SEMICON WEST HYBRID FORWARD AS ONE

Too Hot to Test?
For Leading-edge SoC and Heterogenous Integrated IC Stack

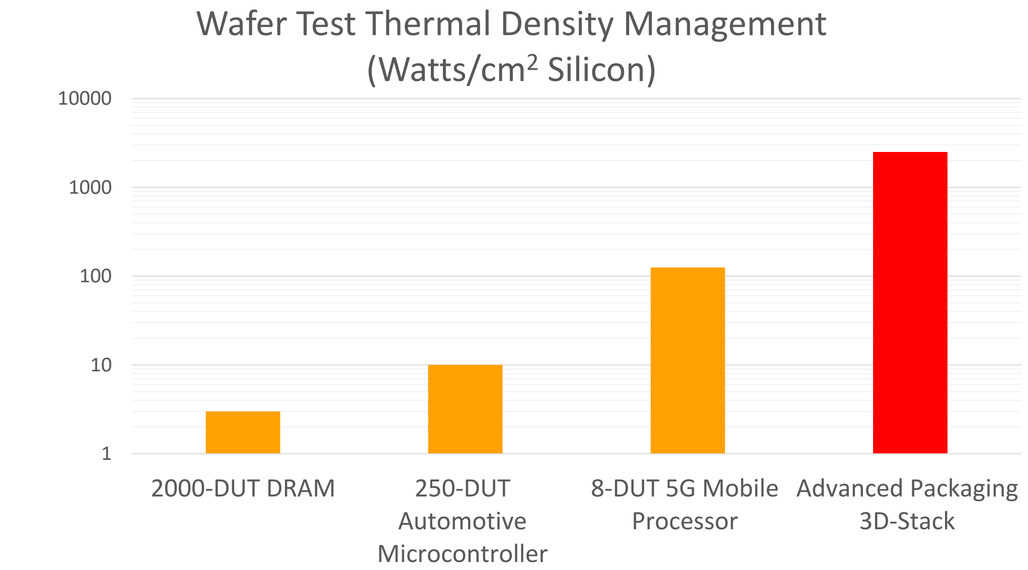
Markus Kindler | Ferdinand Wimmer (ATT Systems) and Amy Leong (FormFactor Inc)

December 2021

semi

Wafer Test Trends – Too Hot To Test?

- Testing of high power IC's (i.e. AI/Processors) + 1TD DRAM is approaching an inflection point
- High power density of DUT's need better thermal chuck to dissipate the peak power
- Standard wafer chucks are not able to sense temp increase and to dissipate the applied energy, resulting in
  - device damage
  - burned probes
  - inaccurate test results
- Heterogenous integration will further increase power densities by >10X
  - processor + HBM (8 – 16 die) stacked on a base wafer
- Active temperature control solutions are required
  - Low Thermal Resistance
  - MultiSense Temp Control – Liquid Cooling
- ATT's Low Thermal Resistance (LTR) chuck technology addresses these challenges



Systems att
Powered by FormFactor

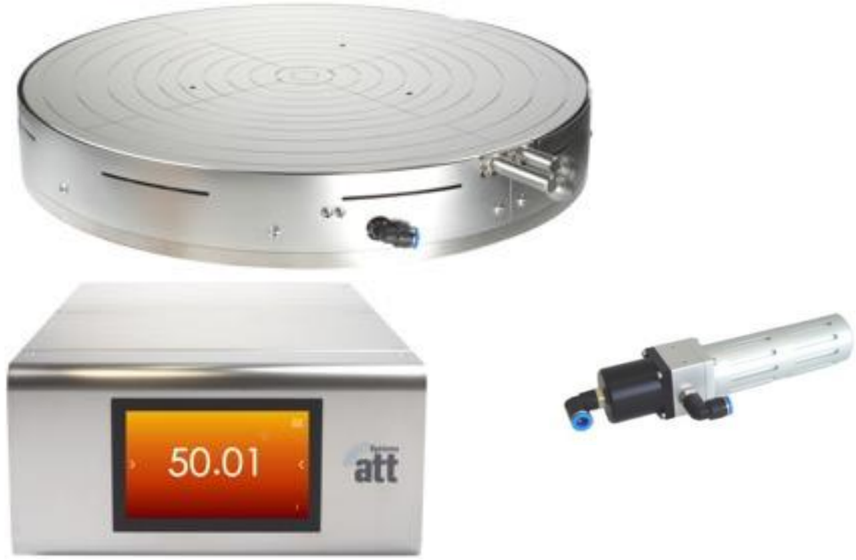
What is a Thermal Chuck?

