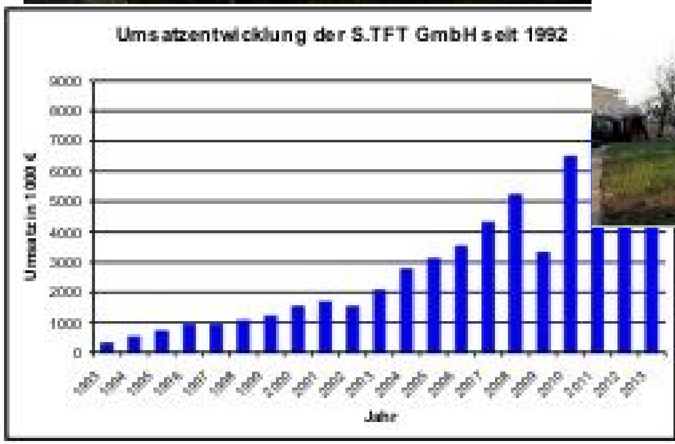
NiC: A new functional layer with high sensitivity for pressure and force sensors



Chemnitzer Seminar: „system integration technologies“

14.06.2016

SIEGERT THINFILM TECHNOLOGY

Dr. Tobias Liese

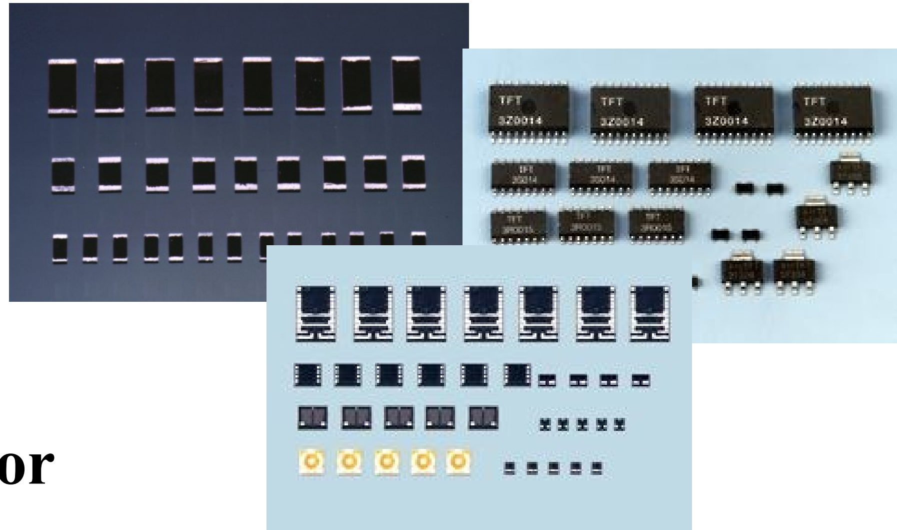
Overview

- Short introduction to products of S.TFT
  - Thinfilm resistors and resistor networks, thinfilm structures for sensors
  - Metal based pressure sensors
- NiC: new functional layer for pressure and force sensors
  - Production technology
  - Microstructure
  - Electrical parameters: gauge factor, TCR
- Sensor principles for high pressure applications
  - Metal based membrane pressure sensor
  - Membrane-free ceramic pressure sensor

Products of S.TFT

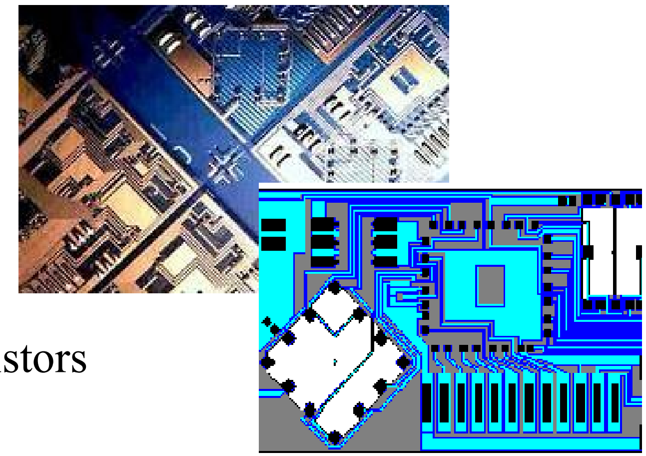
SMD high precision resistors and resistor networks

- Very small tolerances
- lowest TCR (abs. / rel.)
- Excellent long-term stability
- Standard and custom parts
- Components for high temperatures up to 260°C



High precision thin-film structures for electronics, sensors and RF applications

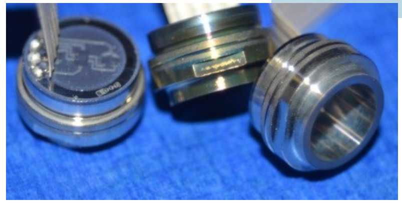
Standard substrates
    glass, ceramics (Al_2O_3, AlN), silicon (max. 8“)
Standard metallization:
    Al, Au, Cu, CrNi, Ti, Pt, ...
Standard systems:
    Flip-Chip / Chip & Wire / SMT, integrated thinfilm resistors
Structure dimensions:
    width min. 20µm, distance min. 10µm



