SAW SENSORS

Explore

New Measurement Horizons

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Overview

- Carinthian Tech Research – Who we are
- CTR SAW System – Tags / Readers / Software
- SAW Applications – Automotive / Food / Oil
  Steel / Energy
- CTR SAW R&D – Pressure / Strain
  High Temperature

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SAW Wireless Sensors Products and Technology

CTR: Center for intelligent sensors and industrial R&D

Founded	1997
Shareholders	Federal State of Carinthia City of Villach Fraunhofer Gesellschaft
ISO 9001	since 2003
Employees	40
Turnover 2011	~5 Mio. €

SAW Wireless Sensors Products and Technology

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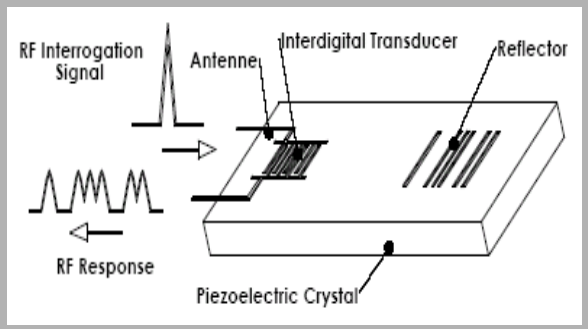
SAW Wireless Sensors Products and Technology

- Wireless
- Passive
- Very Small
- Robust
- …

- ID
- Temperature
- Pressure
- Force
- Strain
- …



- High Temperature
- Low Temperature
- High Voltage
- High Current
- Shock-proof
- X-Ray
- …

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➢ System Specifications – Sensors & Tags

Temperature	Celsius	Fahrenheit
Range	-55°C to +400°C	-67°F to +752°F
Accuracy	±2°C	±3.6°F
Resolution	0.1°C	0.18°F
Read range	**Meters**	**Feet**
9 dBi antenna	up to 2m	up to 6.6ft
18 dBi antenna	up to 4.5m	up to 14.8ft

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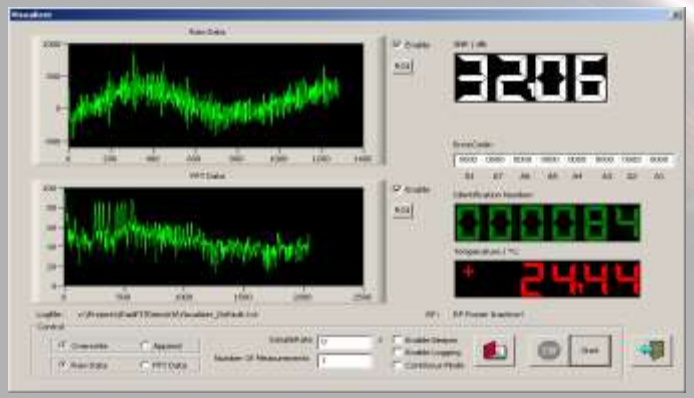
➢ System Specifications – Readers

Standard Reader (FSCW) :
- Reading-time: 300msec
- 4 channel reader
- 2,45 GHz 80 MHz bandwidth ISM Band
- LAN Interface
- EN 300440, FFC Part 15, JP

Fast Reader (FMCW):
- Frequency sweep: 100µsec
- 1 channel reader
- 2,45 GHz 80 MHz bandwidth ISM Band
- LAN Interface
- EN 300440

Handheld-Reader (S-FSCW):
- Reading-time: 100msec
- 1 channel reader
- 2,45 GHz 80 MHz bandwidth ISM Band
- Bluetooth
- Battery life > 10.000 read outs

➢ System Specifications – Software



Visualizer:

- Online visualization of signals
- Quality validation in applications
- Easy detection of interferences in bandwidth
- Helpful tool during system setup

Panel:

- Display of ID und temperature
- Different antenna configurations
- Display of signal quality

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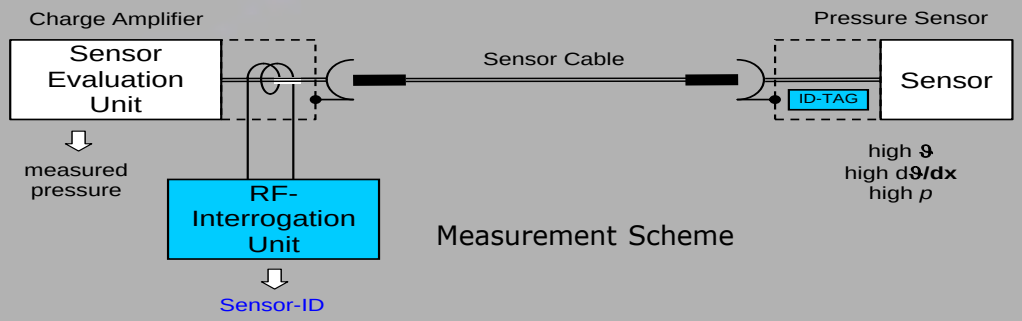
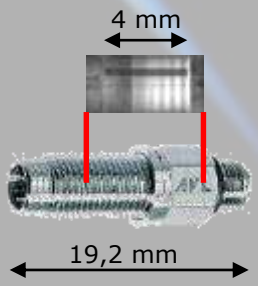
Identification of Pressure Sensor

- Size
  - Integration into the sensor
  - SAW tag less than 5 mm in length
- Signal chain
  - Insulation resistance of 10^{14} Ω @ 20 °C
  - cable & connector have to remain unchanged
- Stability against temperature
  - 2000 h @ 300 °C (572°F), 10 h @ 400 °C (752°F)
- Shock
  - 2000 – 3000 g
- Integration
  - Integration into AVL-pressure monitoring system



Measurement Scheme



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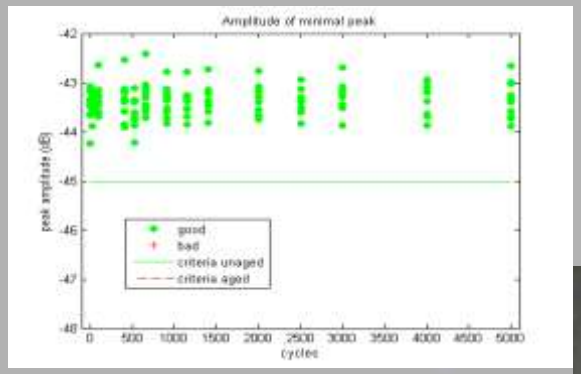
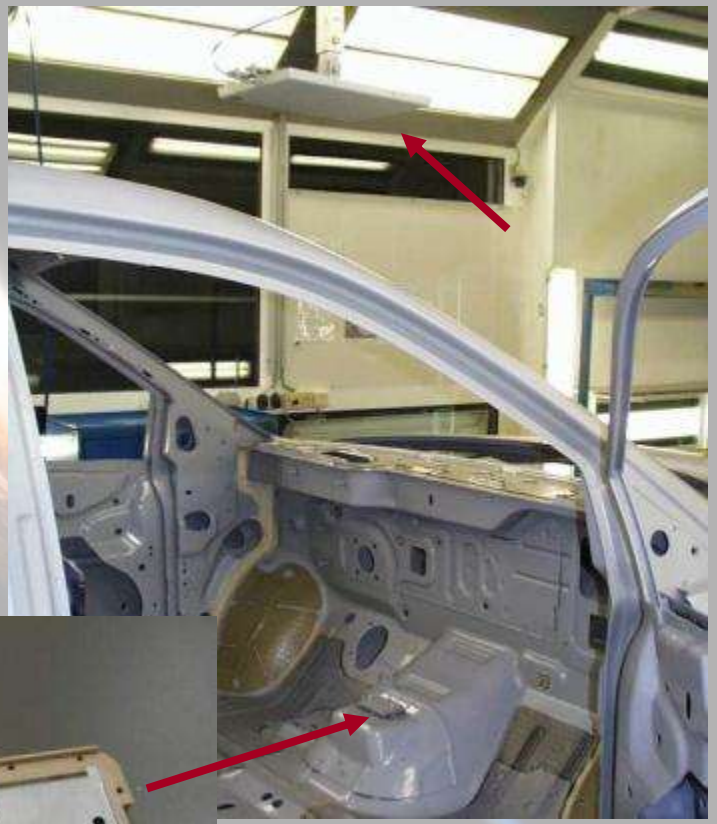
Identification in Varnishing Lines

- high reading range on metal surfaces
- high temperature cyclic requirements
- up to 250°C (482°F)



RT -> 225 °C (437°F) -> RT



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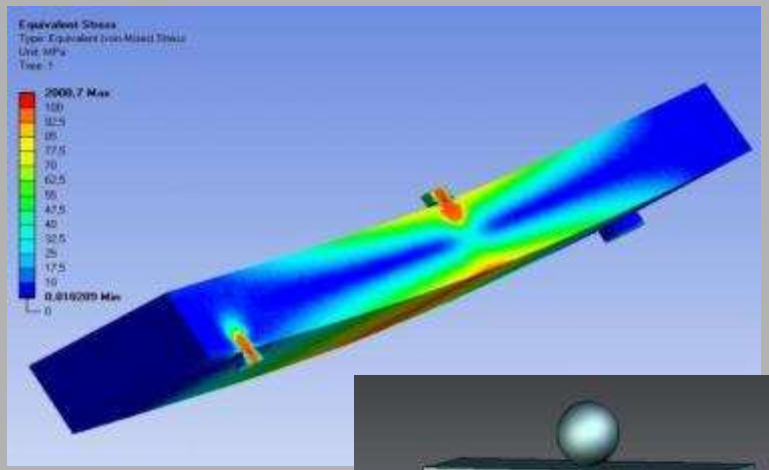
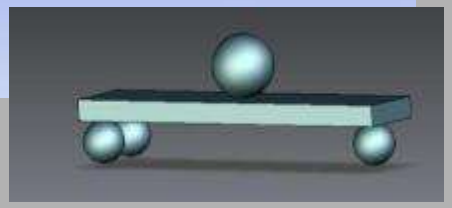
ID, pressure and temperature measurement of baking plates

- 1 sensor 3 functions (ID/T/P)
- Up to 176 baking plate pairs per oven
- Real time measurement for machine control
- Temperature up to 250°C (482°F)
- Pressure up to 6 bar





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Identification of drill pipes

- Automatic identification of drill pipes
- Identification of drill pipes on the rig
- Identification of drill pipes during transport (handheld reader)
- Harsh environment:
  - +250 °C (482°F)
  - 1300 bar (20.000psi)
  - Abrasive liquids

