# Detecting *Thermo-Mechanical Stress* Induced Damage in Conformal Coated ***WLCSP*** Interconnects

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# Electronics in our daily life

**Energy sector**
With the expansion of the smart grid, most of the monitoring occurs in real time with a vast amount of data, whether it is a nuclear plant, of wind farm.

**Aerospace sector**
Airplanes, satellites and spacecraft have different requirements to assure their performance. They experience higher and lower temperature changes with mechanical shock and vibration during service.

**At Home, Home network**
Everything is connected to the network. From home router to home security, energy bill to home entertainment, our dependence on electronic devices is higher than ever.

**Wind farm**
Wind mills are located at various locations. On land, these turbines experience extreme heat during the summer and those located near the sea shore experience a corrosive environment. This is a significant factor because the electronic devices in marine environments are usually not easy to access, and thus expensive to repair.

**Oil drilling and underwater mining**
One equally important area for the energy sector is the underwater environment. It has high pressure, high vibration conditions and is not easy to access. Thus it is costly to replace or repair down hole electronic devices/ sensors. With drilling, devices requires a good stability at high temperature.

**Wearable electronics**
The human body can have lots of electronic gadgets. From wearable glasses with HD camera, to every day music devices and smartphones are all close to your body surface which can easily react with body fluids and sweat. Also there are implantable medical devices which have direct contact to various bio-corrosion environments.

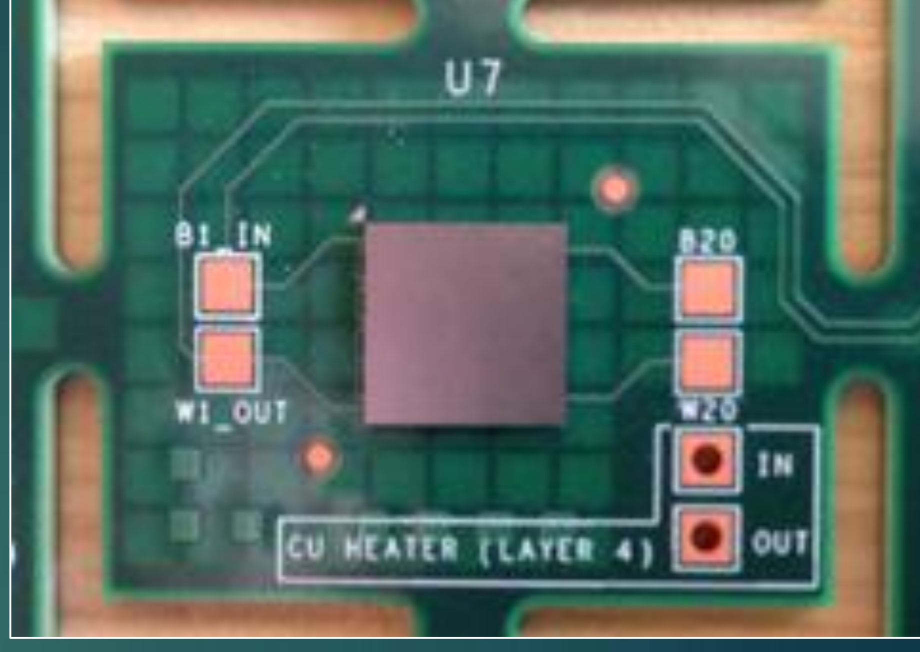
**The Vehicle**
The car, which was a once a recreation vehicle or a commuter vehicle is now an entertainment system with safety devices that monitors and controls real time performance. The recently tested self driving vehicle shows that the vehicle is becoming a high reliability product which cannot afford any failure during functioning, especially an unmanned car

# What is a PCB & SAC alloy?

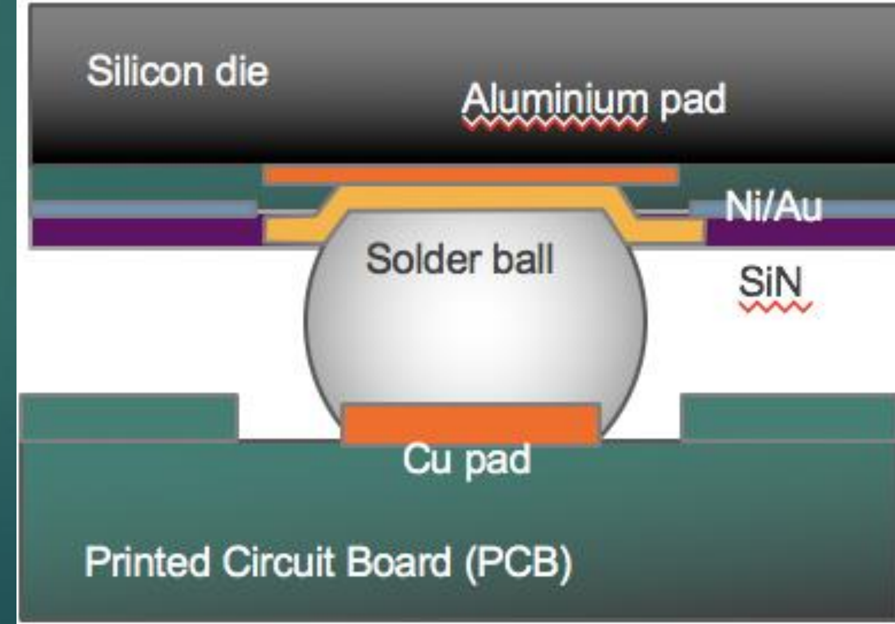
**Printed circuit board** (PCB)- allows for a system of components to work as a network for conductive pathways for information to be passed on.

**SAC alloy-** A combination of 3 materials. Tin(Sn), Silver(Ag) and Copper(Cu)

**Types of SAC alloys- 305** and **105** most used in industry.




Multi axis loading impact: Dr. Lee Power Point



# Types of packages

Wafer Level Chip Scale Package

Plastic Ball grid array

Fine Ball grid array

Board on Chip

Package on Package

Ceramic Ball grid array

| | | | | |
|---|---|---|---|---|
| Ball Grid array | Wafer Level Chip Scale Package (WLCSP) | Si die directly BGA ball attached. Available in direct bump on pad and bump on repassivation and redistribution | | |
| | Plastic Ball grid array (PBGA) | A plastic overmolded product using 2,4,6 and 8 layer substrate with die-up configuration and passive attach. | | |
| | Fine Ball grid array (FBGA) | Die up wire bonded, overmolded configuration with ball pitches ranging from 0.4 mm - 1.0 mm. Thin core laminate and thin mold also called CTBGA or CABGA | | |
| | Board on Chip (BOC) | Designed as a cost-effective CSP (chip scale package) solution specifically for high-frequency memory devices. | | |
| | Package on Package (PoP) | Combine vertically discrete logic and memory ball grid array (BGA) packages. Two or more packages are installed atop each other | | |
| | Ceramic Ball grid array (CBGA) | Ceramic substrates can endure much higher temperature without serious warpage but are also very stiff | | |

