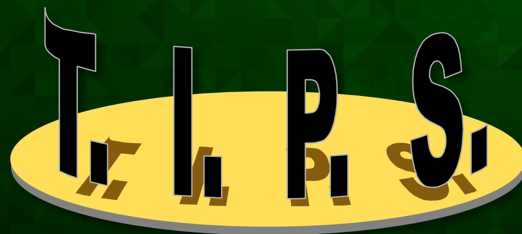
SWTEST

PROBE TODAY, FOR TOMORROW

High Temperature Wafer Probing of Power Devices



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Overview

Georg Franz

1. Introduction to Power Devices
2. Testing Requirements
3. Probe Card Solution

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4. Prober Chuck Improvement
5. Experiment: Chuck Thermal Stability
6. Conclusion, Follow-On Work

Power Devices - Applications

- Power supplies
- Air Condition
- Electric Vehicles
- Industrial Automation
- Trains, Wind Turbines, Photovoltaic
- Power Transmission

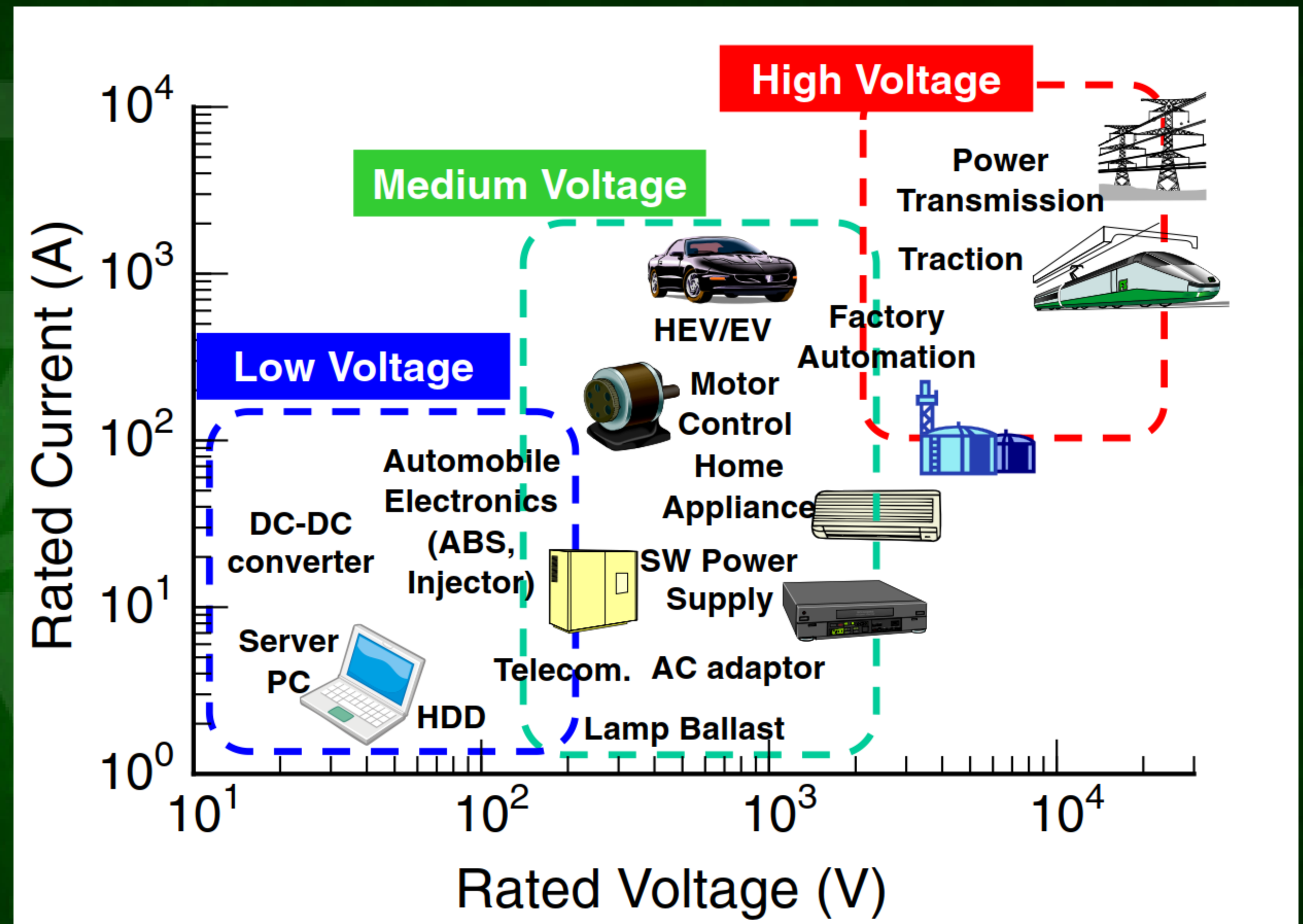


image source: Tsunenobu Kimoto, Japanese Journal of Applied Physics 54, 040103, 2015

Power Devices - Applications in HEV/EV

- **Rectifiers**

  Grid AC -> DC charger

- **Inverters**

  DC 800V -> AC motor winding

- **Converters**

  DC 24V -> HV bus

  Generator -> HV bus

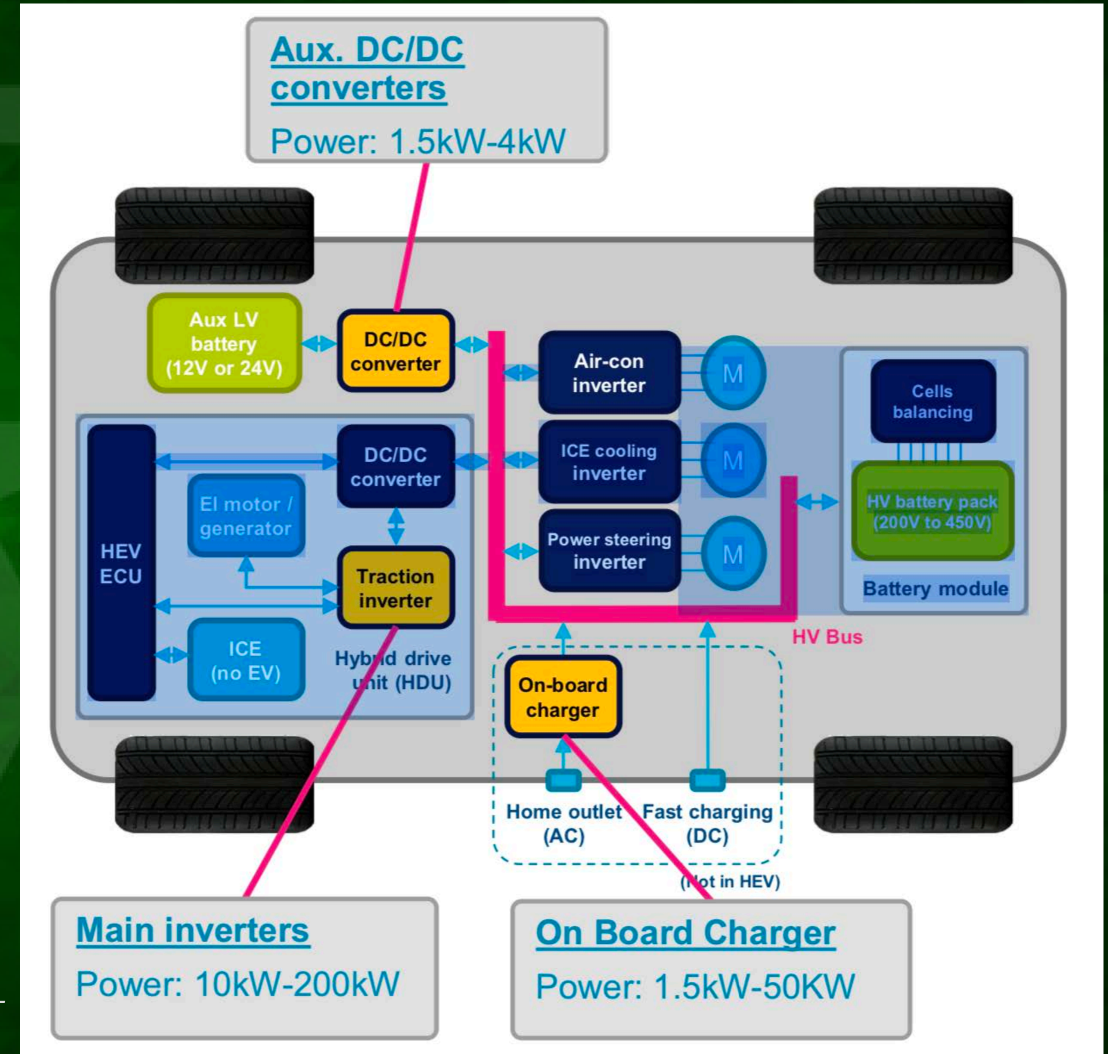


image source: ST Microelectronics

Power Devices - Types

- **Si-based devices:**
  - PIN, SBD
  - IGBT
  - GTO

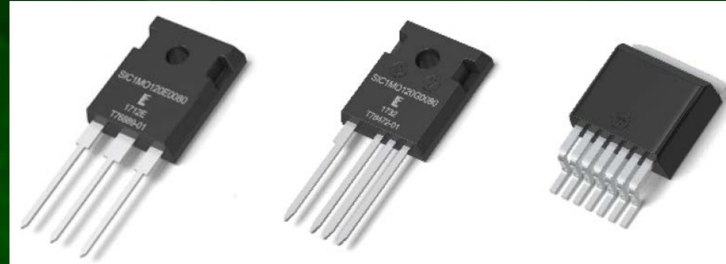
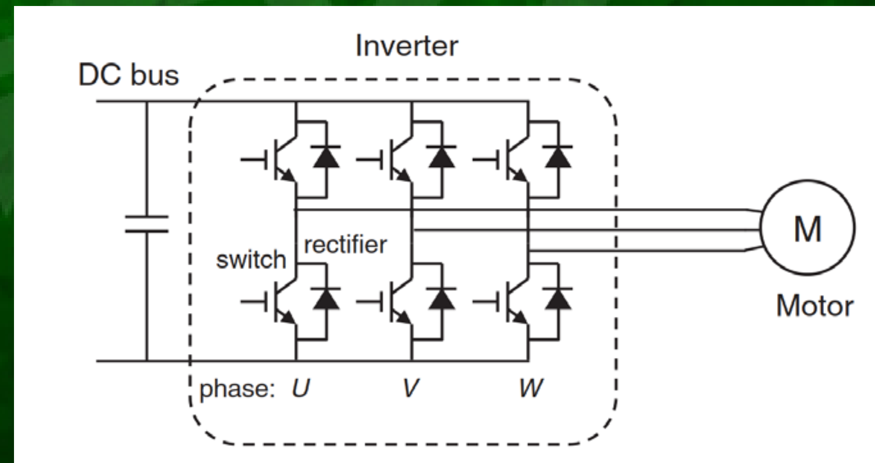


image source: Littelfuse

image source: ABB

- **SiC/GaN-based devices:**
  - MOSFET
  - BJT
  - JFET



PowerDevices – Wide Band Gap

- Silicon Carbide
- Gallium Nitride

- Smaller Devices
- Higher Efficiency
- Less Cooling Effort

- Higher Operating Voltage!
- Higher Operating Temperature!