SAW HPHT Headers

www.hmenergyllc.com
Kathleen Hanafan
President
khanafan@hmenergyllc.com
214-755-1892

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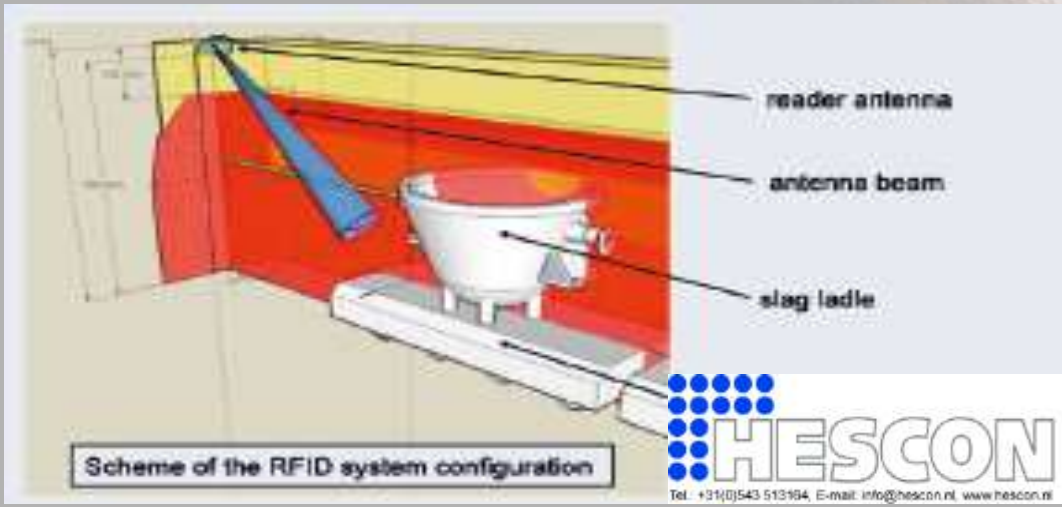
Identification of slag vessel

- Automatic identification of slag vessel
- Harsh environment:
  - Temperature > +200 °C
  - Heavy duty casing to protect tag
- Identification on the rail gate



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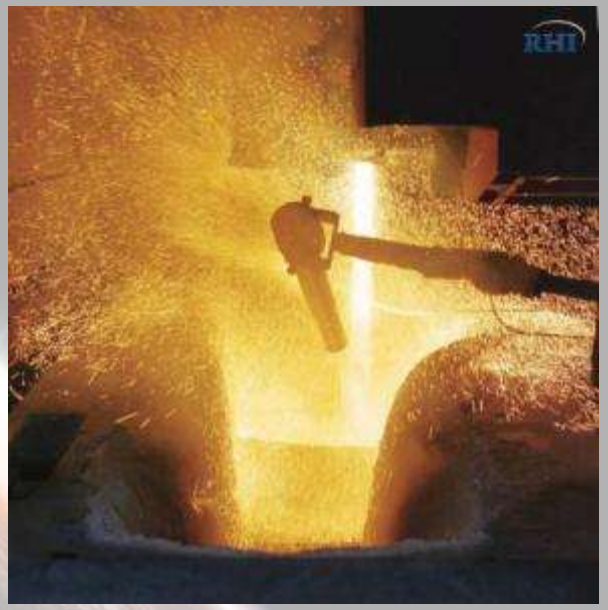
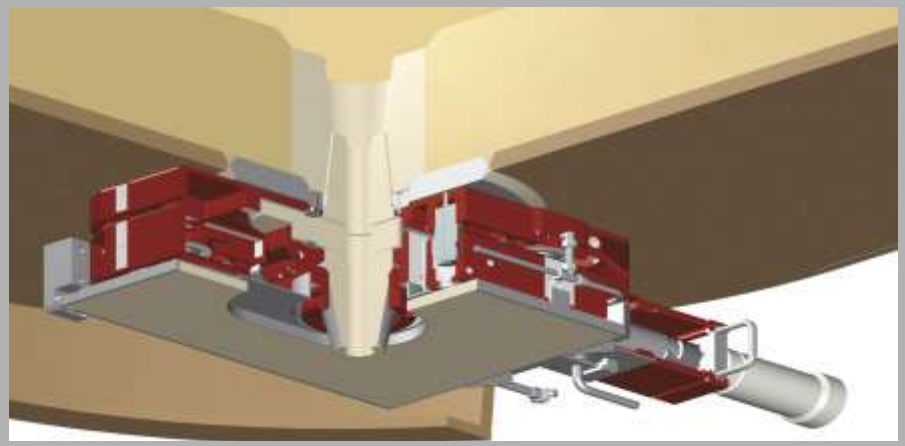
RFID and sensing in slide gate plates

- automatic identification of slide gate plates
- temperature monitoring during casting process
- harsh environment
  - sensor temperatures up to +400°C
  - dust, rude handling
  - impact loads





SAW transponder

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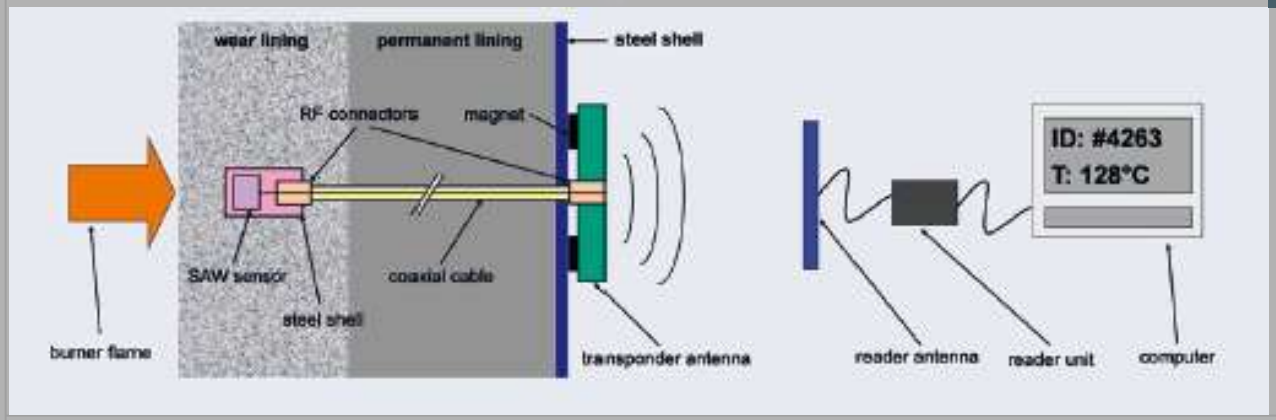
ID & temperature control of drying process in refractory products

- Prevention of remaining humidity
- Harsh environment
  - high temperature
  - metallic surrounding
- Online monitoring of drying
- Tracking of hot, moving equipment



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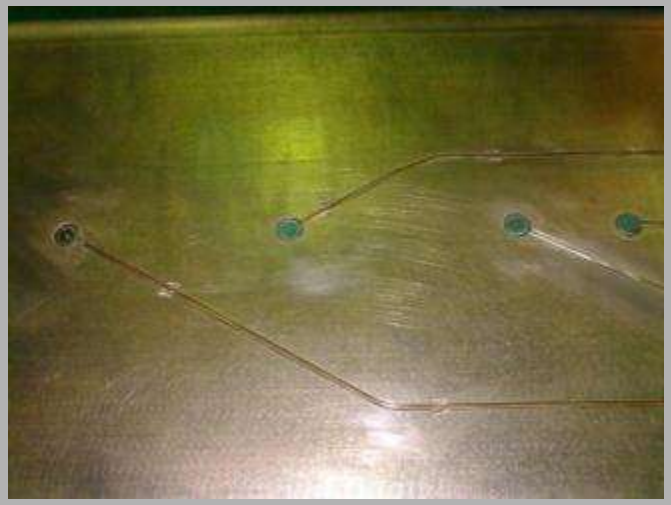
Temperature monitoring of continuous cast molds

- Sensor integration in the copper mold
- Wireless interrogation of sensors via antennas in the mold casing
- Extension to multiple sensor readout of 4 sensors per antenna
- Patent application filed



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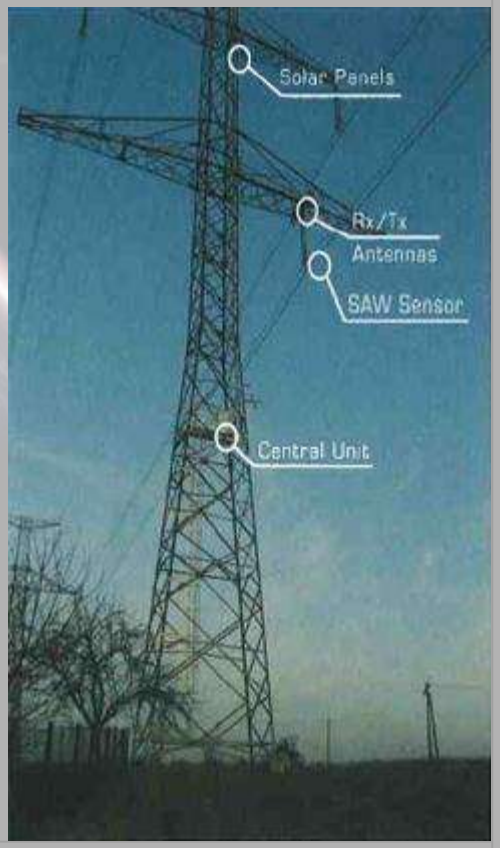
Temperature monitoring of power transmission lines

- Preventing exceeding of the rated temperature
- Overloading with no exceeding of the rated temperature
- Measuring stations are fully remote configurable
- Measuring range up to 15 m
- Temperature accuracy: 0,5 K
- Temperature resolution: 0,01 K
- Temperature range: -40 °C to +150 °C (-40°F to +302°F)
- Measuring Interval 60 sec for computing the free span temperature of the OHTL
- OEM electronics and sensor from CTR AG