Fundamentals of Lead-Free solder interconnect technology: Dr. I

# Connections and Reflow

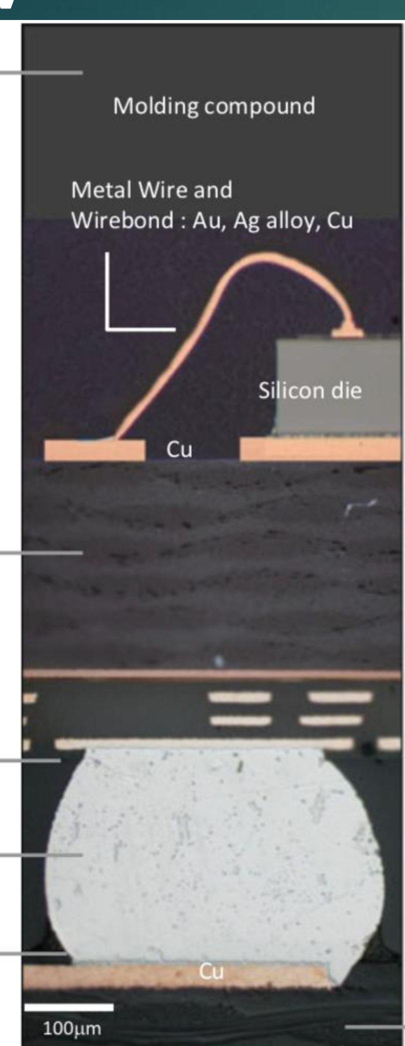
Package **Overmolding**

**Substrate**
Organic, thin-core, coreless, Ceramic

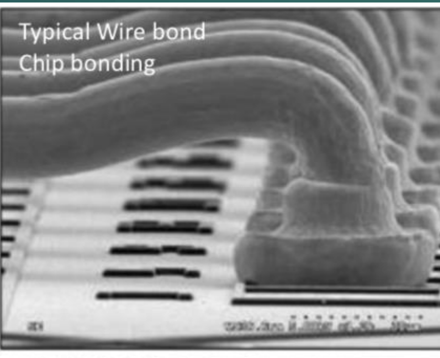
**Substrate surface** finish
: SOP, ImSn, NiAu, ENIG, ENEPIG

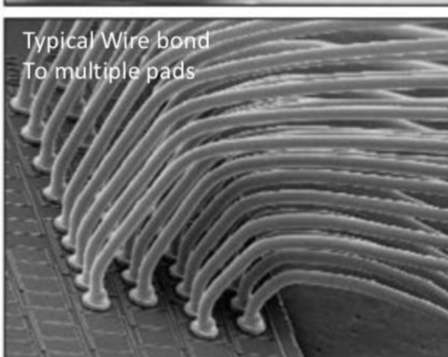
**Solder** joint

**Board side surface finish**
OSP, ImSn, ENIG, ENEPIG, HASL, ImAg




**Printer Circuit Board** (PCB)

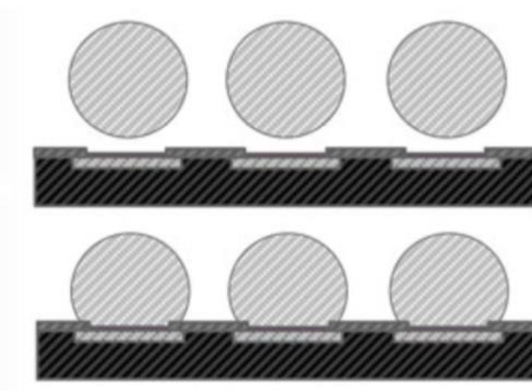


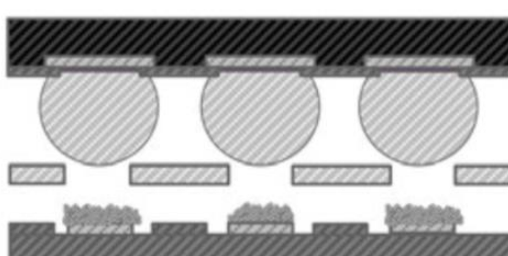

* SEM picture, courtesy of MKE

Flux applied to the package substrate before ball placement

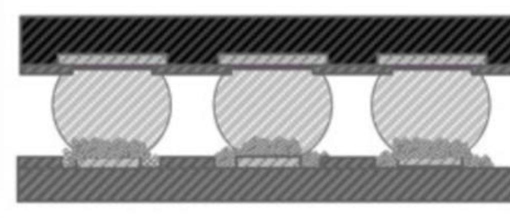
After ball placement, the package go through a reflow for Ball attachment



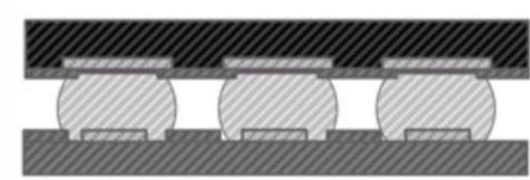
For the PCB side, solder paste is applied using a stencil, which matched the foot print of the PCB layout

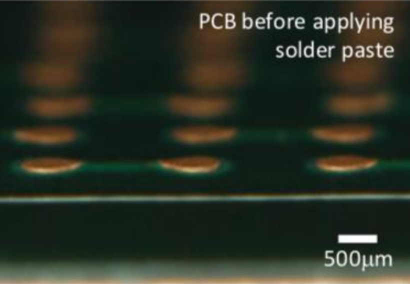


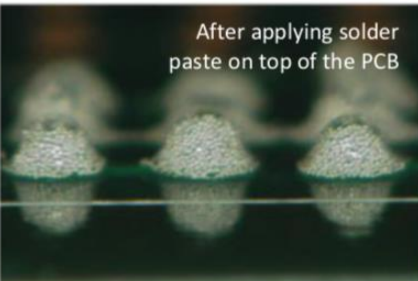
Then the component is placed on top of the PCB

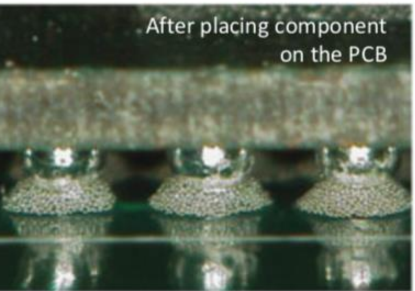


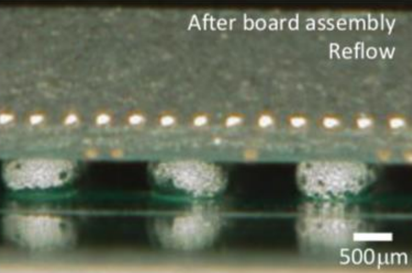
The board goes through a board assembly reflow based on the pre programed reflow profile