Products of S.TFT

High precision thin film pressure sensors

- Sputtered thin film strain gauges
- Pressure range: 1,0 …2000 bar (15 … 30,000 psi)
- Static and dynamic measurements
- Excellent stability and accuracy
- Stainless steel membranes (17-4PH, Hastelloy C22, 316L, …)
- Extended temperature range up to 260°C available



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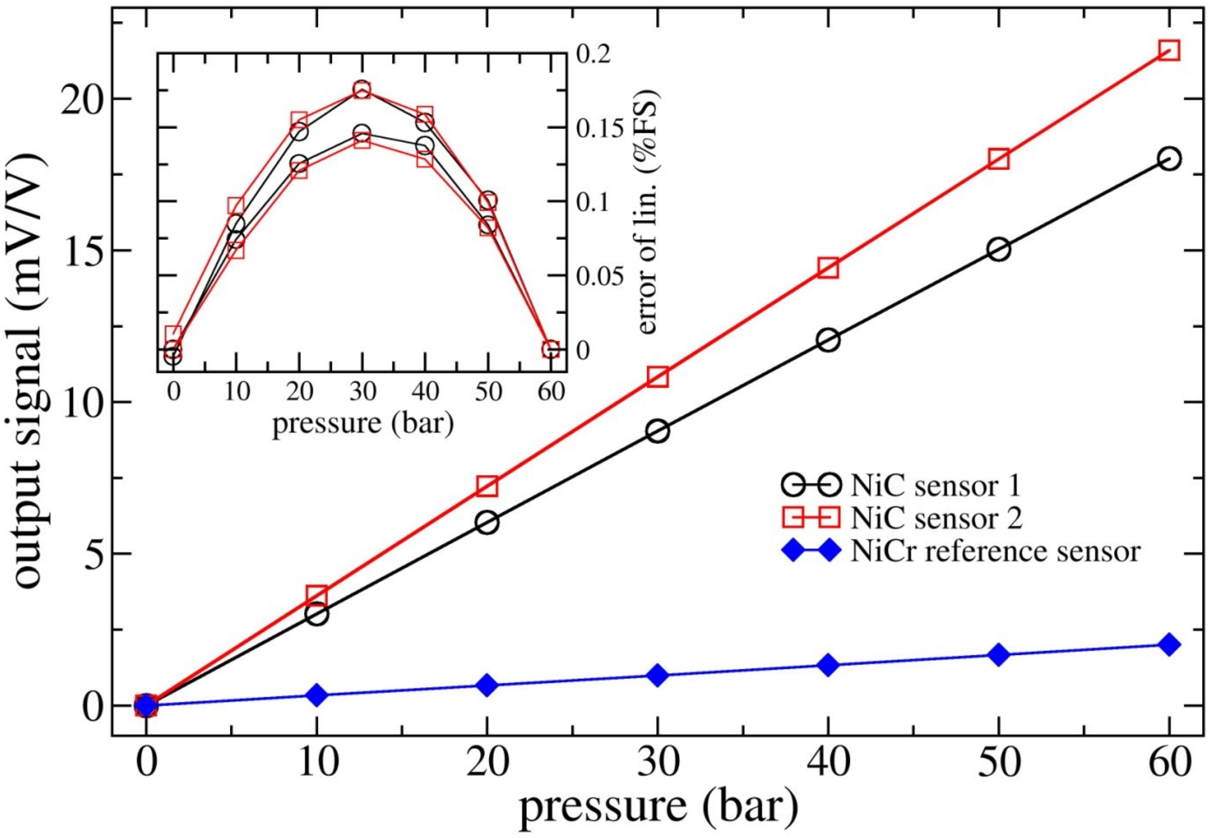
Steel membrane pressure sensors with NiC layer



Stainless steel membrane pressure sensors with thin film strain gauges:

- CrNi functional layer with 2 mV/V output
- New development: NiC functional layer with approx. 25 mV/V

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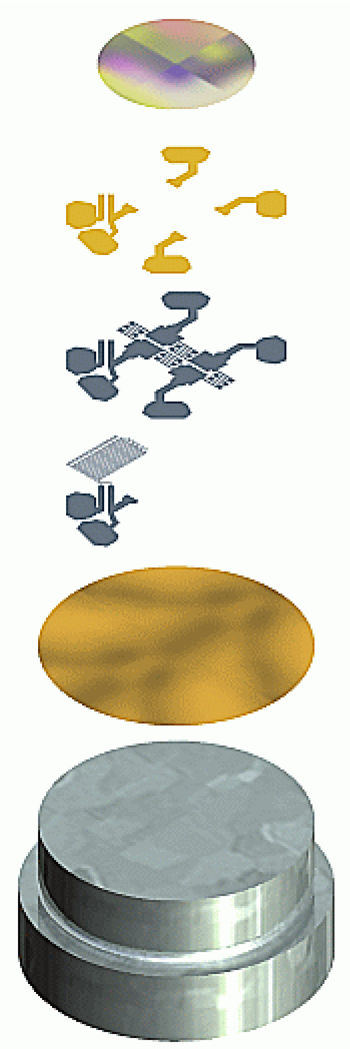
NiC-pressure sensors



→ Passivation layer (SiO_2)

→ Contact layer system (Ti / Al / FeNi)

→ **Functional layer (NiC)**

→ Temperature sensor ($CrNi\text{-}O_xN_y$)

→ Insulation layer system ([CrNi], Al_2O_3, SiO_2 / Si_3N_4-Sandwich)

base body (stainless steel 1.4542)