image source: ST Microelectronics

Test Requirements - Overview

- **Reverse Voltage (Breakdown Voltage)**

  -> Up to several kV

- **Reverse Voltage (Leakage Current)**
- **Forward Current (On-state resistance)**

  -> Up to several kA

- **UIS – Unclamped Inductive Switching (max power dissipation)**

  -> Up to several kA / kV

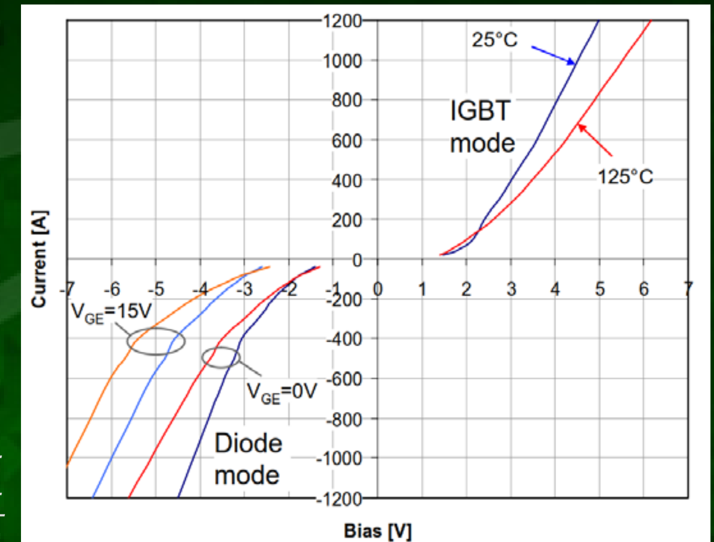


image source: ABB, 6.5kV-600A Si-IGBT

image source: Wolfspeed, SiC-MOSFET

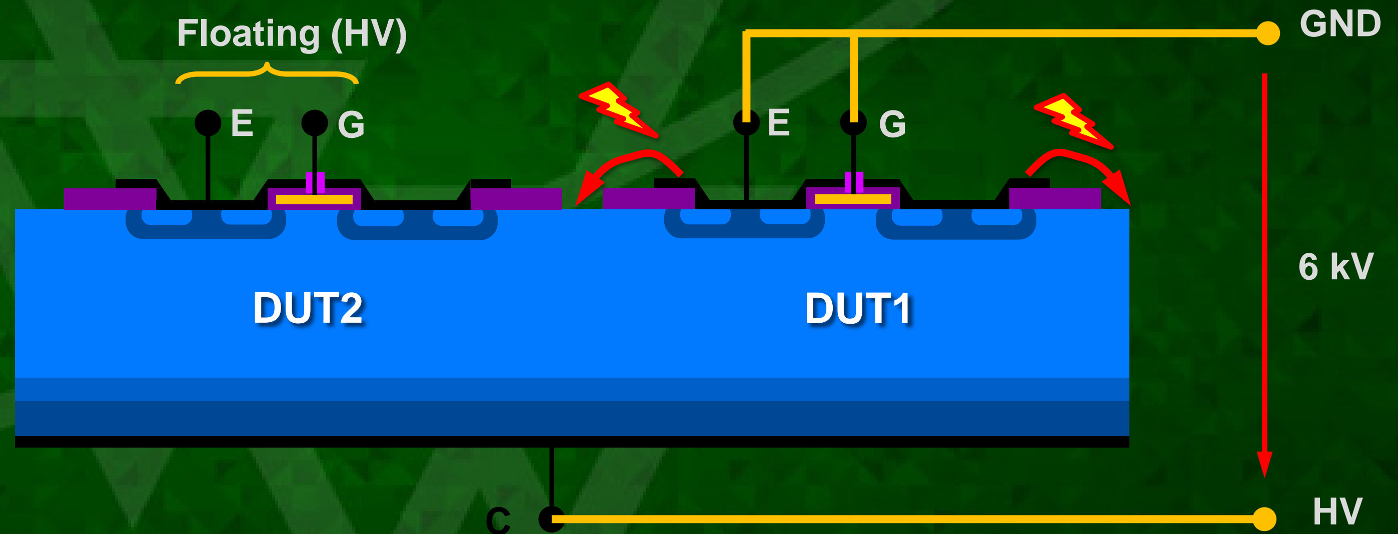
Wafer Test

- **Current test applications:**
  - Bare Die
  - Engineering/Characterization

- **Potential test applications:**
  - Tri-Temp Automotive
  - Move from package to wafer test
  - Reduce test cost by 50%

High Voltage Wafer Test

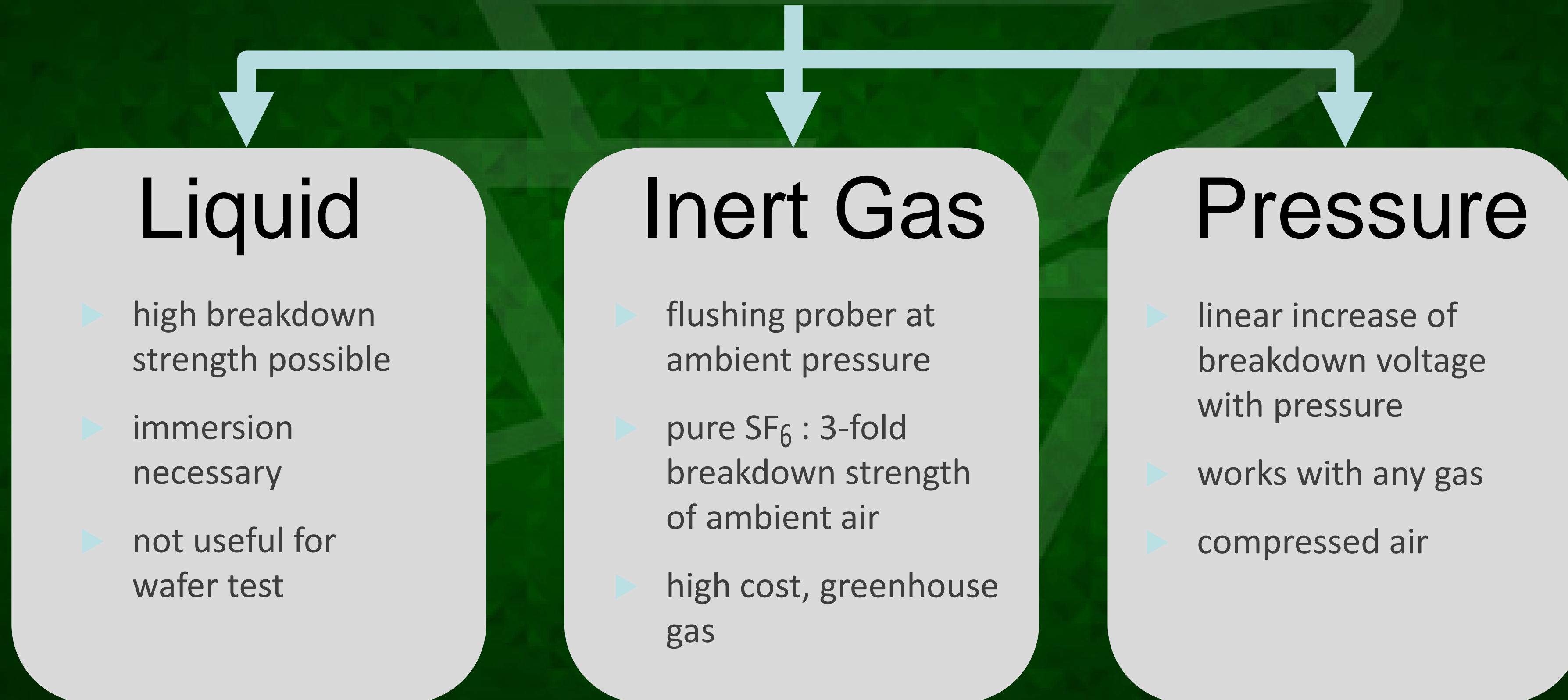
- Vertical Device
- Wafer Bulk on HV
- Flash-over risk to dicing frame!



Example: Vertical Device, IGBT (Insulated Gate Bipolar Transistor)

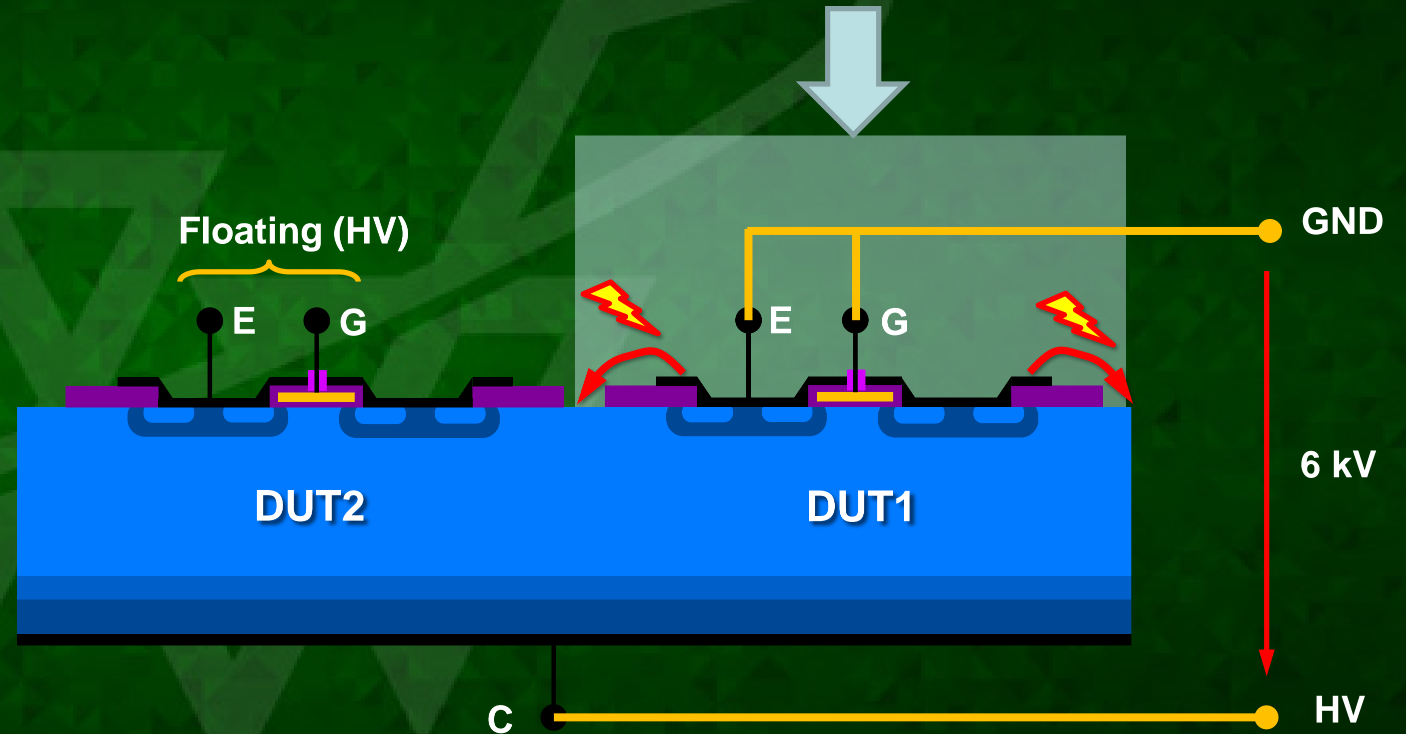
Flash-Over Suppression

Approaches:

