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Smart sensors - Smart Probe Cards

Probing sensor devices requires stimulation with magnetic fields, infrared radiation or humidity

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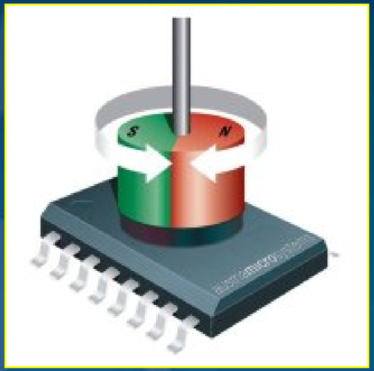
Overview

- Wafer level sensor test
- Concept of smart probe cards
- How to stimulate sensors (IR, humidity, magnetic)
- Principal approaches
- Choosing a technology
- Design examples and performance data
- Summary: Considerations for the test engineer

Smart sensors

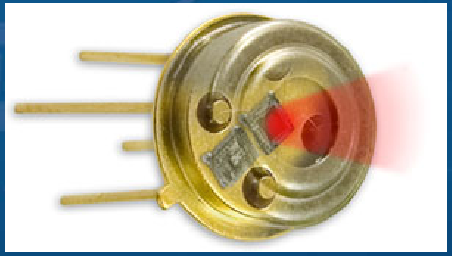
Application examples

- Automotive:
  magnetic angle sensor



picture source:
austriamicrosystems

- Automotive: contactless temperature sensor



picture source:
Melexis

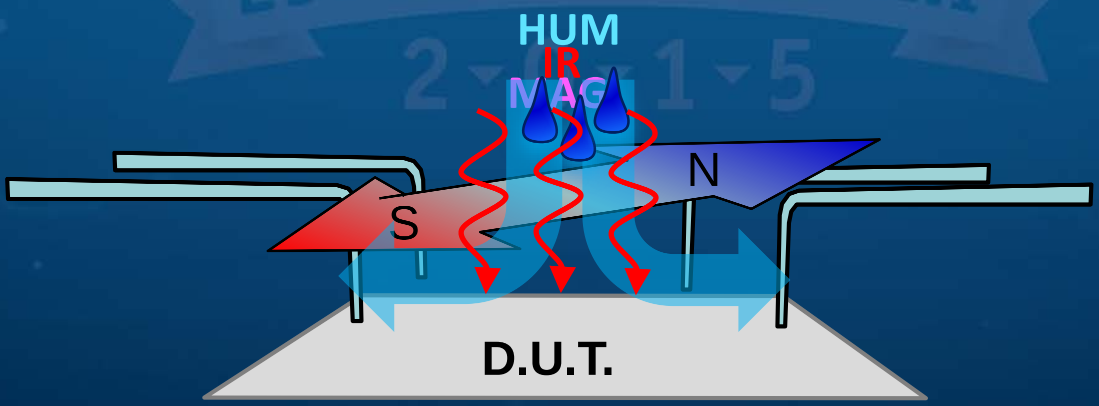
- Industrial Automation:
  humidity sensor

picture source:
IST-AG.com

Sensor test

Wafer level test

- electric and sensor test
- standard probing
- additional sensor excitation
- fast multi-site capability



Smart probe cards

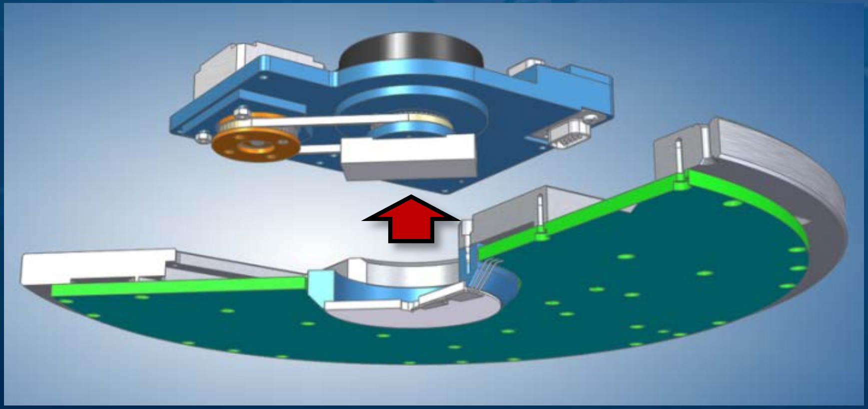
Requirements

- Standard Testing Platform
- Automatic Probe Card Changer
- Dockable Interface for sensor excitation
- Volume Production
- Alignment / Maintenance friendliness

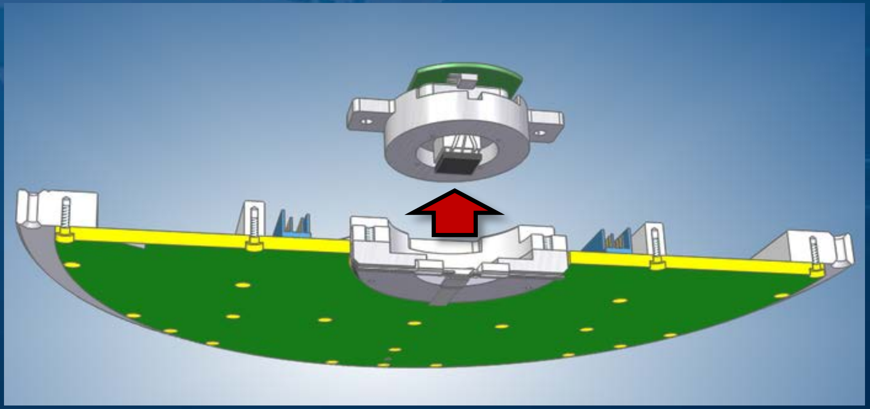
Smart probe cards

Modular design

- Sensor excitation module
- Detachable from probe card
- One excitation module, multiple probe cards
- Module supply through probe card contacts



