Smart Systems for Industry 4.0

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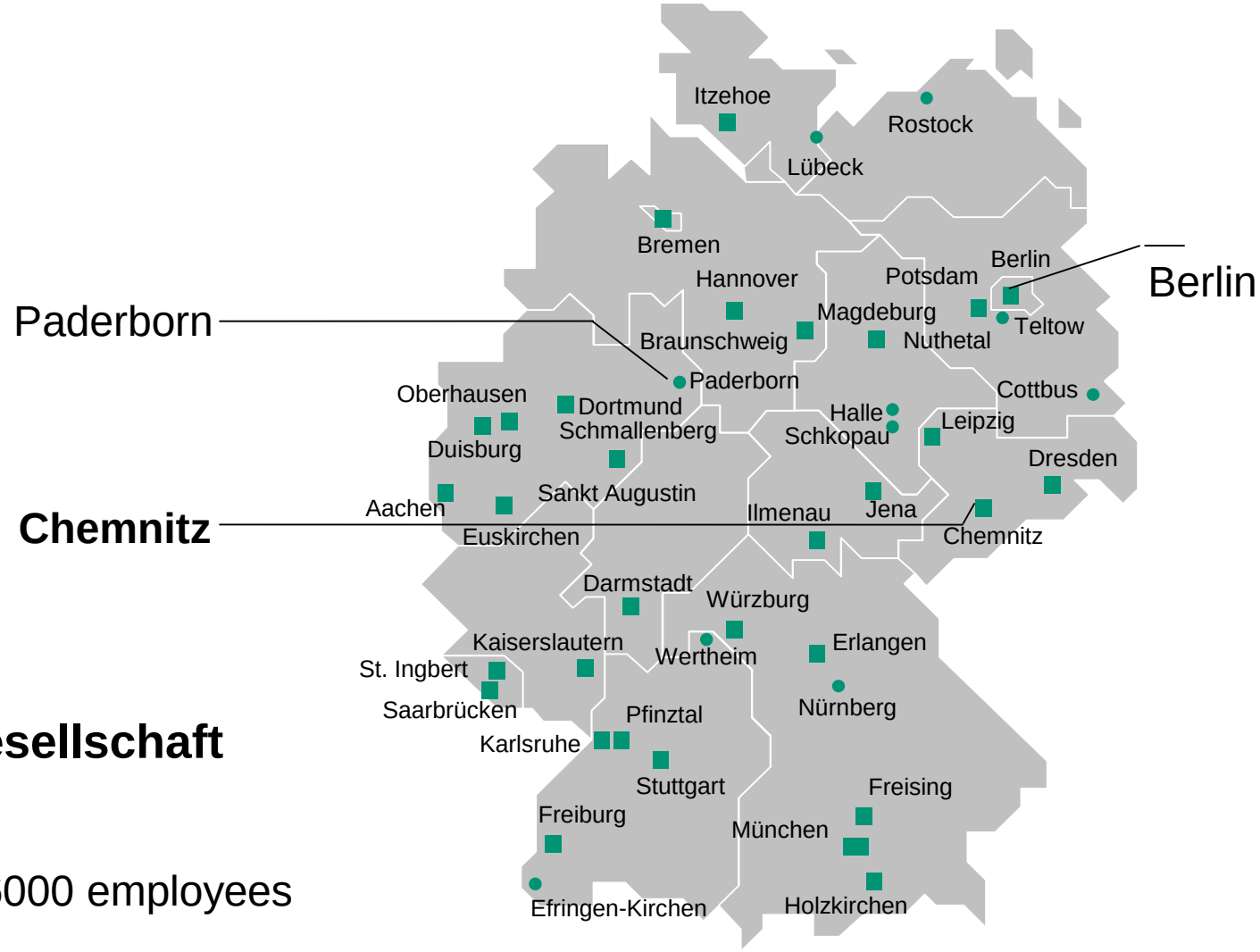
Outline

1. Working fields Fraunhofer ENAS
2. Industry 4.0 – general trends
3. Hybrid sensors and sensor systems for Industry 4.0
4. Lighthouse project Go Beyond 4.0
5. Spectroscopy - application in agriculture monitoring
6. Summary

Locations Fraunhofer ENAS



Fraunhofer-Gesellschaft

- 72 institutes
- more than 26000 employees

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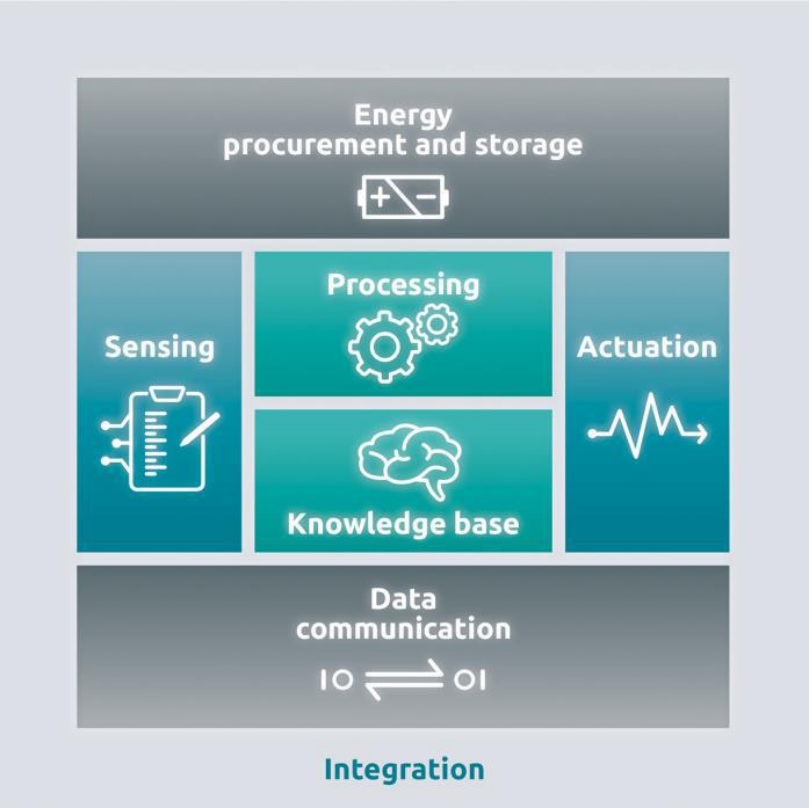
Main Working Field - Smart Systems Integration

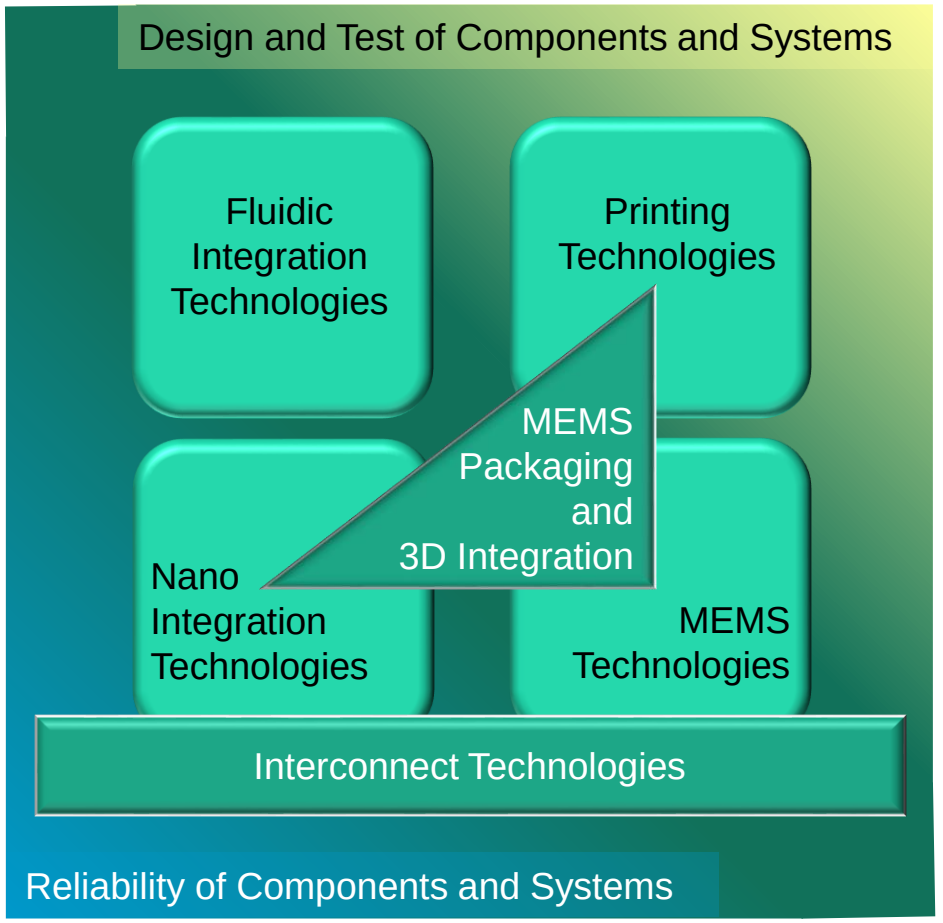
- Self-sufficient intelligent technical systems or subsystems with advanced functionality
- Bring together sensing, actuation and data processing, informatics / communications
- Autonomous systems
- Highly reliable, often miniaturised, networked, predictive
- Their operation being further enhanced by their ability to mutually address, identify and work in consort with each other