Source: LDIC GmbH



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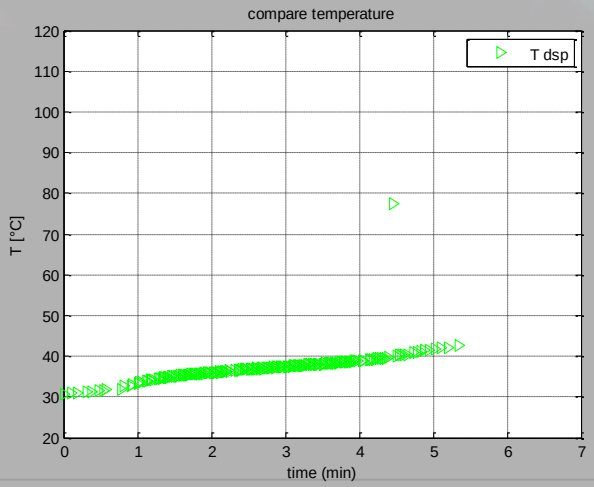
Temperature monitoring of rotating machine elements

- Prevent damage on machine parts
- Condition monitoring
- Rotor speed 15000 rpm
- Measuring range up to 0,5 m
- Temperature accuracy: 1 K
- Temperature resolution: 0,2 K
- Temperature range: -20 °C to +250 °C (-4°F to +482°F)



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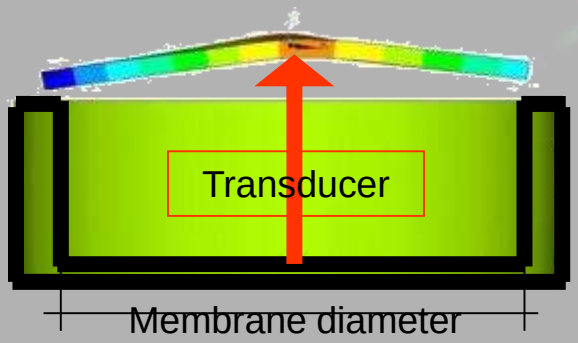
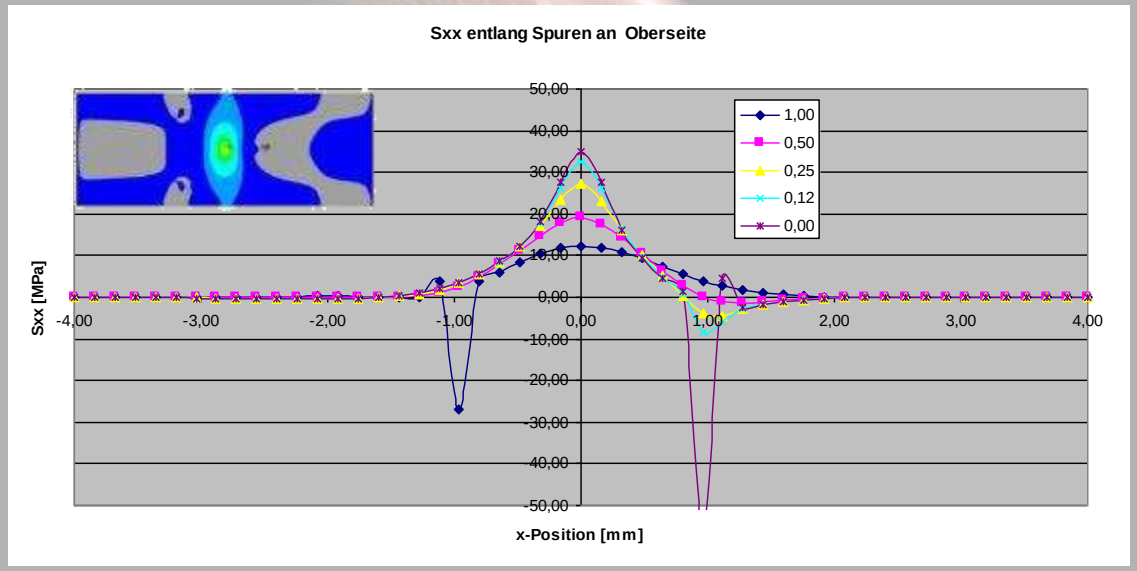
Beam based pressure sensor

- Pressure Sensor: <6 bar
- 200°C operating temperature
- combined temperature sensor
- combined RFID for individual sensor





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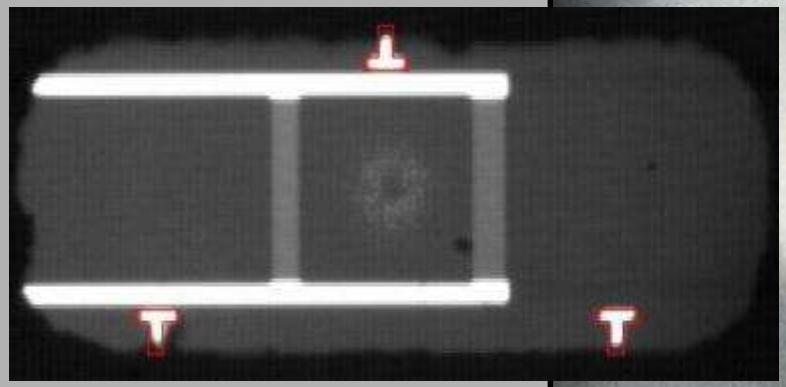

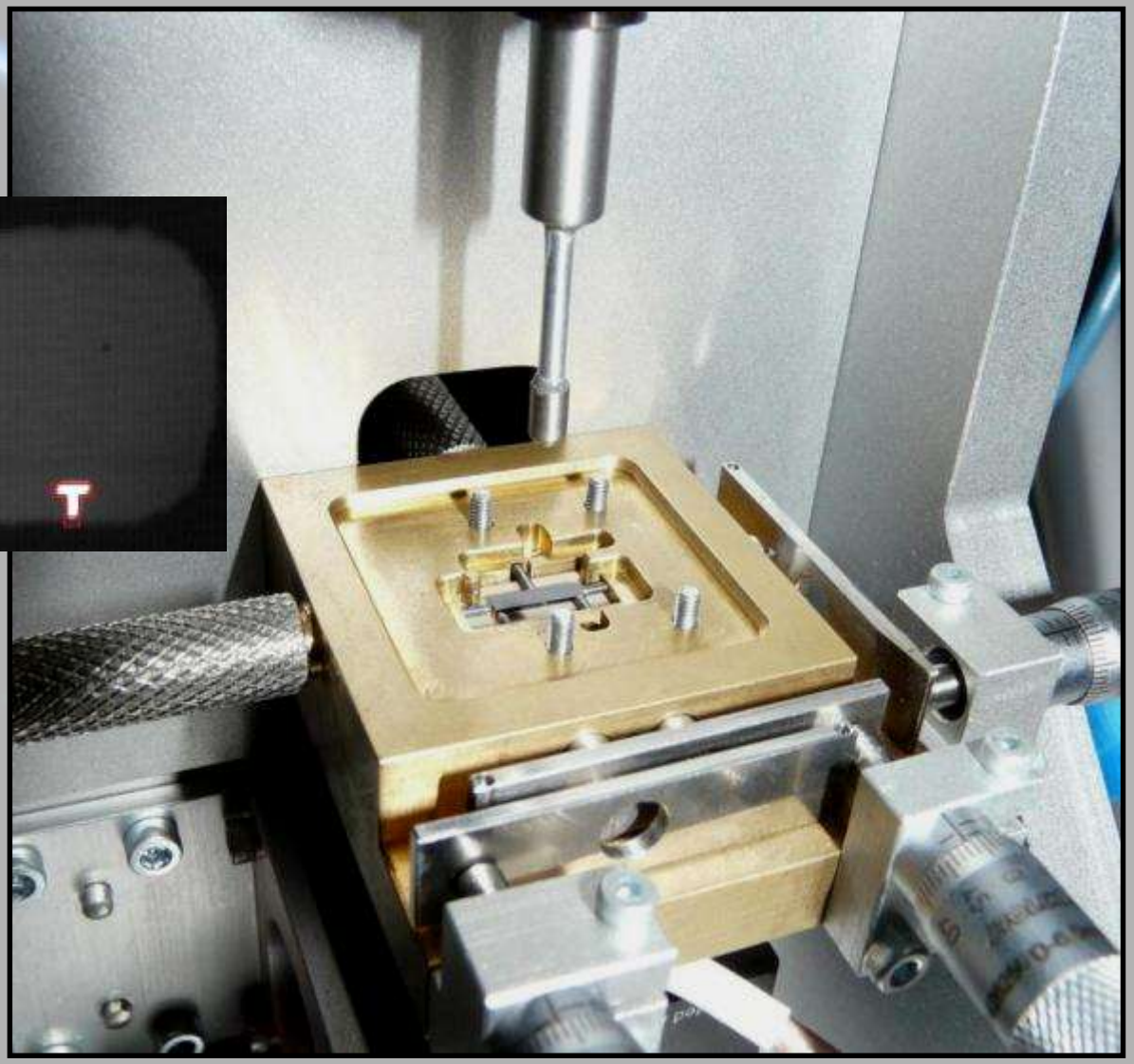

High precision in the setup and a statically defined geometry allow the correlation of simulation and measurement

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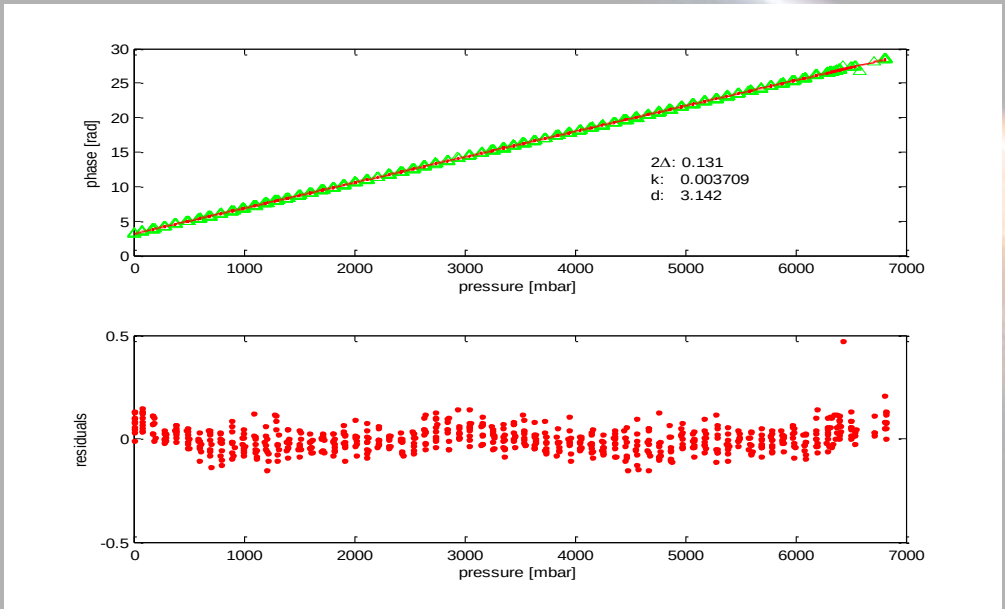