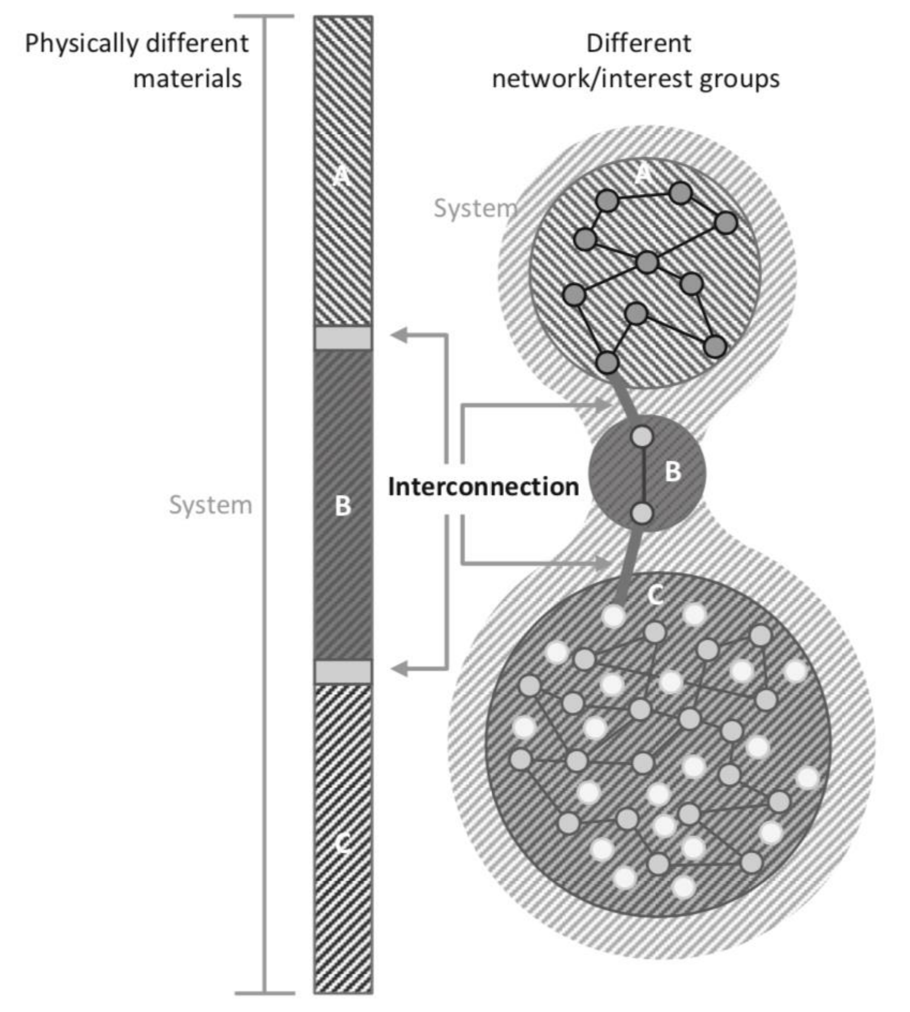



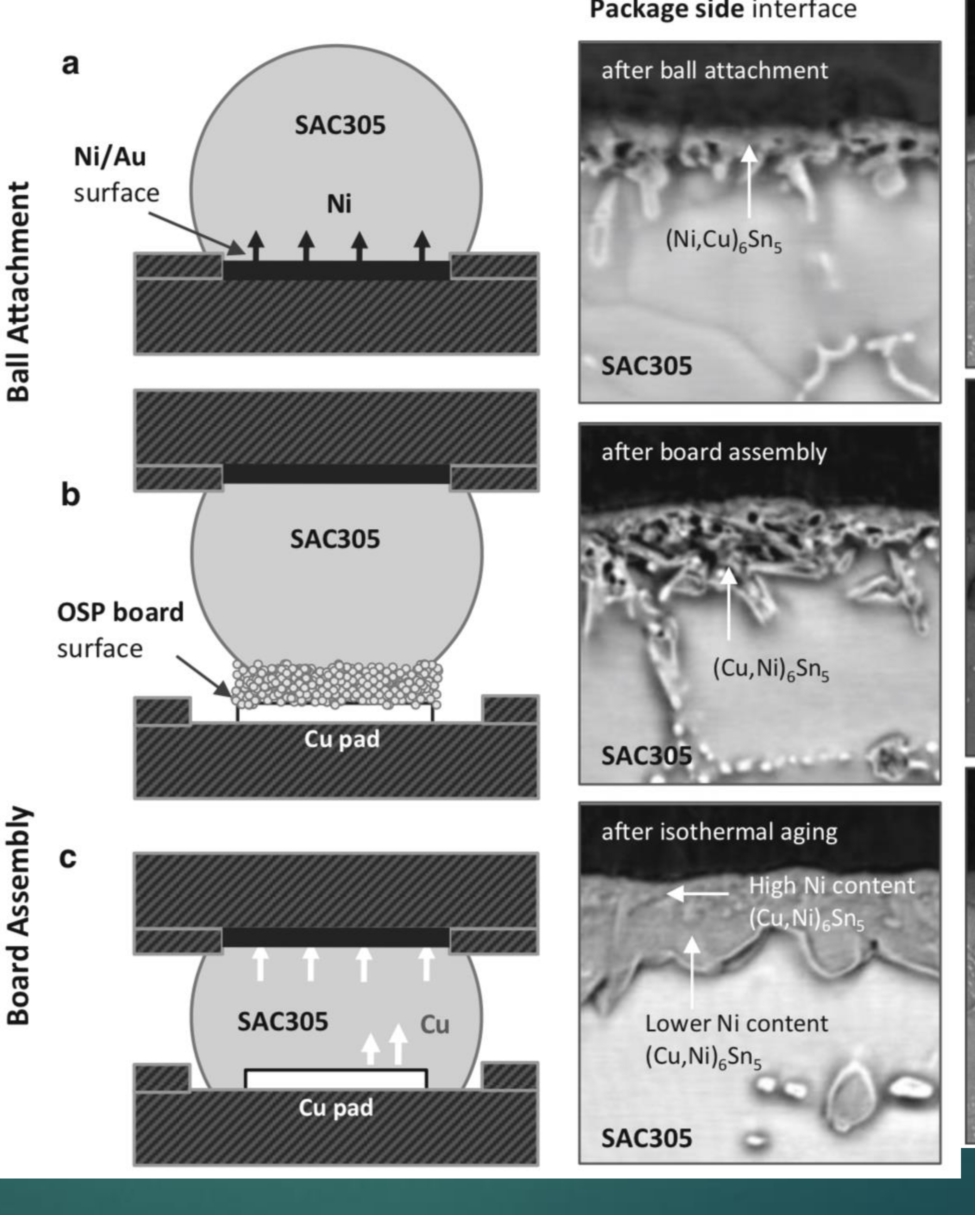



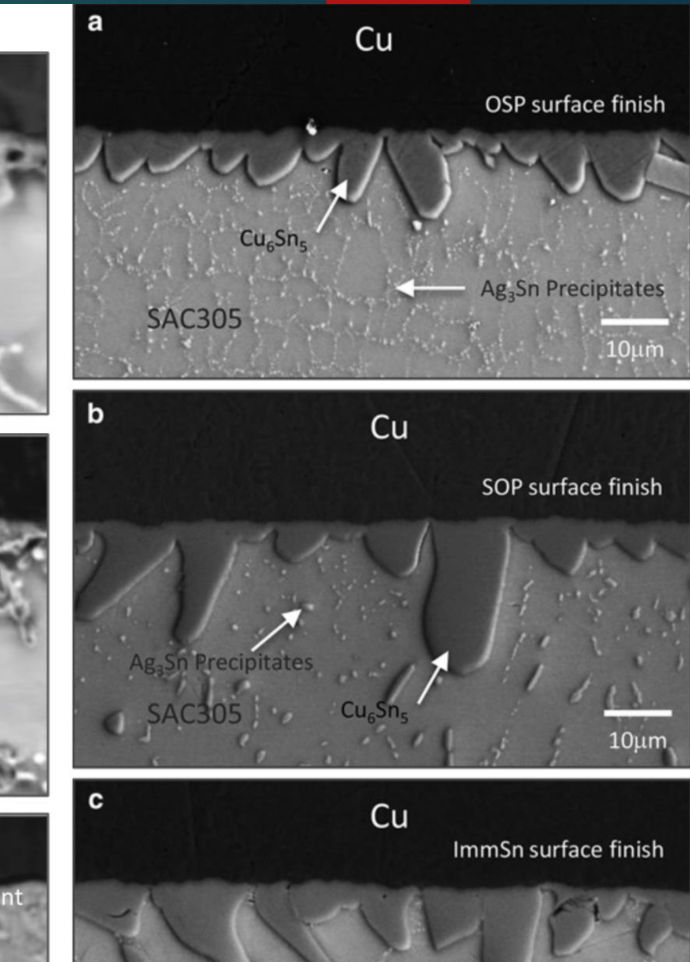




Fundamentals of Lead-Free solder interconnect technology: Dr. Lee 2015

# Interconnect



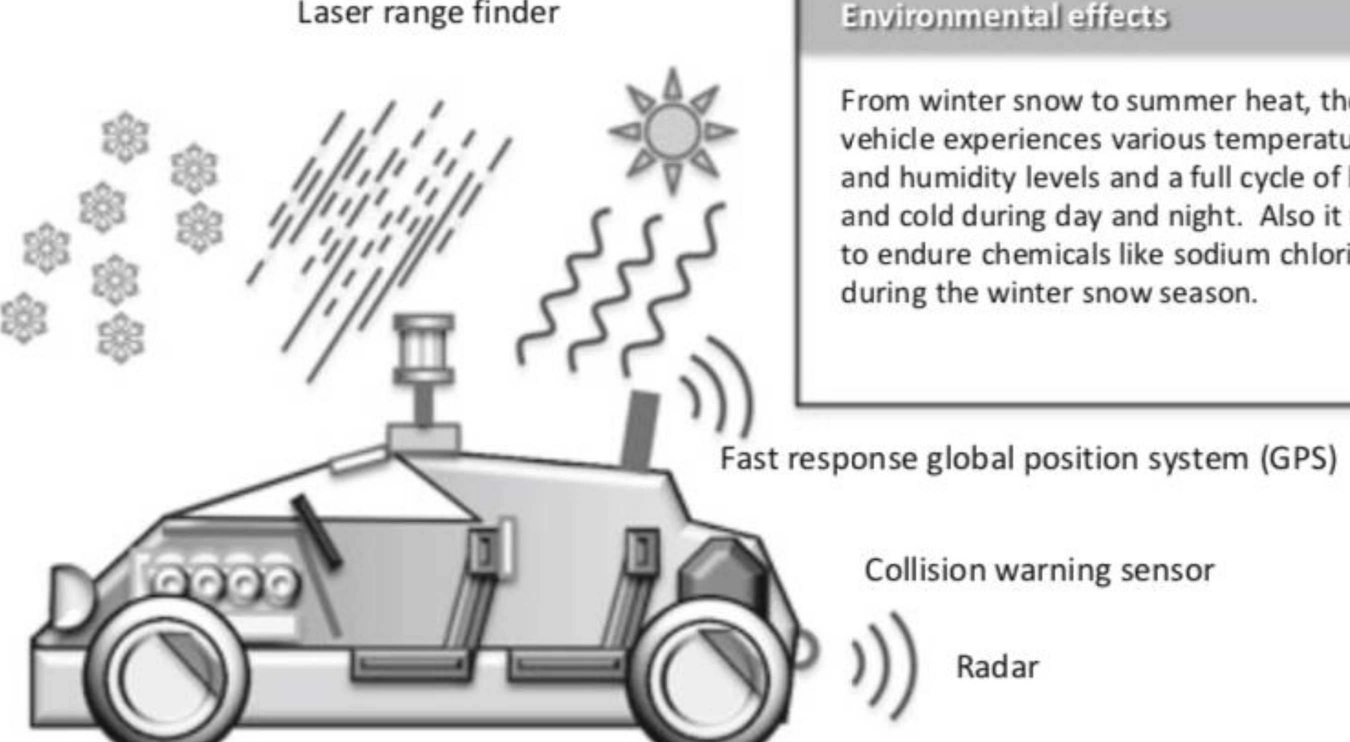

Fundamentals of Lead-Free solder interconnect technology: Dr. Lee 2015

# Reliability

- *What can affect the reliability of a product?*

### Thermal effects

Regular thermal cycling is expected if the vehicle is exposed to open air, since the temperature changes from day to night, or during winter and summer. A more direct thermal challenge comes from the engine. An increasing number of electronic devices are installed near the engine to monitor or control the engine performance. These devices need higher temperature performance materials than conventional solder alloys.