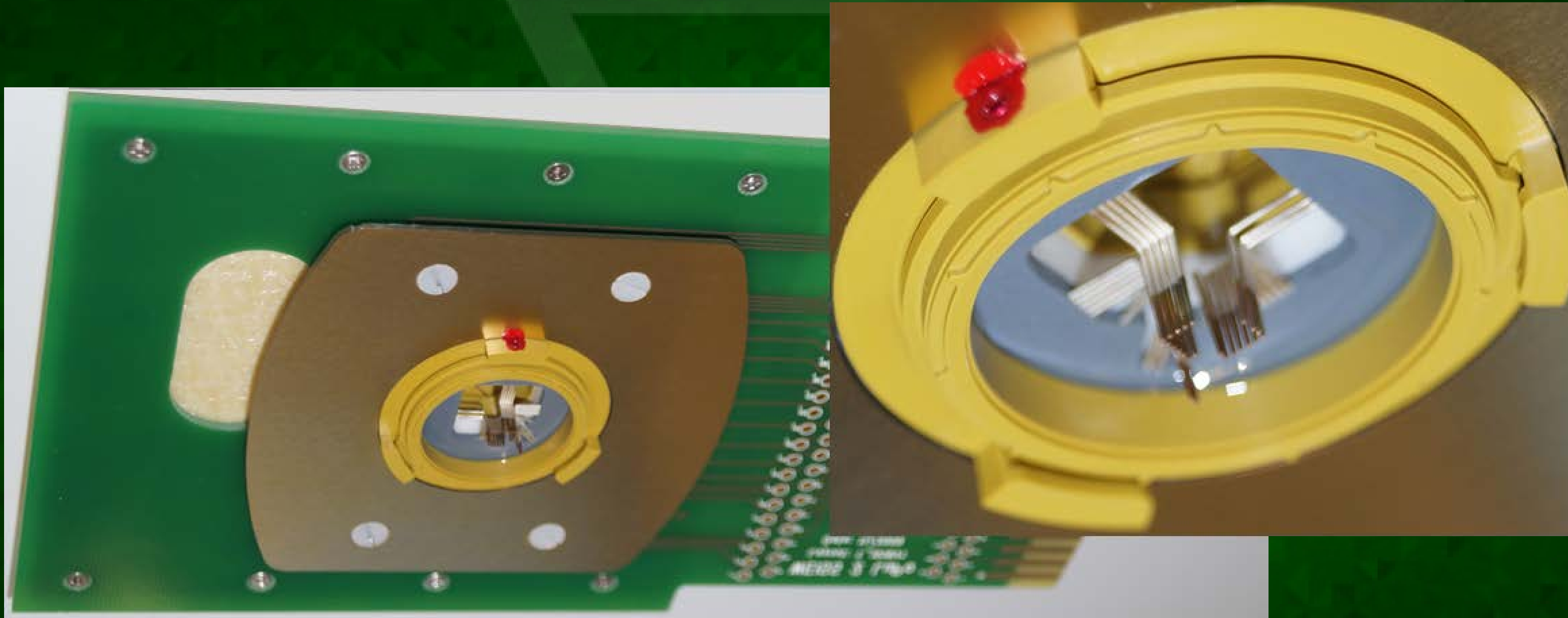


Flash-Over Suppression - Solution

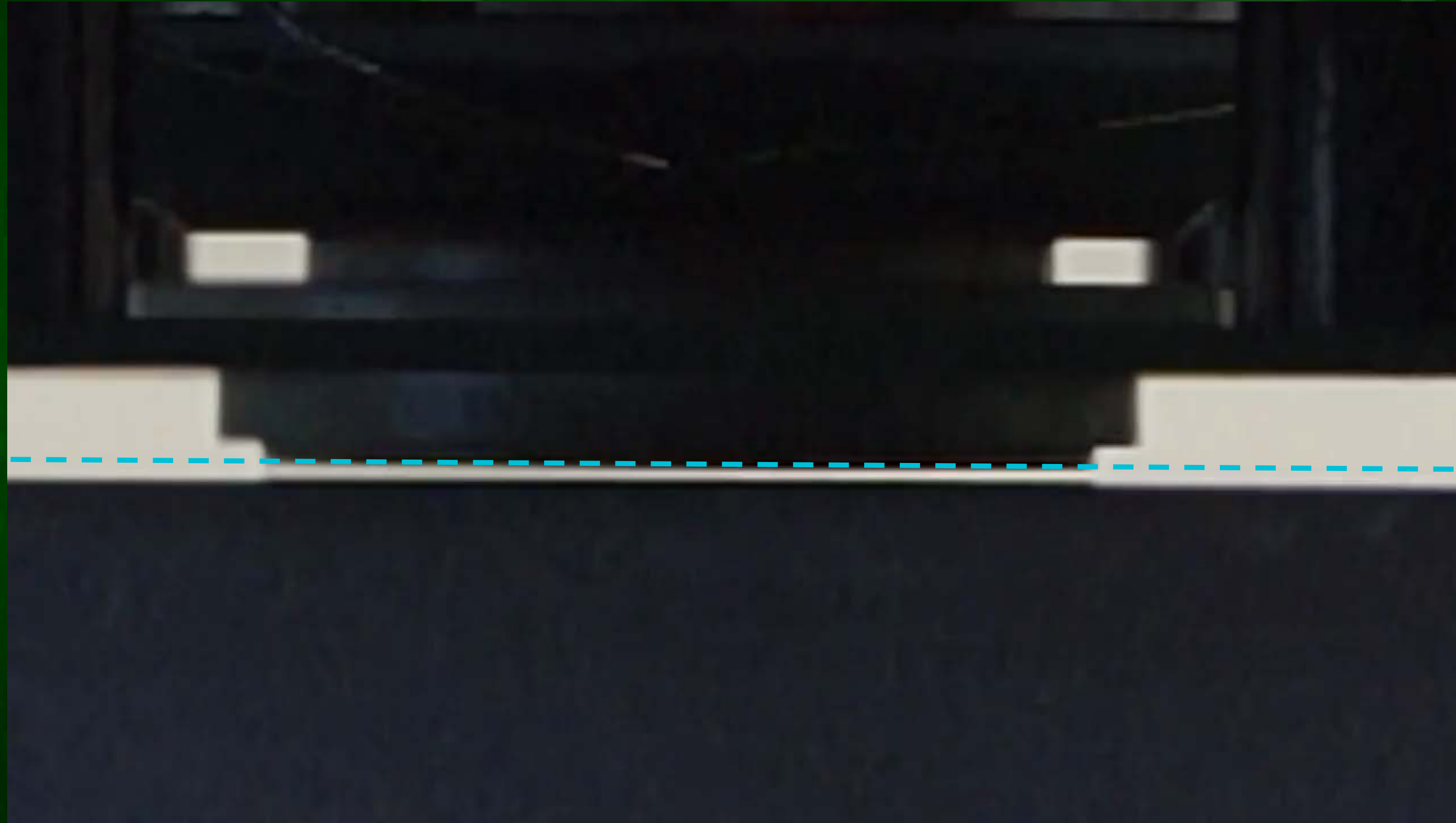
- **Air under higher pressure (Paschen)**
  - whole prober under pressure
  - whole wafer under pressure
  - chip-scale chamber
  - contactless chip-scale chamber