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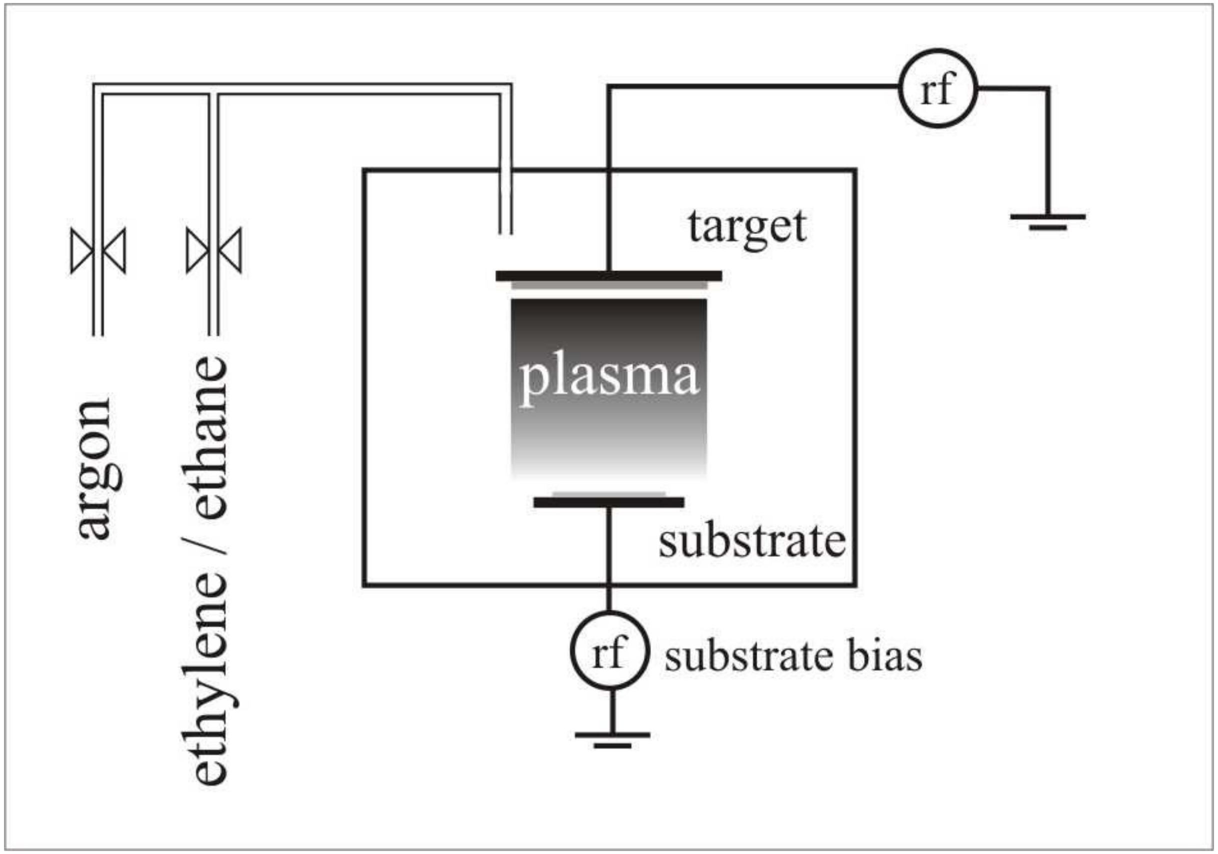
NiC thin film deposition technology



- Reactive rf-sputtering from a pure nickel target
- Argon as sputtering gas
- Carbon containing reactive gas (ethylene, ethane,…)
- **Decomposition of reactive gas**
  - ➢ **Cluster structure of thin film layer**

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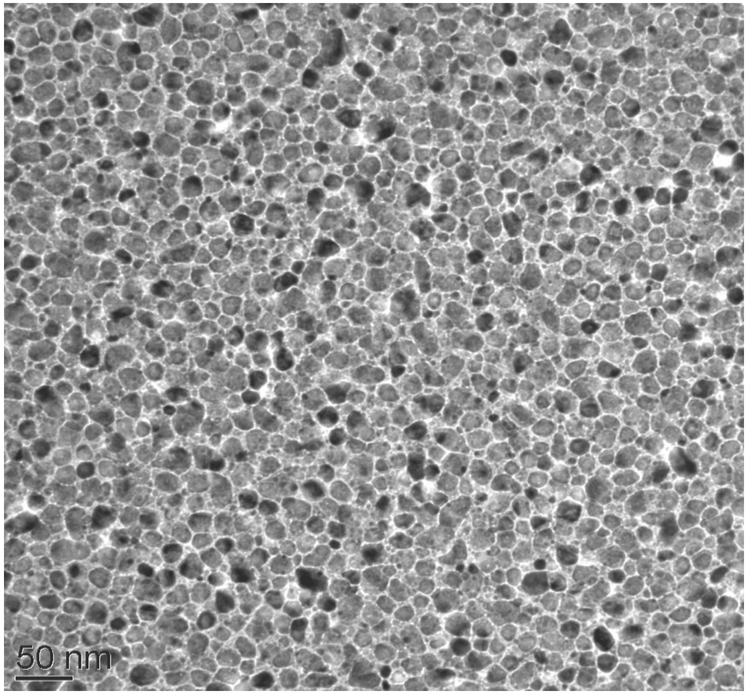
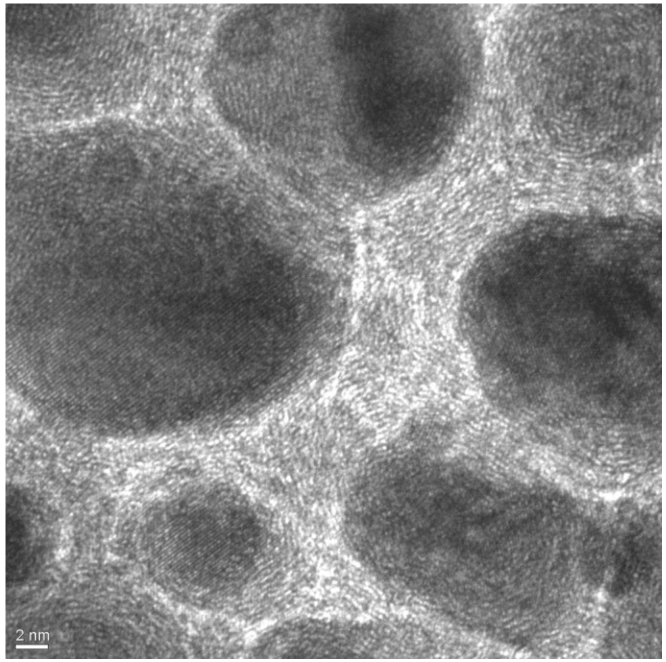
Structure of the NiC thin film layer