Linear pressure signal until chip fracture

Challenges:

- temperature drift
- sensitivity variation of sensors
- cost

Test setup in environmental chamber
Pressure and temperature testing

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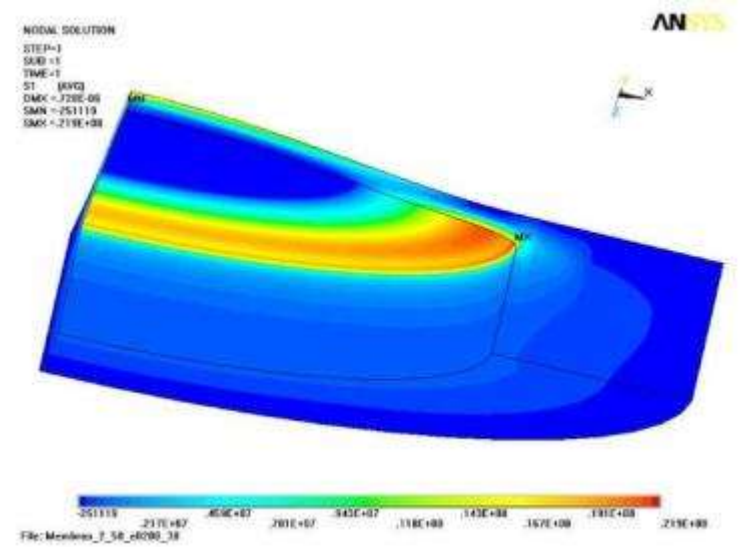
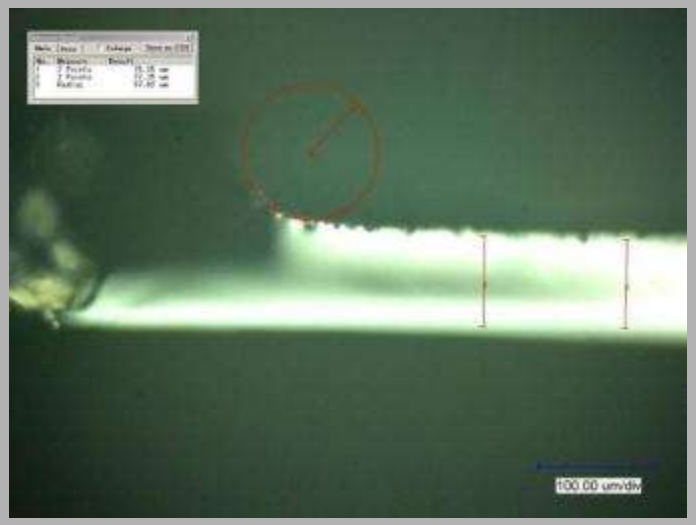
Membrane based pressure sensor

- Microprocessed thin membranes
- Thickness <50µm, diameter 3mm
- Temperature compensated with SAW-Design
- Objective: accuracy < 1 mbar
- Achievements: accuracy < 2 mbar

Challenges:

- Production of thin membrane, Yield





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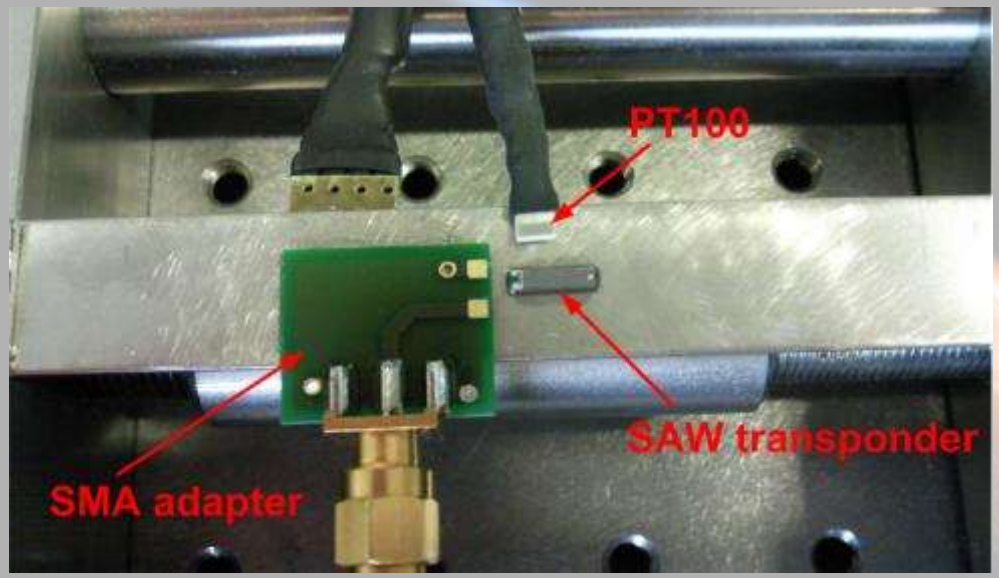
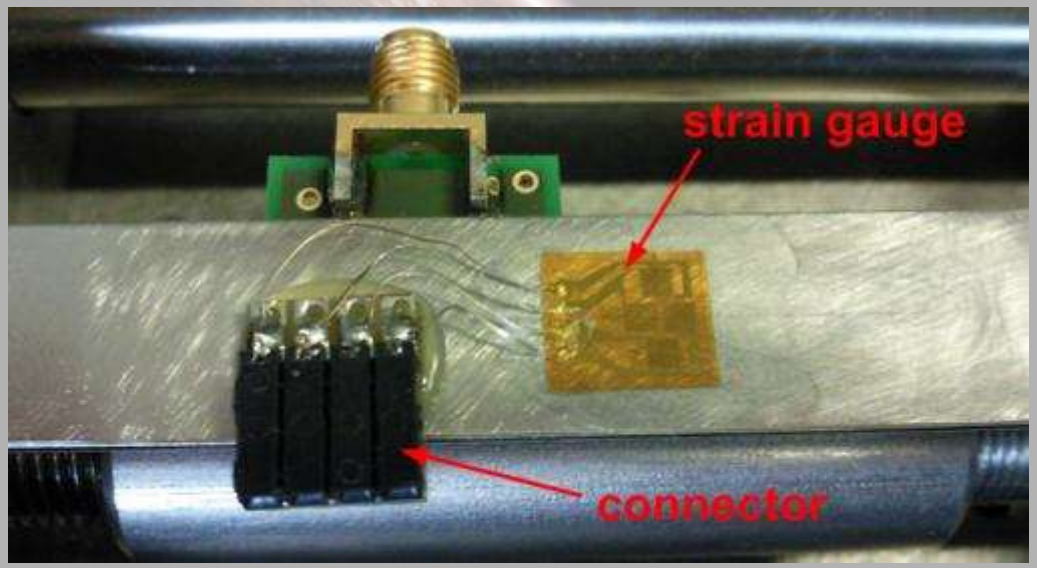


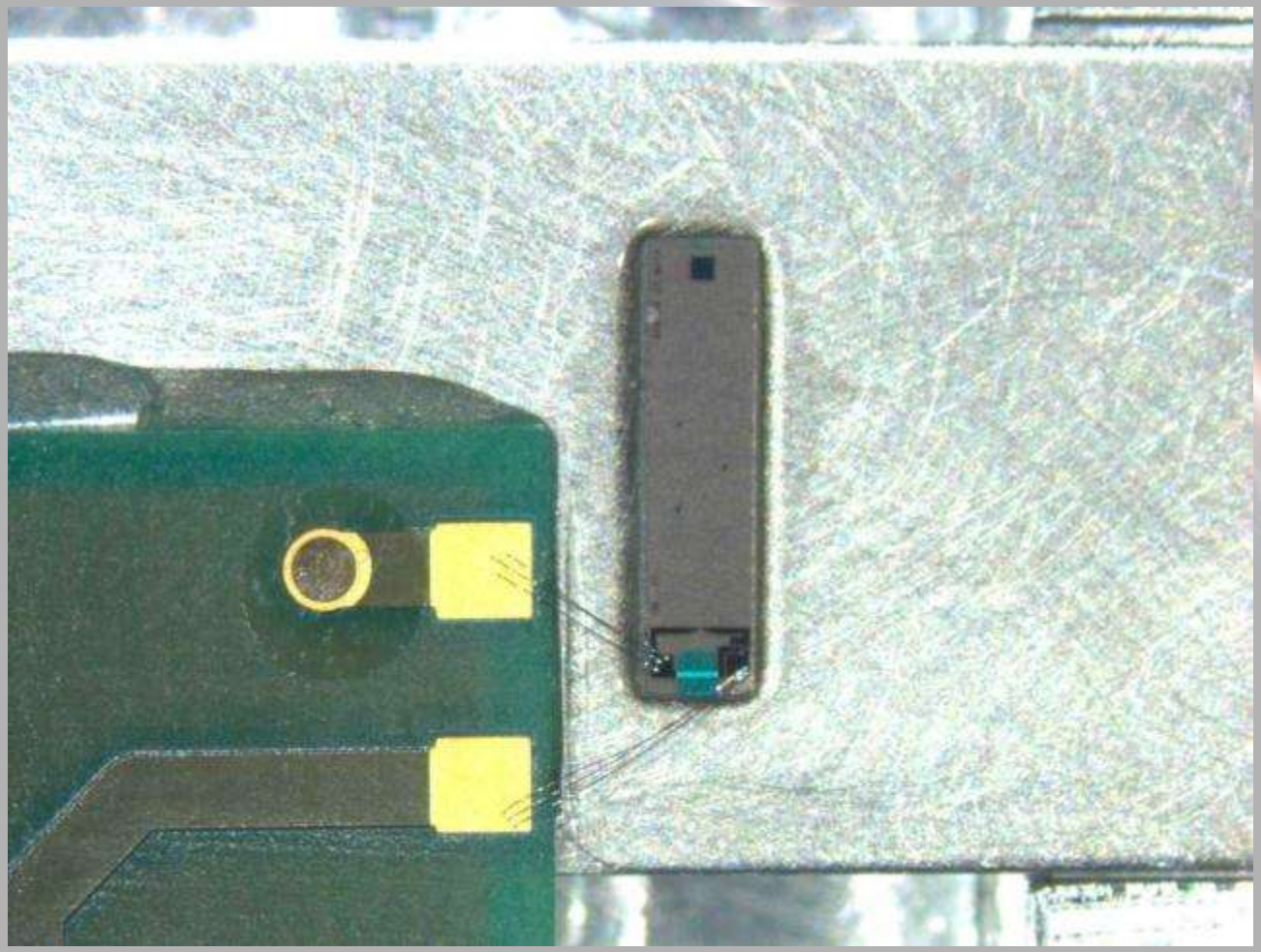
Top side with SAW sensor glued and bonded to SMA adapter