Air Cooled

-40C to +200C

-60C to +200C

Modular Base Chuck System



Universal chuck and controller

2 independent cooling circuits

+20C to +200C without chiller

Liquid Cooled

-20C to +200C

-40C to +200C

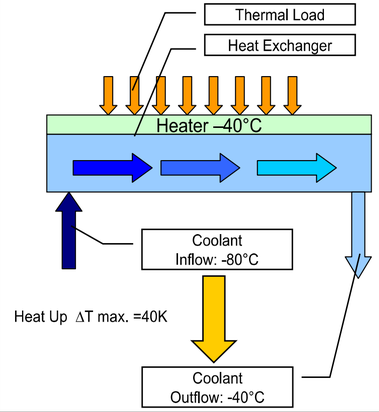
-60C to +200C

High Power Testing – Why Liquid Cool?

Air-Cooled

Cooling with air

What power do we need to test at -40°C



Maximum Airflow: 320l/min

$\varsigma_{AIR} = 0{,}00129 kg/dm^3$

$c_{AIR} = 1{,}0 KJ/(KgK)$

$m_{AIR} = 410 g$

$\Delta T_{max} = 40 K$

$P_{max} = 275 W @ -40°C$

$$Q = \frac{c \cdot m \cdot \Delta T}{t}$$

$$\Delta T = \frac{Q_{Last} \cdot t}{c \cdot m}$$

As the idle power @-40°C is about 180W there are left about **100W** to take away heat generated by testing.

Max. Cooling Capacity is **low at** 275W

Effective Cooling Capacity is low at 100W

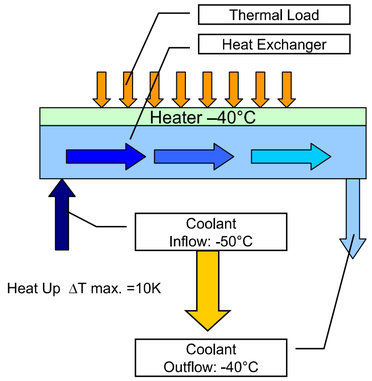
***ΔT* high – impact on temp. uniformity**

High air-flow@high pressure

Liquid-Cooled

Cooling with liquid

What power do we need to test at -40°C



Coolant Flow:10l/min

$\varsigma_{ZT130} = 1{,}8 kg/dm^3$

$c_{ZT130} = 1{,}1 KJ/(KgK)$

$m_{Zt130} = 18000 g$

$\Delta T_{max} = 10 K$

$P_{max} = 3300 W$

For 200W and 600W heat load applied by testing following ratios are calculated

$P_{load} = 200 W$

$c_{ZT130} = 1{,}1 KJ/(KgK)$

$m_{Zt130} = 18000 g$

$$\Delta T = \frac{Q_{Last} \cdot t}{c \cdot m} = 1{,}15 K$$

$P_{load} = 600 W$

$c_{ZT130} = 1{,}1 KJ/(KgK)$

$m_{Zt13m} = 18000 g$

$$\Delta T = \frac{Q_{Last} \cdot t}{c \cdot m} = 2{,}35 K$$

Max. Cooling Capacity is **high at >3000W**

*Δ*T low – low impact on temp. uniformity

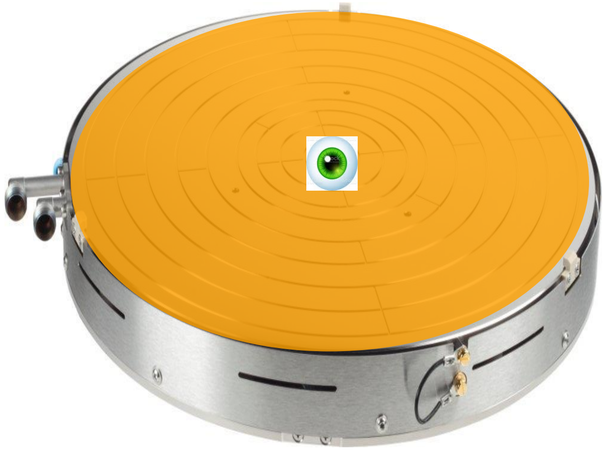
Reas**onable cooling fluid consumption**