→ Basic components for Internet of Things



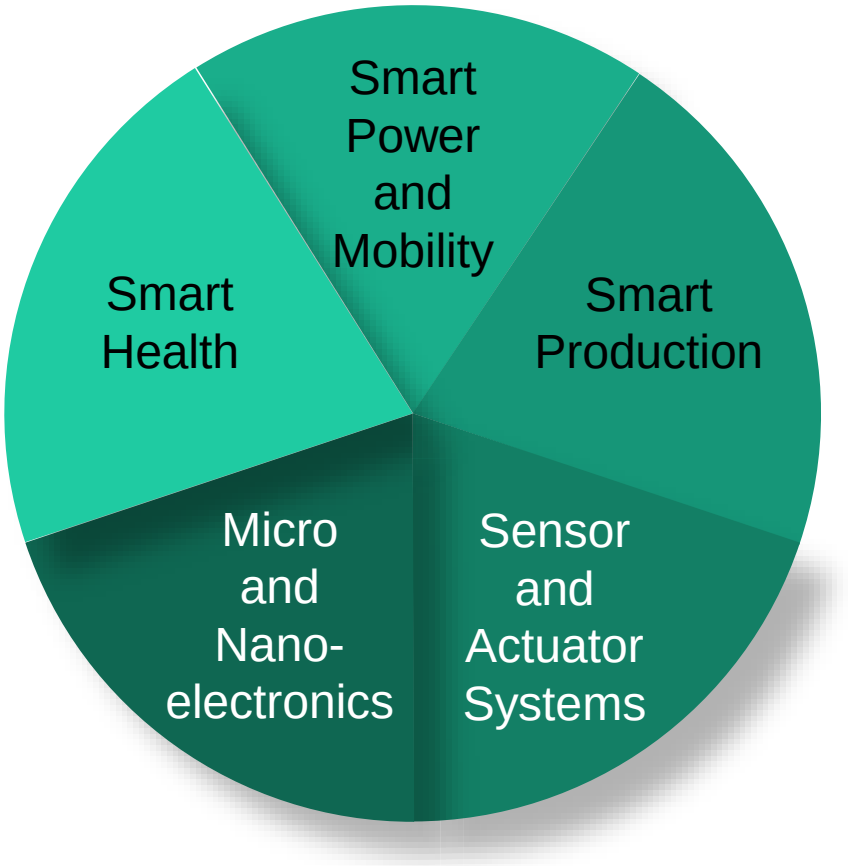
Core competences

- Based on the core competences - research and development services starting from idea, via design and technology development, realization based on established technologies, up to prototype or demonstrator (transfer to industry)
- High-performance/ high-precision sensors and actuators
- Microfluidic systems and biosensor integration
- Printed functionalities
- Sensors and actuator systems with control units, integrated electronics, embedded software and user interface for application in different branches



Business Units

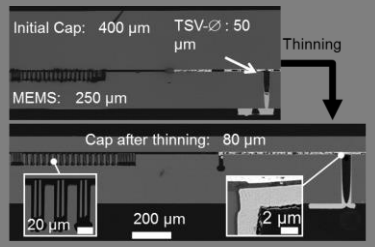
- Three application oriented business units
  - Technologies and systems for Smart Power and Mobility
  - Technologies and Systems for Smart Health
  - Technologies and Systems for Smart Production
- Two business units related to technologies
  - Micro and Nanoelectronics
  - Sensor and Actuator Systems

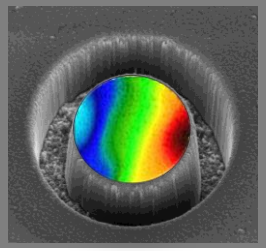


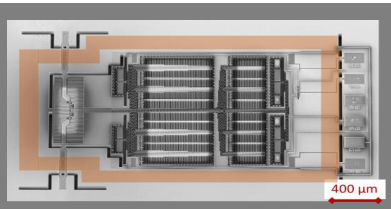
Technology-oriented business units

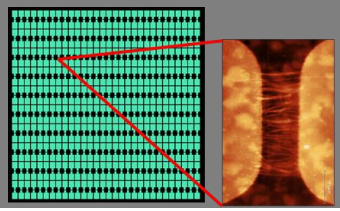
Micro and Nanoelectronics

- Back-End of Line and Interconnects
- Modeling and Simulation
- Beyond CMOS and RF Devices
- Integration and Packaging
- Characterization and Reliability



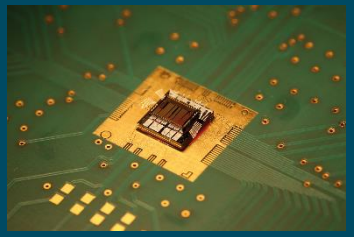


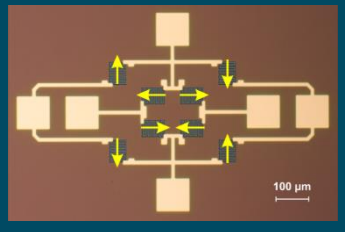


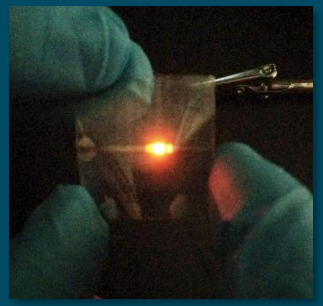


Sensor and Actuator Systems

- Inertial Sensors
- Pressure and Power Transducer
- Material and Structure Sensors
- Optical Systems/MOEMS
- Electromagnetic Sensors







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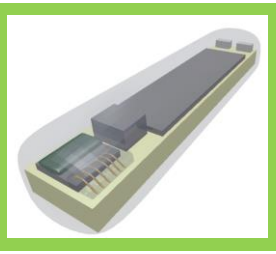
Application-oriented business units

Technologies and systems for Smart Power and Mobility

- Network Monitoring
- Reduction of Power Consumption
- Power Supply
- Electromobility

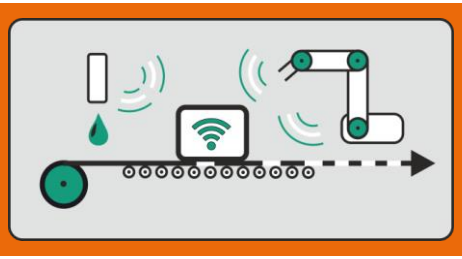
Technologies and Systems for Smart Health

- Microfluidic and Spectroscopic Analysis
- Medical Devices
- Implants



Technologies and Systems for Smart Production

- Smart Digital Production
- Sensor Systems for Process and Condition Monitoring



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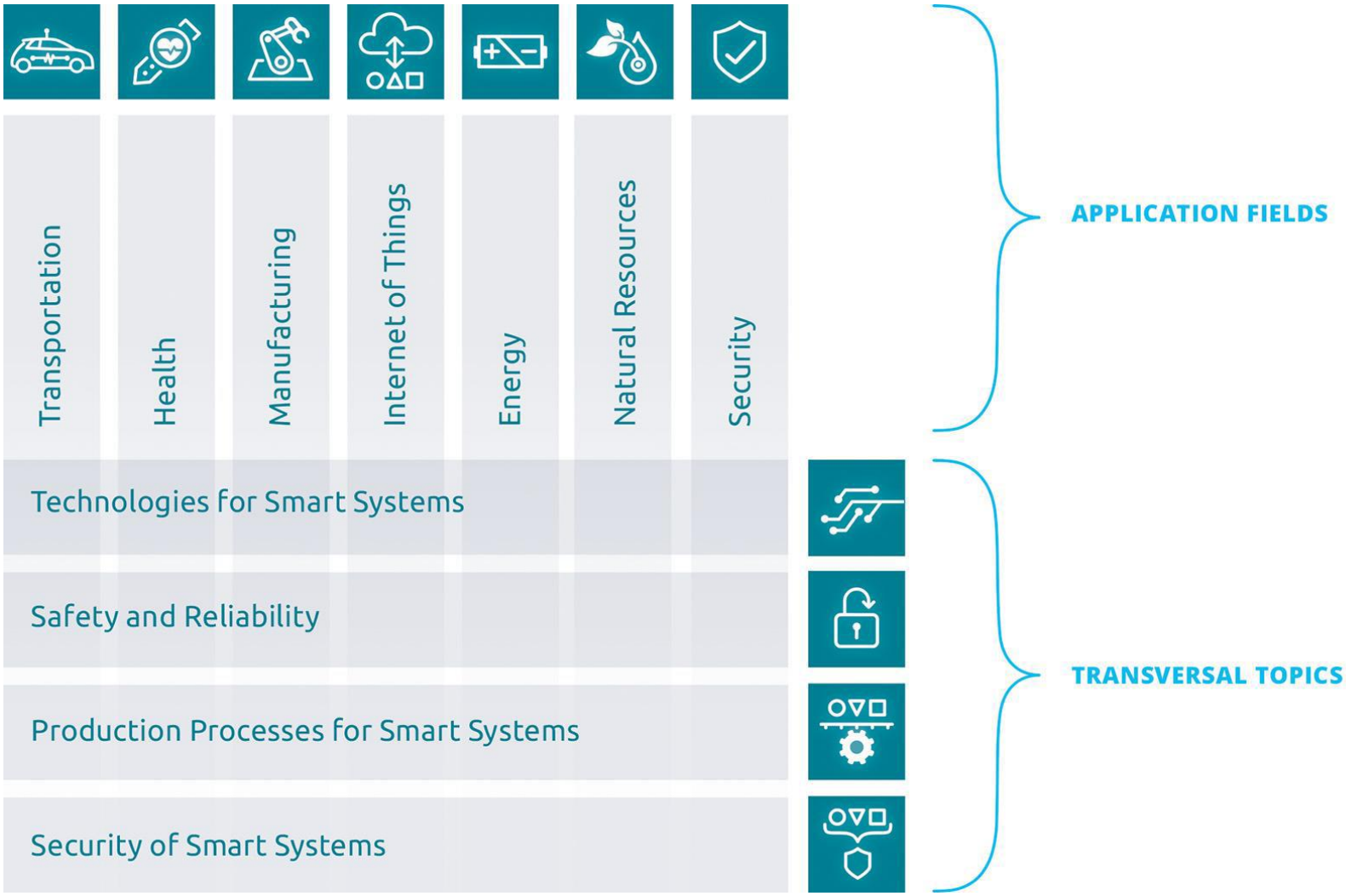
Smart Systems – Application Fields