Rotating Magnet Probe Card



IR Radiation Probe Card

Smart probe cards

Smart module

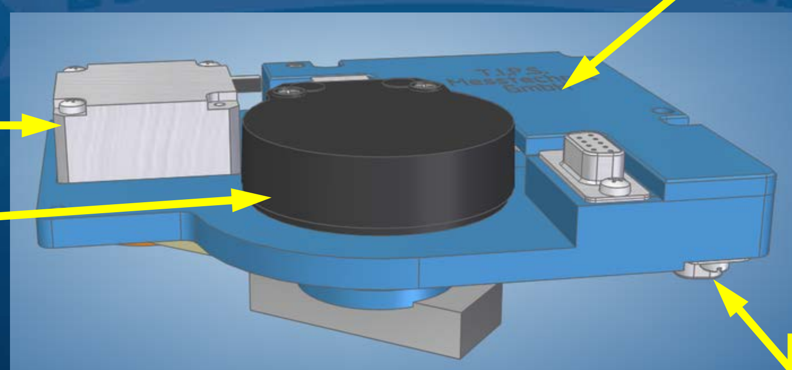
- integrated microcontroller
- digital interface: set point, status
- keeps set point on test interruption: temperature, position, ...
- precise closed-loop control

Microcontroller

Actor (Drive)

Sensor (Encoder)

Closed control
loop



Digital Interface

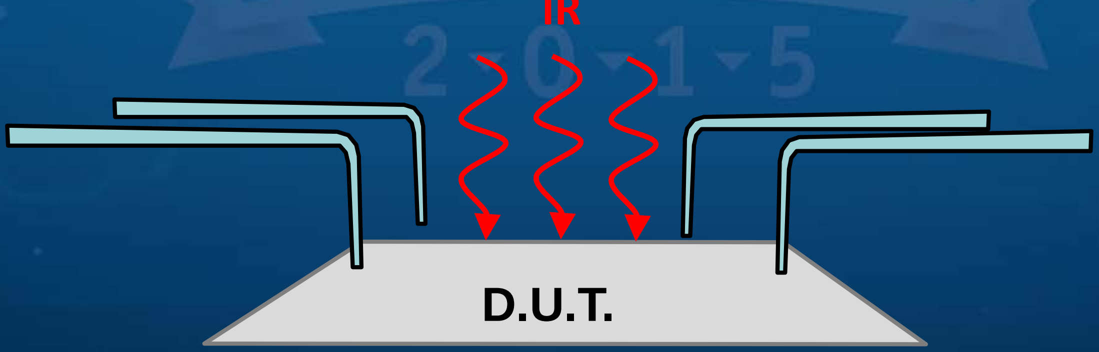
Example: Rotating Magnet module

Sensor excitation

Temperature Sensors

– thermal radiation

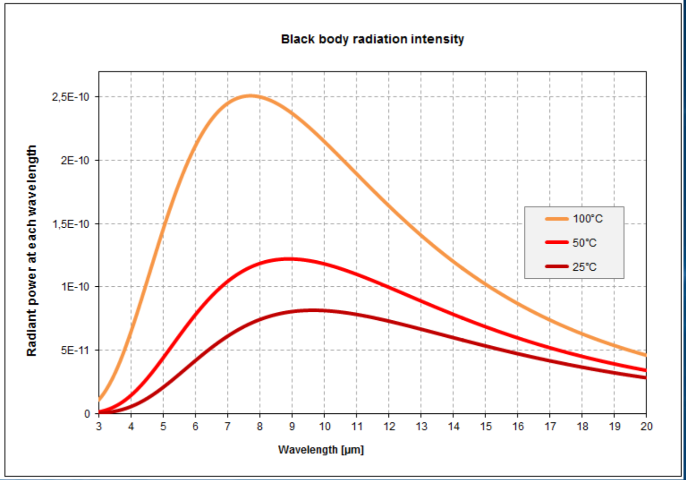
– signal ~ absorbed radiation



Infrared radiation

Physics

- surface emission
- surface temperature: T
- surface emissivity: ε
- radiance ~ $\varepsilon \cdot T^4$