Nickel cluster with a diameter of approx. 10 to 25 nm in a hydrocarbon-matrix

Nickel cluster with a carbon shell of a few bended graphene layers



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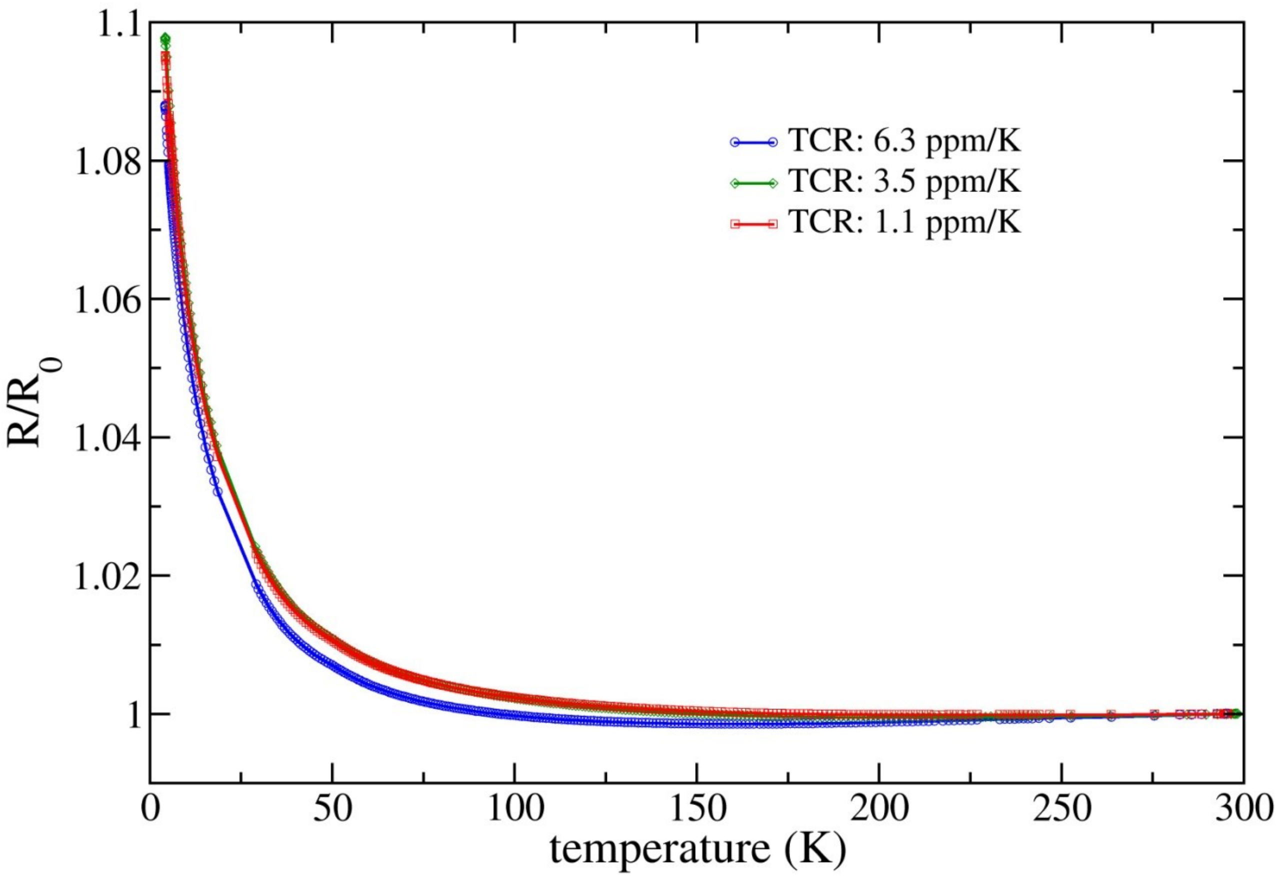
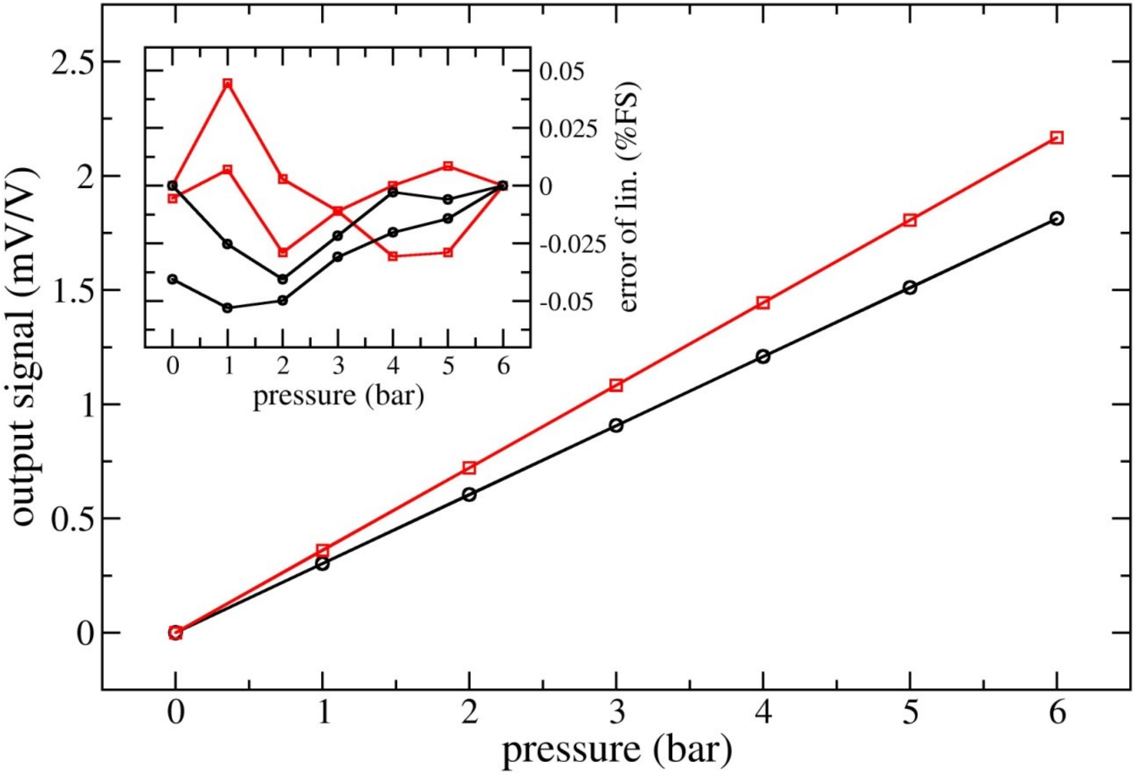
Electrical parameters of the NiC layer