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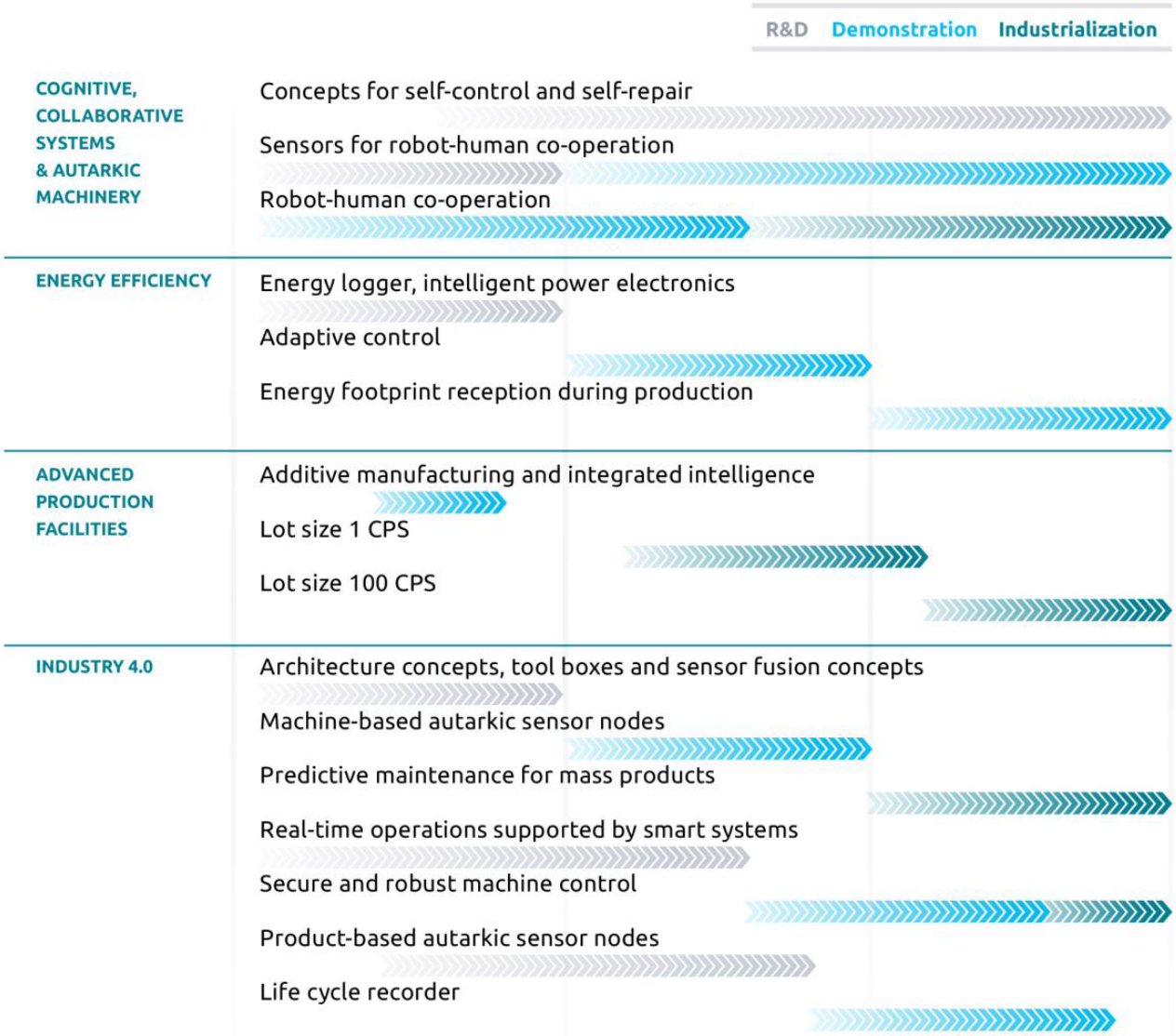
Roadmap Topic: Manufacturing/Factory Automatition



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Technologies and Systems for

Smart Production

Automation and Digitization of Production (Industry 4.0)

Sensor systems supporting production

Process control in mechanical engineering

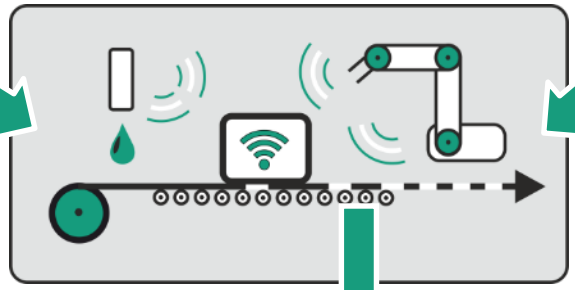
- Process monitoring
- Process optimization
- Condition monitoring

Smart digital production

Transition to flexible production

Series production of lot size 1

Digital production



Individualized products

Supporting topics

Specific ressources

- Reliability of components and systems
- Wireless data and power transmission

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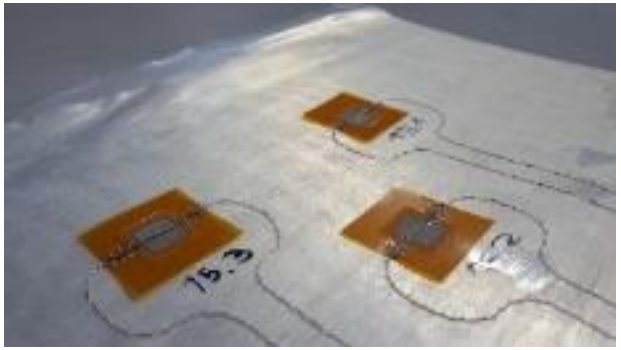
Nanocomposite Humidity Sensors

General:

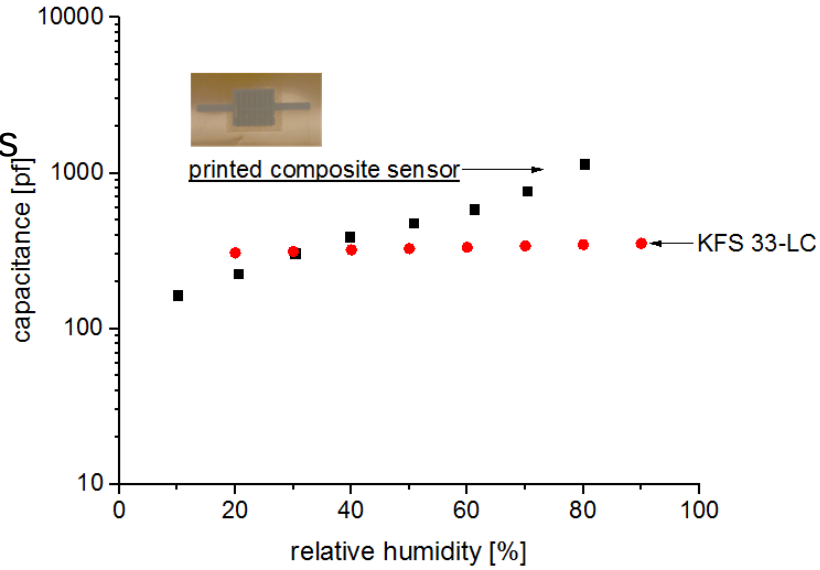
- Printable humidity sensors based on polymeric micro- and nanocomposites
- Very high sensitivity – up to 35 pF / % r.h.
- Response times in the range of 15 - 20 sec (comparable to commercial sensors)



Backstitched screen printed humidity sensors

Benefits:

- Low cost – high sensitivity
- Easy production (e.g. printing), also on flexible substrates
- Easy scale-up / arrangement of multi sensor arrays for detection of moisture distributions
- Wireless readout capability



Applications:

- Air humidity determination in buildings, warehouses, …
- Detection of leakage of containers or packages
- Detection of cracks and water penetration into lightweight structures

Technology Readiness Level: 4

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MEMS fluid sensor

General:

- Sensor for fluid quality measurement
- Viscosity range 5 cP… 100 cP
- Density range: 0.65 … 1.50 kg/l
- Dielectric constant range: 1.0 … 6.0
- Temperature range: -40°C…150°C

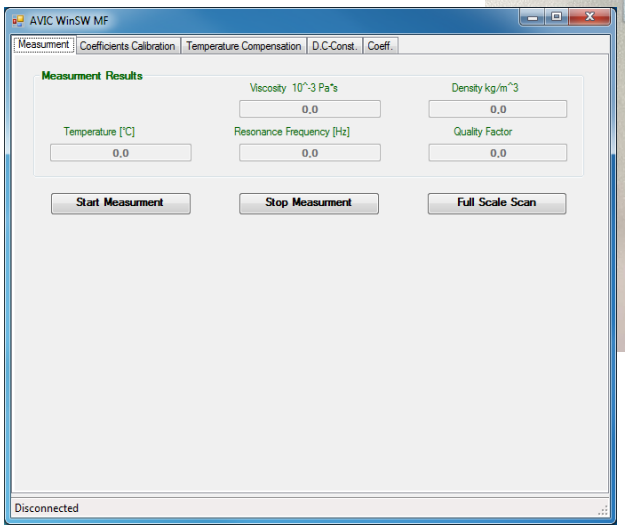
Working principle:

- Silicon resonator interacts with the fluid
- Evaluation of resonant frequency and damping to determine the fluid properties

Applications:

- Oil quality measurement
- Chemical industry
- Food industry
- Test of fuel

Technology Readiness Level: 6



Screen shot of the user interface

MEMS sensor and electronics in mechanical adapter

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iSeal

General:

- Integration of autarkic sensors into a shaft seal to monitor both sealing function, temperature, rotational speed.
- Intelligent shaft seal is made up of subassemblies for sensing, signal processing, radio transmission, and an energy converter for autarkic operation

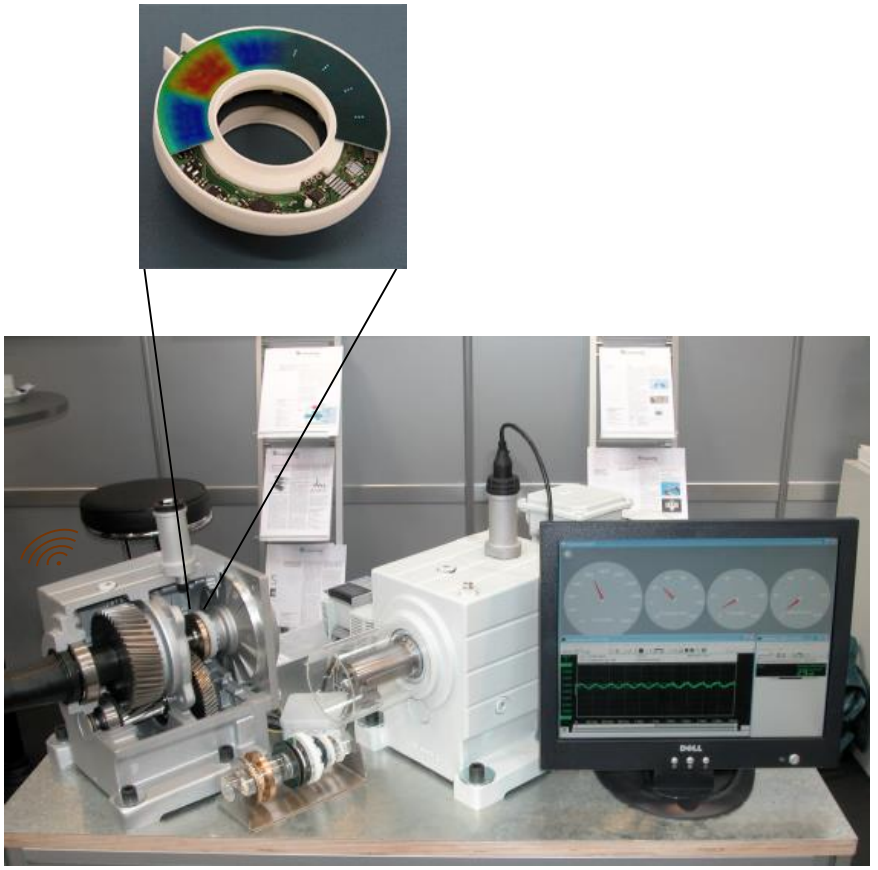
Benefits:

- ensures a trouble-free working of the machine,
- avoids cost-intensive down time or failures

Applications:

- Online monitoring of shaft seals inside gearbox
- Online monitoring lubricants inside gear box

Technology Readiness Level: 6



iSeal inside gear box

Structure-integrated, wireless sensor / actuator technology in machine construction

General:

- Sensor ring with integrated force and temperature measurement:
  - Forces up to 11 kN
  - Resolution < 5 N
  - Data Rate 10 SPS
- Vibration sensor:
  - Frequency range: 10 Hz to 20 kHz
  - Analog and digital signal output
  - MEMS sensor and ASIC in one housing

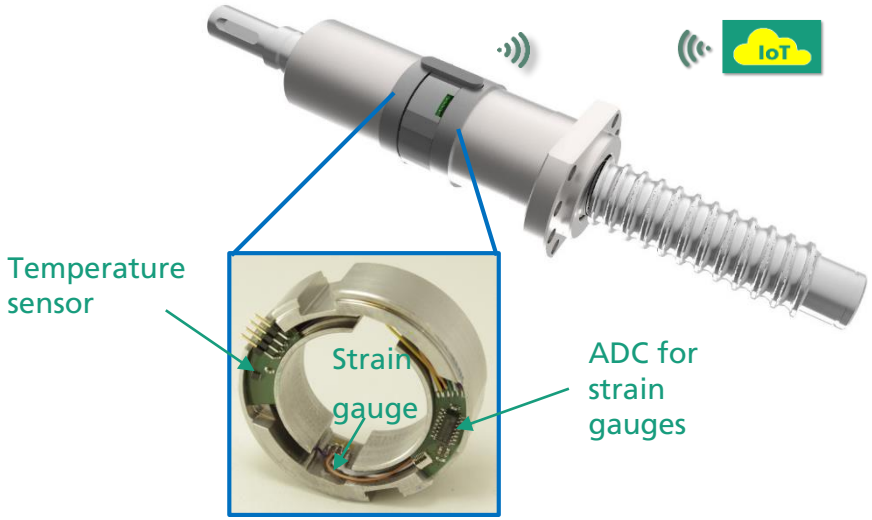
Benefits:

- Process-controlled status monitoring in mechanical engineering by structure-integrated wireless sensor technology

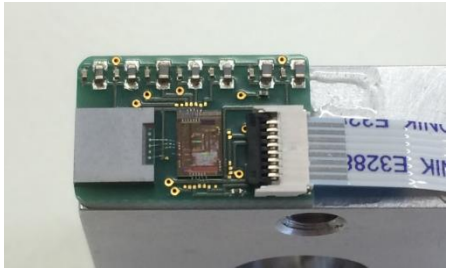
Partners:

- ENAS, IWU, IIS/EAS, IPMS, IZM/ASSID, IKTS

Technology Readiness Level: 4



Sensor ring with integrated force and temperature measurement



Vibration sensor

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FRAUNHOFER LIGHTHOUSE PROJECT 2016

DIGITAL MANUFACTURING IN MASS PRODUCTION

INNOVATION OF SERIES PRODUCTION BY DIGITAL PRINTING AND LASER PROCESSES

Fraunhofer Institute

for Electronic Nano Systems **ENAS**, Chemnitz, *consortium leader*
for Manufacturing Technology and Advanced Materials **IFAM**, Bremen
for Laser Technology **ILT**, Aachen
for Applied Optics and Precision Engineering **IOF**, Jena
for Silicate Research **ISC**, Würzburg
for Machine Tools and Forming Technology **IWU**, Chemnitz and Dresden

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Digitalization of production for the individualization of mass-produced components

Market trends:

- Increasing product diversity with decreasing batch sizes
- Efficient use of high-quality functional materials
- Intelligent products with integrated data collection, processing and communication
- Further individualization of the product geometry beyond the software-based customization

⇨ urgent **need for research** of **future-proof production strategies**

Digital fabrication in mass production

… with the aim of networked and highly efficient production with minimal resource use through digital manufacturing and integration of innovative functional materials

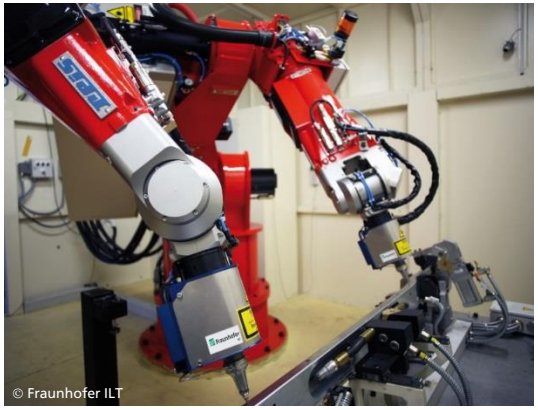
… the successfull
massproduction concept
of printed flexible hybrid electronics:

Roll-to-Roll printing

Orientation of
the markets:

Individualization of every mass-produced components

→ **Printing by robot on product**

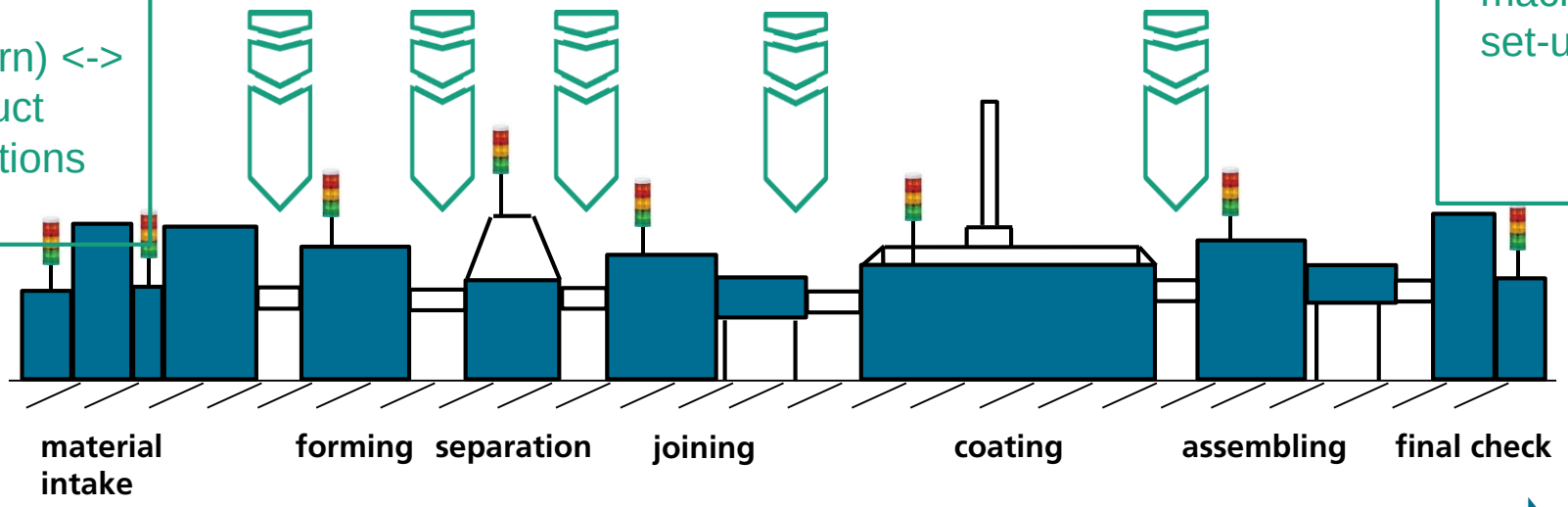


Crosslinked digital functionalization and individualization technologies within existing production lines

