



High Reliability, Harsh Environment Electronics

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Imagination at work.

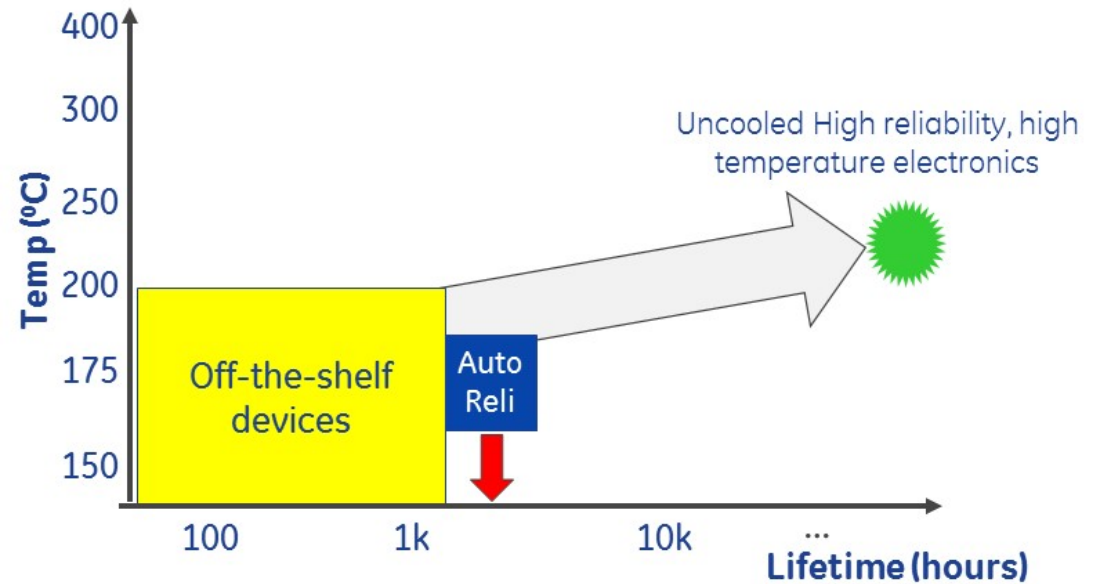
High Reliability Harsh Environment Electronics

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:

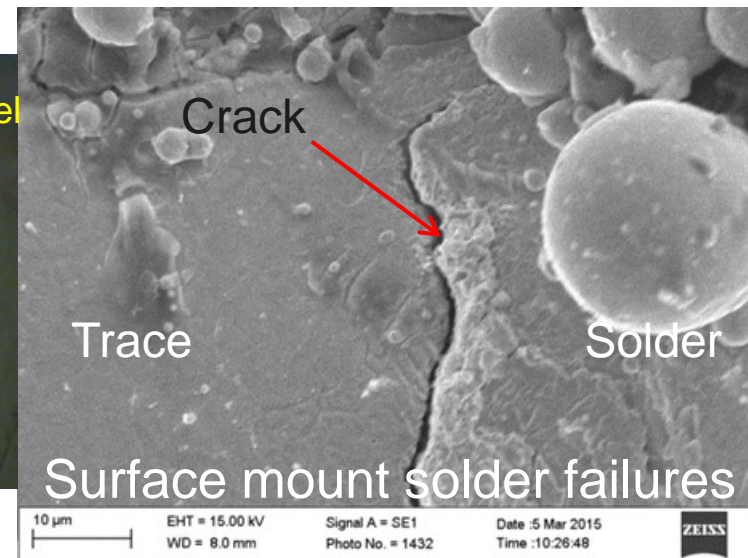
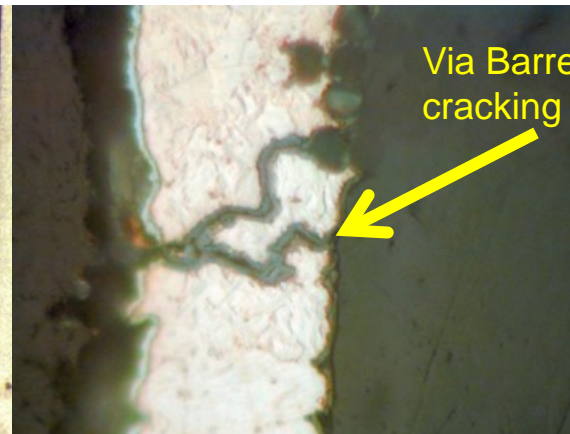
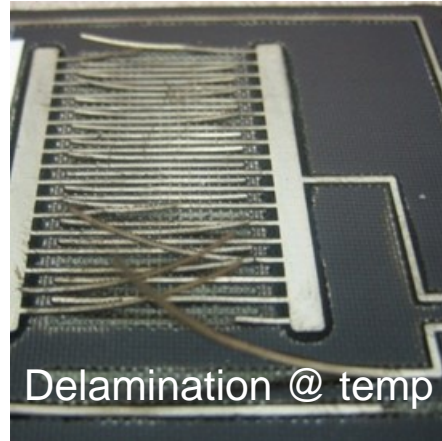
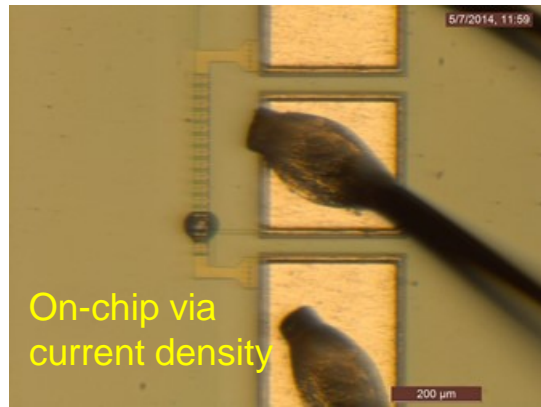
- Parameter shifts over temperature and time
- Integration potential



