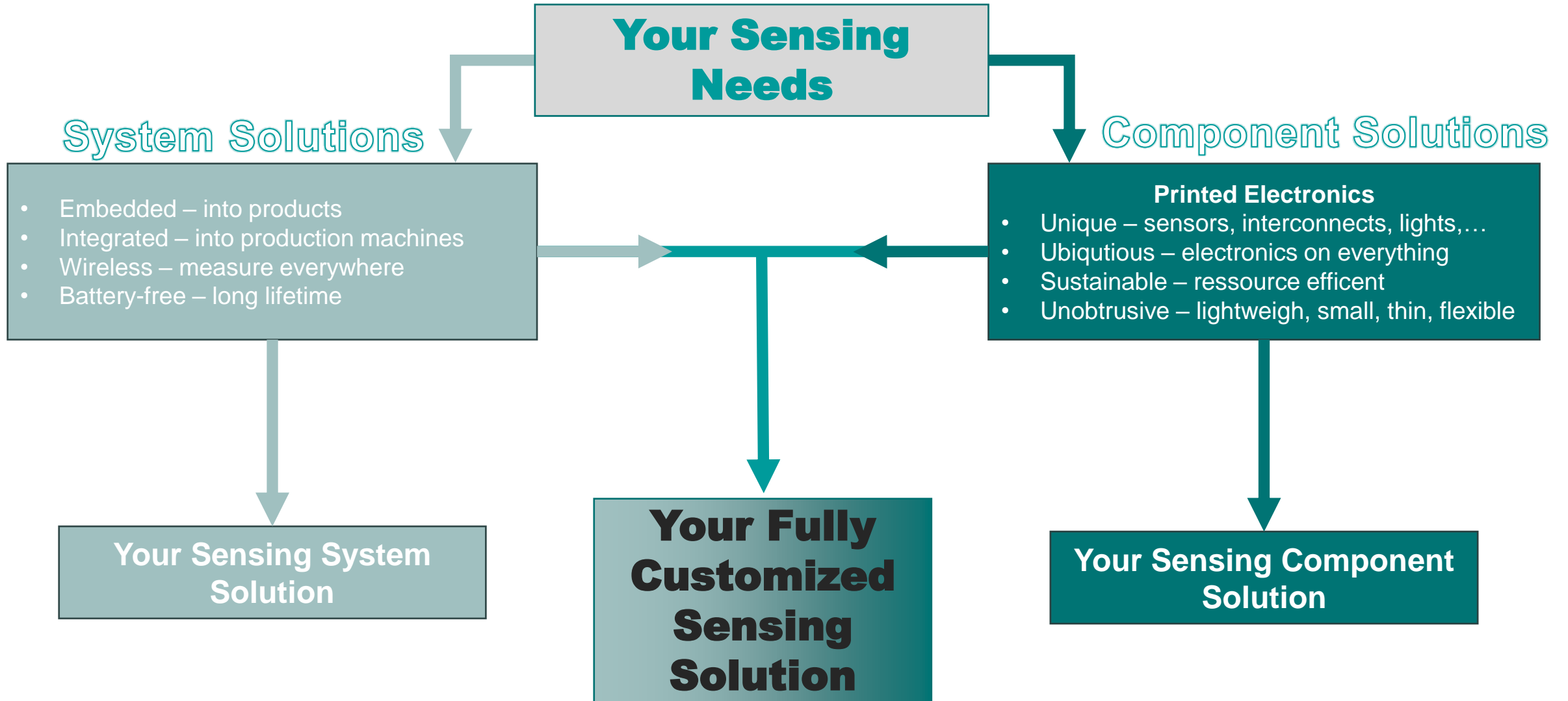




# ADVANCED SENSORS AND ELECTRONICS TECHNOLOGIES

JÜRGEN KOSEL  
HEAD OF RESEARCH UNIT

# IN A NUTSHELL



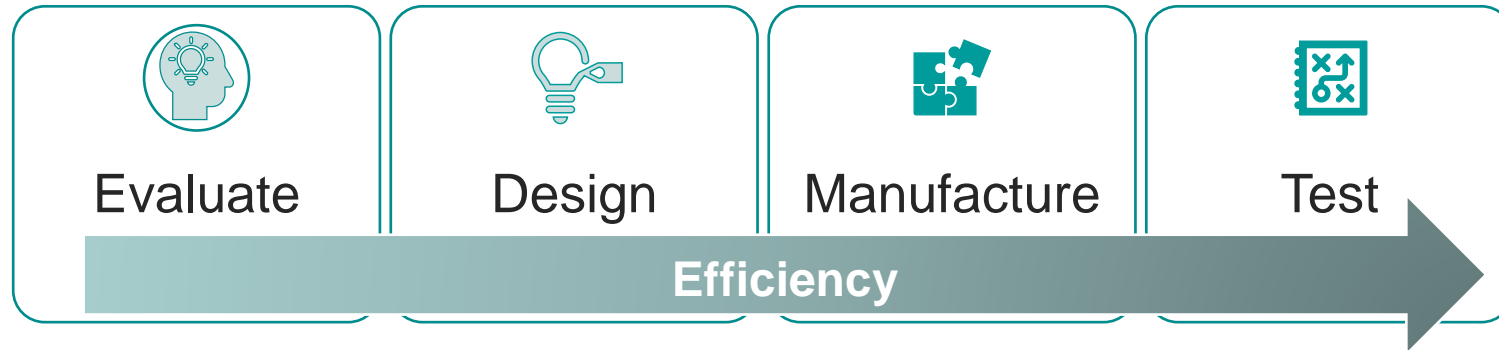


**SAL**

SILICON AUSTRIA LABS

# SENSING SYSTEM SOLUTIONS

# SENSING SYSTEM SOLUTIONS



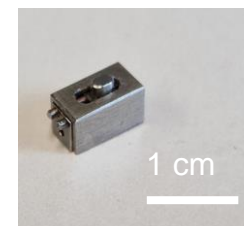
## What we offer

- ≡ Develop sensors systems where commercial solutions fail
- ≡ Sense in harsh conditions
  - ≡ Rotating machines, high temperatures, high pressures
- ≡ Non-contact (inductive, NFC, UHF, BLE) communication for sensor read-out