- Temperature coefficient of resistance (TCR) adjustable by layer composition
- TCR is constant over a wide temperature range from 100 K to approx. 450 K
- Linear resistance characteristic within this temperature range

Application of pressure sensors with NiC-layer



- Construction of sensors with high overload resistance for a high reliability
- By restriction to 2 mV/V up to 10 times overload resistance
  - Extremely increased burst strength, resulting in high reliability
  - Lower linearity and hysteresis errors by minimal deflection of the membrane
- Steel membranes for the low pressure range

- Use of poor elastic steel like 316L for special pressure sensors applications like offshore, chemical industry, oil, gas and hydrogen

Government funded projects

NaFuSS: nano-functionalized thin film systems for sensors in the hydrogen technology (316 L steel membrane pressure sensors)

- Critical points are:
  - Diffusion through the membrane
  - Hydrogen embrittlement of the membrane material

- Very limited choice of materials
  - Materials with poor properties for pressure sensors have to be used
  - Typical mechanical stress is too high for this kind of material

➢ The use of a highly sensitive functional layer (NiC) is necessary

➢ Application of a diffusion barrier (dielectric thin film layer system of doped Al_2O_3 / SiO_2 / Si_3N_4)

Fraunhofer FEP

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Government funded projects

EFRE
EUROPA FÜR THÜRINGEN
EUROPÄISCHER FONDS FÜR REGIONALE ENTWICKLUNG

Pressure sensors for 25.000 bar

- **Development of pressure sensors for the measurement of the highest pressure range**
  - Two concepts have been implemented:
    - Classical membrane sensor (tube sensor: steel base body with a blind hole, measurement of the strain of the body)
    - Membrane-free ceramic sensor (direct pressure-sensitive functional layer)

MAXIMATOR® Maximum Pressure.

