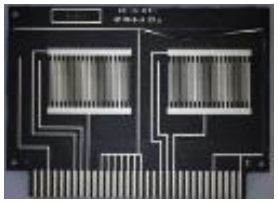
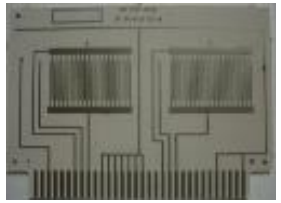
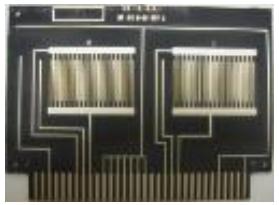
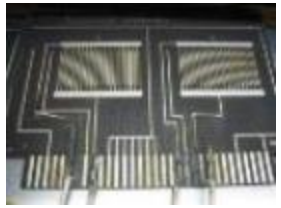
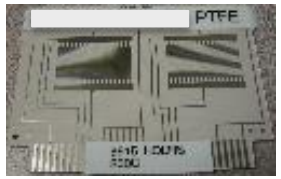
Laminates attractive from cost, circuit density and assembly perspective. Suitability for high temperature, high reliability applications unknow.

Screen laminates with common circuit board test methods: via thermal cycling, weight loss, peel strength, and surface insulation resistance (SIR).

Materials selected from those with high T_g(>250˚C), low CTE_z, and modulus.



Isothermal Aging at 200˚C Images

	Polyimide 1	Polyimide 2	Polyimide 3	PTFE
0 hours				
4000 hours				
5000 hours				
6000 hours				

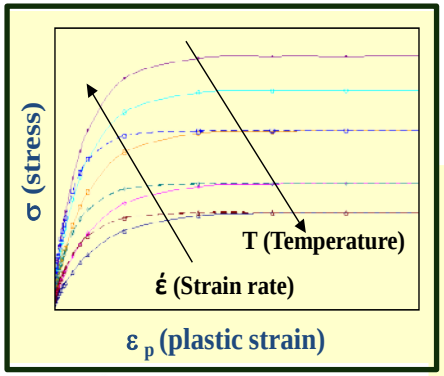
Polyimides have little remaining structure after 5000 hours (~5%wt loss). PTFE is still surviving >8000 hours at 200˚C.

Solder Model Characterization

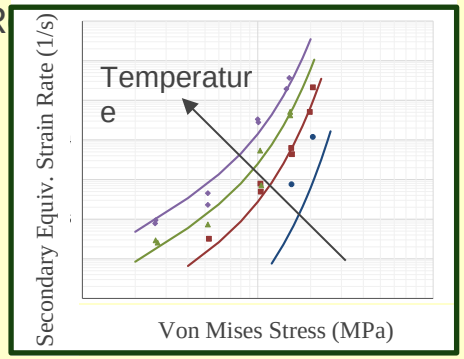
Controllable Parameters:

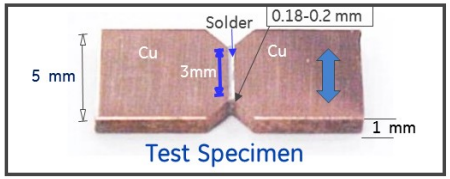
- Stress level
- Strain rate
- Load amplitude
- Temperature
- Multiple strain-range modes