Sensor

- temperature sensing range: ambient to 100°C
- peak radiance: ~ 10µm wavelength

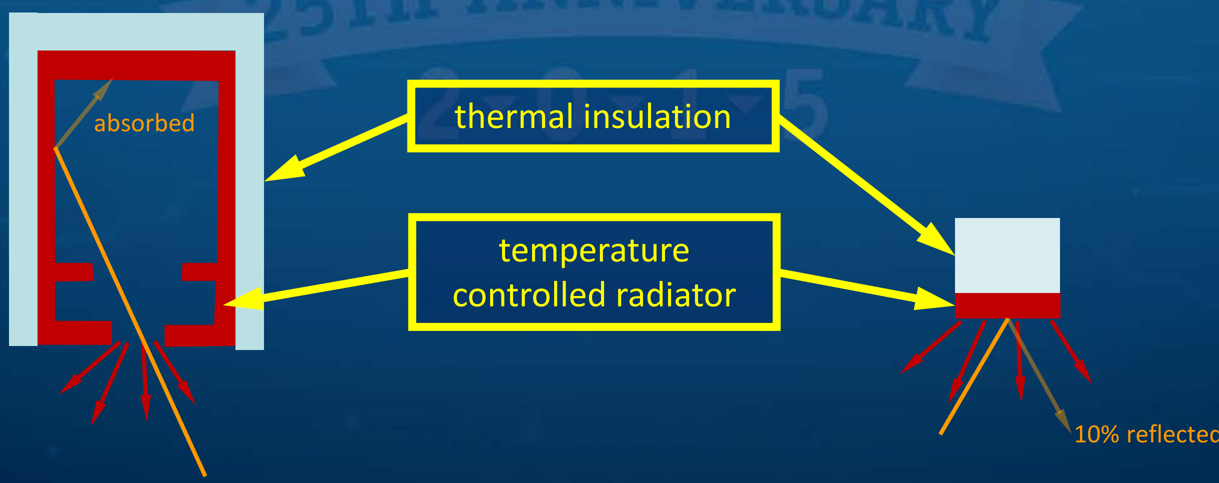
IR Radiation Sources

Black Body

- emissivity 100%
- no reflection
- larger body size
- slower response

Hot Plate

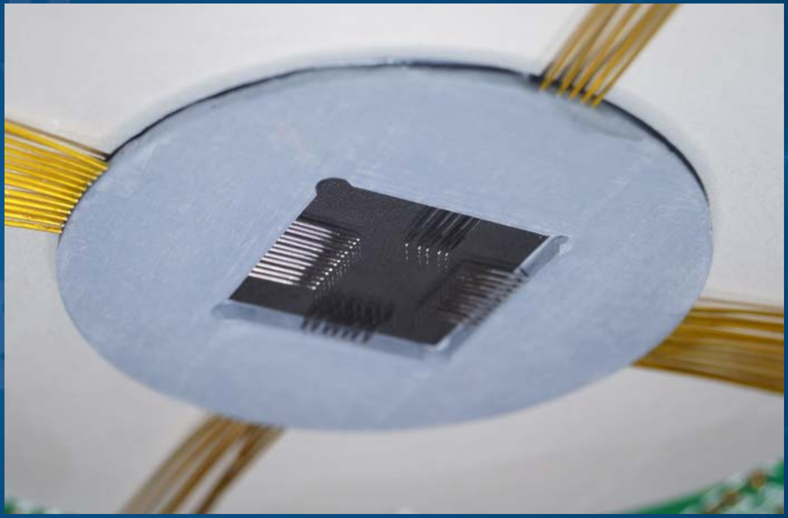
- emissivity 90%
- reflection 10%
- smaller body size
- faster response
- emissivity uncertainty



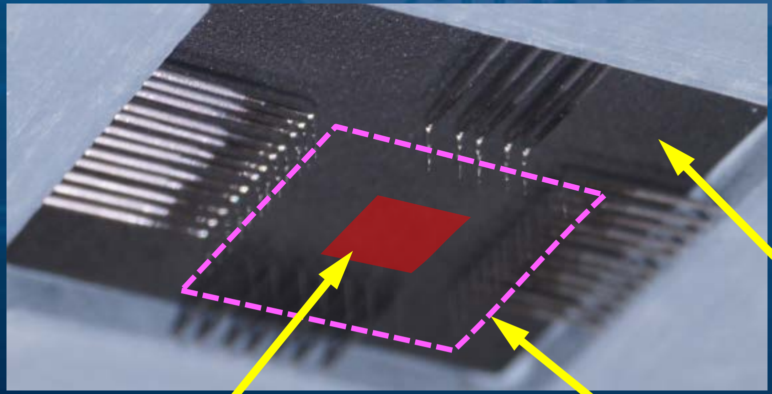
IR Probe Card

„Hot plate“ design:

- large view angle of sensor
- large radiator
- close distance
- placement inside spider



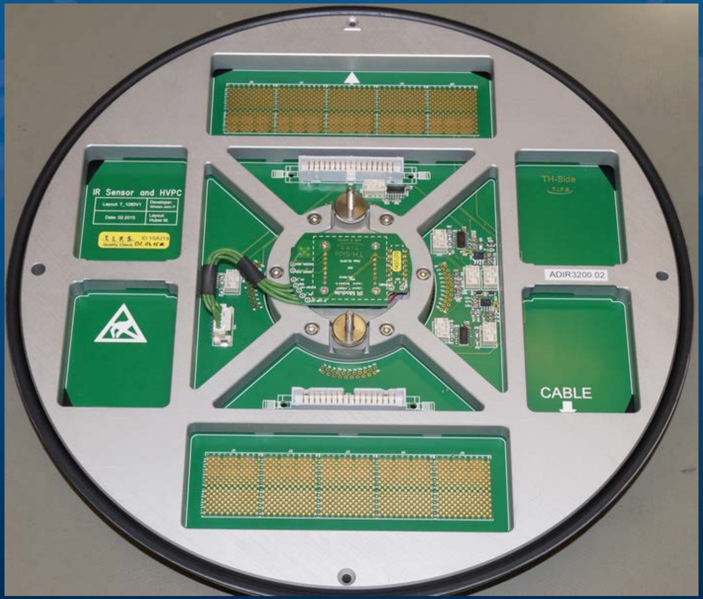
Needle spider with IR radiator installed