PT100 temperature sensor

Bottom side with standard strain gauge



90° alignment of the sensor to measure the lateral strain



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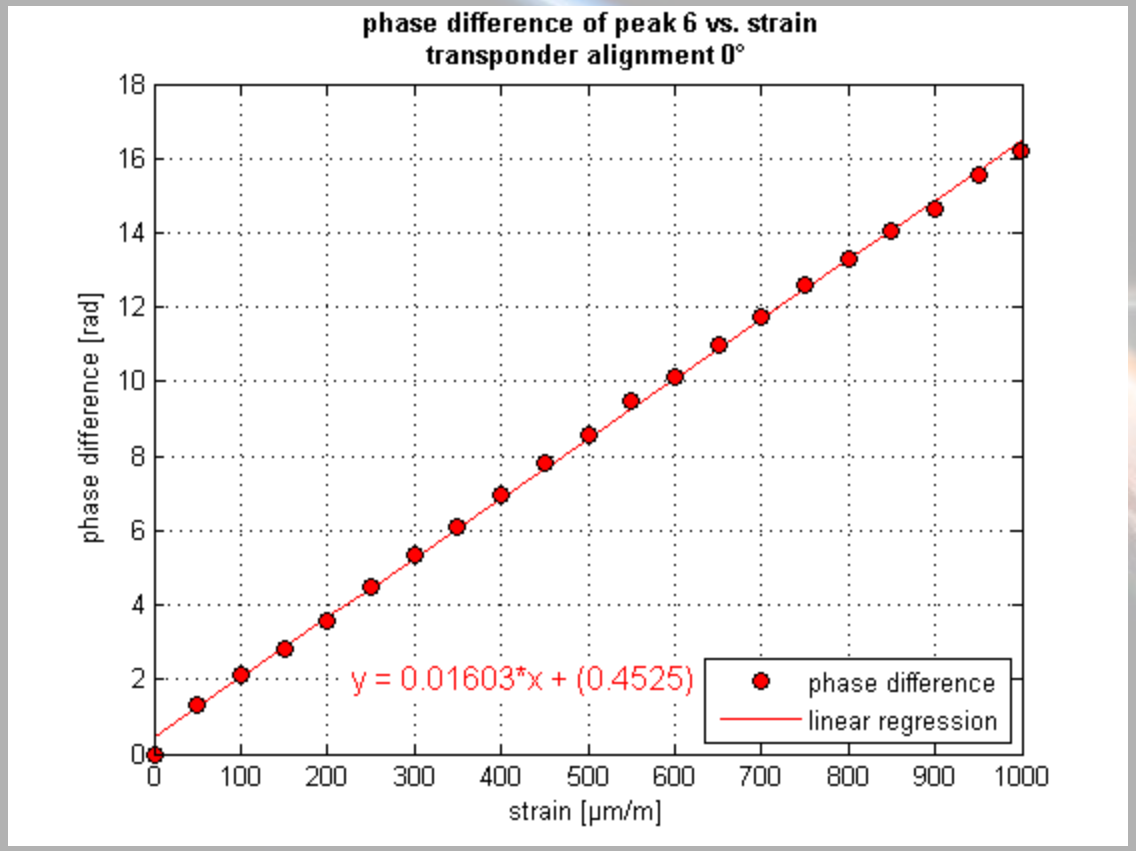

Sensitivity:

$$S_\varepsilon = \frac{\Delta\varphi}{\varepsilon_x}\left[\frac{rad}{1}\right]$$

$S_\varepsilon \approx 16.2*10^{-6}$ rad

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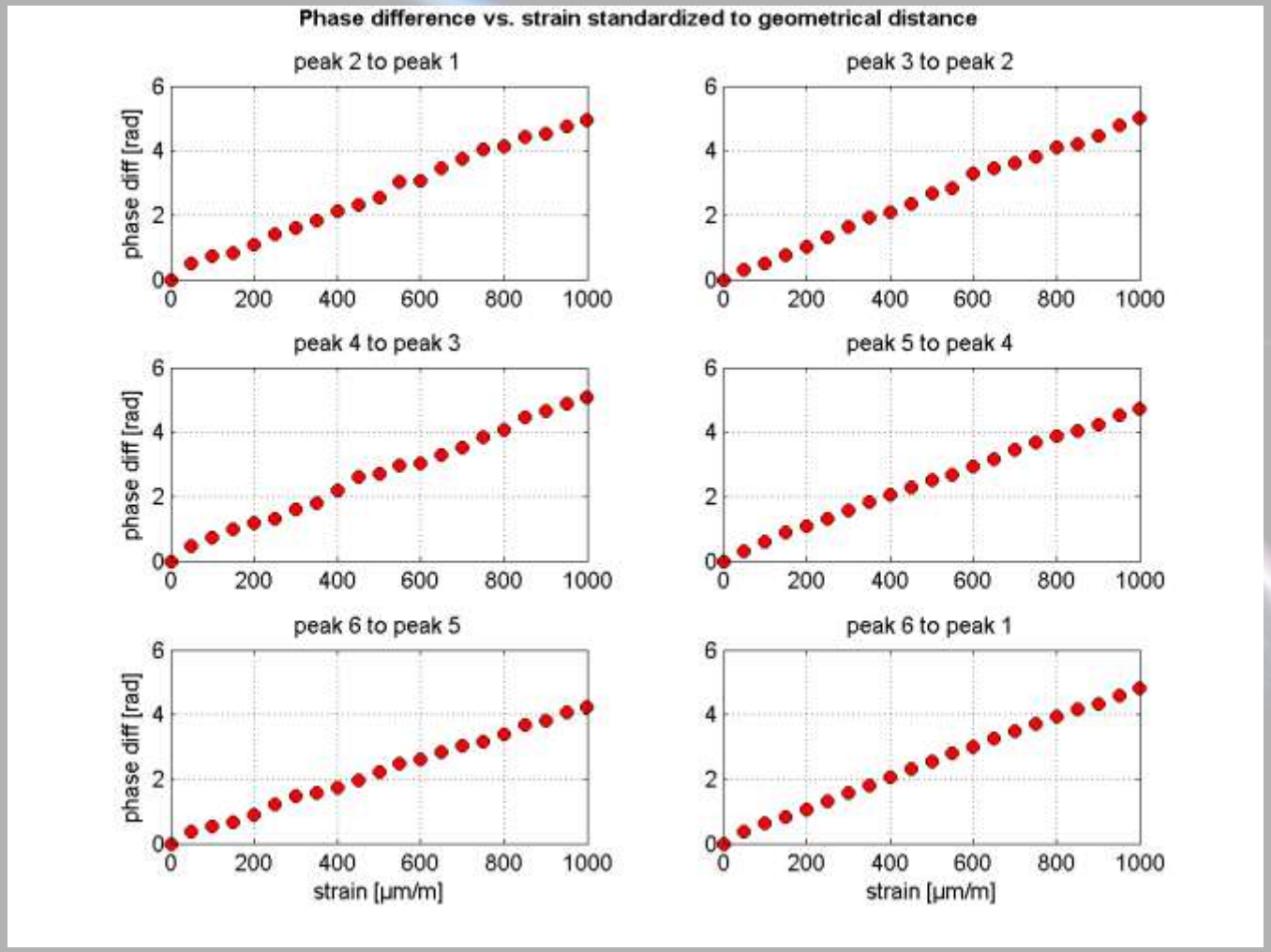
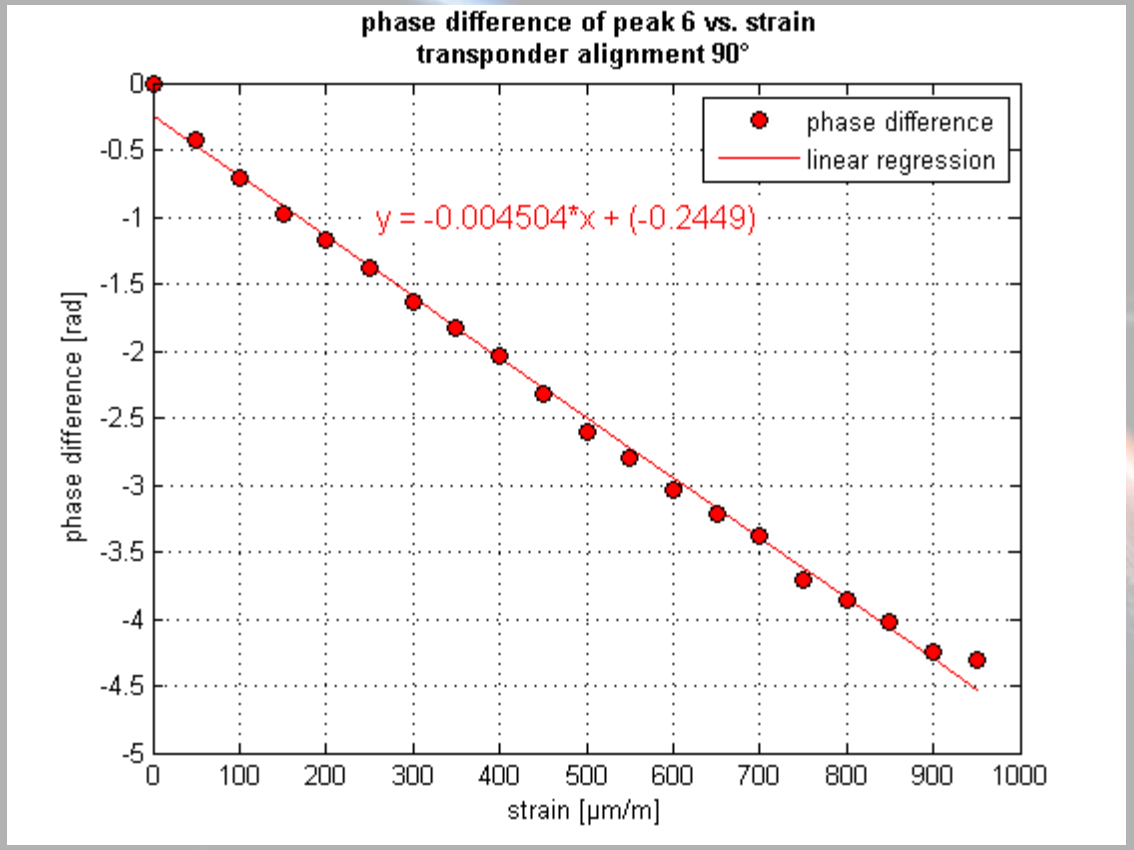


Phase difference of neighboring peaks standardized to the geometrical distance.