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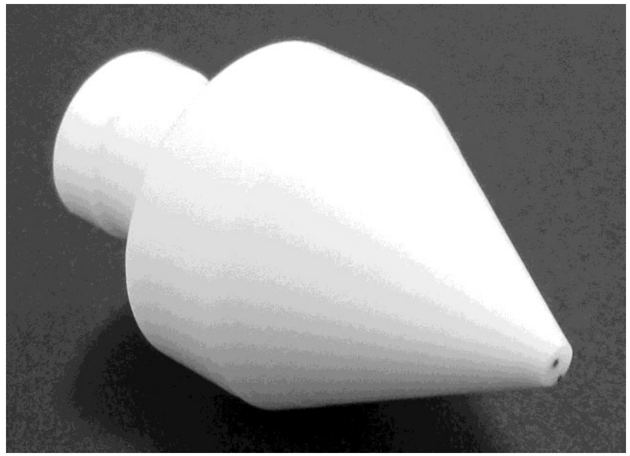

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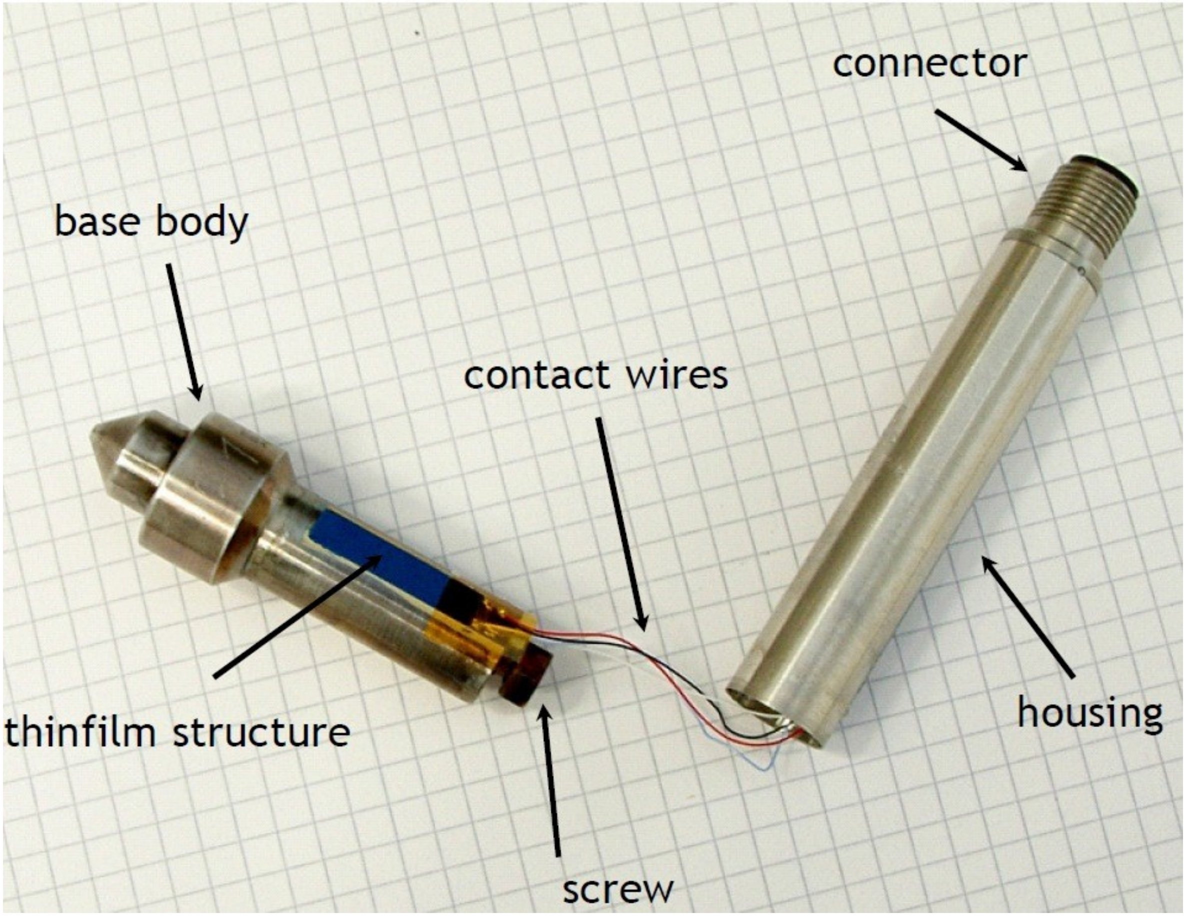
Construction of tube sensor prototypes



Tube sensors with functional layers

Housing: integrated electronics with voltage output

Direct integration possible in the overall system

Ignobly, high-strength steel causes problems in the wet chemical structuring of the thin films