IR Probe Card

Characteristics

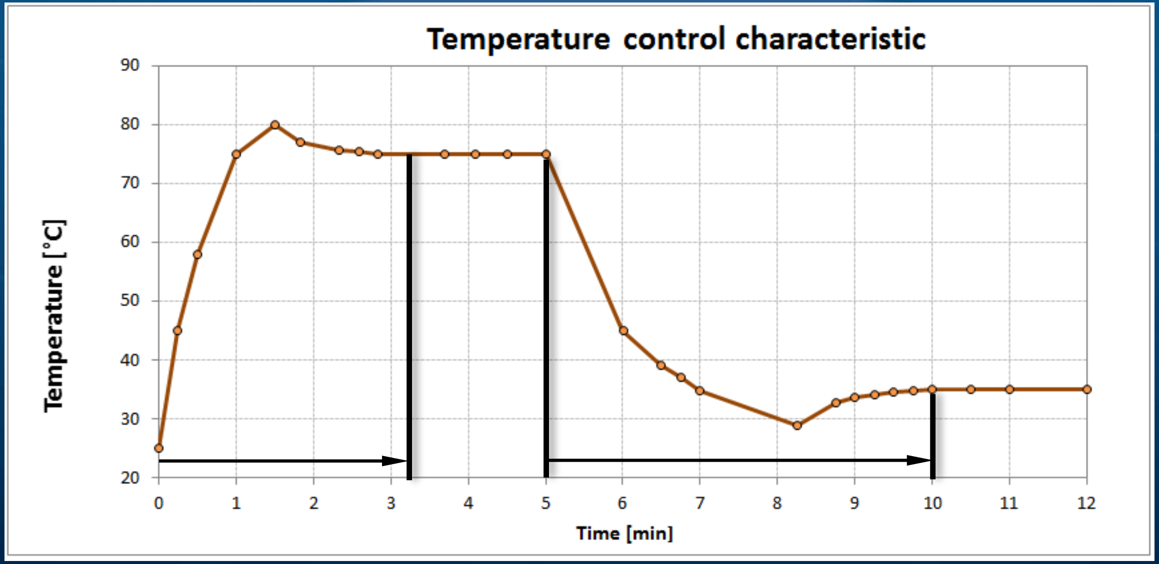
- View factor >90% possible
- Temperature Range: ambient+10°C to 80°C
- Temperature Accuracy: ± 1°C



IR Probe Card

Performance

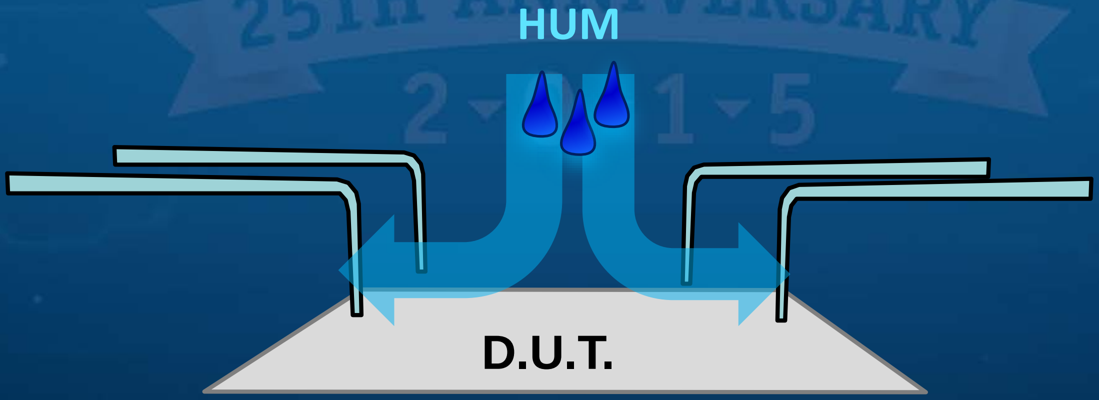
- Temperature Stability: ± 0.1°C
- Temperature Uniformity: ± 0.2°C
- Stabilizing time: 5 minutes (40°C step)



Sensor excitation

Humidity Sensors

- capacitance ~ relative humidity (% r.h)
- 100% = saturated air
- strong temperature dependance