Contactless chip scale pressure chamber

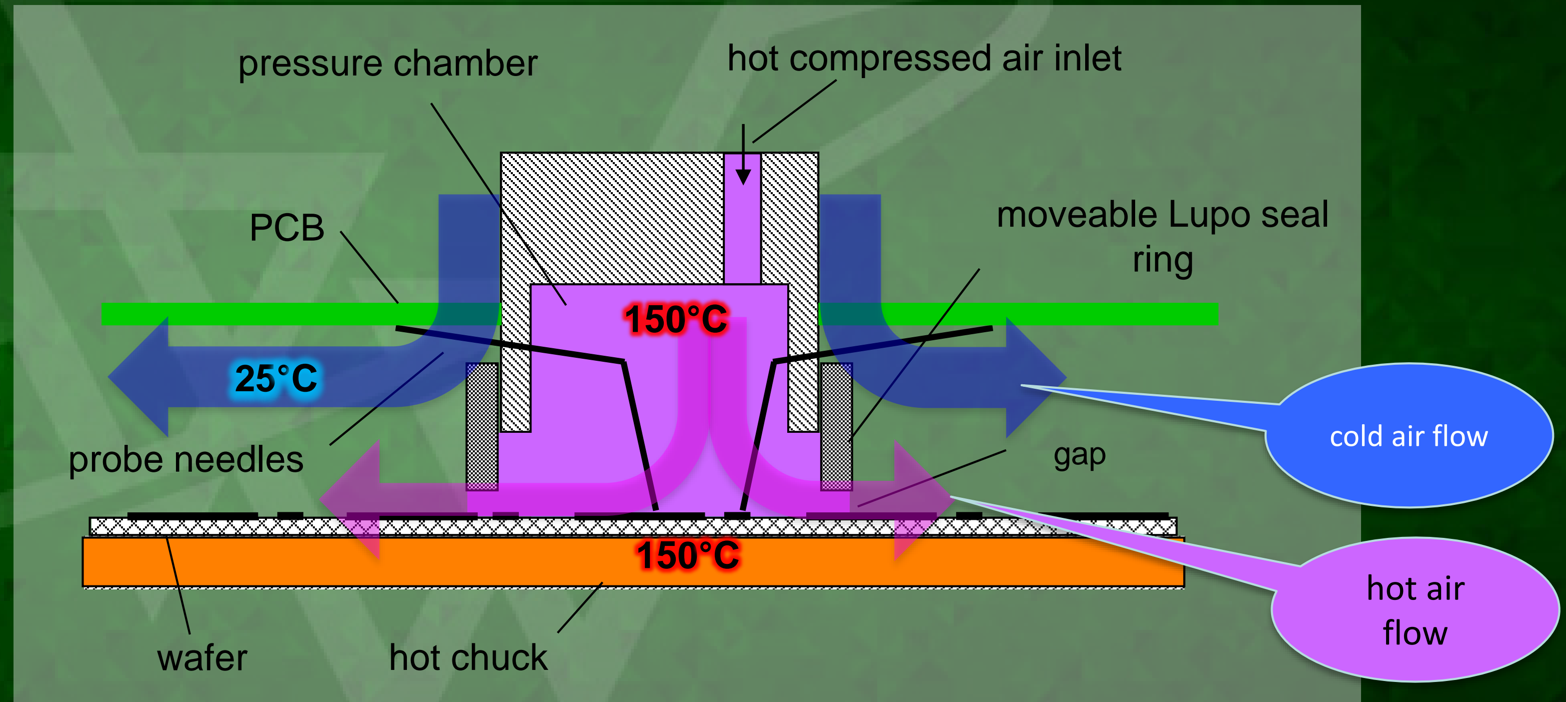


Contactless Seal Operation



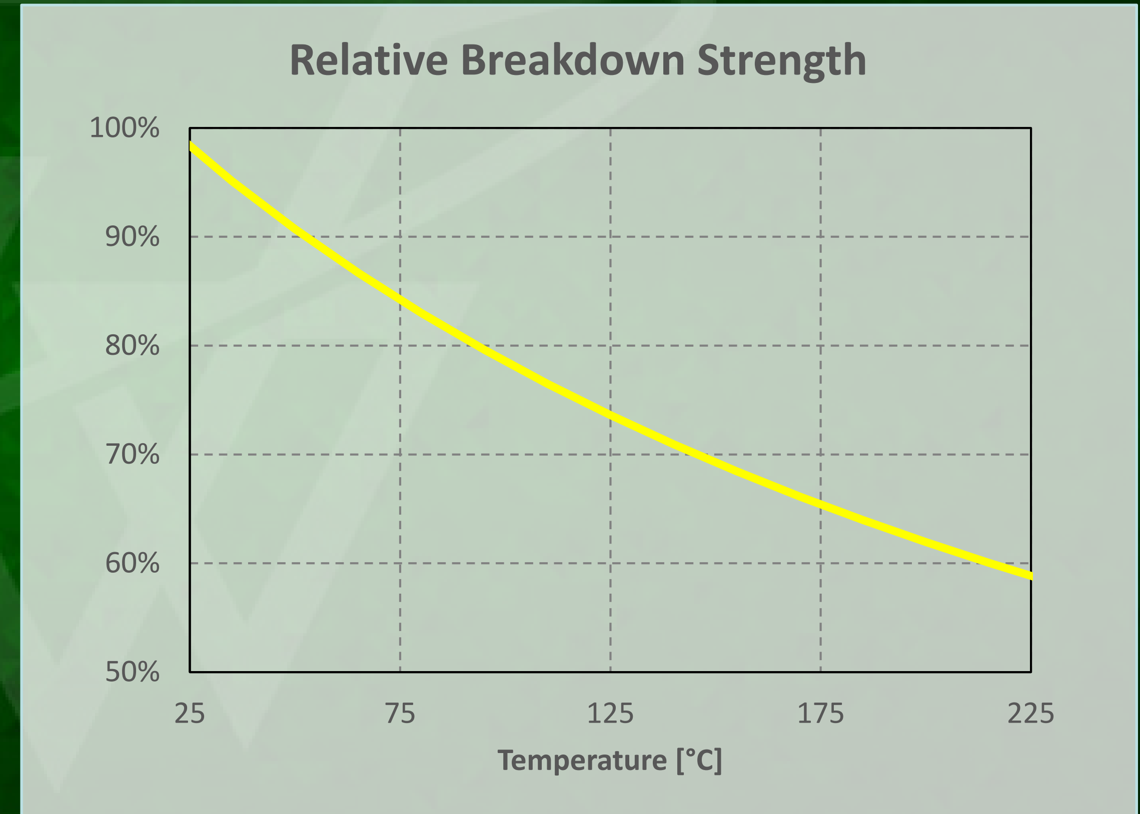
HV-HT Probe Card

- Hot compressed air supply
- Dual hot-cold air stream to protect probe card



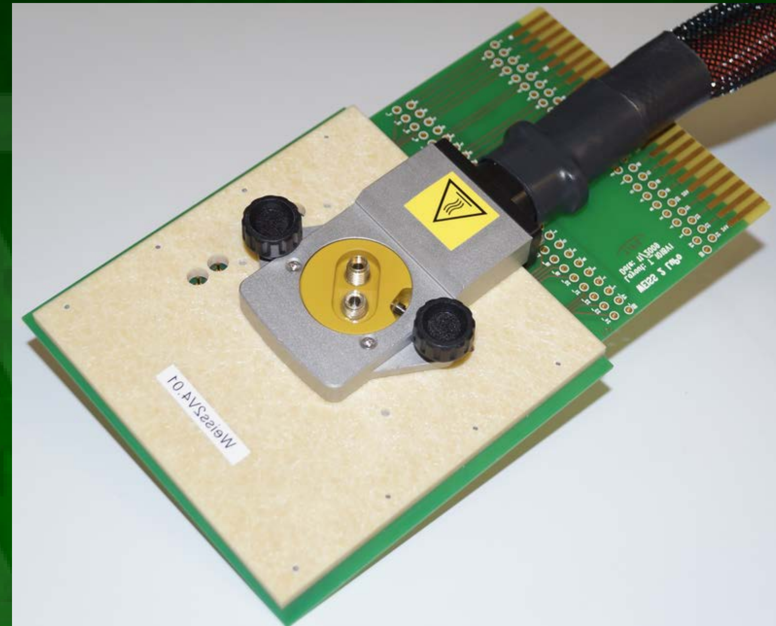
High Voltage – High Temperature

- Hot air has lower density
  -> reduced breakdown strength
- Pressure must be increased
  to get same breakdown strength
- At 125°C -> 36% higher
  pressure needed!



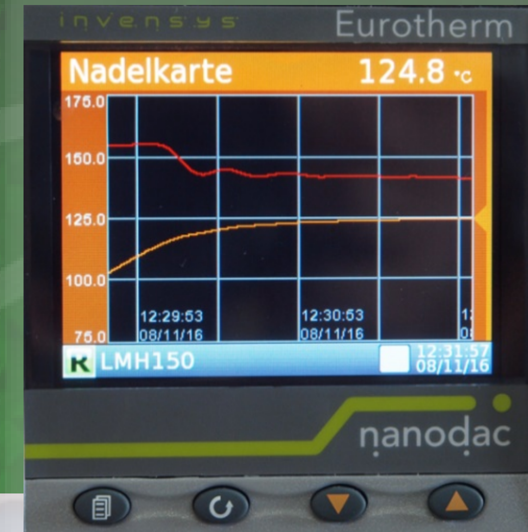
HV-HT Probe Card

- production wafer sort
- hot wafer chuck 150°C
- hot compressed air 150°C
- non-contact Lupo seal



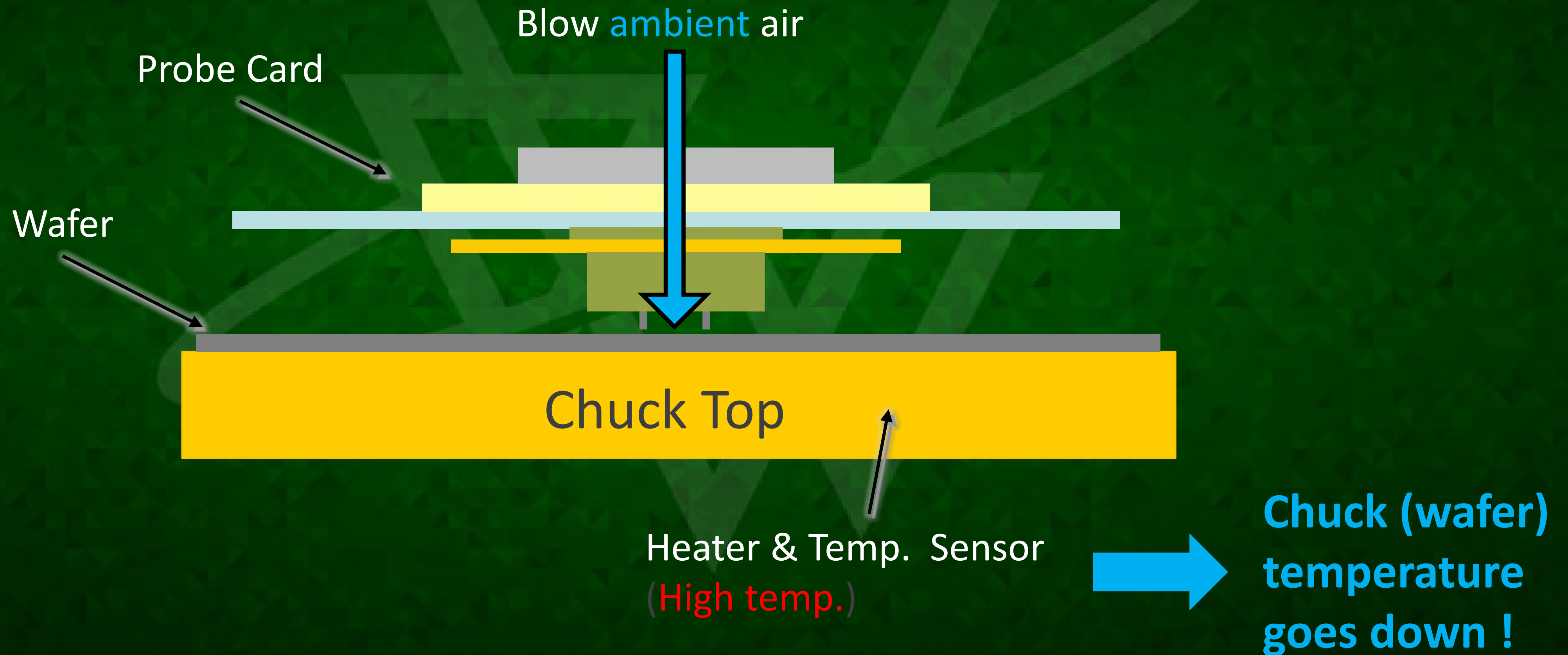
High Temperature Pressurized Air Supply

- Electrical heater
- Heats cold compressed air to 150°C
- closed-loop temperature control
- temperature sensor in probe card
- fast settling, stable operation
- integrated air cooling for probe card