### Environmental effects

From winter snow to summer heat, the vehicle experiences various temperature and humidity levels and a full cycle of hot and cold during day and night. Also it needs to endure chemicals like sodium chloride during the winter snow season.

### Mechanical effects

It is easy to imagine the variety of mechanical impacts during driving the vehicle, such as vibration, bending, shock and other forms of mechanical fatigue.

### Electronic effects

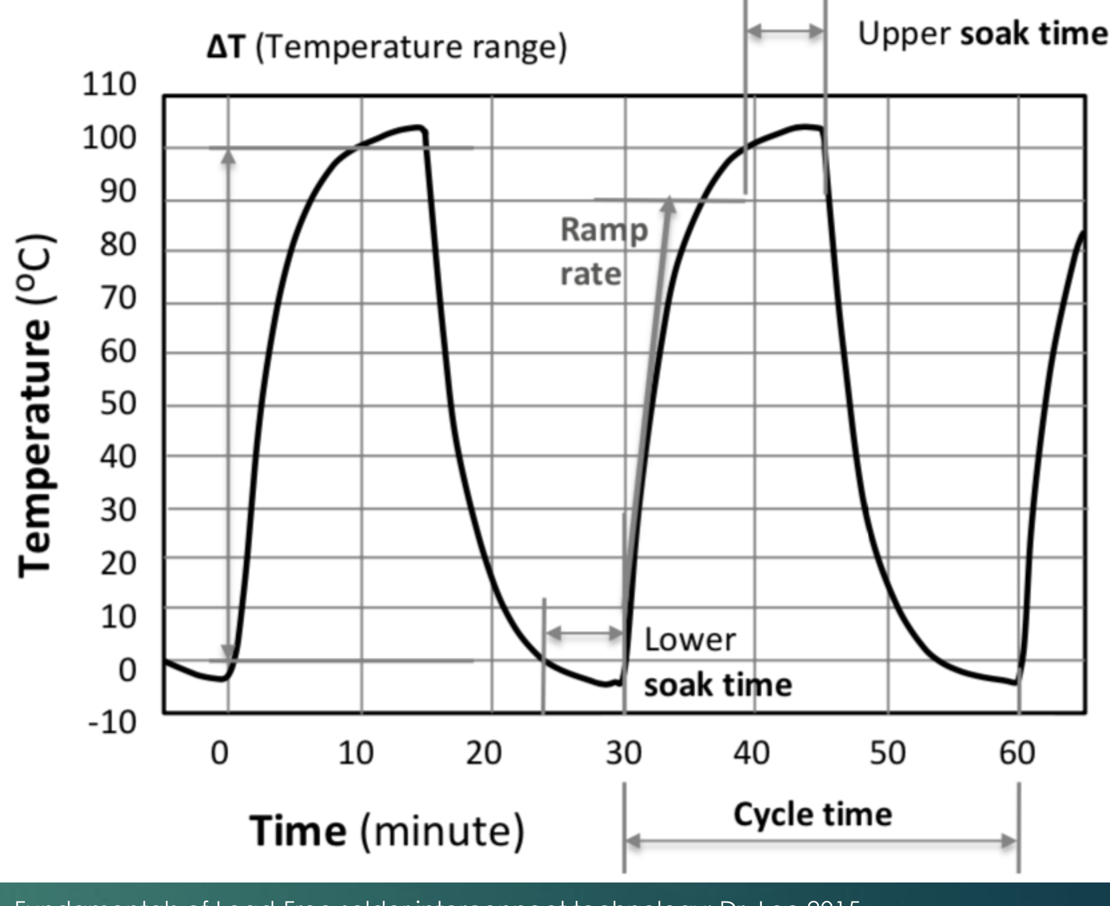
Direct control by electric power involves high current density in various spots inside the vehicle. Components need to endure and perform with multiple constraints of high current density, thermal cycling, and environmental conditions such as high humidity.