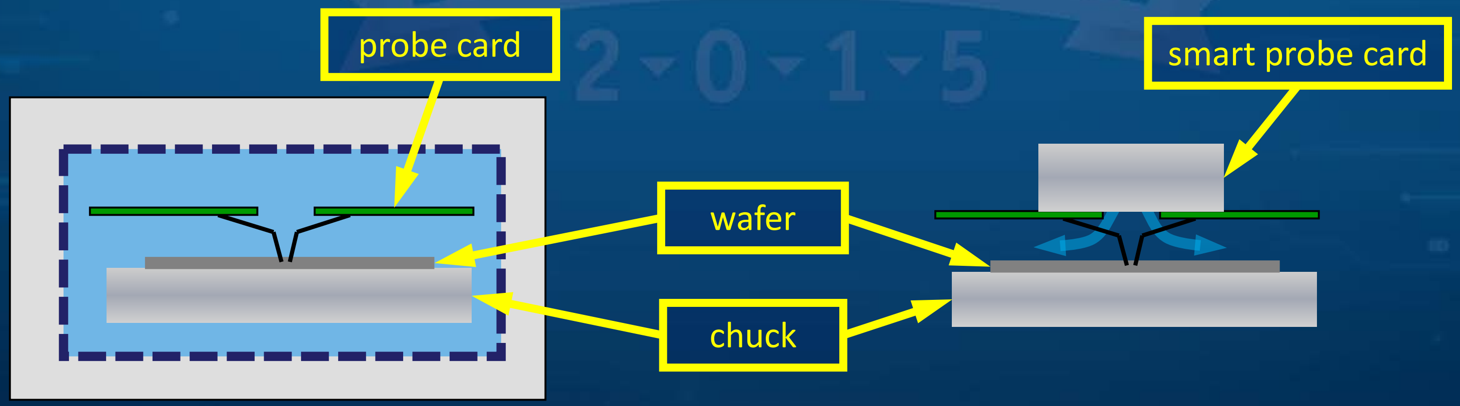
Humidity Testing

Closed System

- prober inside chamber
- controlled atmosphere
- high accuracy
- slow

Open System

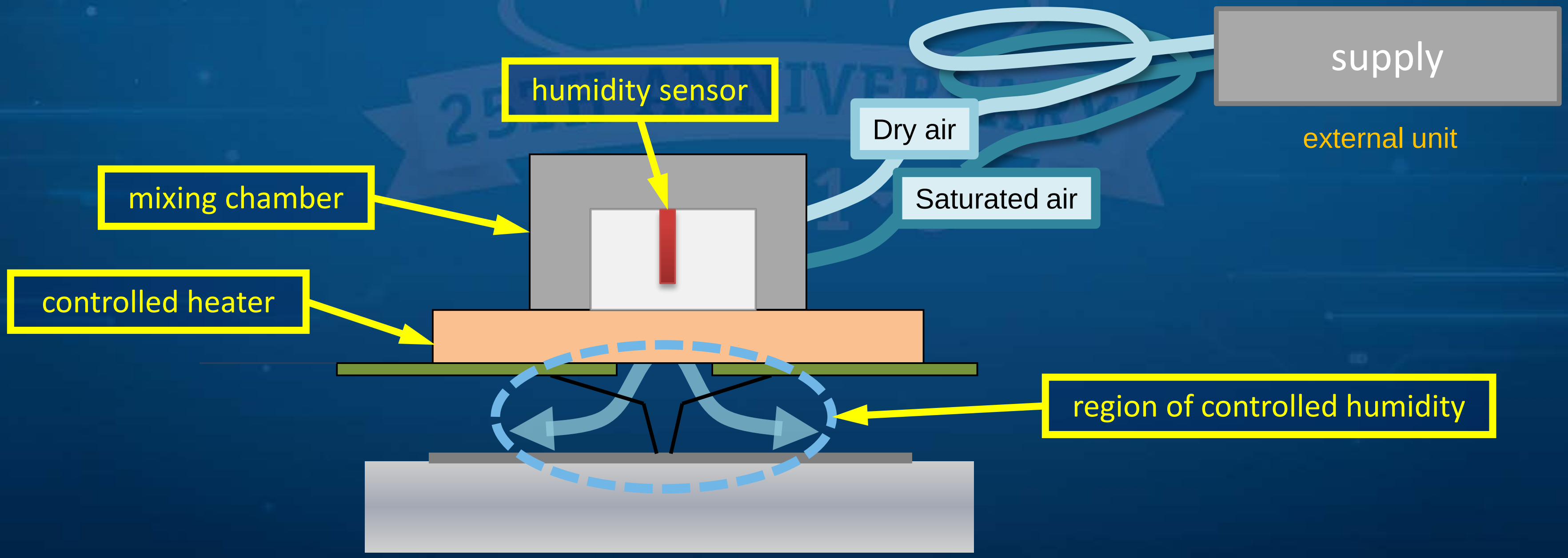
- standard prober
- humidity generator
- continous flow
- mix dry + wet air
- fast