Use of high strength steels needed

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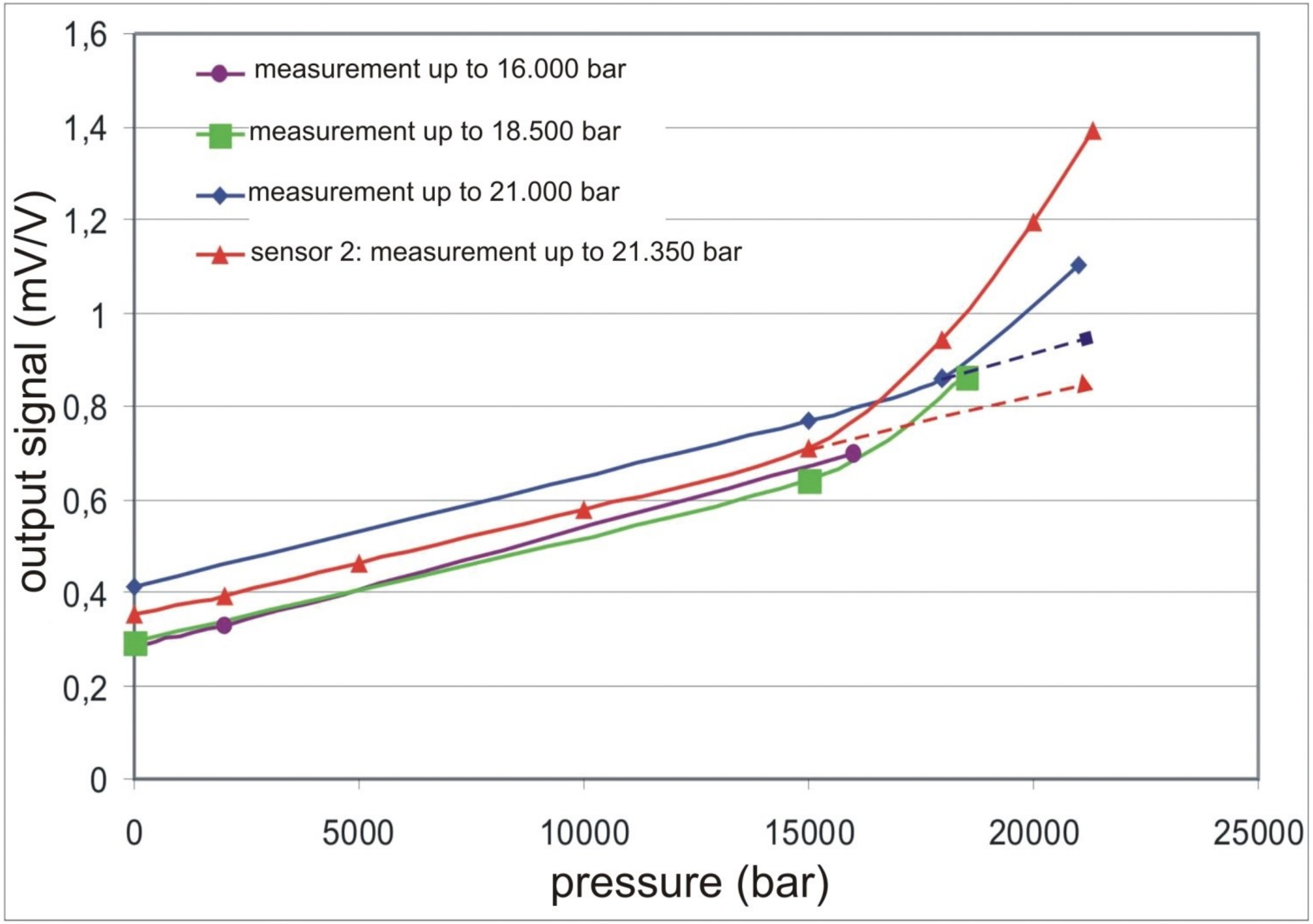
Application of tube sensors up to 21 kbar



Test run of the MFPA testing machine

Measurement up to approx. 21.5 kbar possible

Nonlinearity visible through autofrettage effect

Preload of the sensors with pressure > nominal pressure necessary

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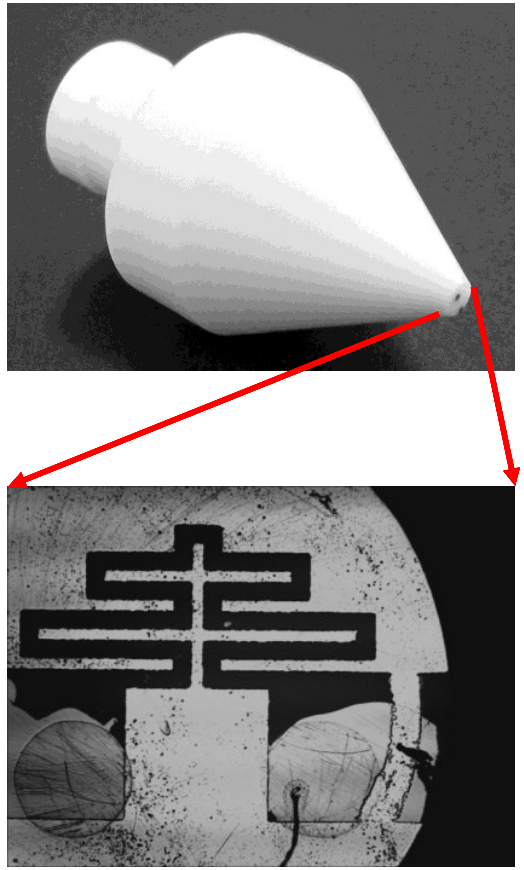
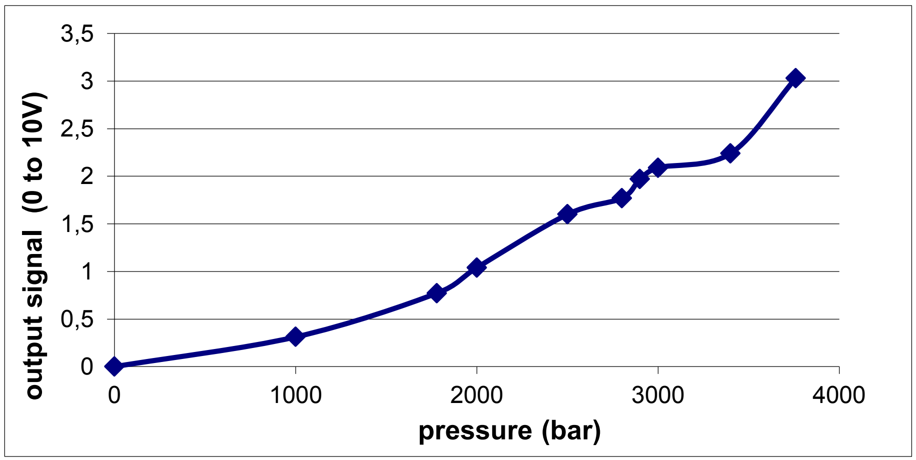
Membrane-free ceramic sensors