# Thermal cycling

- Thermal cycling has an affect on pack design due to CTE

- WLCSP will usually fail after a hundred cycling

- Crystal orientation within the joint affects stress evolution

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# Test

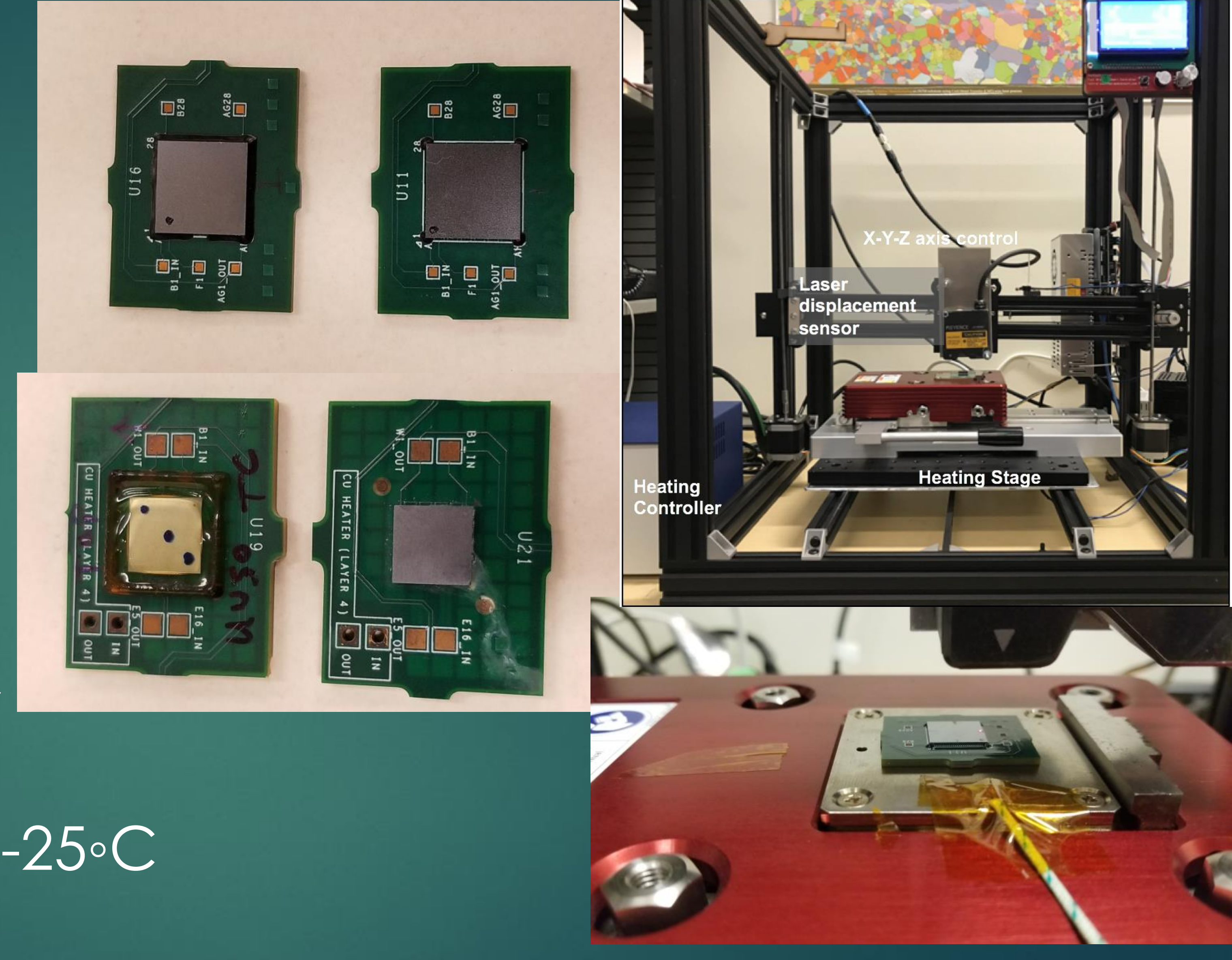
-Profilometer
(Keyence LK-H022)
Wavelenght: 655nm
Max output: 0.95mW

-Nordson-DAGE

-Hioki LRB431-20 Data logger

Sample is started at temp 22-25◦C

Runs for approx. 15 minutes.