Humidity Probe Card

Characteristics

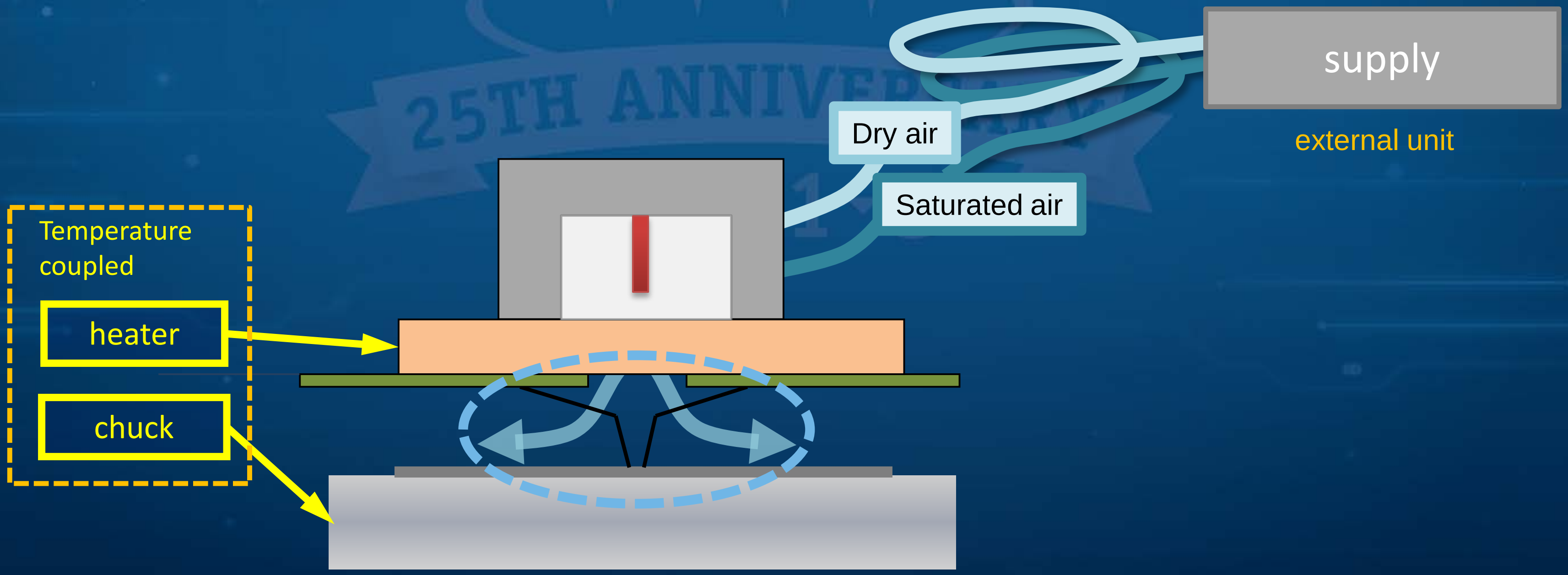
- small mixing chamber
- closed-loop humidity control
- fast change of humidity possible



Humidity Probe Card

Characteristics

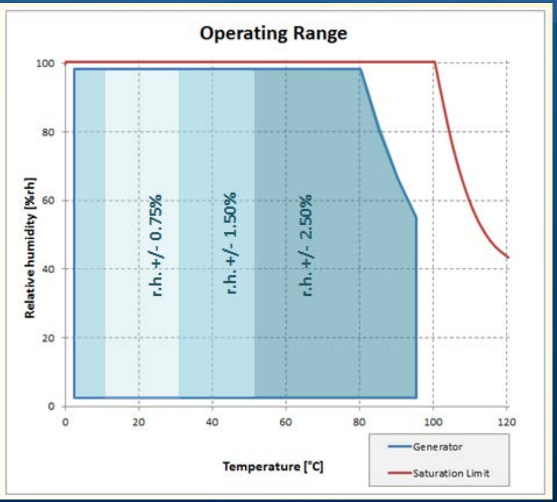
- Humidity range: 2 to 98 % r.h.
- Temperature range: +5 to +80°C
- Flow rate: < 0.5 liter/min



Humidity Probe Card

Performance

- Humidity Accuracy: ± 3% r.h. (10-40°C)
- Humidity Stability: ± 1% r.h.
- Temperature Accuracy: ± 1°C
- Stabilizing time: 10 sec. (10% r.h. step)
- Stability / Drift: < 1% r.h./year (calibration poss.)

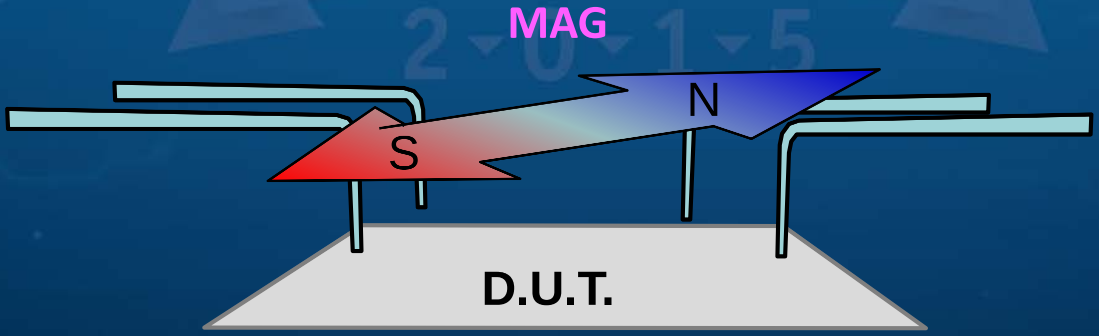


Accuracy of integrated sensor for humidity control depends on temperature

Sensor excitation

Magnetic Sensors

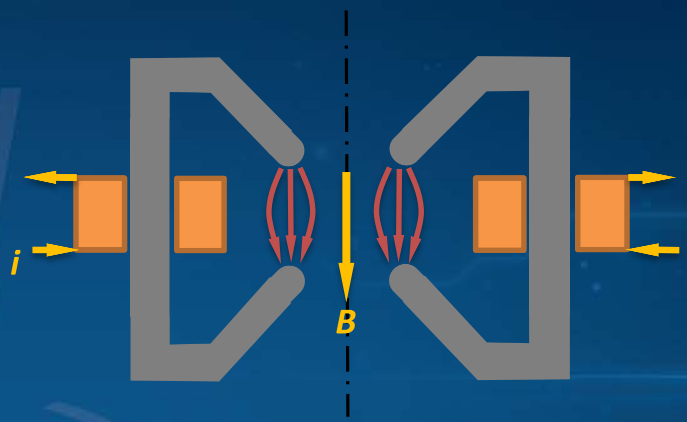
- magnetic flux parallel wafer
- signal ~ flux density and direction