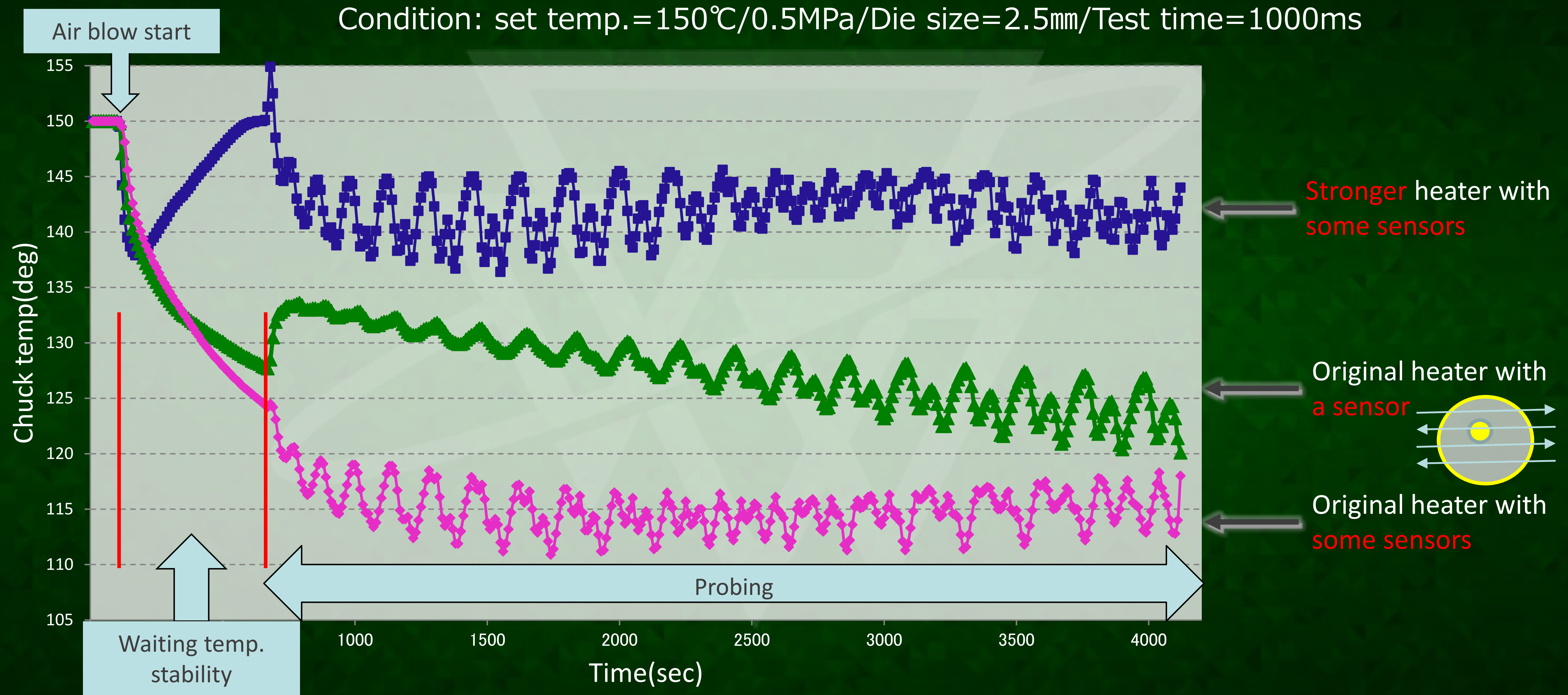


High temperature test

Conventional high temperature test condition.



Current issue and improvements



High temperature test with Hot air controller

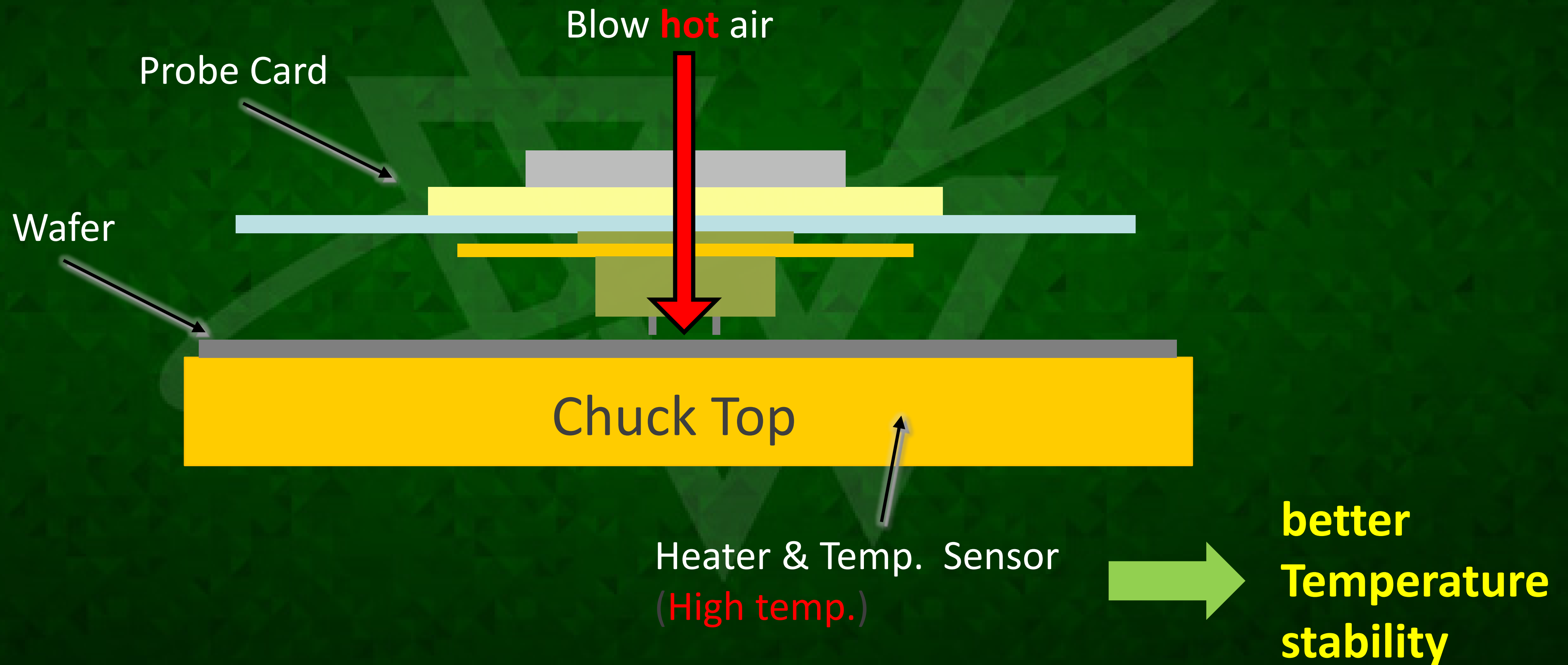
Prober:UF2000

Hot air controller: LMH150

Probe card: ACTP001-HT

High temperature test enhancement

Blow hot air into probe card instead ambient air.

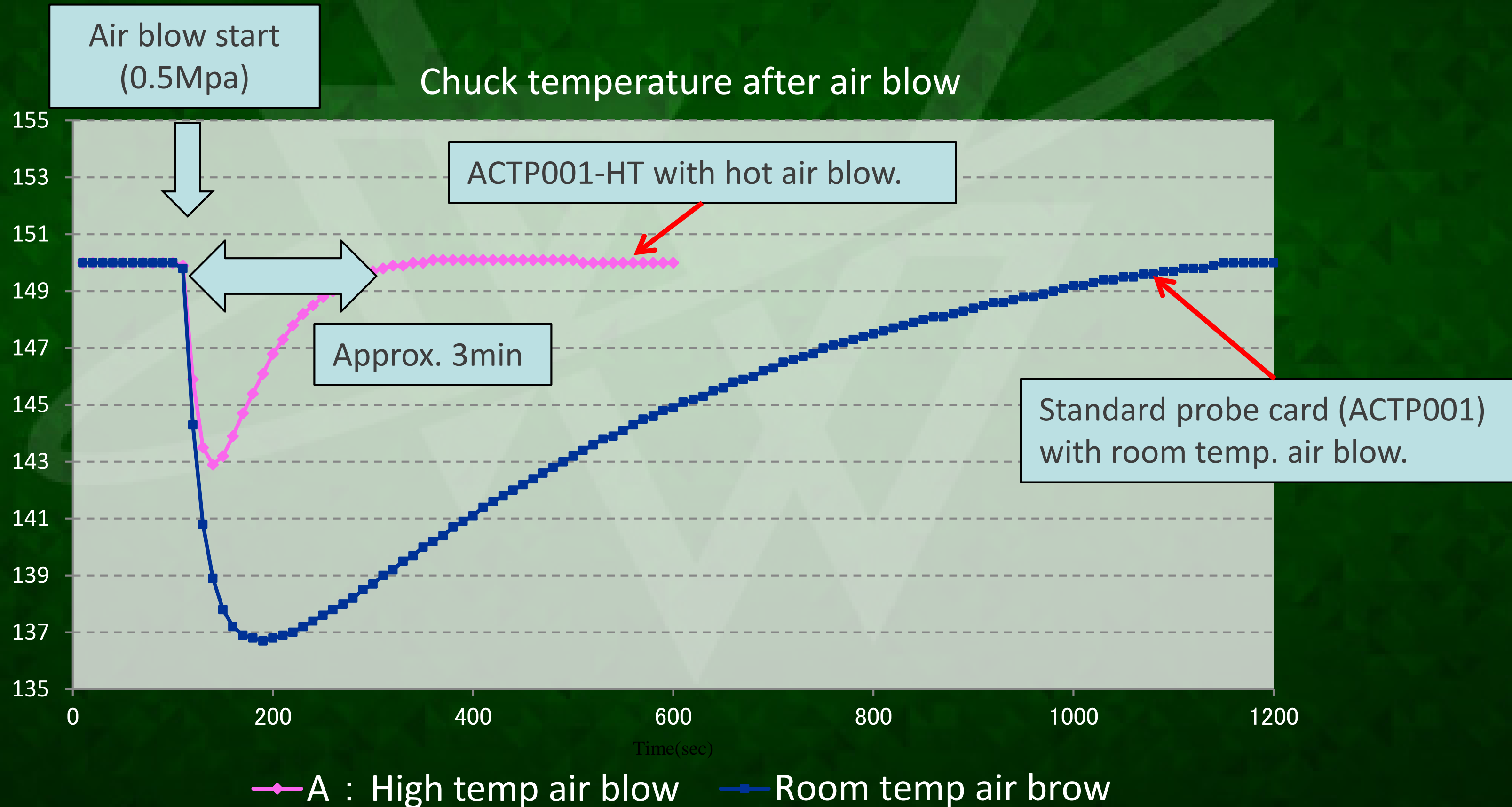


Experiments

- **Temp. test-1 :**
  - Chuck temperature stability time after hot air blow start.
- **Temp. test-2 :**
  - Chuck temperature variation during probing.
    by changing compressed air pressure, Die size, Testing time, etc.
- **Flash-over spark test :**
  - With compressed hot air & T.I.P.S. HV demo wafer.