Wider temp range might require other fluids

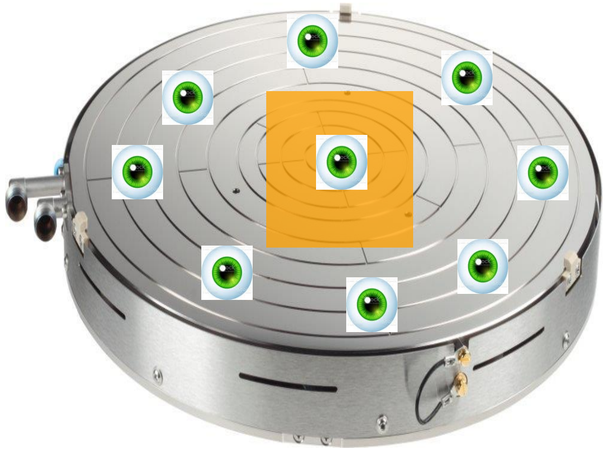
Liquid cooled systems are the tools of choice due to the high cooling power and better temp. uniformity!

Active Temperature Control – MultiSense

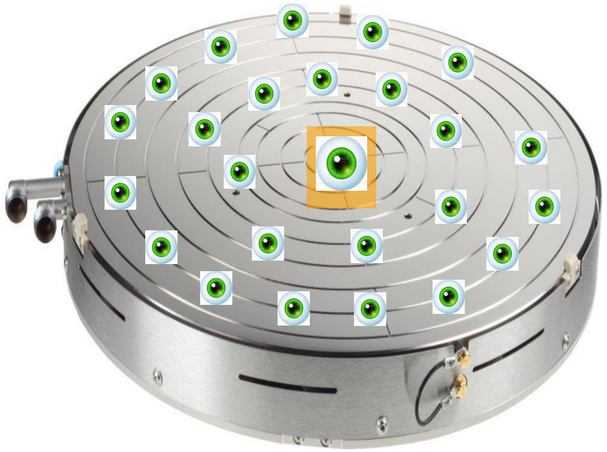
Full Wafer Contact



100x100mm



20x20mm

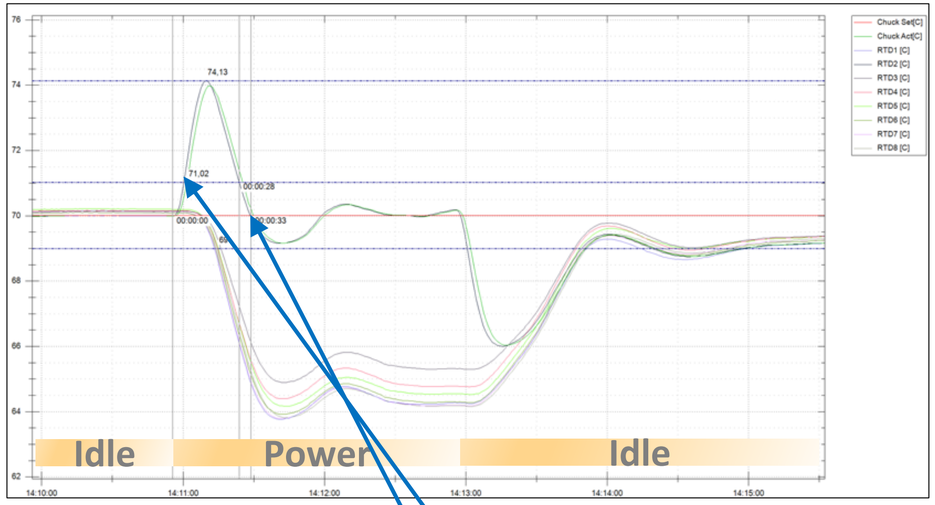


- Full Wafer Contact: Uniformly distributed thermal load - one control sensor is sufficient
- Smaller Contact Areas: Require multiple control sensors to detect temp changes
- Number of built-in sensors is limited due to chuck complexity – total of 9 control sensors
- MultiSense AddOn sensors is scalable, currently up to 21 sensors
- Requires advanced temp control algorithms