Electromagnet

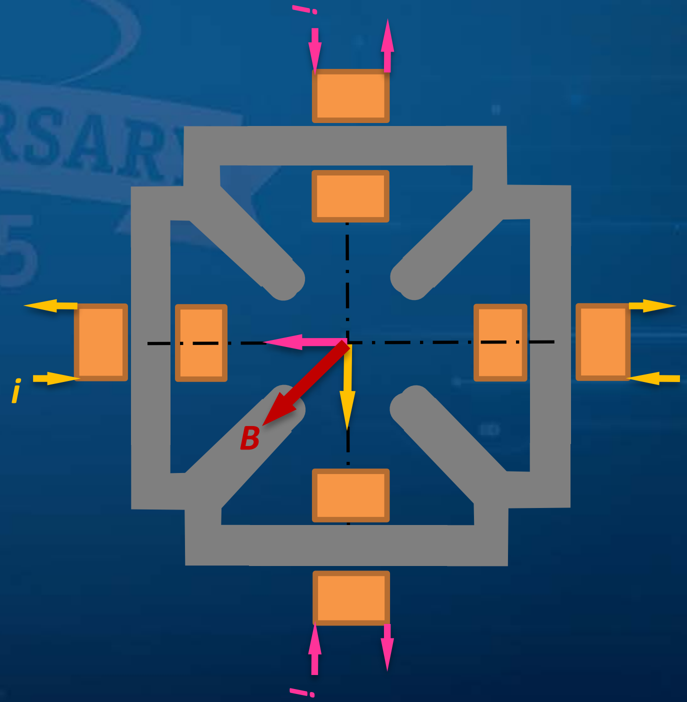
2 Dipoles

- coil and yoke
- symmetry arrangement
- field lines straight on symmetry



2N-Pole

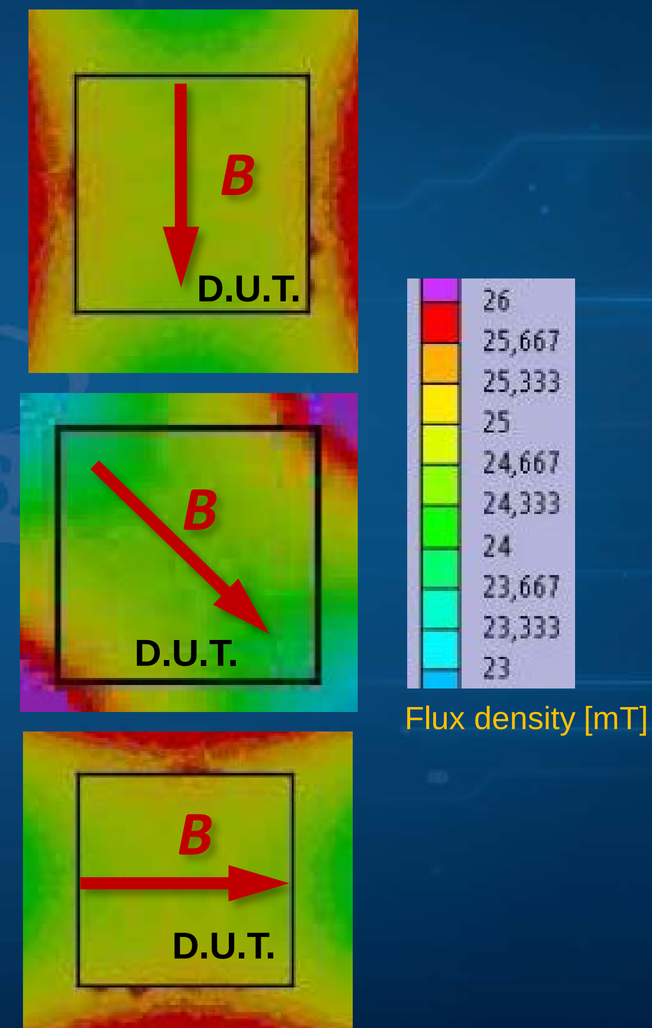
- Superposition of above
- Field by vector sum
- Direction by coil currents



Electromagnet

Field homogeneity:

- strength and direction non-uniform
- can be measured and compensated
- additional calibration device needed



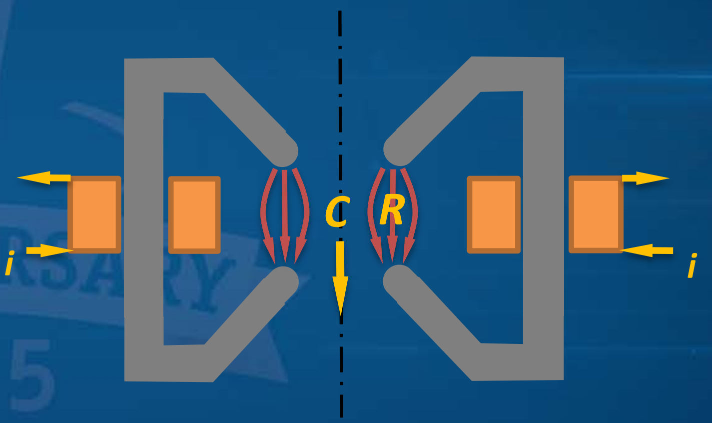
Electromagnet

Material Nonlinearities:

- Soft magnetic core saturates
- Small but visible hysteresis

Reference sensors:

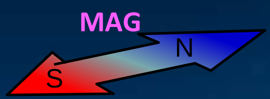
- reference sensors (R) fixed to yoke
- calibration (C) with precision probe
- correction of DUT data



Electromagnet

Performance:

- DUT size: 3x3mm
- field strength: 25mT
- angular accuracy: ± 1°
- repeatability: ± 1°
- rotational speed of field vector max. 10 Hz



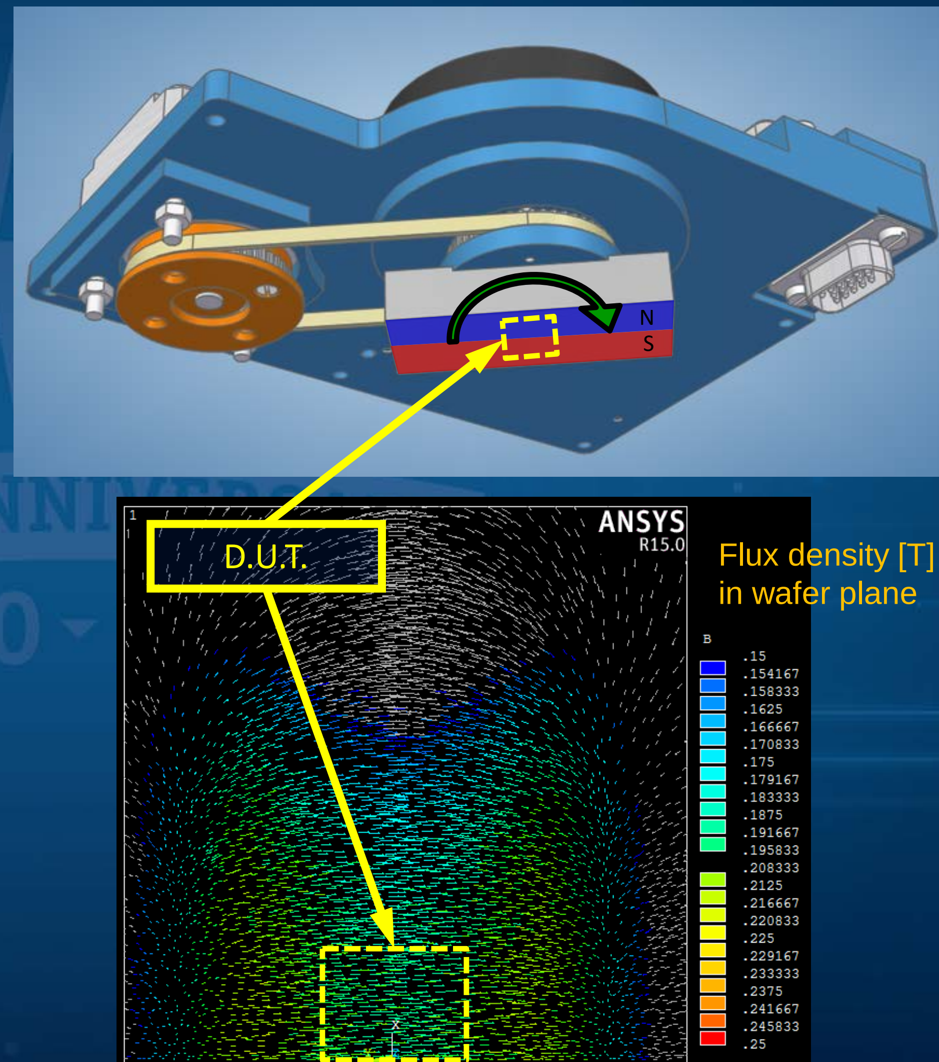
Permanent Magnet

Characteristics

- DUT size : 10x10mm
- field strength: 150 mT

- good field homogeneity
- large field for multi-site testing
- constant over time

- once-only calibration for large multi-site or high angular precision



Permanent Magnet

Performance

- positioning time 45°: 200 ms
- continouos rotation: 150 rpm
- positioning accuracy: ± 0.1°
- repeatability: ± 0.1°

- positioning modes:
  5 and 45° increments,
  single rotation,
  continouos rotation

Comparison

Permanent Magnet

- \+ precise angular position
- \+ always constant strength
- \+ always constant offset (multi-site)
- \+ no heat dissipation

- \- slower stepping

Electromagnet

- \+ fast change of magnetic angle
- \+ adjustable strength

- \- coil heating / cooling requirement
- \- reference sensors / correction
- \- speed limit: 10 Hz
- \- low accuracy

Summary

Smart probe cards help to achieve higher accuracies by precision controlled sensor excitation. They can also reduce test complexity and effort.

Still wafer probing of sensor devices is a challenge:

- In some physical domains it remains difficult to reach the required accuracy of sensor excitation.
- Test engineers must consider effort for calibration of test equipment in a production environment.
- In addition to probe cards calibration tools must be purchased.

Acknowledgements

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