Temp. test-1

- Chuck temperature stability time after air blow start.
- Result: Return to chuck set temperature (150℃) within 3min using LMH150



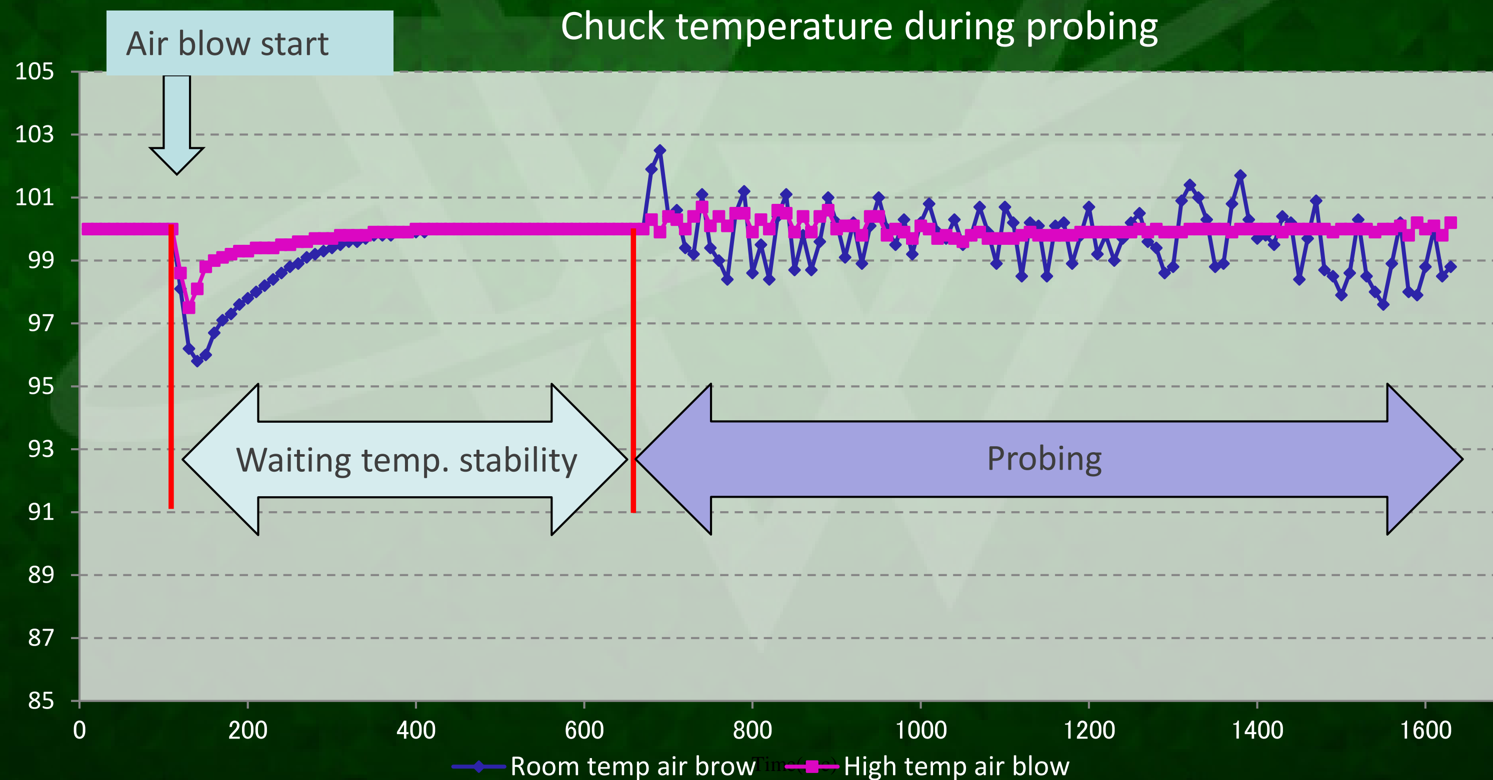
Temp. test-2

– Chuck temp. during probing with different conditions

Chuck Temp. (°C)	Pressure (MPa)	Chip size（mm）	Test time（msec）
100	0.3	5.0	300
100	0.5	5.0	1000
150	0.3	5.0	300
150	0.5	5.0	300
150	0.5	5.0	1000
150	0.5	2.5	1000

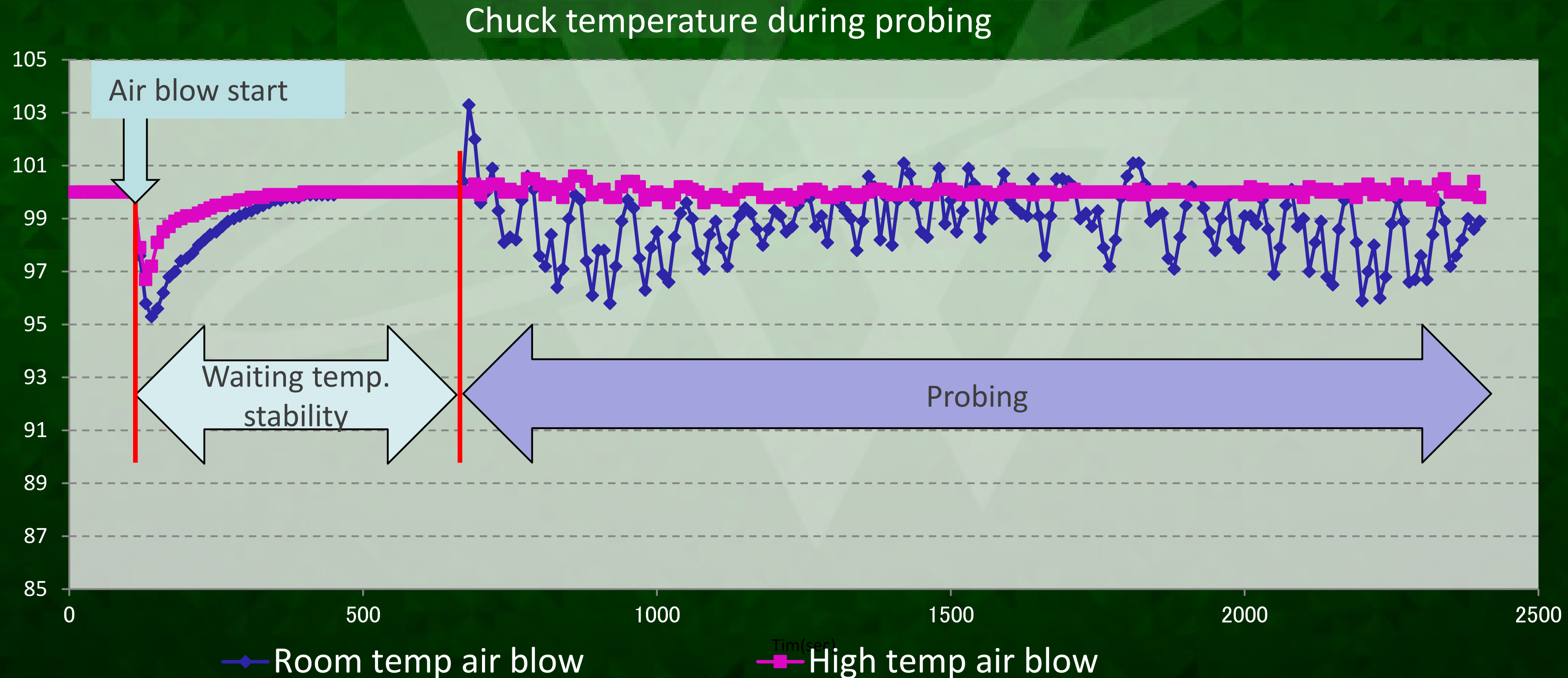
Temp. test-2

- Chuck temp. variation during probing-1
- Condition: Set temp.=100℃/0.3MPa/Die size=5㎜/Test time=300ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



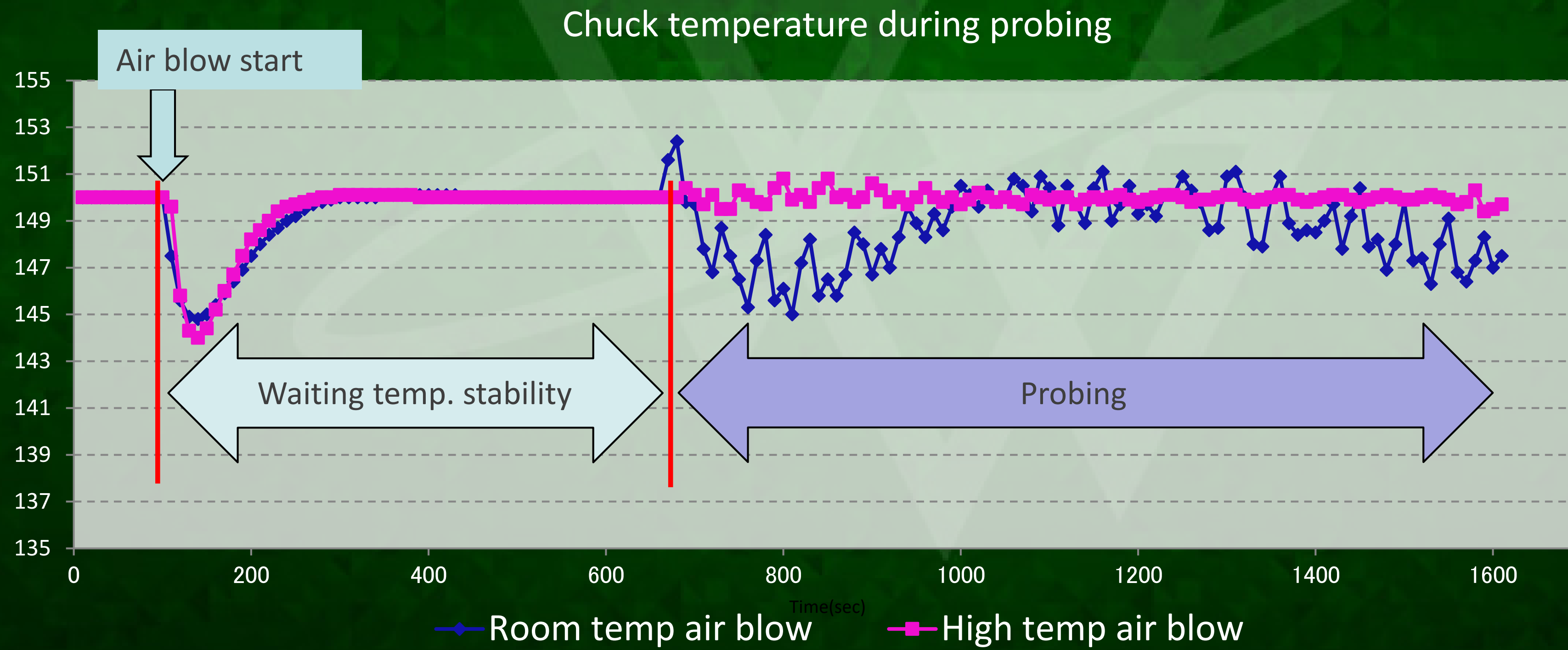
Temp. test-2

- Chuck temp. variation during probing-2
- Condition: Set temp.=100℃/0.5MPa/Die size=5㎜/Test time=1000ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