# WLCSP with coating and without

8x8

U1

As-assembled + TC

WLCSP component

WLCSP component

93mil, 2.4mm

PCB Side view

8x8

U1

Fully covered coating

WLCSP component

WLCSP component

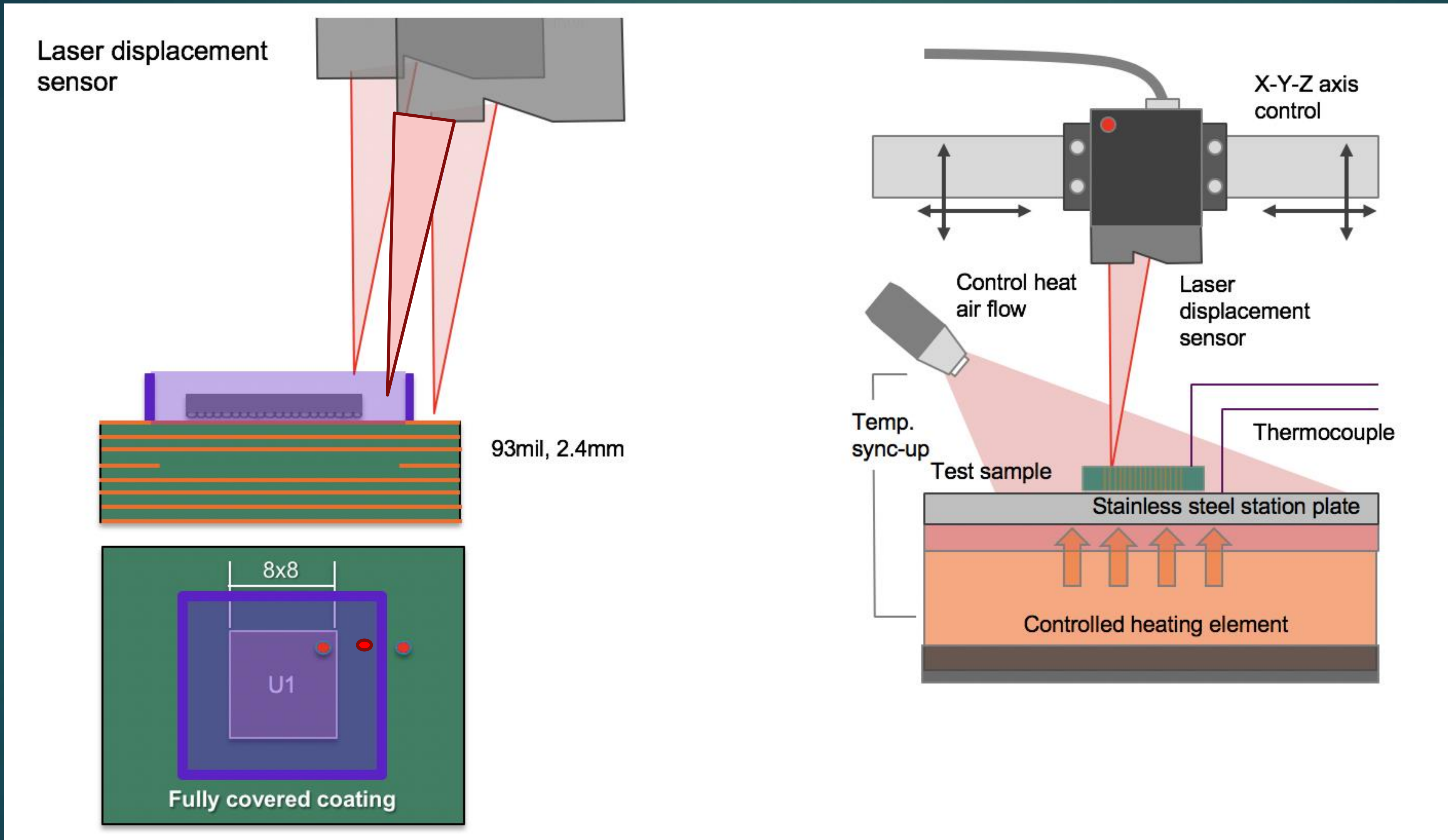
93mil, 2.4mm