MultiSense vs. No MultiSense

+70°C, 200W, 21x22mm contact area, 2 min test time, liquid cooled

With MultiSense



Limited temp increase – 74.1°C

+/- 1°C after 28 sec

Power dissipated after 33 sec

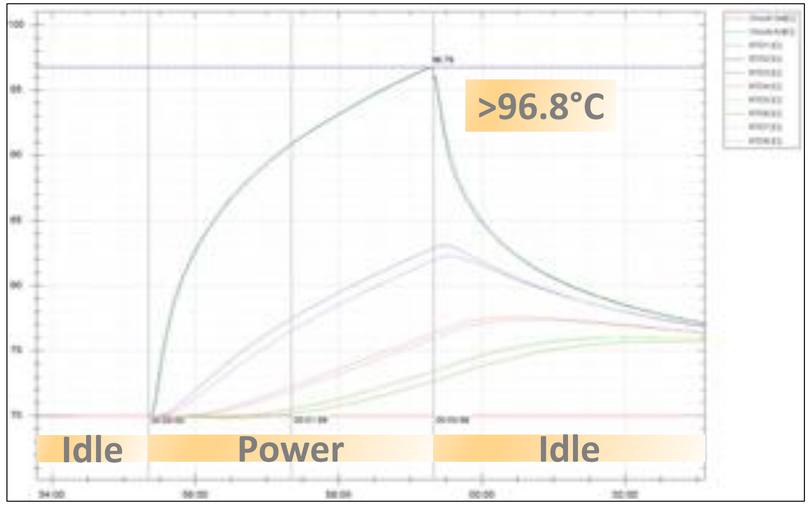
Test Set-Up

Resistor 21x22

200W max

Test Time: 2 min

Without MultiSense



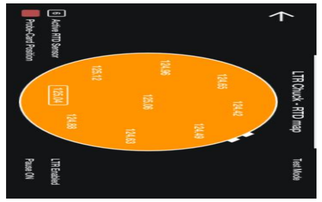
Uncontrolled temp rise to >96°C

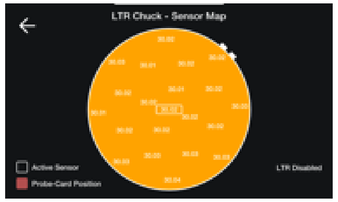
No temp change detection

No Active Temp Control

ATT's Low Thermal Resistance (LTR) Chuck Technology

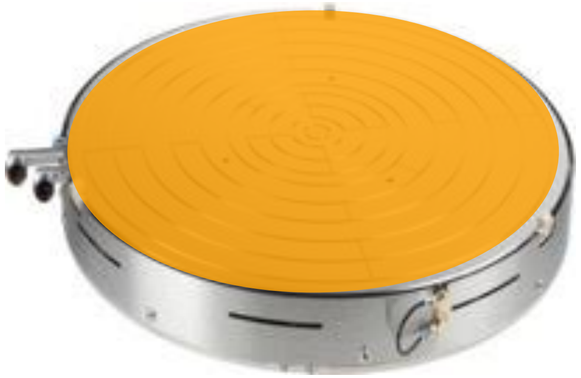
- Developed for High Power (HP) and High Accuracy (HA) Applications
- AI devices, GPU's, CPU's, Stacked Memories, Heterogenous integrated devices
- Low Thermal Resistance chuck design w/ MultiSense Active Temp Control
- Scalable number of temp control sensors (e.g. 9 or 21 sensors)
- Scalable cooling power options, upgradeable as needed (600W to >20KW)





Application Examples

Full Wafer Contact
DRAM, Flash, HBM



- Contact Area: Large
  Parallelism: High
- Power/Die: Low
  Density: Low (3W/cm^2)
- Heat transfer: up to 2000W
  Temp. Range: -40°C to +125°C