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



HTS to 260 ° C



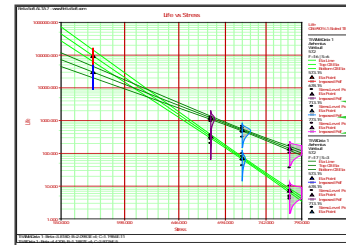
HTS to 704 ° C



Thermal shock chambers
-70 to 350 & 370 ° C



High Temp Vibration to 300 ° C



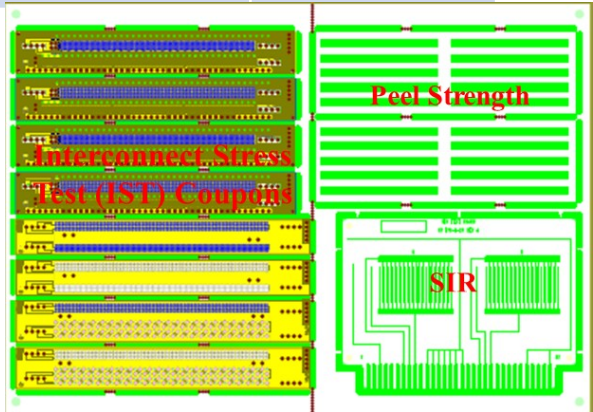
High Temperature Circuit Substrates

	Cost	Feature size	Lifetime above 200C	CTE to Semiconduct or	Circuit Density	Second level assembly	Thermal conductivity
Circuit board laminates (FR-4)	Green	Yellow	Red	Red	Green	Green	Yellow
Thick film/ Al_2O_3	Yellow	Red	Green	Yellow	Red	Yellow	Yellow
Thin film/ AlN	Yellow	Green	Green	Green	Yellow	Yellow	Green
LTCC	Red	Yellow	Green	Green	Yellow	Yellow	Red
HTCC	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow

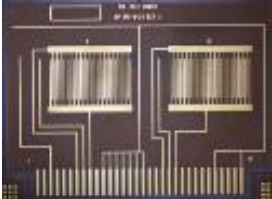
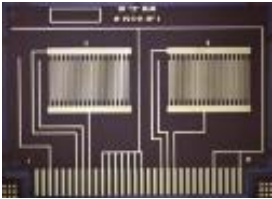
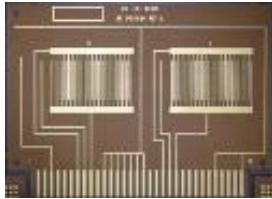

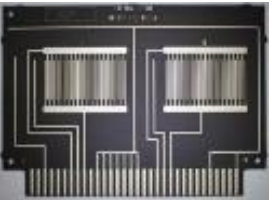
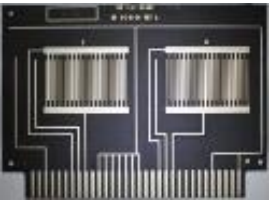