Conformal coating

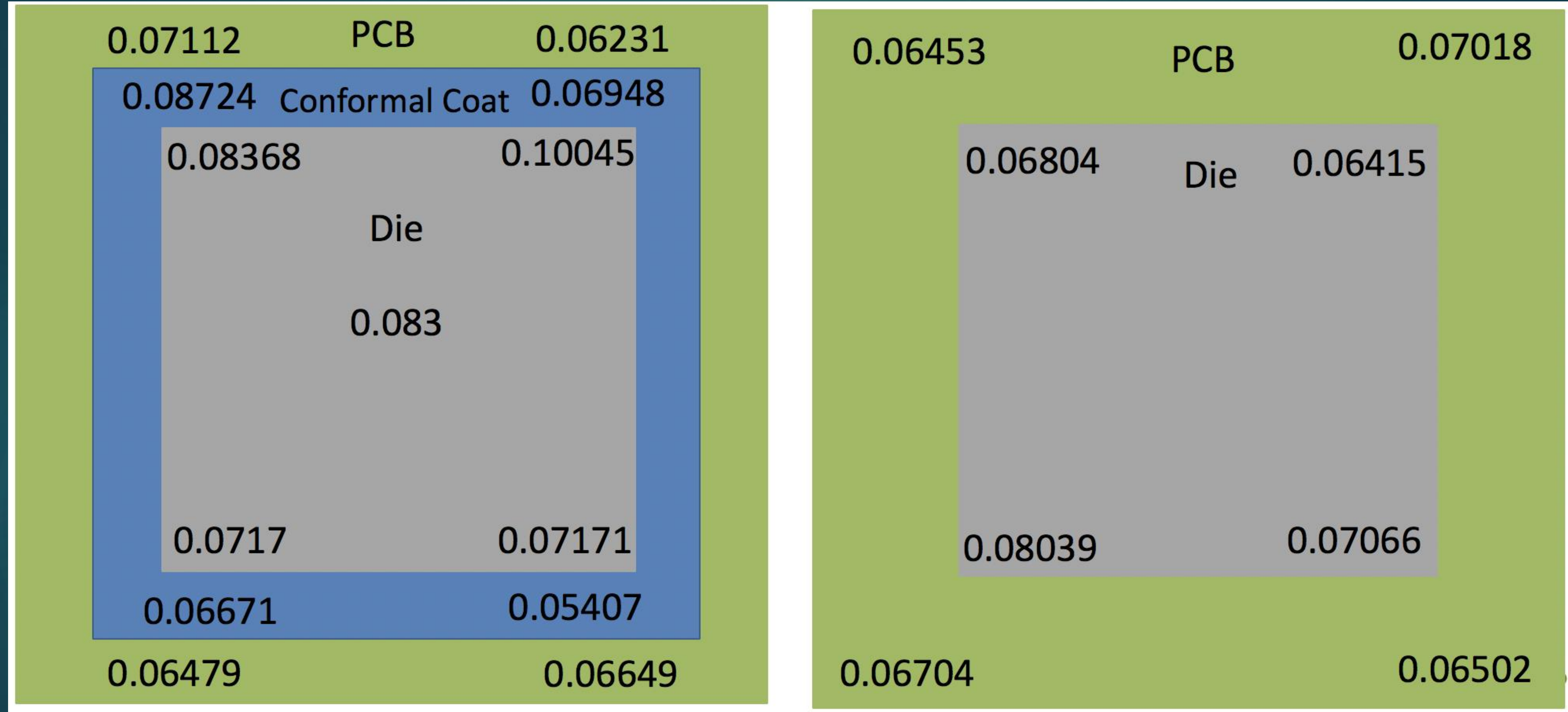
PCB Side view

Multi axis loading impact: Dr. Lee Power Point

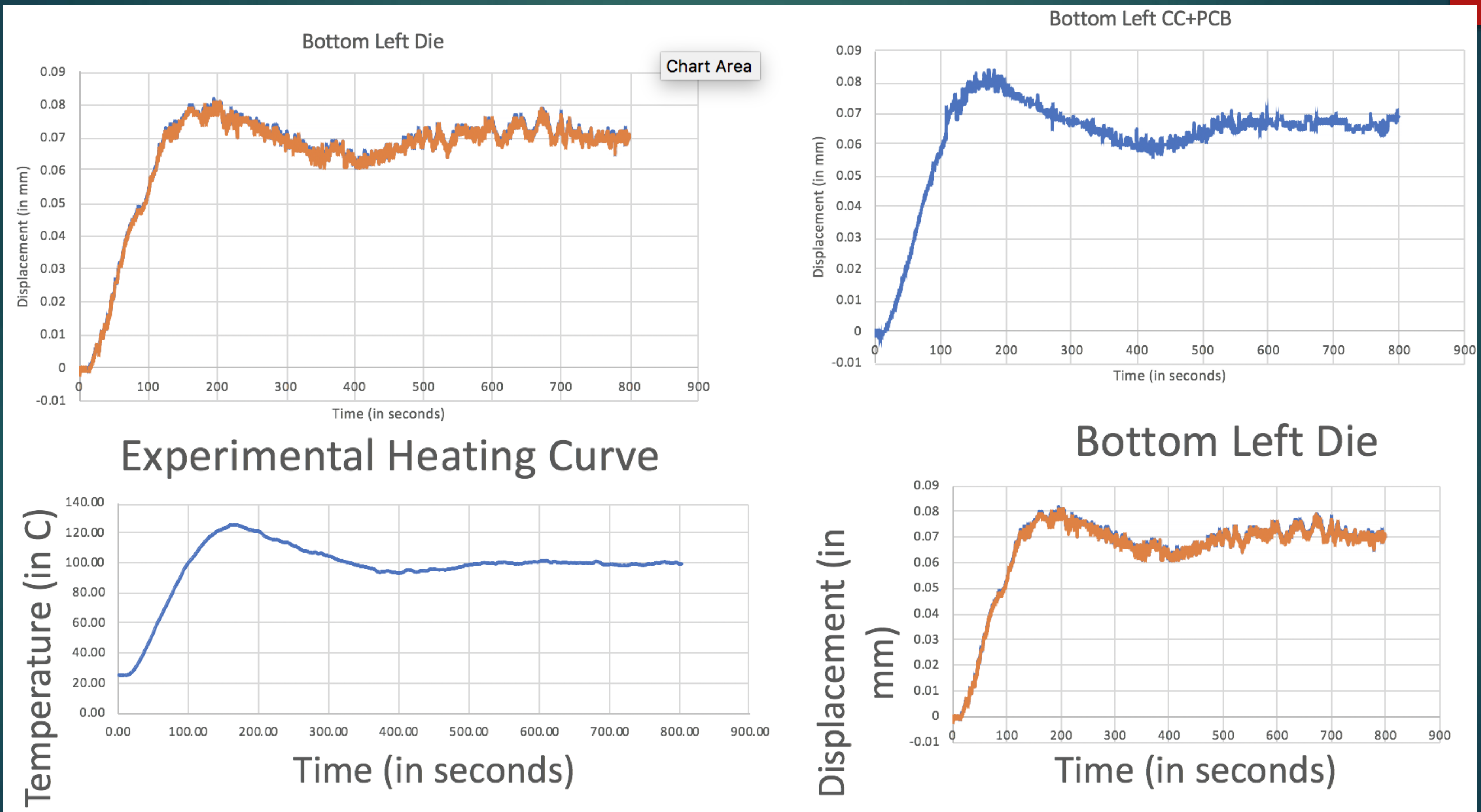
# Test set up



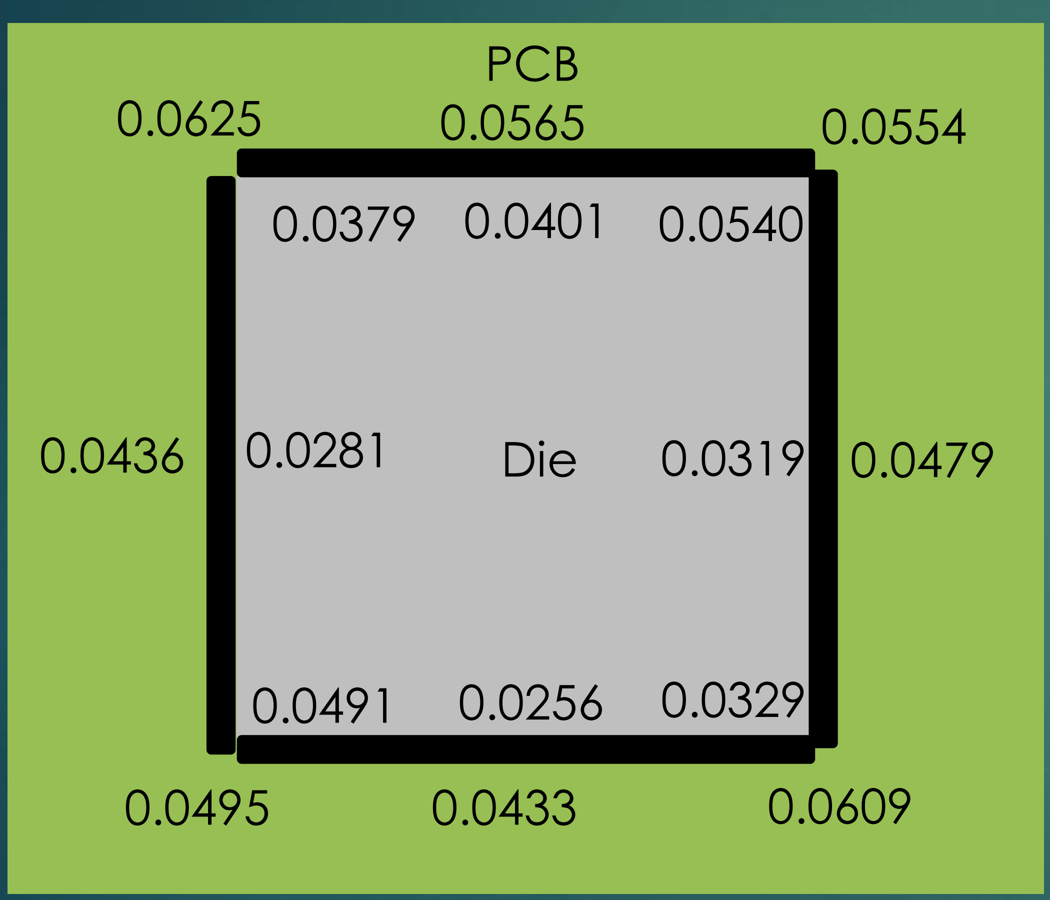
# Results: Conformal coating and without