All curves feature nearly the same slope.

→ Uniform strain distribution over the whole reflective area!

Development of Sensors for Strain



Sensitivity:

$S_\varepsilon \approx -4.5*10^{-6}$ rad

Ratio 90°/0°:

-4.5/16.2 ≈ -0.28

Poisson ratio:

u (steel) ≈ 0.3

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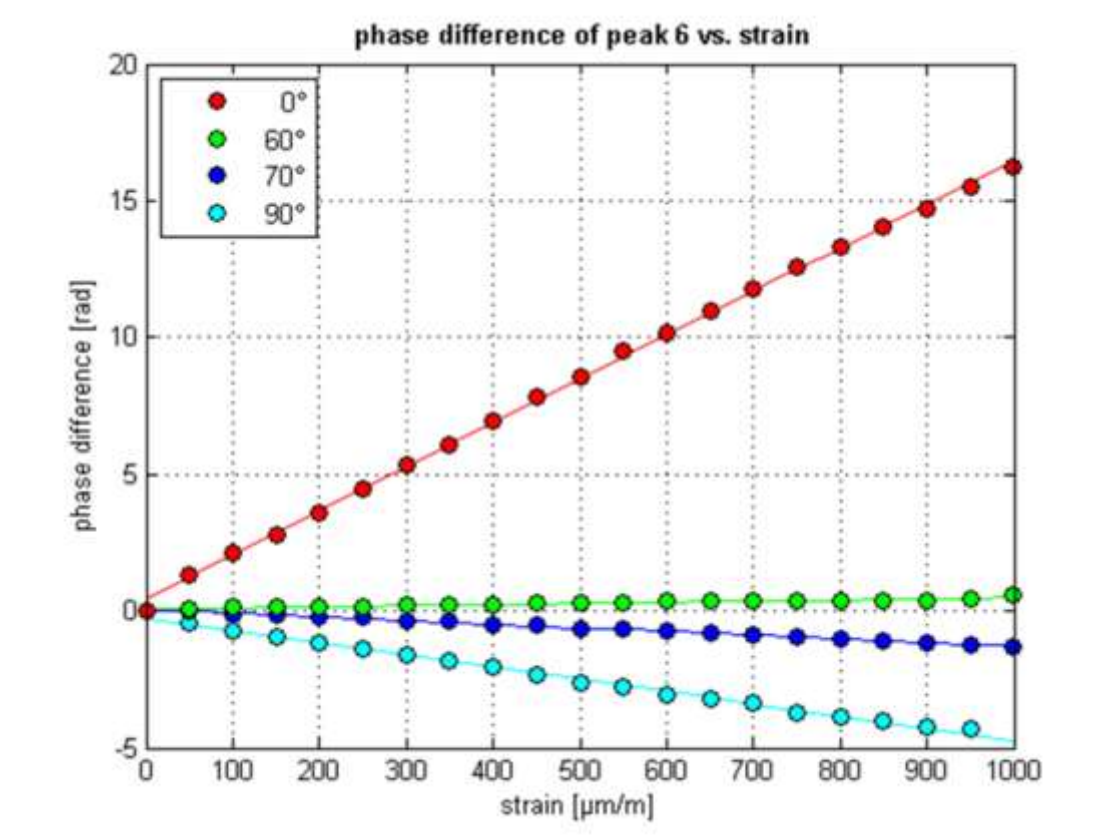

Tensile strain measurement at 0° angle
Temperatur compensation with a second chip at 60° angle

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High Temperature SAW Sensors

Objective:

Development of a wireless interrogateable SAW sensor
for a working temperature of 600°C (1112°F), 800°C (1472°F) short term.

Challenges:

- Find and test a substrate crystal capable to withstand 650°C (1202°F).
- Develop a metal thin film with long-term stability based on Platinum.
- Find and/or develop a metal or ceramic housing for this temperature regime.
- Test available high-temperature (ceramic) adhesives w.r.t. stress absorption and adhesion strength on Kovar after annealing.
- Development of different test setups for the annealing of test devices with or without housing.

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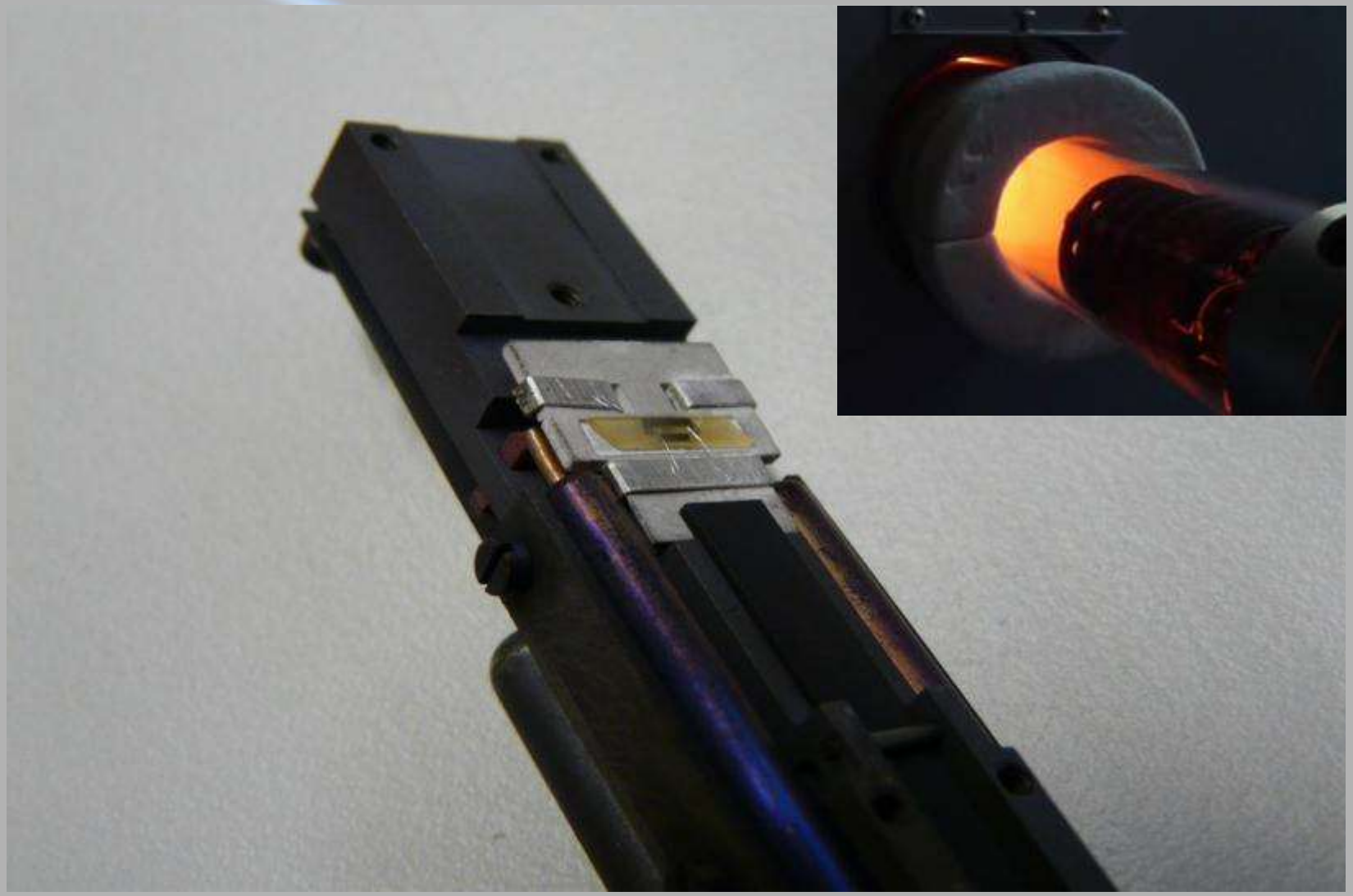

In-situ measurment setup with mounted chip (Langasite)

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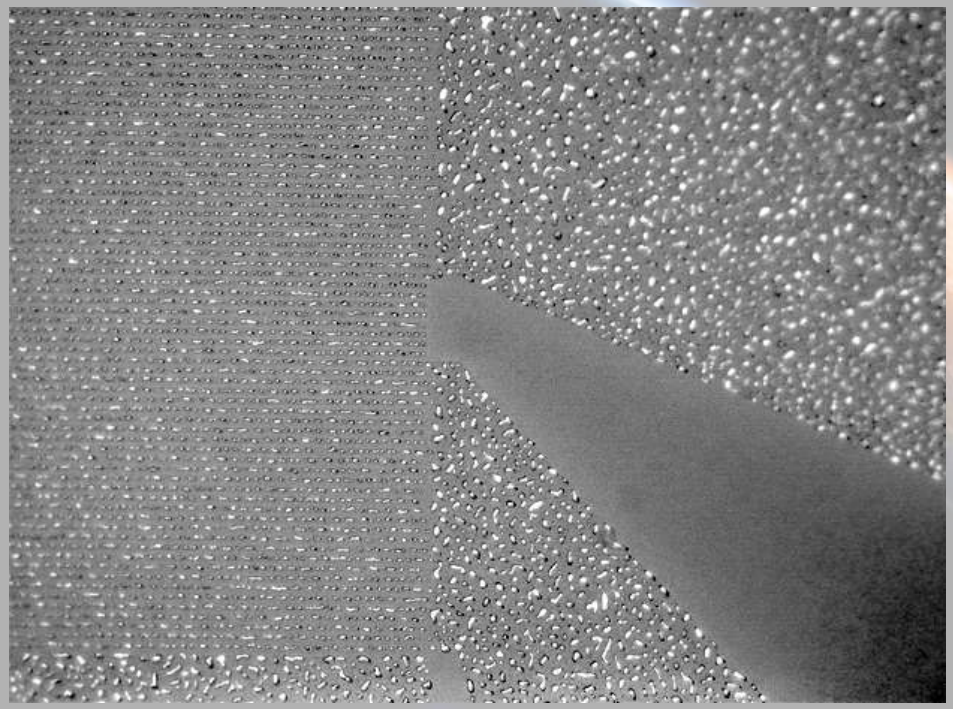