Digital function-nalization: digital data change (print pattern) <-> product adaptions

Integration of one or more
Digital modules
based on digital printing and laser processes
Development of reliability guidelines for the processes

Benefit: product adaptions without machine set-up time



State of the art mass production line

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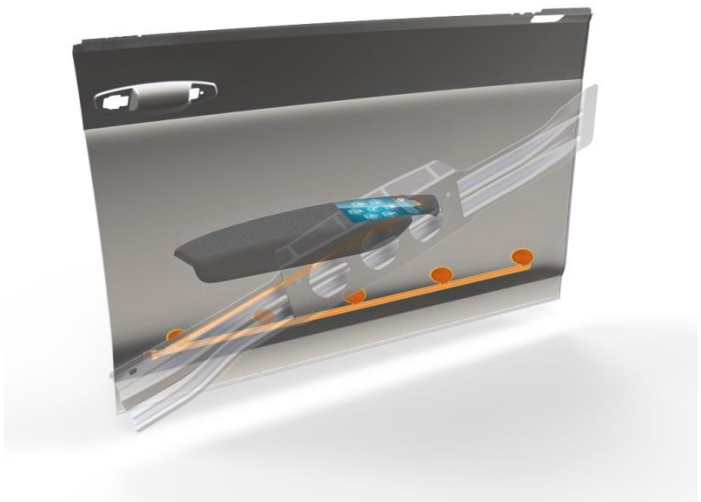
Applications

DIGITAL MANUFACTURING IN MASS PRODUCTION
INNOVATION OF SERIES PRODUCTION BY DIGITAL PRINTING AND LASER PROCESSES

„Smart Door“



Trend: Individualization & functional enhancement in automotive (40.000 individualized vehicles per day at VW)

Challenge: Variety of variants with decreasing batch sizes

Aim: Differentiation and increased efficiency of the production by means of printing and laser technologies demonstrated on printed conductive paths / cable trees, sensors and control elements of a car door

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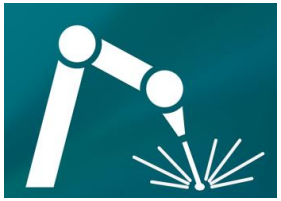
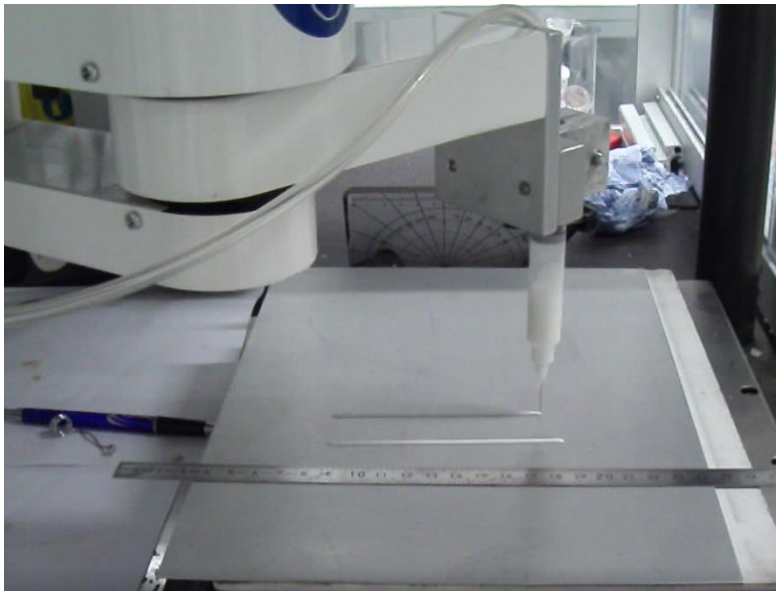
Technology

Digital modules based on digital printing and laser processes

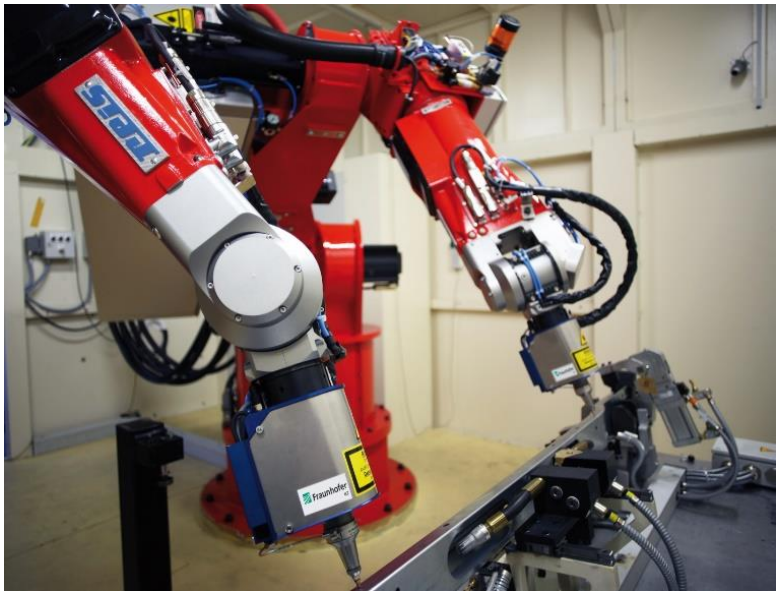
Additive material deposition



Laser sintering & laser ablation



Robotic printing system Fraunhofer ENAS, Chemnitz/Germany



Robotic laser system Fraunhofer ILT, Aachen/Germany

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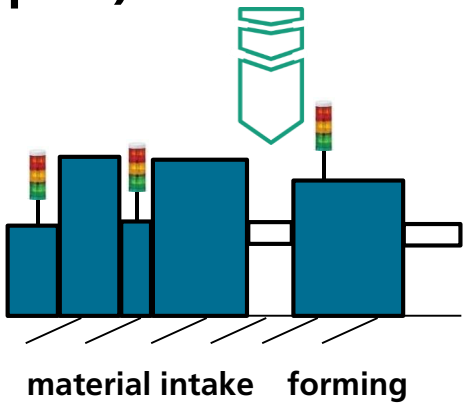
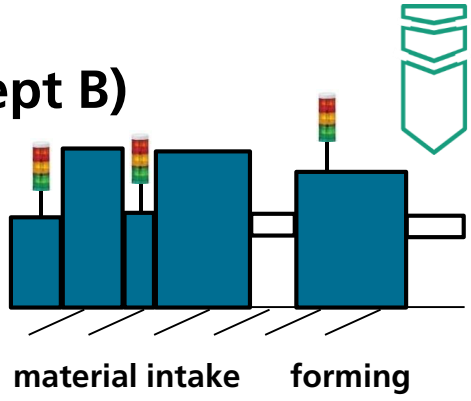
Printed automotive wiring harness on metal

Concept A)



1. Printed automotive wiring harness
   on sheet metal
2. Metal forming

Concept B)



1. Metal forming
2. Printed automotive wiring harness
   on 3D metal object

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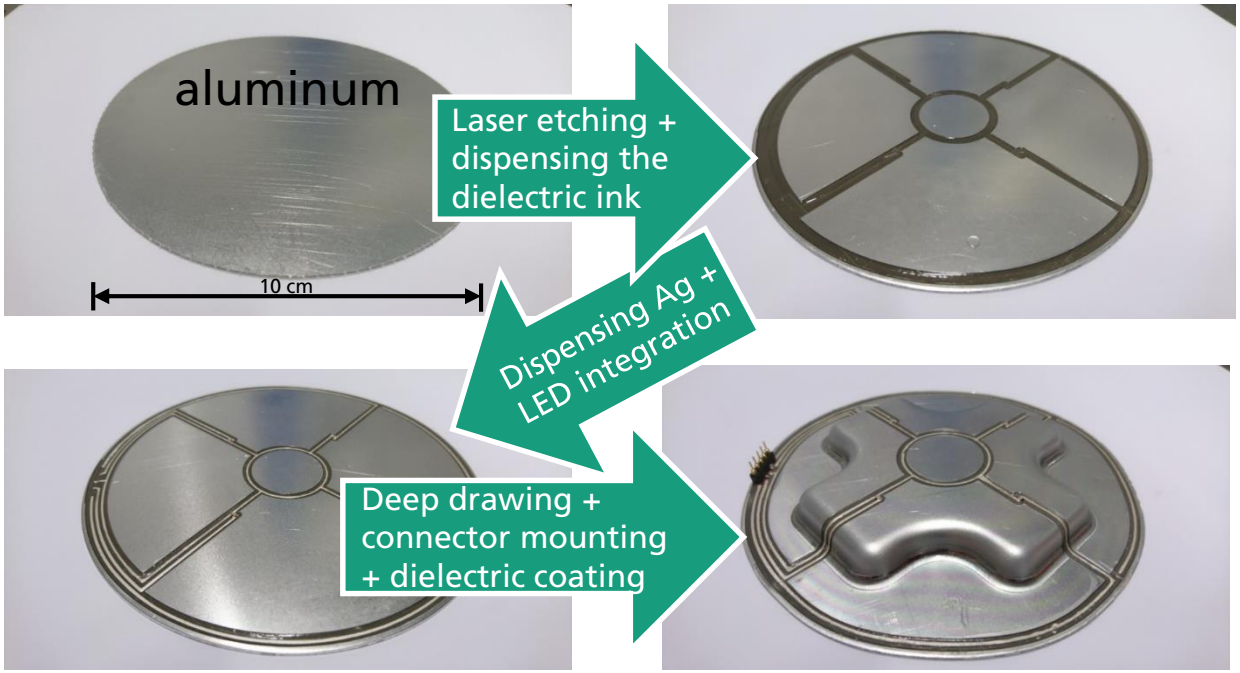
Printed automotive wiring harness on metal