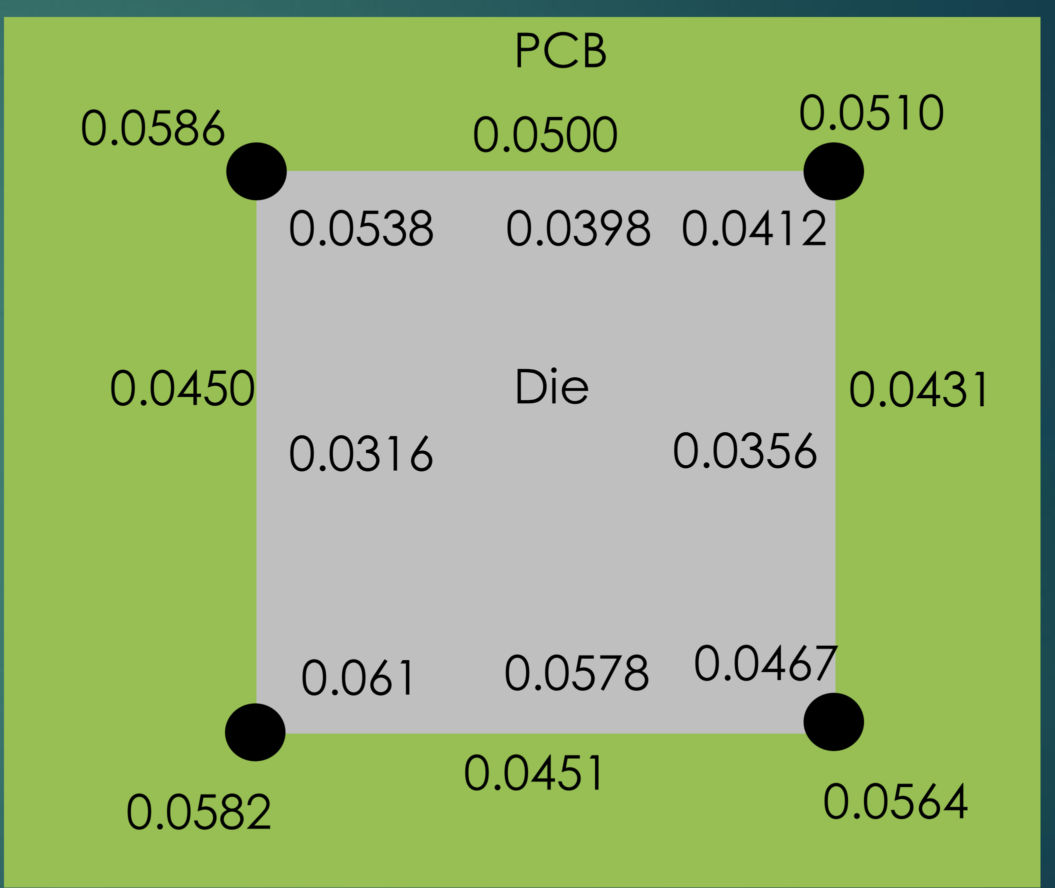


# Displacement graph



# Results: Displacement for Edge bond



# Displacement sample with no Edge bond.

0.0538 0.0597 0.0575

0.0407 0.0471 0.0434

0.0395 0.0459 0.0434 0.0457

0.0551 0.0368 0.0372

0.0574 0.0491 0.0557

# Bond Tester

- Used to determine the following:

-Ball shear/Solder ball shear

-Cold Bump Pull

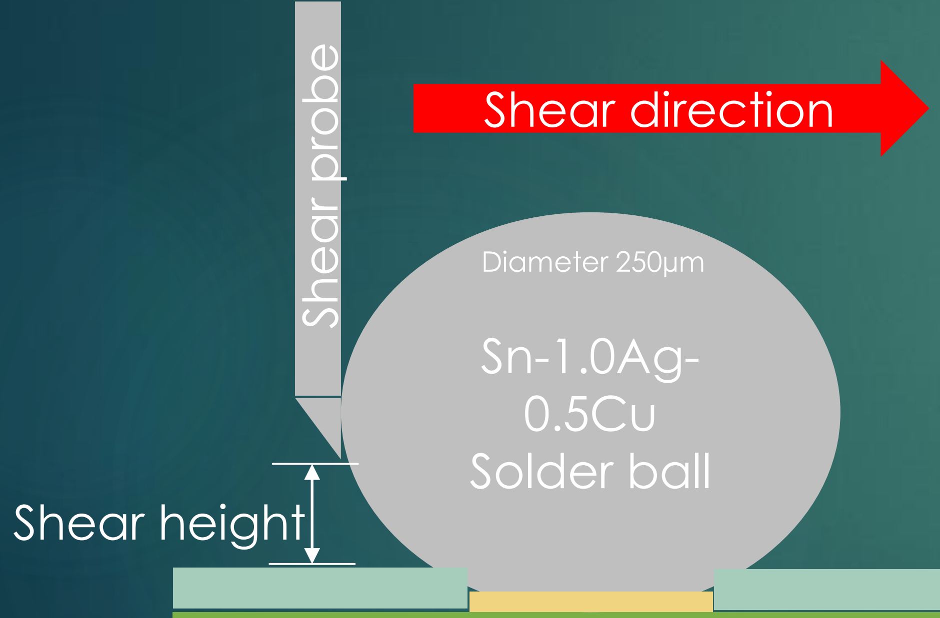
-Die shear/crush

Gives an understanding of how Intermetallic compounds growth affect the reliability of the solder ball.

# Test

Nordson DAGE(400 plus) Bond tester

Shear height is adjusted from 5μm -50μm



# Results

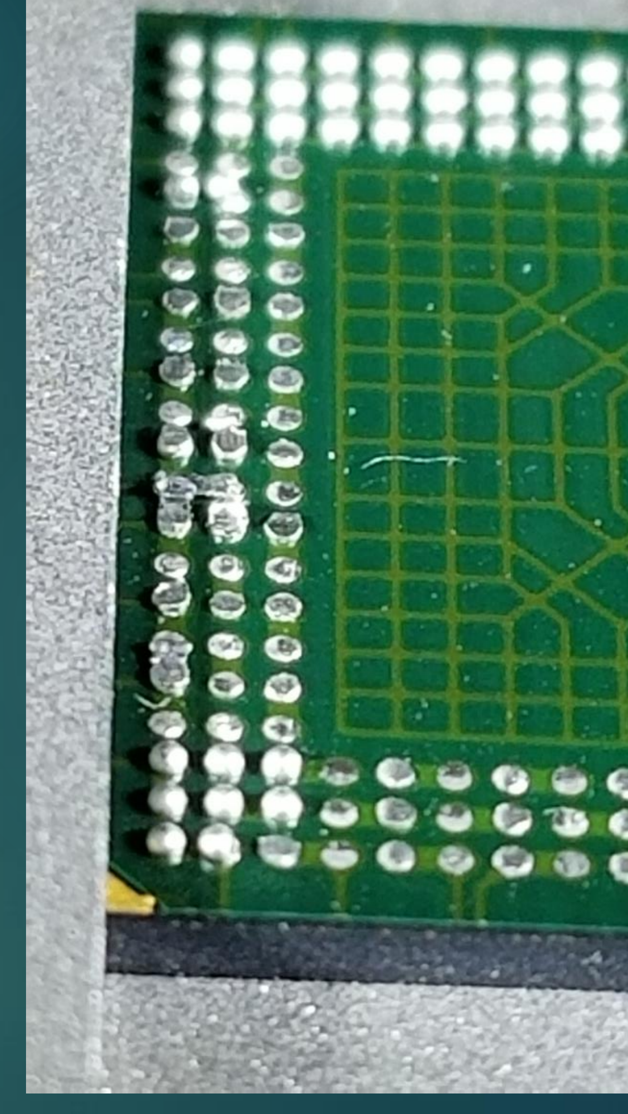
## Force chart at different shear height

Max Force (g)

300
250
200

10 20 30 40 50

Shear height (um)



Sample after shear test

# Summary

-PCB & SAC alloys

-Types of packages

-Reliability

-Thermal Cycling

By knowing the failure mode that occurs during thermal cycling and shear test, reliability of the component at the interconnect can be improved which will lead to longer consumer use product.

# Acknowledgement


- Special thanks to:
- Dr. Tae-Kye Lee
- Andy Hsiao
- Mohamed Sheikh
- Everyone involved in the REU program
- National Science Foundation
- God

# References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# Questions?