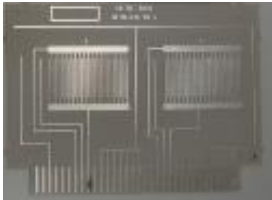



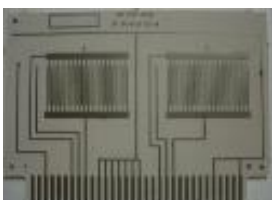

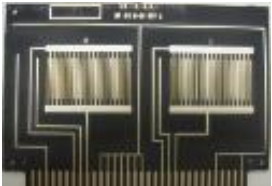
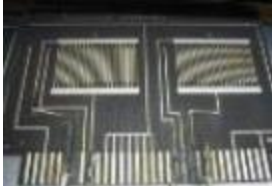

Laminates attractive from cost, circuit density and assembly perspective. Suitability for high temperature, high reliability applications unknown.

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 $T_g (>250^\circ C)$, 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.

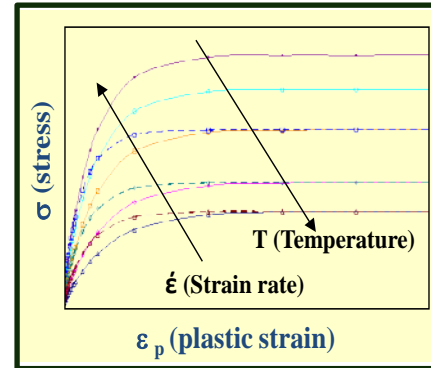


Solder Model Characterization

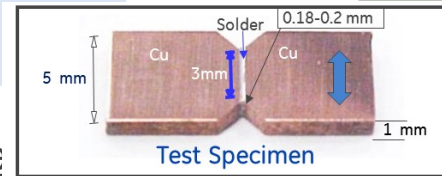
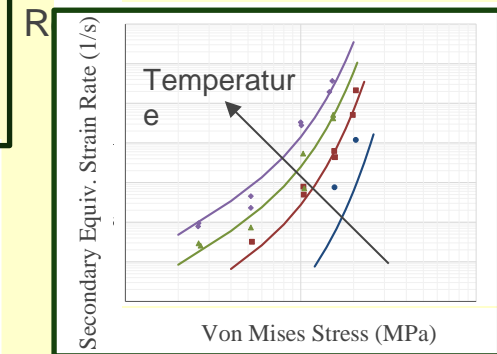
Controllable Parameters:

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

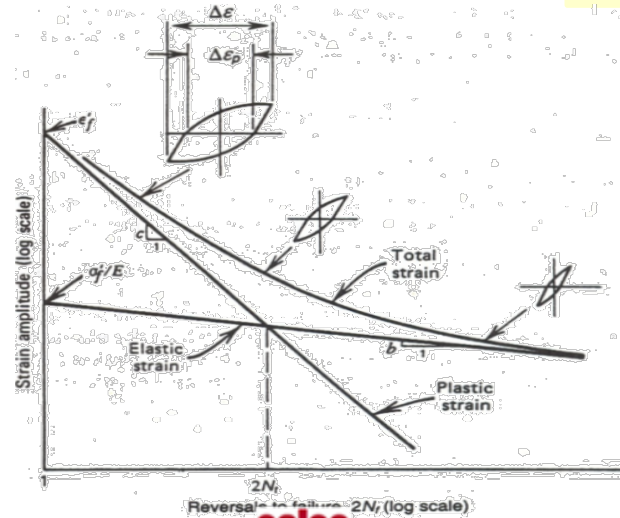
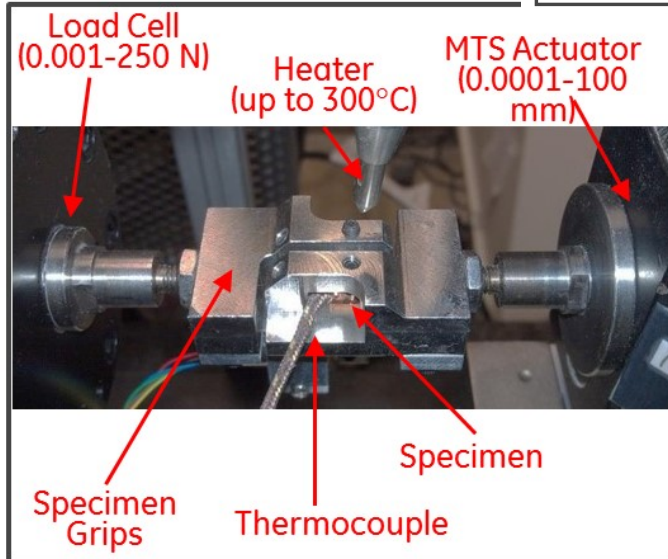
Elastic-Plastic Tests