Concept A) **Printing → Metal forming** (deep drawing)



deep drawing

Stretchability: up to 20 %

Bendability: up to 105°

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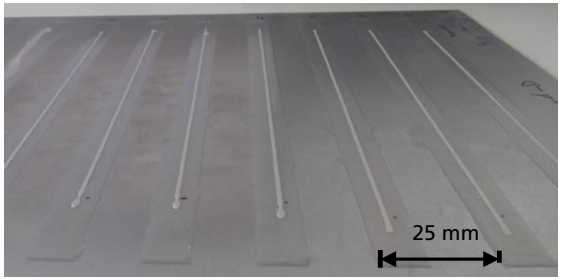
Printed automotive wiring harness on metal

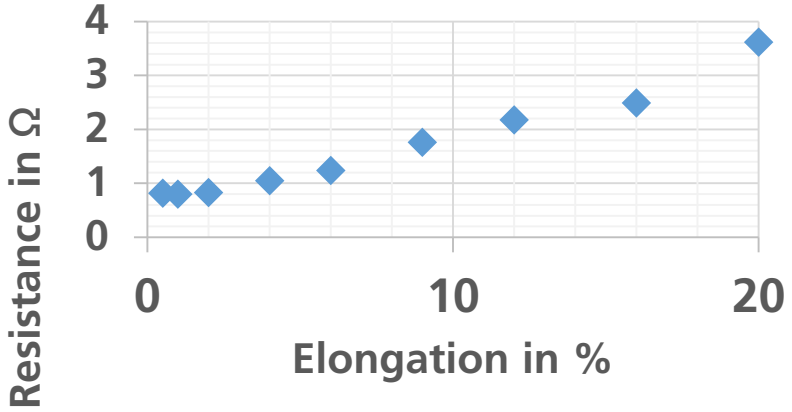
Concept A) **Printing → Metal forming** (deep drawing)

Printed automotive wiring harness on metal

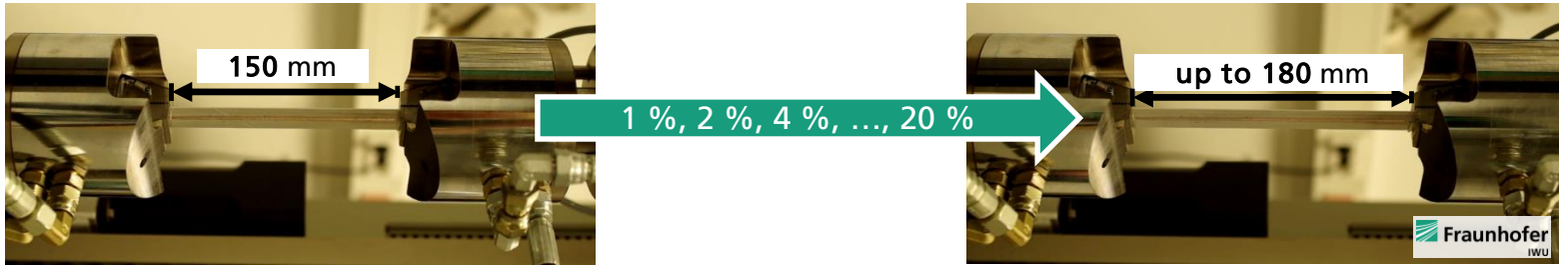
Concept A)

1. Printed automotive wiring harness on sheet metal (aluminum)





2. Metal forming (stretching)



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Roadmap Topic: Natural Resources

R&D | Demonstration | Industrialization

DEEP SEA MINING
- Sensors and monitoring systems
- Autonomous vehicles

CIRCULAR ECONOMY
- Life-cycle-monitoring of materials
- Smart systems for recycling processes

WATER QUALITY
- Smart Systems for ensuring high water quality

WATER MANAGEMENT
- Smart diagnostic systems for water systems
- Smart systems for water distribution

FOOD PRODUCTION
- Smart systems for agri- and aquaculture
- Automation in harvesting

FOOD QUALITY
- Smart systems for food quality
- Smart systems for food safety

FOCUS AREAS

Milestone 2020	Milestone 2025	Milestone 2030
Industrial uptake	Demonstration in field tests	Wide use in action fields

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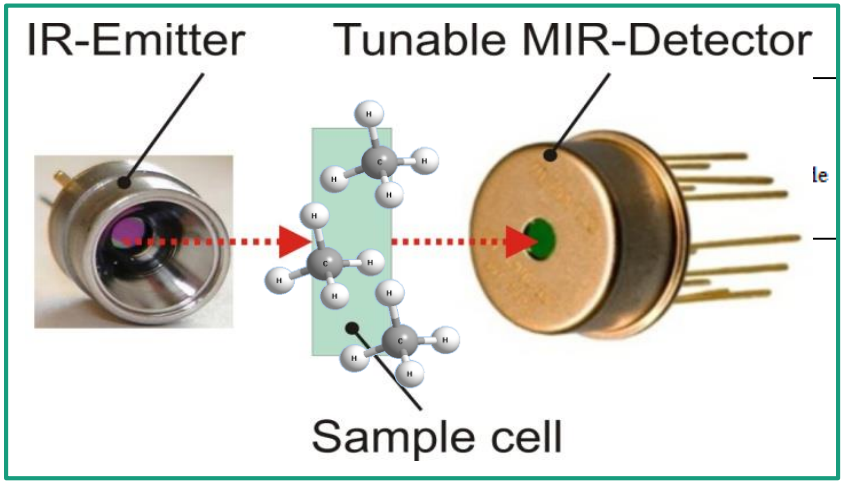
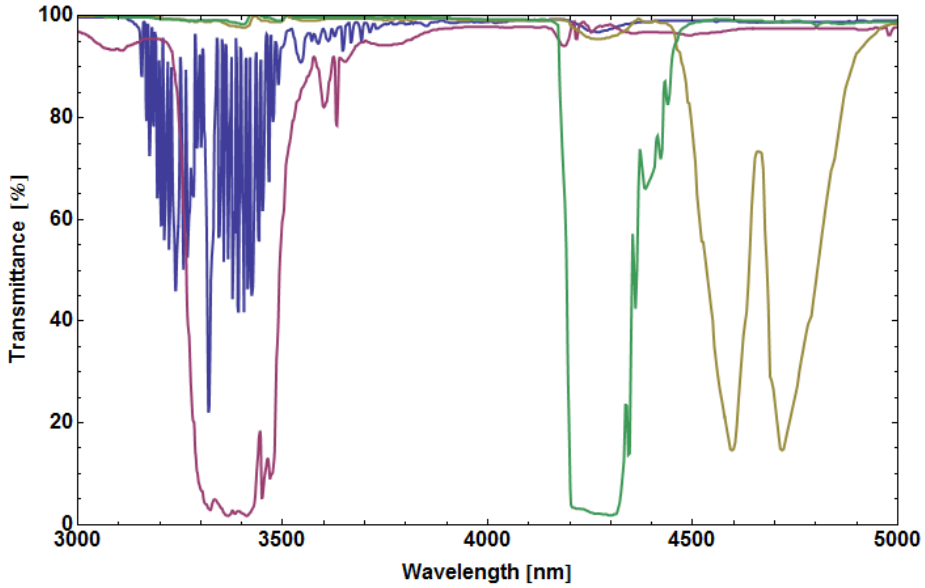
Analysis by spectroscopy:
Detect the composition of substances!