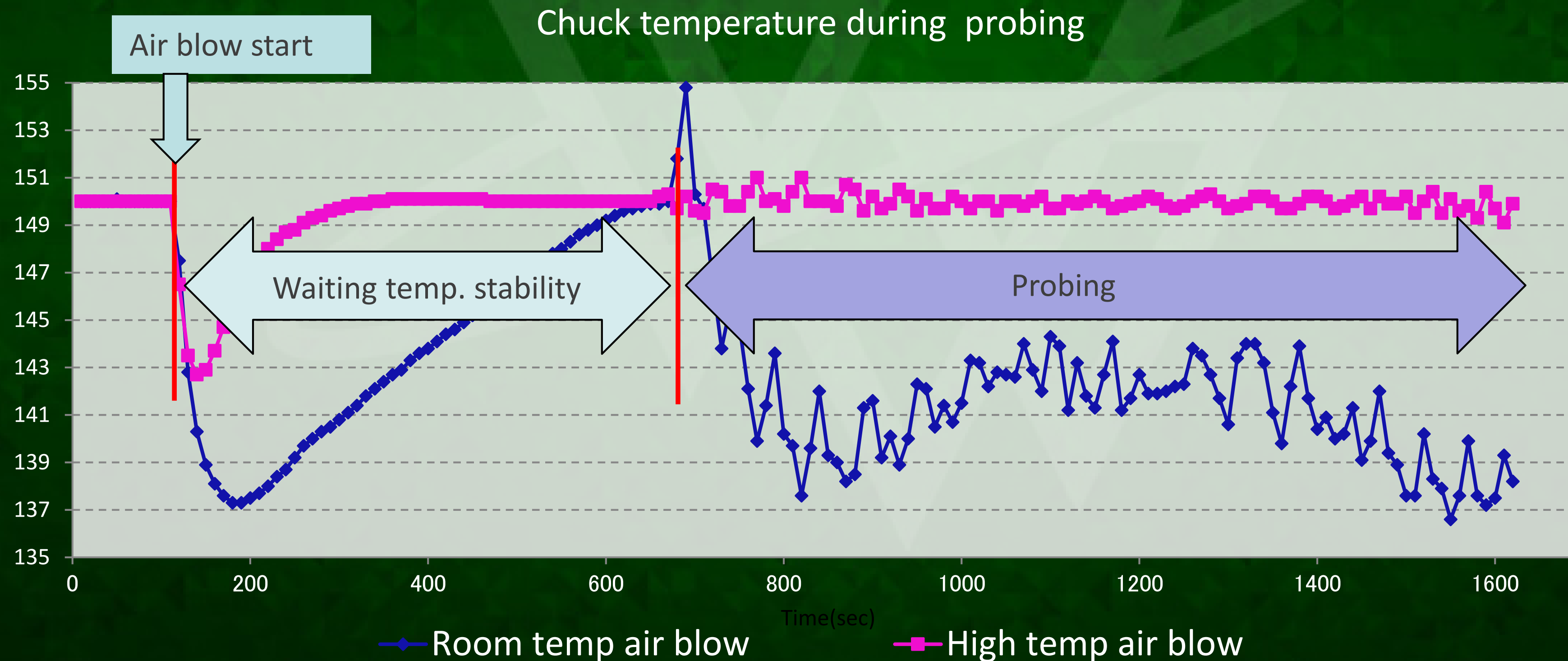
Temp. test-2

- Chuck temp. variation during probing-3
- Condition: Set temp.=150℃/0.3MPa/Die size=5㎜/Test time=300ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



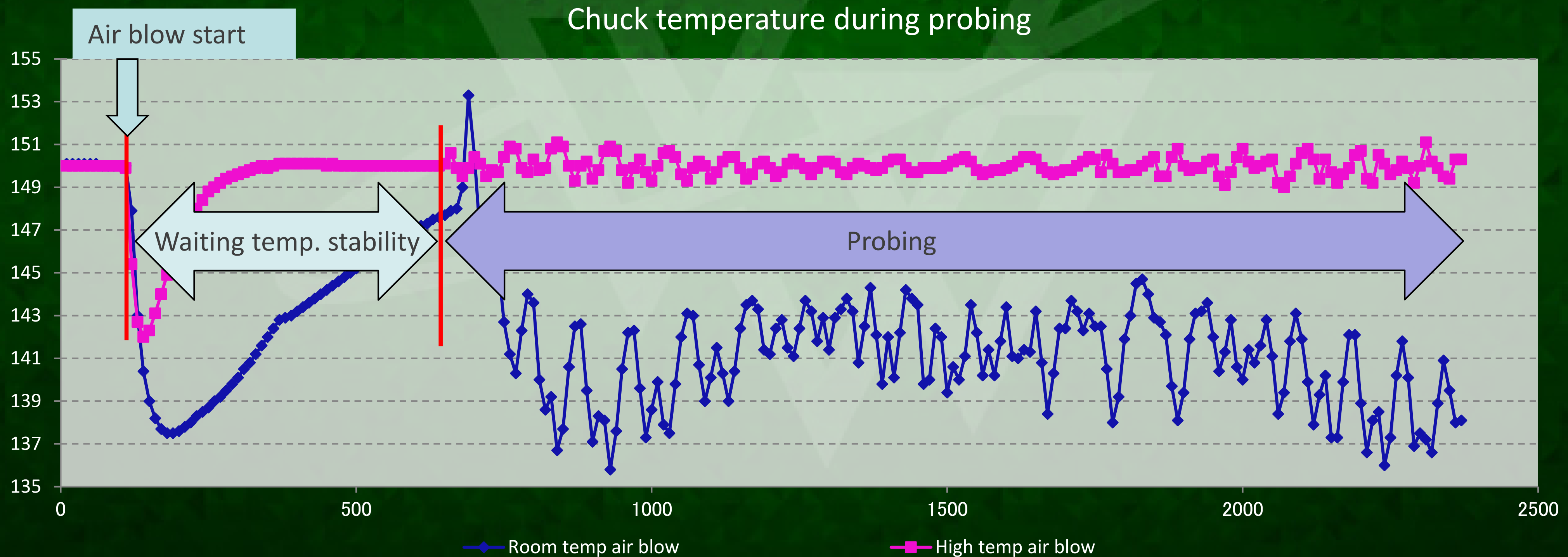
Temp. test-2

- Chuck temp. variation during probing-4
- Condition: Set temp.=150℃/0.5MPa/Die size=5㎜/Test time=300ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



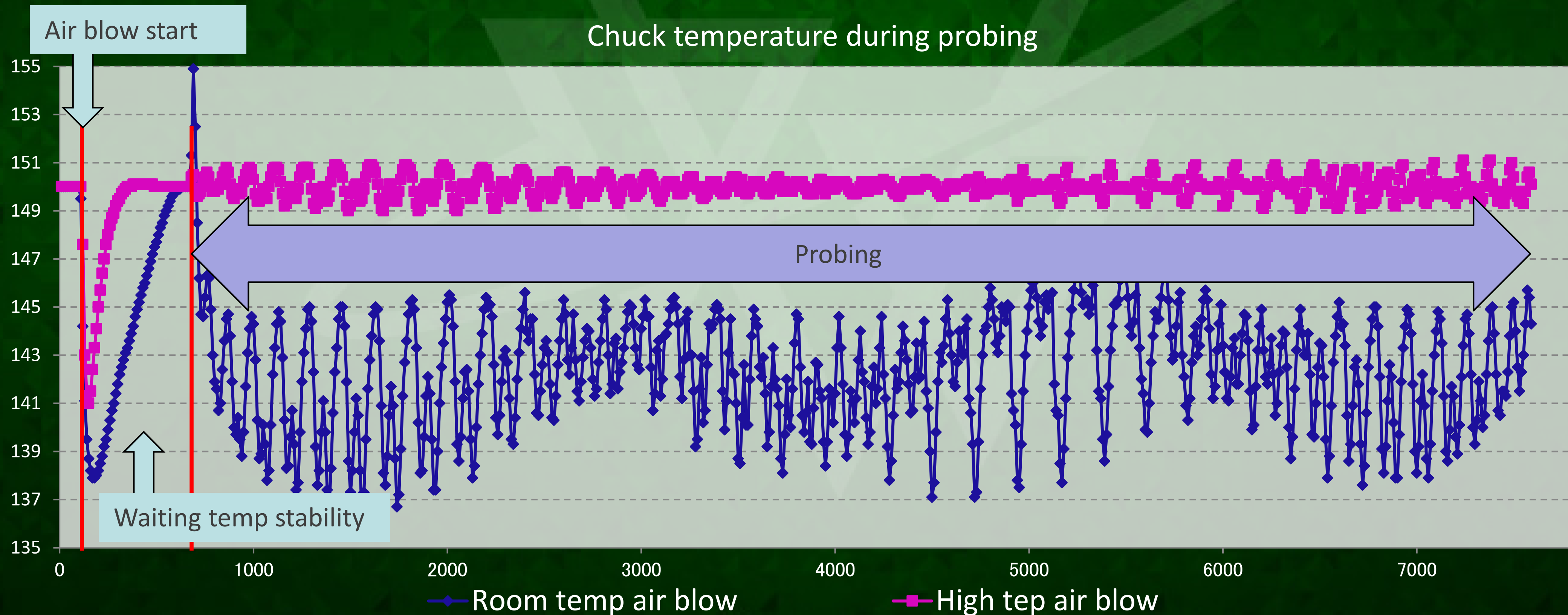
Temp. test-2

- Chuck temp. variation during probing-5
- Condition: Set temp.=150℃/0.5MPa/Die size=5㎜/Test time=1000ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