Secondary Creep Test



MTS Test Frame

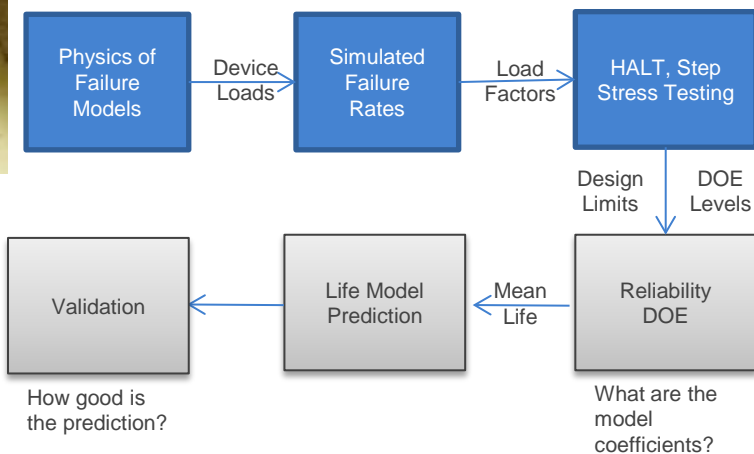


$$N_f = \left[\frac{\theta}{\Delta W} \right]^\alpha$$



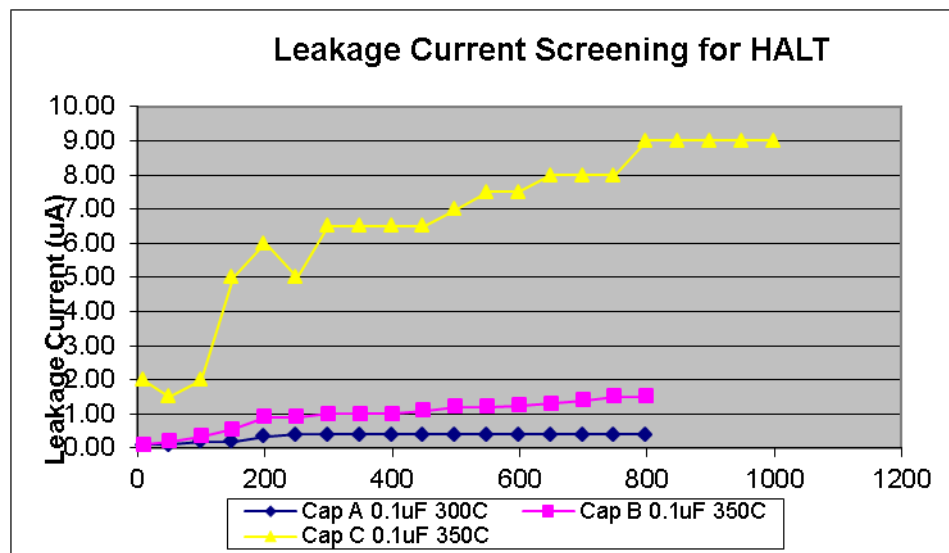
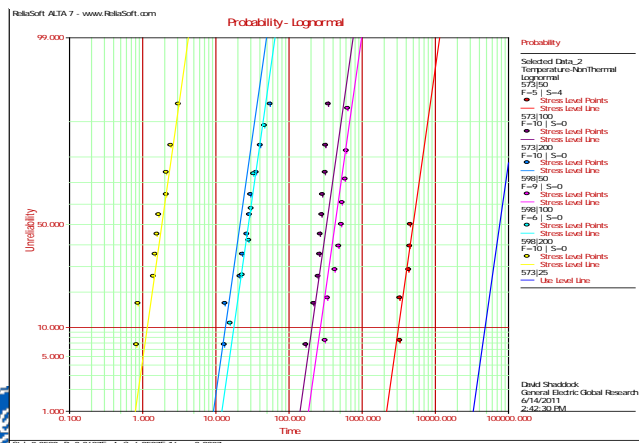
Reliability model development example: Passives

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.