Source: http://webbook.nist.gov/chemistry



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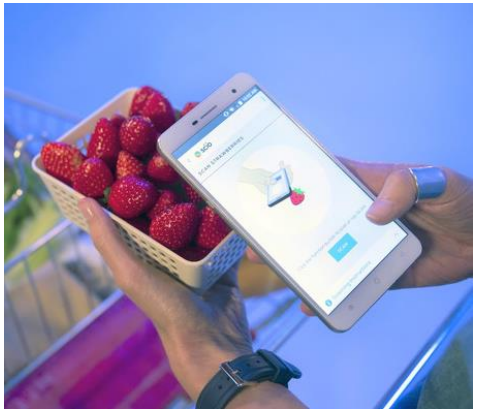
Motivation – infrared spectroscopy for daily use

Large, >10kg, xx k€

Source : https://www.bruker.com/products/infrared-near-infrared-and-raman-spectroscopy/ft-ir-routine-spectrometers/tensor/overview.html

Small, < 1kg, x k€

Source : http://www.rgb-photonics.com/products/



Source: http://www.digitaltrends.com/cool-tech/changhong-smartphone-spectrometer-ces-2017/

Ultra small, < 10g, xx €

Source http://labinyourpocket.com/near-infrared-analysis-by-portable-mini-spectrometers-and-mobile-phones/

Fabry-Pérot interferometer (infrared spectral range)

General:

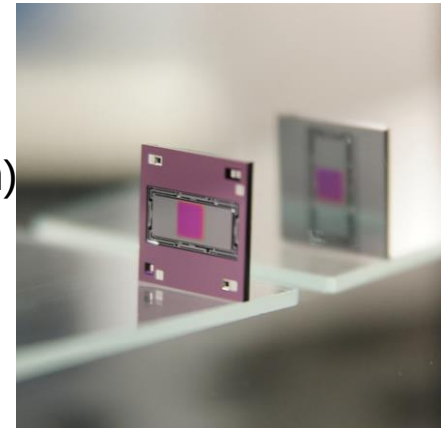
- Electrically tunable MOEMS band-pass filter for infrared spectral range (3-5 µm, 5-8 µm, 8-11 µm)
- Transmittance > 70%
- Bandwidth (FWHM): 25-200 nm
- Control voltage: 15-60 V
- Aperture size: 2x2 mm²

Benefits:

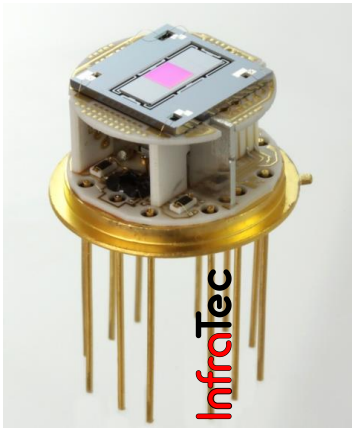
- Small band-pass filter
- Fits in a TO-8 housing (7 x 7 x 0,6 mm³)
- Low influence of vibration and gravitati central wavelength

Applications:

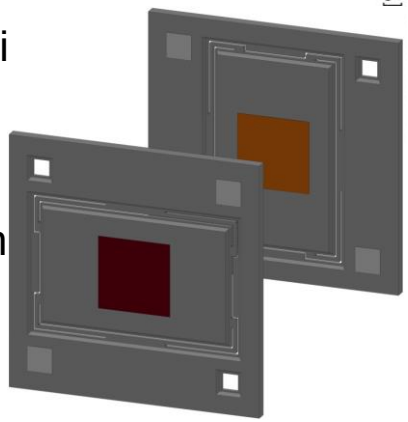
- Infrared measurement instrumentation
- Spectral gas analysis
- Spectral imaging



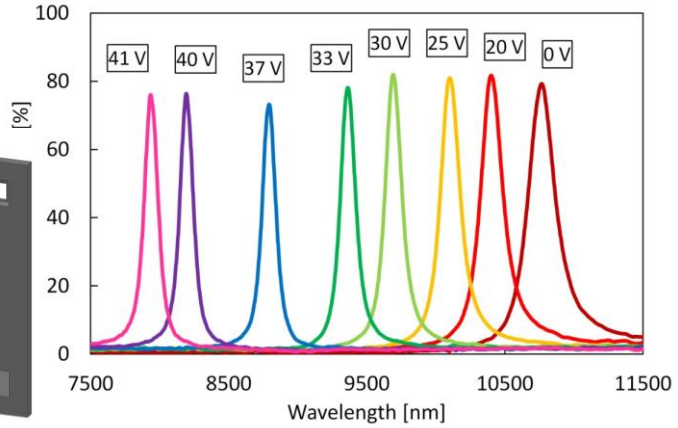
Fabry-Pérot Interferometer chip



Detector with integrated FPI



Two symmetric parts with Bragg reflectors and ARC



Spectral transmittance of FPI

Technology Readiness Level: 6

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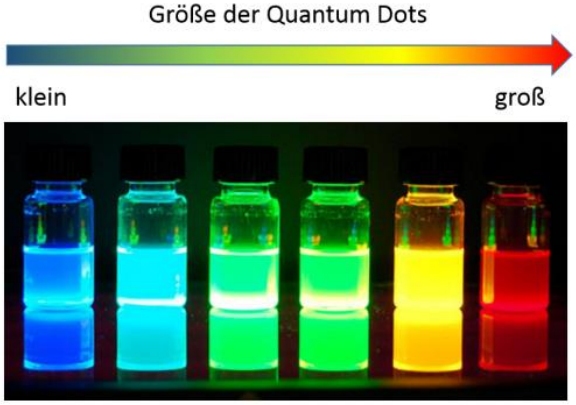
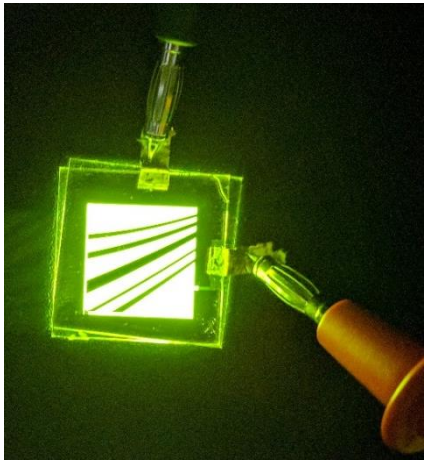
New developments and directions: Emitter based on quantum dots

- Charge carriers with limited mobility and discrete states
- Optical properties depend on material and size of the particles
- Wavelength of emission and of absorption can be tuned
- High quantum efficiency (EQE: ~ 2 %)
- QDs in suspension to apply by printing, spin coating ...



Kolloidale Quantum Dots

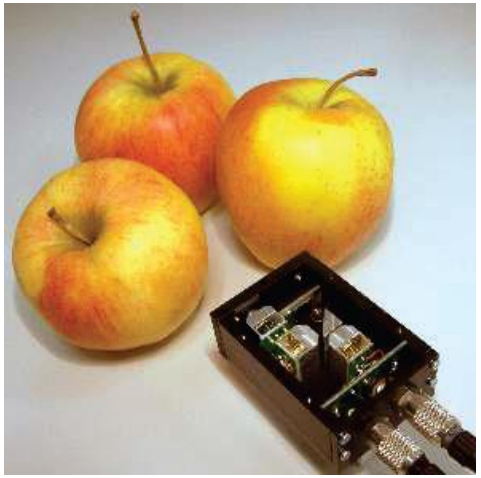
Source: http://www.sigmaaldrich.com/materials-science/nanomaterials/quantum-dots.html



Photoimage of QD-LEDin operation

Applications

- Warning and safety systems
- Gas analyzers in for medical and power applications
- Raman spectroscopy and ATR sensors for chemical industry and bio-analysis
- Application in handheld devices and unmanned vehicles
- Spectral imaging



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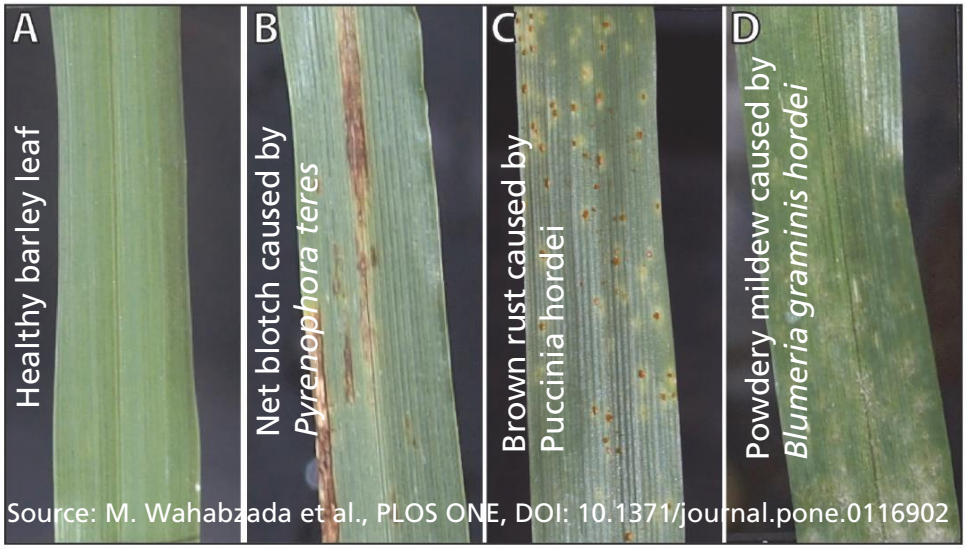
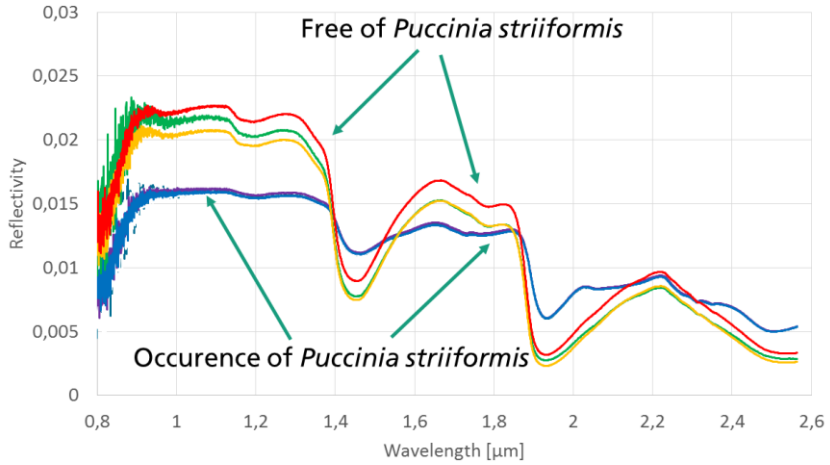
Spectral data based detection of plant disease

- Spectral data collection and derivation of hyperspectral signatures
- Data processing (PCA, neuronal network)



Applications:

- Optimization of crop crow conditions:
  - Photo synthesis,
  - Transpiration,
  - Stomatal conductance
  - Internal CO_2- concentration
- Detection of plant diseases
- Optimum application of fertilizers and plant protection chemicals



Reflection spectra of wheat with and without Puccinia striiformis

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eGrains system for precision farming and pest control

General:

- Diagnose system for stress and damage of crop
- Detection of pests in crop culture
- Miniaturized Sensor nodes
- Technology approaches for biodegradability

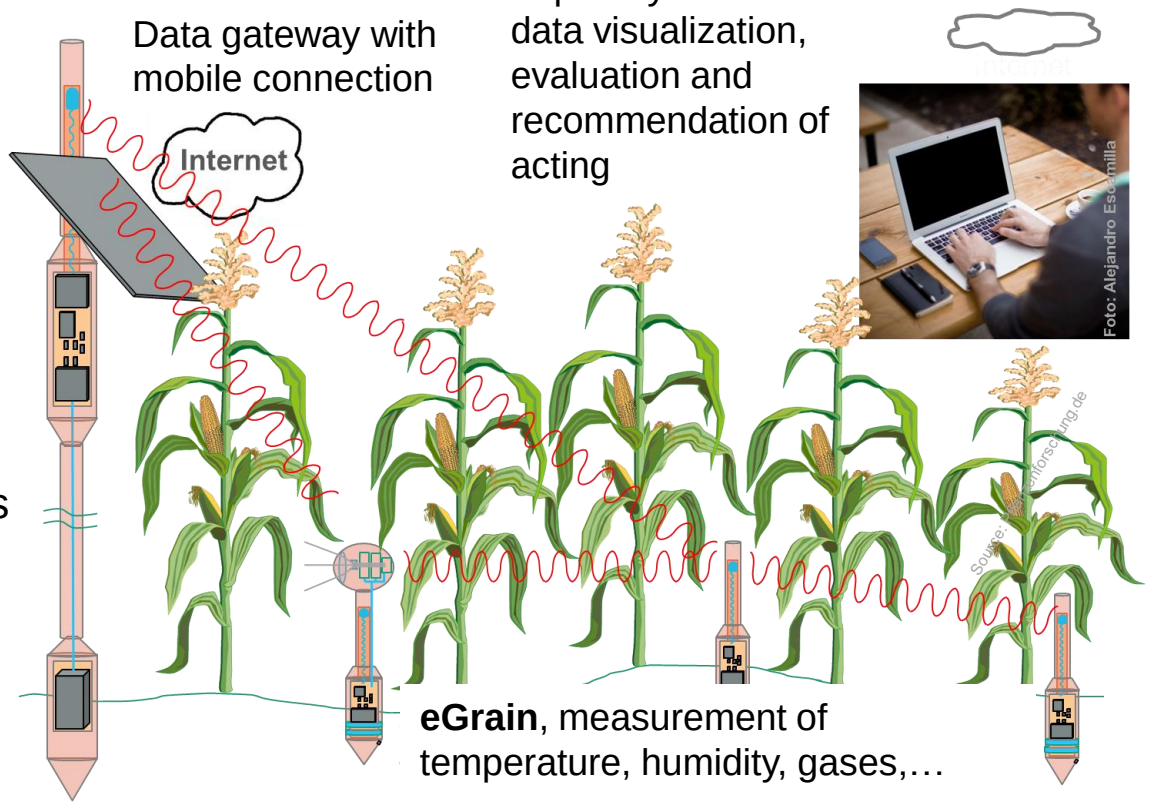
Benefits:

- Autonomous work, no manual inspections
- Continues supervision of temperature and wetness of leafs

Applications:

- Crop cultures
- Vegetable cultivation

Technology Readiness Level: 2



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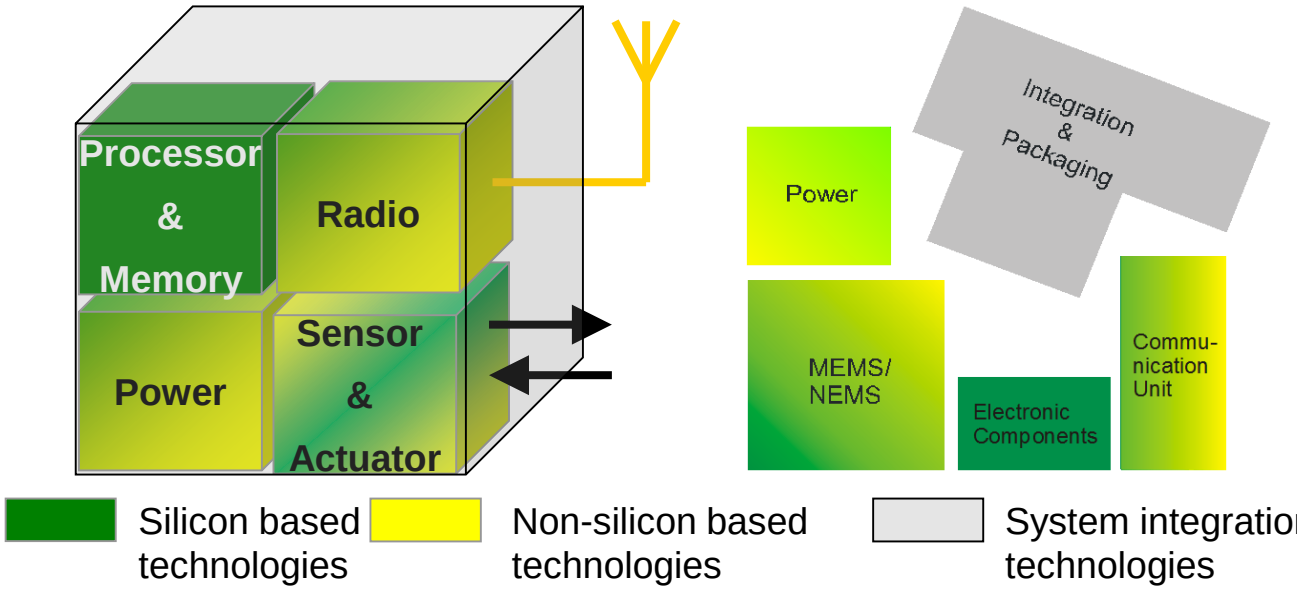
Fraunhofer ENAS

Outline

1. Working fields Fraunhofer ENAS
2. Industry 4.0
3. Hybrid sensors and sensor systems for Industry 4.0
4. Lighthouse project Go Beyond 4.0
5. Spectroscopy - application in agriculture monitoring
6. Summary

New and multifunctional Smart Systems



Key factors

Technologies

MEMS technologies

Advanced integration

Sensors

Accurate, Small

Low power, Reliable

Low cost

Issues and goals: Size! Price! Nice!

International Conference & Exhibition on integration issues of miniaturized systems – MEMS, MOEMS, ICs and electronic components

smartsystems integration

14. Conference: 01-02 April 2020, Grenoble, France

Organizer: Mesago Messe Frankfurt, Fraunhofer ENAS, Fraunhofer IZM

Part of the Activities of: EPoSS European Technology Platform on Smart Systems Integration

Chair: Prof. Dr. T. Otto, Fraunhofer ENAS

Co-Chair: Dr. Stefan Finkbeiner, Bosch Sensortec and EPoSS

Wolfgang Gessner, EPoSS

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Fraunhofer ENAS

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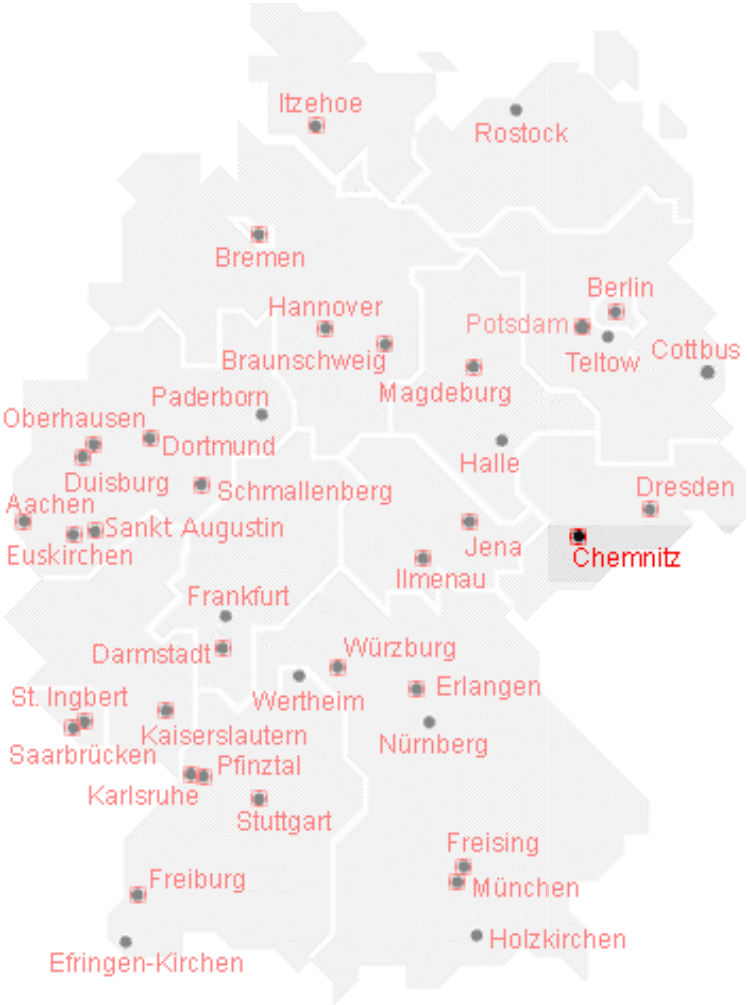

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