Elastic-Plastic Tests

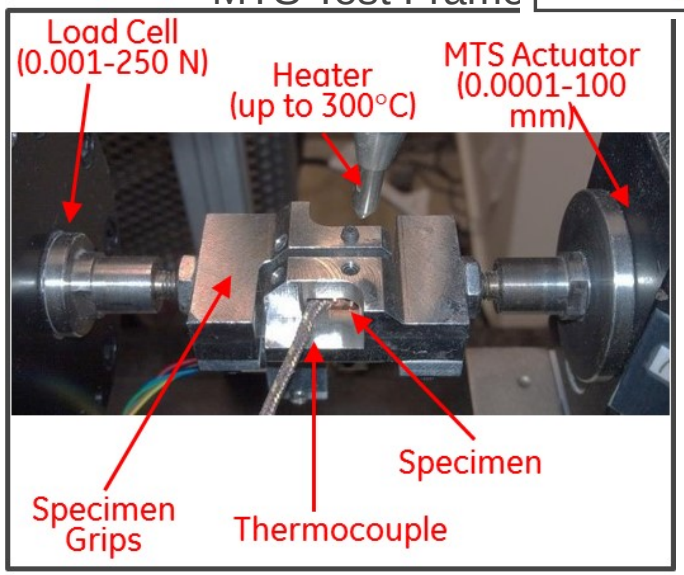


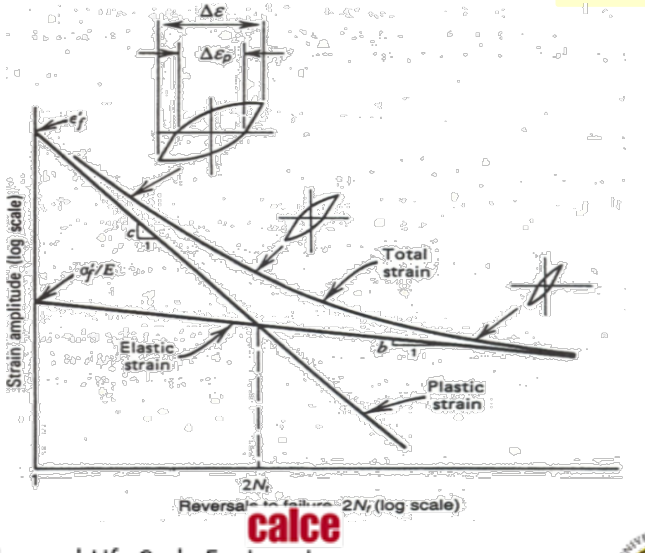
Secondary Creep Test R





MTS Test Frame





$$N_f = \left[\frac{\theta}{\Delta W}\right]^{\propto}$$

calce

Center for Advanced Life Cycle Engineering

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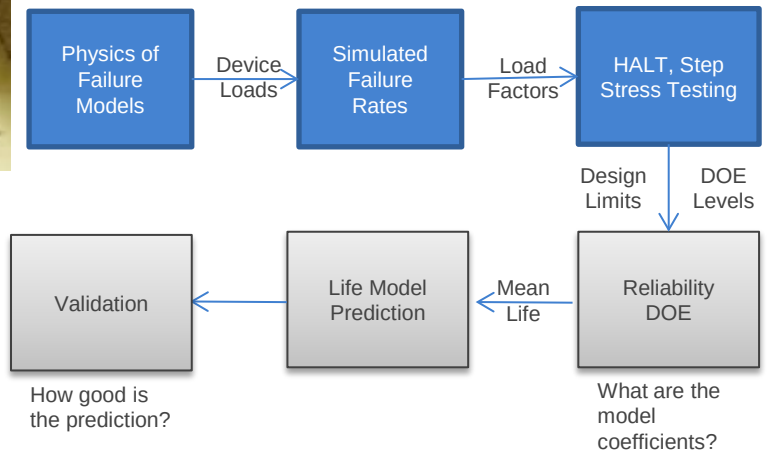
Reliability model development example: Passives

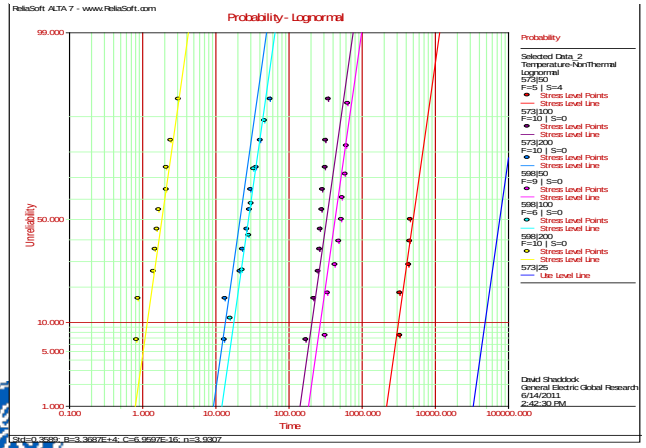
Test Setup

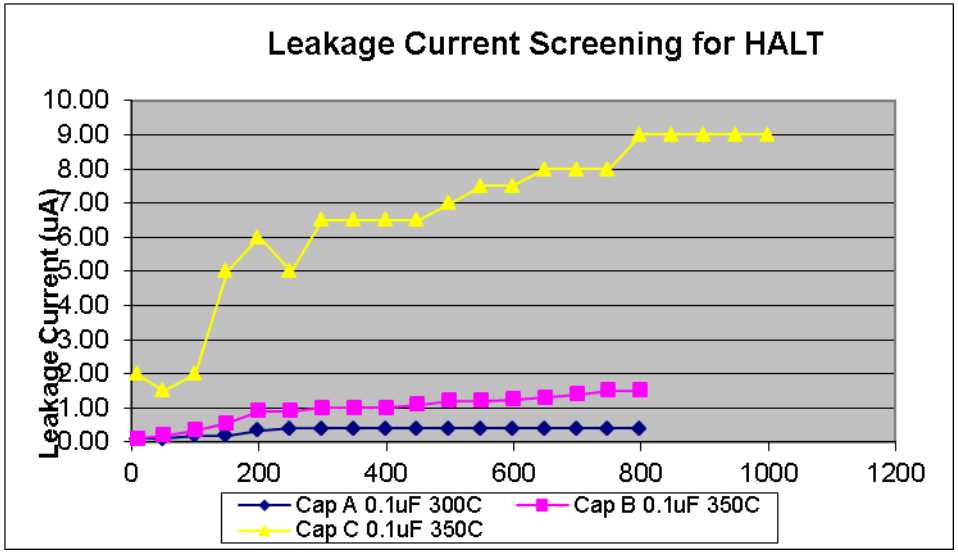


Failure Model:
Prokopowicz equation

$$\frac{t_1}{t_2} = \left(\frac{V_2}{V_1}\right)^n \exp\frac{E_a}{k}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Reliability versus stress factor





Summary

- Reliability and performance degrade as temperature increases
- Life prediction models don’t adequately cover operation above conventional (~125C) temperatures
- High reliability applications require test time acceleration
- A number of existing device and packaging options target short duration use.

- Reliability assessment and modeling approach was developed
  - Life prediction and acceleration models at extended temperature.