Temp. test-2

- Chuck temp. variation during probing-6
- Condition: Set temp.=150℃/0.5MPa/Die size=2.5㎜/Test time=1000ms
- Result: Chuck temp. is very stable. (Set temp. ±1℃ during probing)



Temp. test-2

- Chuck temp. during probing – Test result summary

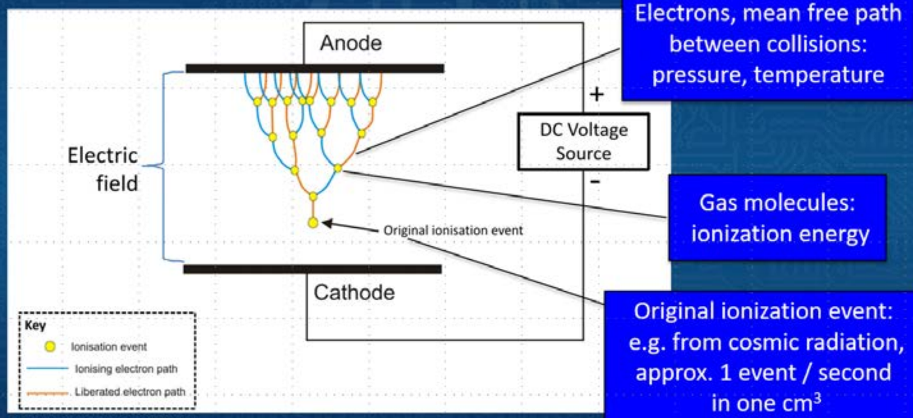
Chuck Temp. (℃)	Pressure (Mpa)	Chip size (mm)	Test time (ms)	Result
100	0.3	5.0	300	+/-1℃
100	0.5	5.0	1000	+/-1℃
150	0.3	5.0	300	+/-1℃
150	0.5	5.0	300	+/-1℃
150	0.5	5.0	1000	+/-1℃
150	0.5	2.5	1000	+/-1℃

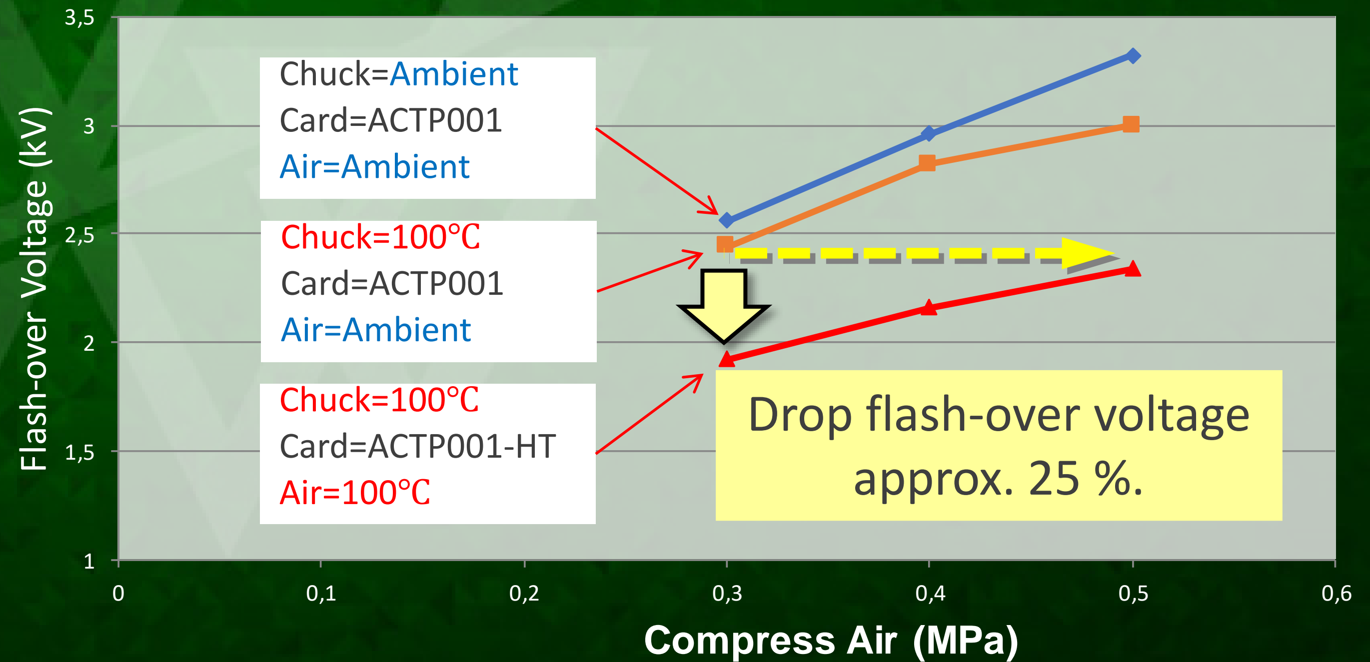
- **Summary:**
  - When using standard probe card with ambient air at 150 ℃, the variation of chuck temp. is +5 to -14℃ max. It is mostly related to air pressure value, not to test time and die size. If using LMH150 with ACTP001-HC, the variation is +/-1℃ under all above conditions.

Flash-Over Spark Test

High voltage at 100°C

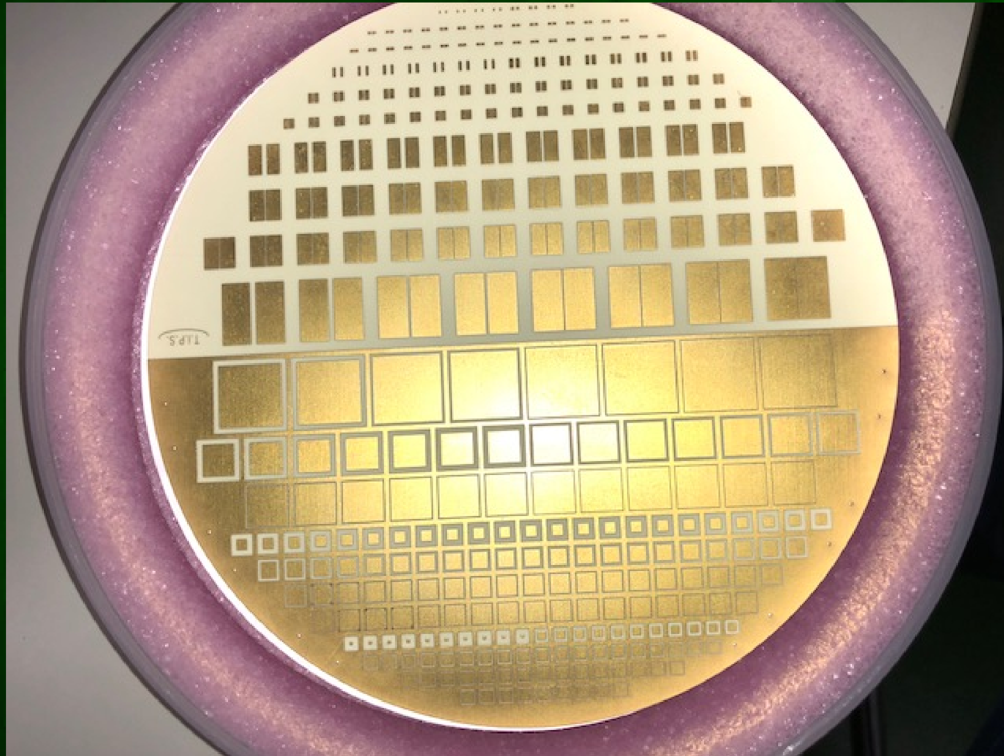
If the test area temp. (inside of Lupo-Ring) is going up, the flash-over voltage is dropped. In case of ACTP001 with ambient air even if chuck temp. is 100℃, the test area temp. must be lower. So the flash-over voltage is just a little bit dropped.



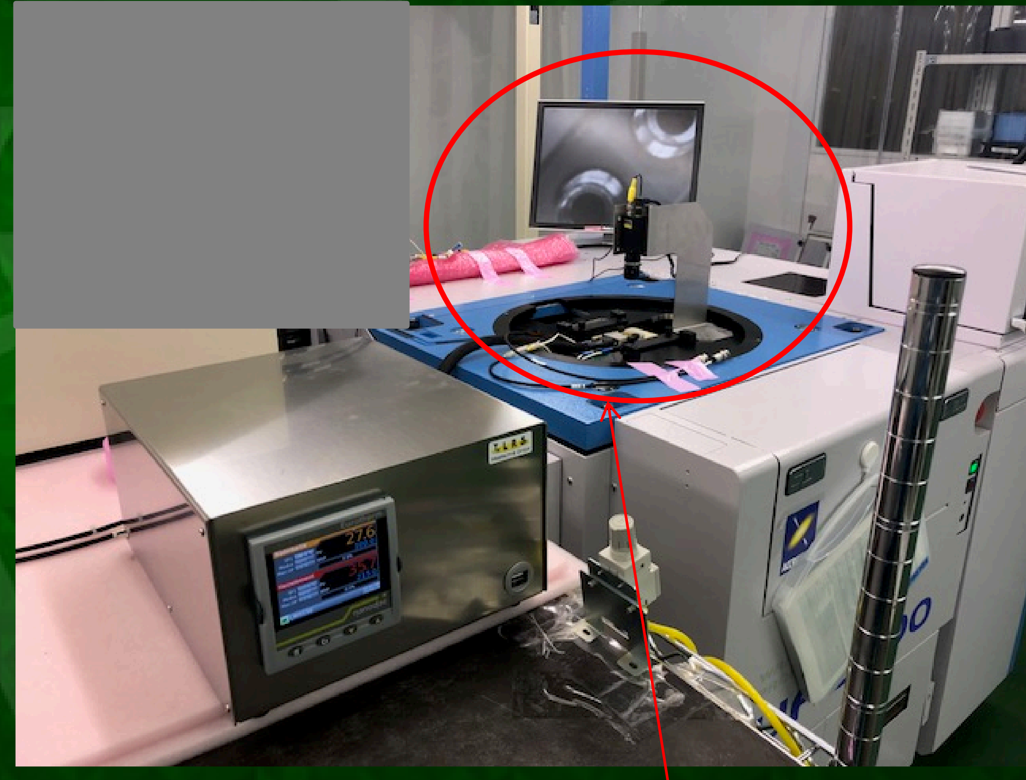


Flash-Over Spark Test

High voltage at 100°C



Test wafer



Check flash-over by camera & monitor.

Conclusion & Follow-On Work

Conclusion

- Proven Solution for High-Temperature High- Voltage Wafer Test
- Achieved the improvement by chuck design change and using hot air controller.

Follow-On Work

- More field test
- Integrate hot air controller into prober
- Extend Temperature Range

Thank you for your attention!

For questions, please contact:

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