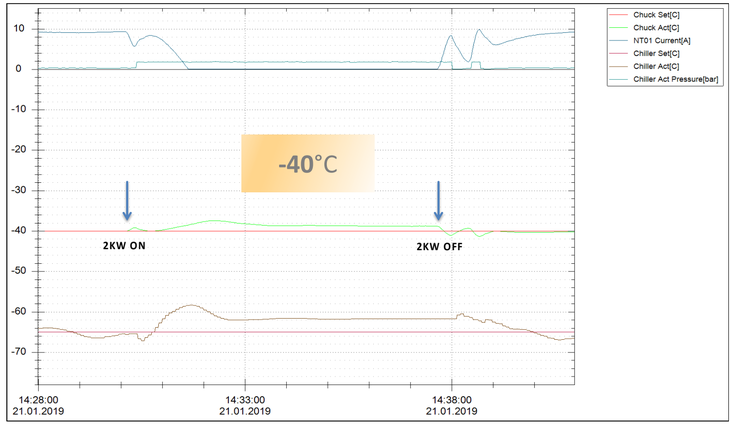
100x100mm
E.g. Microcontroller

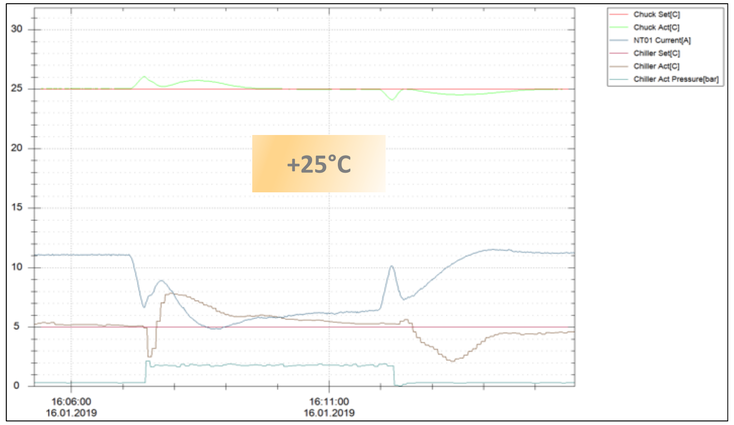
- Contact Area: Medium
  Parallelism: Medium/Low
- Heat transfer: up to 1000W
  Temp. Range: -40°C to +125°C
- Power/Die: Medium/High
  Density: Medium (10W/cm^2)

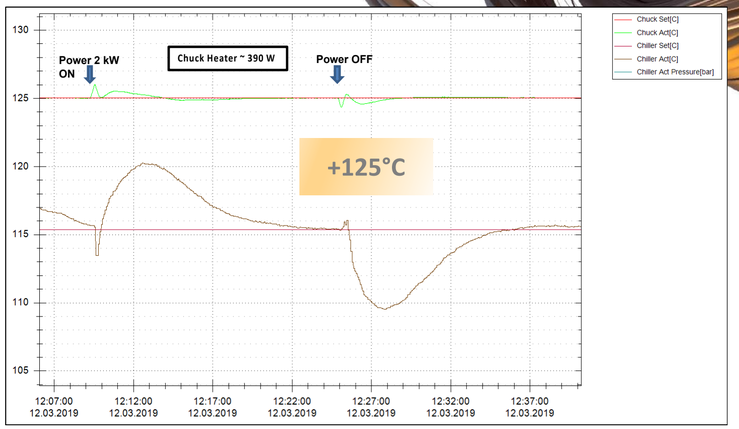
20x20mm
E.g. 5G or GPU devices

- Contact Area: Small
  Parallelism: Low
- Power/Die: High
  Power Density: High (125W/cm2)
- Heat transfer: up to 500W
  Temp. Range: -40°C to +125°C