De-wetting - typical failure of metallisation layer

Tamman Temperature: $T_{Tam} \approx 0.5T^{bulk}$

Pt layer annealing @ 850°C (1562°F)

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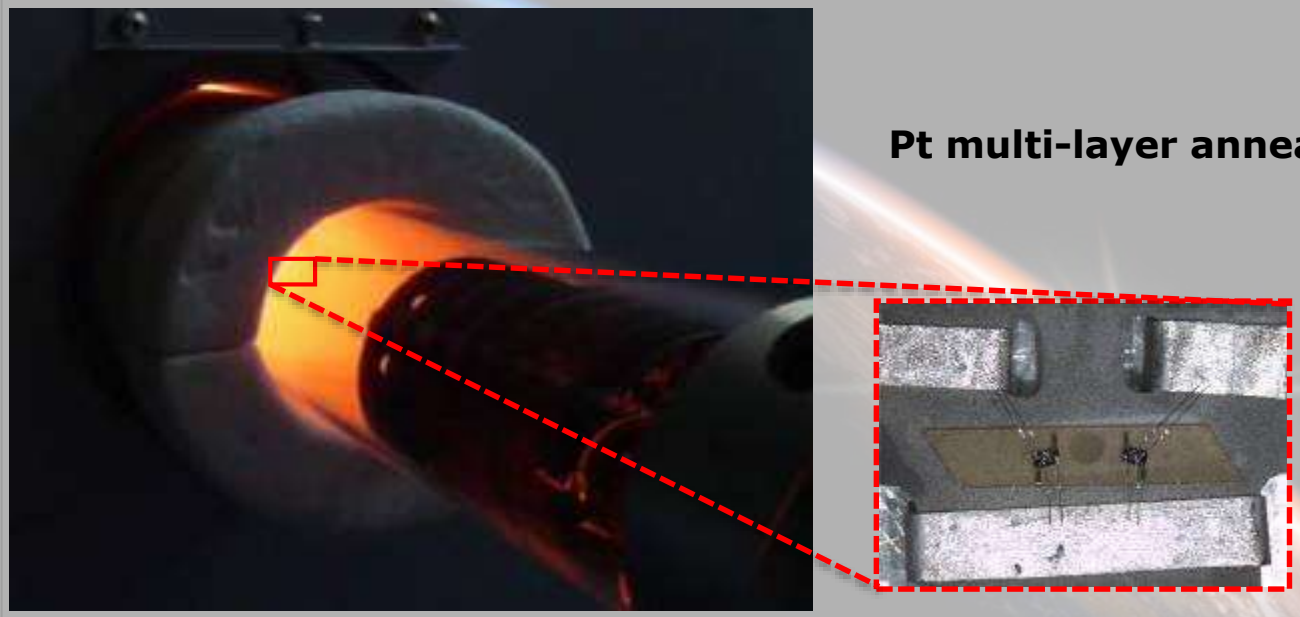
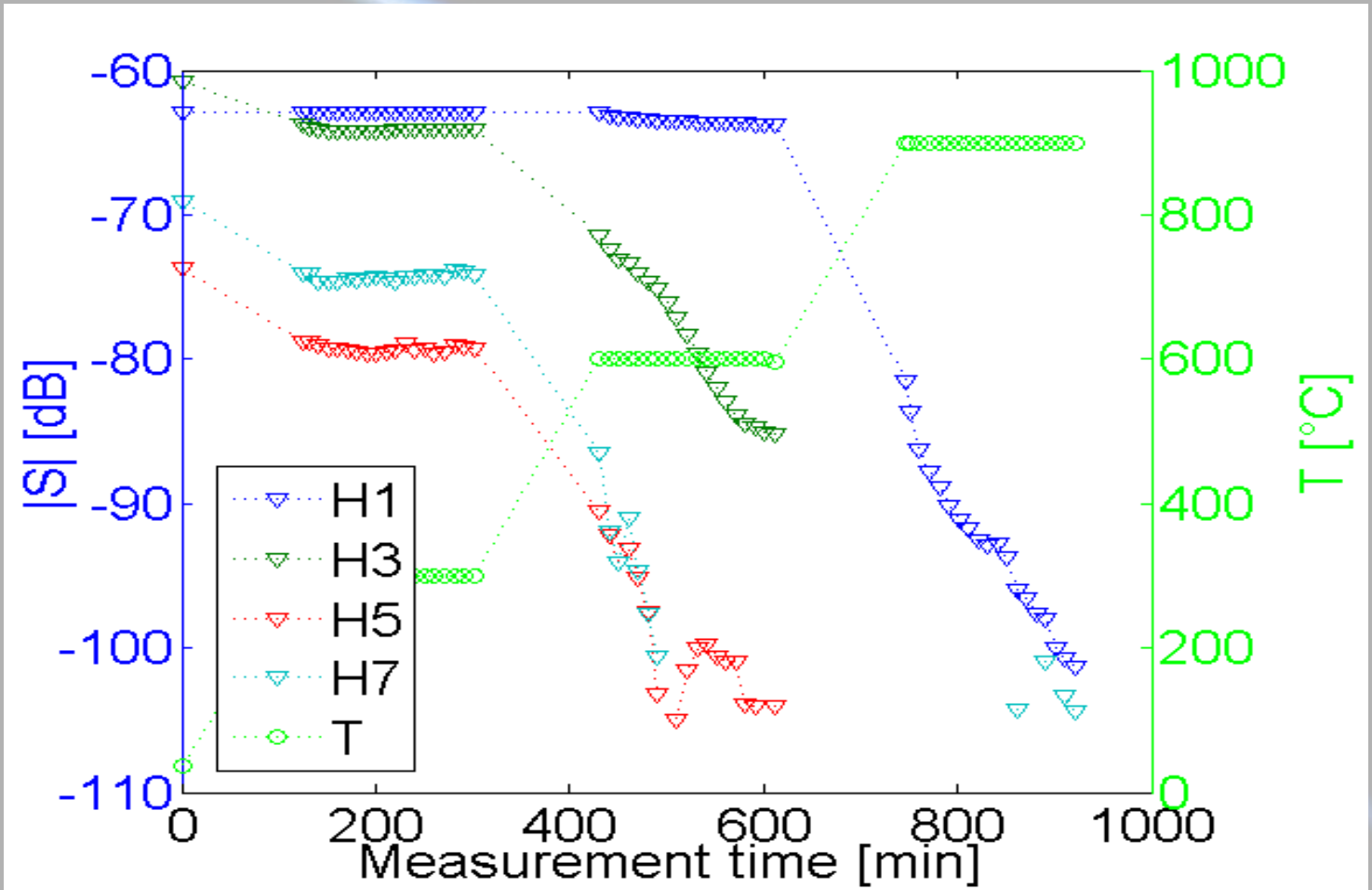


Pt multi-layer annealing @ 850°C (1562°F)

2h @ 850°C
1.2µm, 600MHz

12h @ 850°C
1.2µm, 600 MHz

53h @ 850°C
1.2µm, 600MHz



Degradation of metal layer

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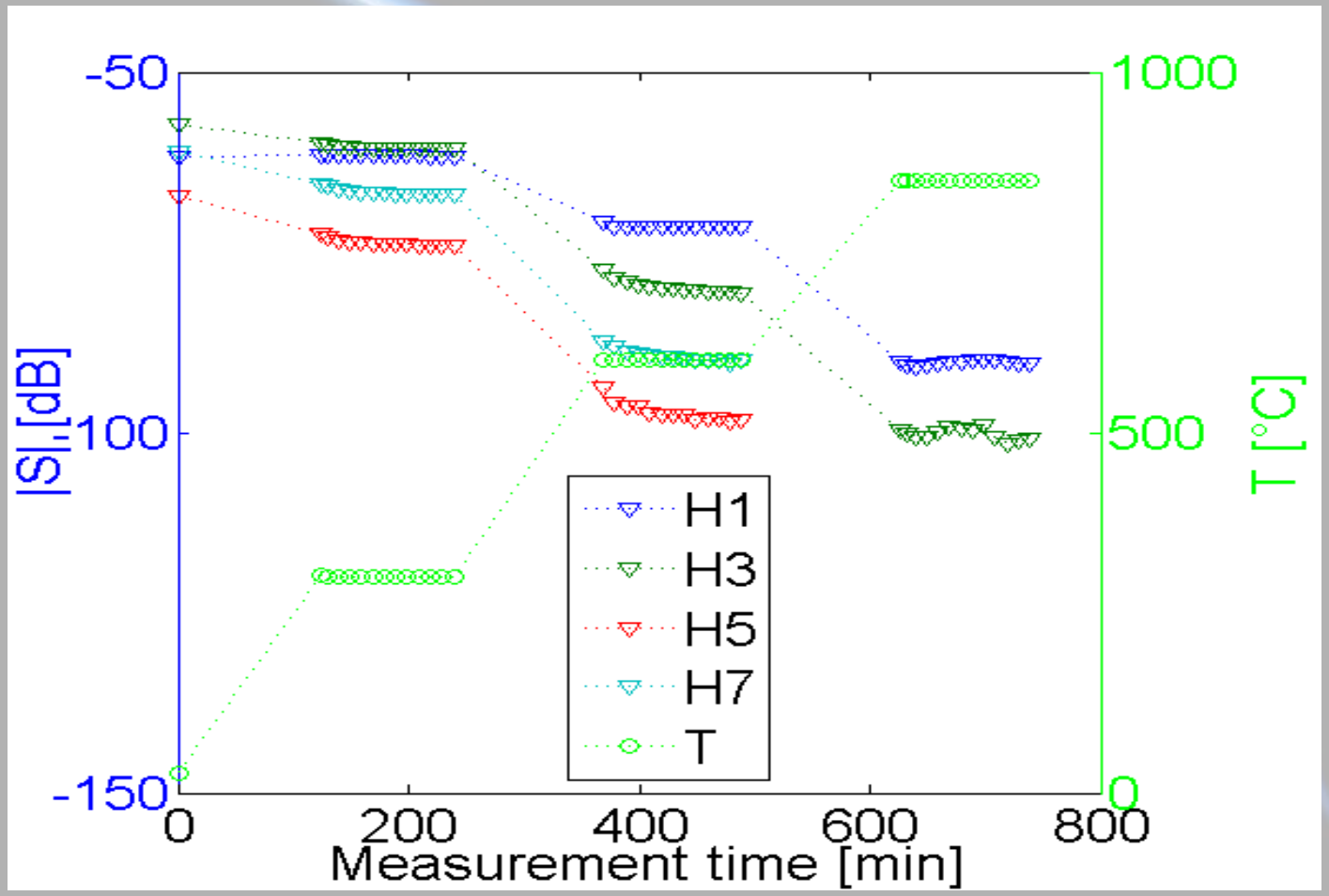
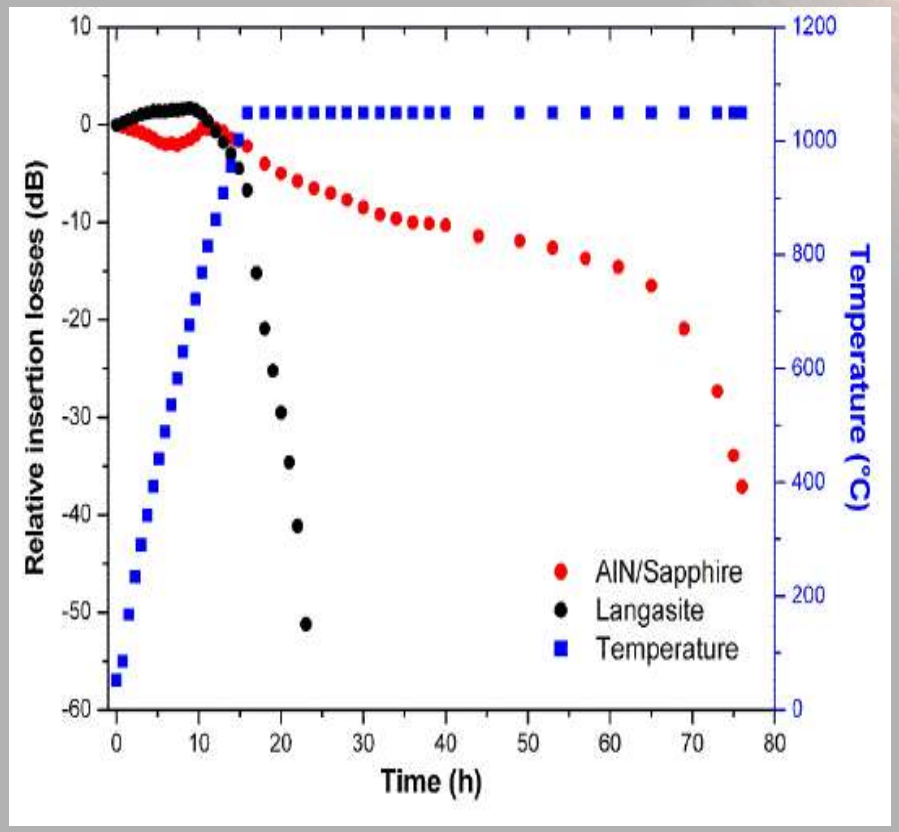