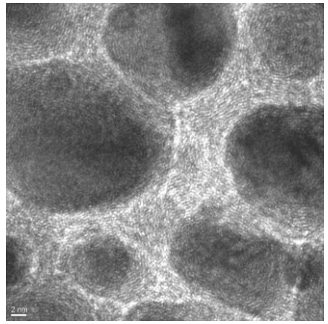
- Ceramic based body, Ø sensor surface: 1.6 mm
- Structure widths of NiC functional layer up to 30 µm
- Passivation of the surface with Al_2O_3
- Two sintered contact wires for contacting the functional layer
- Backfacing solderable contact system (CrNi, Al, FeNi)



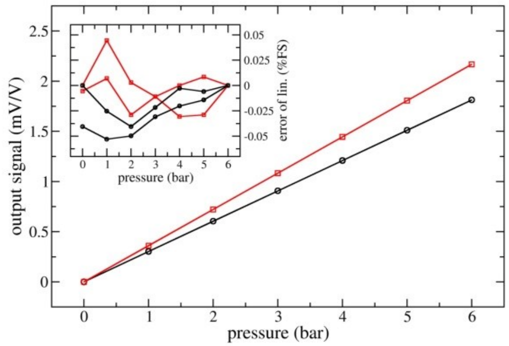


- relative high output signal with NiC
- integration problems leads to linearity errors

Summary and outlook

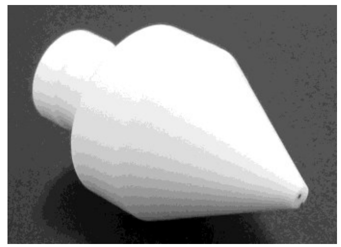


- high sensitive NiC functional layer
- preparation and characterization
- special sensor applications
  (lower/higher pressure range, poor elastic steels)



Outlook:

- development of NiC pressure sensors < 1 bar
- pressure sensors for hydrogen applications
- investigations in upper pressure range with standard base bodies (8000 bar)



Thank you
for your attention!

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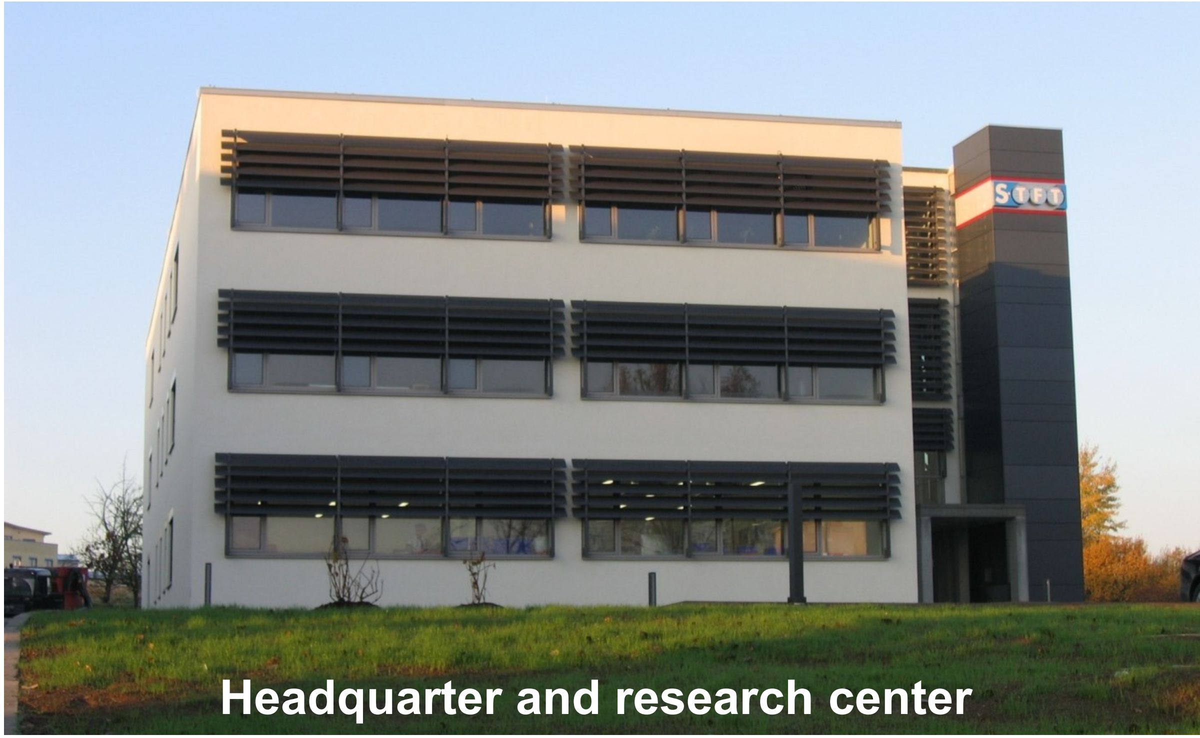

Headquarter and research center