Customer Case Study – Full Wafer Contact, 2000W





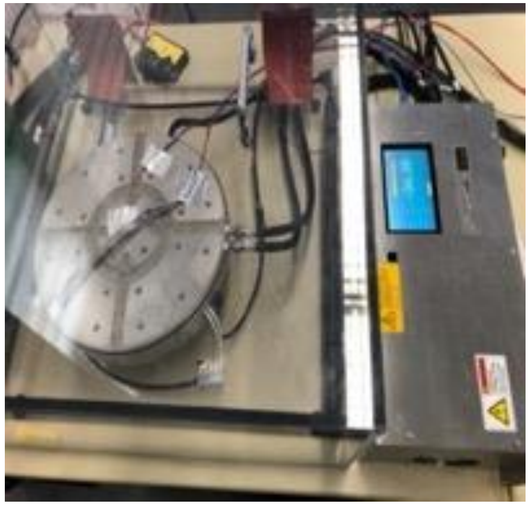


Full Wafer Contact – High Bandwidth Memory Testing

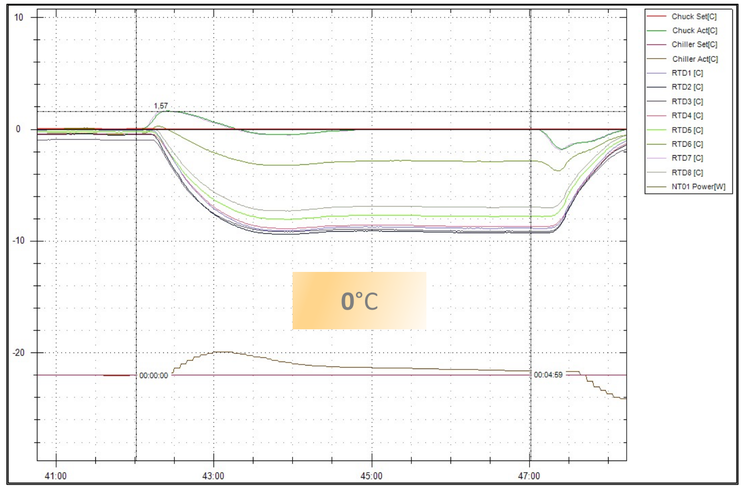
Applied power of 2000 Watts, uniformly distributed across the chuck

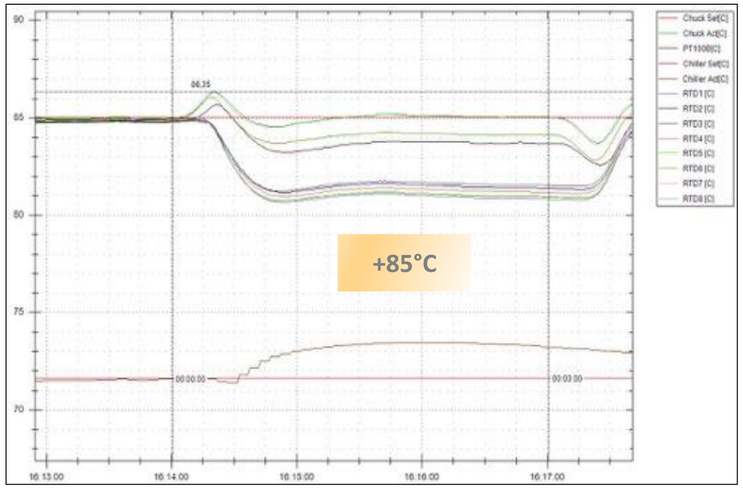
Liquid Chiller, -40°C, +25°C and +125°C

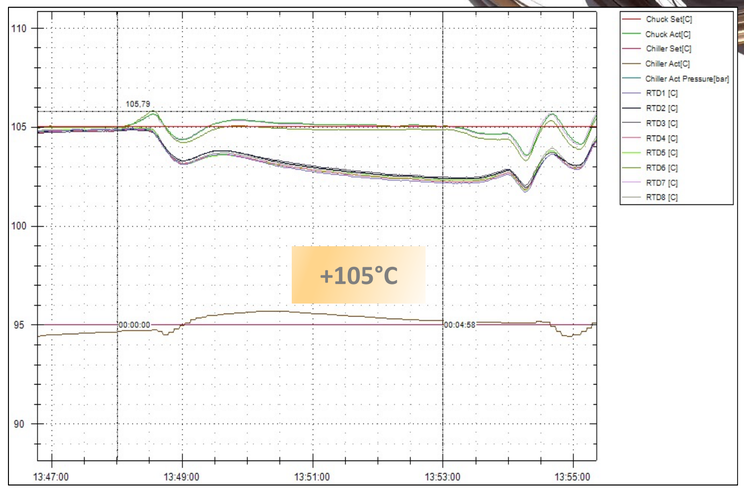
Chuck system is able to dissipate 2000W at all three temperatures