Degradation of substrate

Comparison of LGS and AlN/Sapphire



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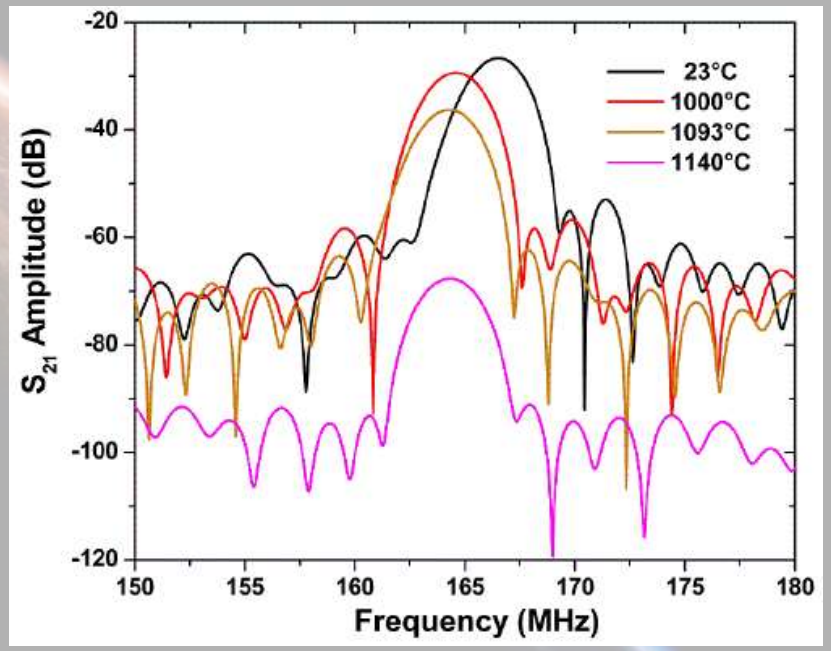
Iridium Metallisation

- Higher melting point than Pt
- Oxidation at 700°C (1292°F)
- Protective, hermetic packacke important



Test Results

- Metal layer system developed:
  - Platinum based layer system is stable up to 800°C (1472°F) (main failure mechanism: dewetting)
  - Iridium based layer system is stable up to 1000°C (1832°F) (main failure mechanism: oxidation)

- Examined substrate crystals performed as follows:
  - Langasite is stable up to 800°C (1472°F) but can be only used in the 433MHz band.
  - (Stochiometric) Lithium niobate can be used in the 2.4 GHz band, but is only stable up to 500°C (932°F).
  - First Tests of Aluminum Nitride thin film layers on Sapphire substrate show good stability up to 1100°C (2012°F) and the potential to be used in the 2.4 GHz band. To be continued as a research topic.

Test Results

- Housing and interconnection development:
  - Ceramic housings show considerable degradation of contact pads and an aggressive atmosphere inside the housing destroying the device at a lower temperature (600°C)
  - Metal housings with small ceramic feedthroughs are hardly available and lack a reliable coating process for the necessary Platinum bonding process on the contact pin.

SAW Wireless Sensors Products and Technology

Wireless Surface Acoustic Wave Sensor Symposium

Passive sensors for harsh and critical environment

SAW Symposium 2012 — Wireless Surface Acoustic Wave Sensor Symposium

Scope

The SAW Sensor Symposium is the exchange platform for research and industry to discuss the latest trends in the surface acoustic wave sensor technology. The symposium is held biennially and will take place for the second time in 2012.

Wireless SAW sensors have a wide field of application, for example RFID transponders for harsh environment, temperature sensors, pressure and force sensors and many more. The wireless SAW sensor symposium wants to build bridges between ideas and applications, between what may be possible and what has been done already. Therefore, the program covers the latest research from the academia and application-related talks from industrial end users.

With the momentum of our successful first symposium, I am looking forward to the next event with old and new attendees, novelty presentations and fruitful discussions.

Alfred Binder

mining medical engineering

Symposium Location

The symposium takes place in the heart of Carinthia. The surrounding invites you to explore the natural beauty of the mountains and lakes, historic towns and castles as well as cultural and culinary traditions. The location is also a perfect starting point for excursions to Italy (Venice, Trieste) and Slovenia (Ljubljana).

Holiday Inn/Villach
Europaplatz 1-2
9500 Villach
Austria

Participants can book their accommodation directly at the hotel; alternative proposals for accommodation are available at the symposium website www.saw-symposium.com

Registration Fee

The registration fee includes admission to the technical program, refreshments during coffee breaks, lunch and networking dinner.

€ 300,-	Early bird registration	*on or before June 15th, 2012*
€ 370,-	Registration	*on or before August 9th, 2012*
€ 400,-	Late / On-site registration	

Please use the **online registration form** on **www.saw-symposium.com/registration.** Thank you!

For further information about the symposium venue, traveling directions and registration please visit the symposium website.

Call for Abstracts

The organisers invite prospective authors to submit abstracts for lectures (10 min oral presentation / 5 min discussion) relating to the symposium topics. Authors will find all the relevant information on the symposium website **www.saw-symposium.com.** All submitted abstracts will be evaluated and accepted authors will be notified.

The deadline for the submission of abstracts is **August 9th, 2012.**

Abstracts should relate to one of the following **subject areas:**

- Potential industrial applications of wireless sensing, challenges, needs
- Wireless tracking in harsh environments
- Wireless sensors for process control quality improvement
- Recent developments for SAW sensors

Program committee:

- Leonhard M. Reindl, IMTEK, Freiburg
- Alfred Binder, CTR AG, Villach

medical engineering

Information

SAW Symposium 2012 — Wireless Surface Acoustic Wave Sensor Symposium

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We are looking forward to welcome you in Carinthia.

Online registration:
www.saw-symposium.com/registration

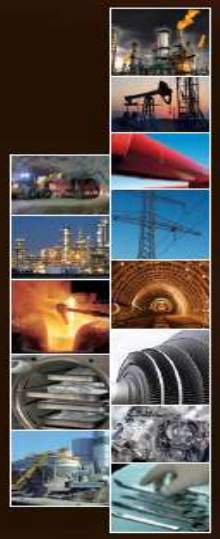
Program

Thursday, September 20th, 2012

11:00	**Registration**
11:00	**Introduction** *Alfred Binder, CTR AG, Austria*
11:10	**Genes, Talents, Chances and Innovation** *Markus Hengstschläger, Medical University of Vienna, Austria*
14:00	**Sc doped AlN: A New Piezoelectric Thin Film for SAW Sensor Applications** *Ken-ya Hashimoto, Chiba University, Japan*
14:30	**AlN/Sapphire, a promising piezoelectric structure for high-temperature SAW applications** *Thierry Aubert, Université de Savoie, France*
15:00	**Coffee break**
15:45	**Recent advances in resonator based high temperature SAW-sensing** *Bert Wall, Vectron International GmbH, Germany*
16:35	**Temperature tracking in Continuous Cast Moulds using SAW sensors** *Guido Michelon, SMS Concast, Italy*
17:15	**Acoustic Event & Dinner**

Friday, September 21st, 2012

9:00	**IC-based or SAW based wireless sensor nodes?** *Leonhard M. Reindl, Albert-Ludwigs-University of Freiburg, Germany*
9:30	**Combined Pressure, Temperature and ID Sensor** *Alfred Binder, CTR AG, Austria*
10:00	**SAW sensors for medical applications** *Peter Schlumpf, Unisensor AG, Switzerland*
10:30	**Coffee break**
11:00	**Session I** *(Call for abstracts)*
12:30	**Lunch**
14:00	**Session II** *(Call for abstracts)*
15:30	**Coffee break**
16:00	**Session III** *(Call for abstracts)*
17:00	**Closing of Symposium**



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Explore SAW Sensors from CTR!

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