Customer Study – 100x100mm, 400W







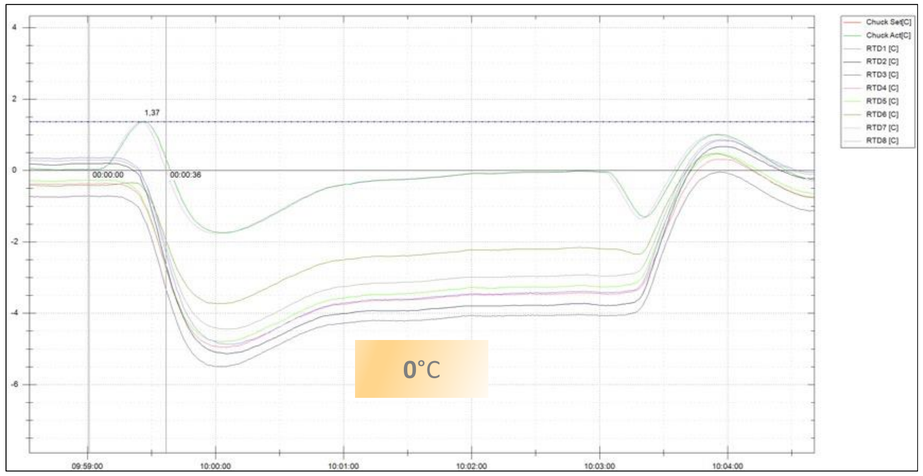
100x100mm contact area – Automotive microcontroller

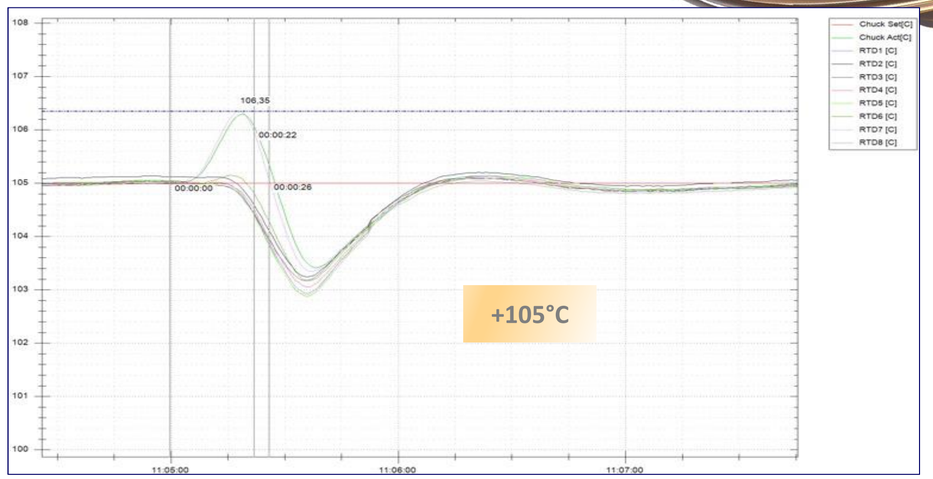
Applied power of 400 Watts

Liquid Chiller, 0°C, +85°C and +105°C

Chuck system is able to dissipate 400W within a +/- 2°C temperature range

Customer Study – 21x20mm – 160W





21x20mm contact area – 5G Device

Applied power of 160 Watts

Liquid Chiller, 0°C and +105°C

Chuck system is able to dissipate 400W within a +/- 2°C temperature range

Summary

- Increasing thermal challenges to test leading-edge SoC, full-wafer memory, and heterogenous integrated device require Liquid Cooled wafer chuck systems for high power dissipation
- Customer case study showed ATT's Low Thermal Resistance (LTR) chuck is doable for
  - Full Wafer Contact up to 2KW
  - 100x100mm up to 400W – higher power possible with stronger chillers
  - 21x20mm up to 160W – higher power possible with stronger chillers
- Wafer test requirements are changing dynamically – Power densities, Parallelism, IC complexity
- ATT is working on new chuck concepts addressing future requirements – Please contact us for more details

Systems att
Powered by FormFactor

Thank You