- ≡ Integration of sensors with hard- and software
- ≡ Enable fast translation to product

## Project Examples

- ≡ Sensing inside of rotating machines
- ≡ Wear or damage detection (Eddy Currents, Ultrasound,...)
- ≡ Quality/Process control & optimization
- ≡ Condition monitoring

Miniaturized shear force sensor

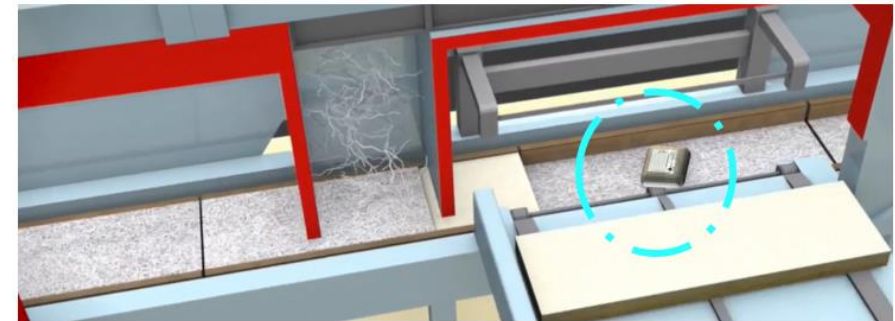
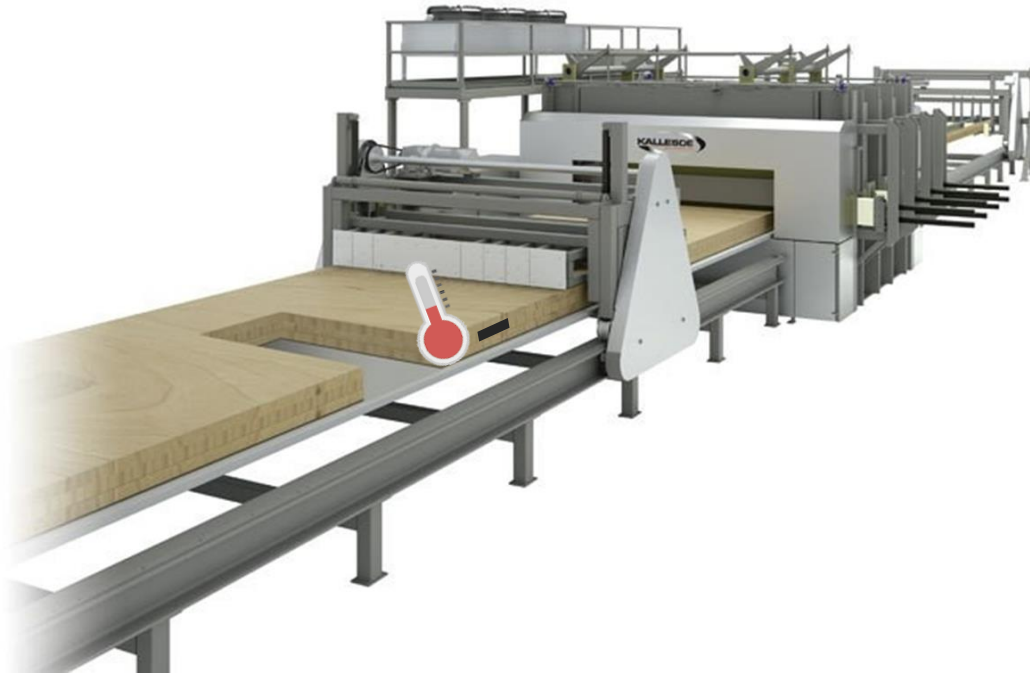


Sterilization counter, energy harvesting, wireless, battery-free, off-the-shelf components



# QUALITY CONTROL & PROCESS OPTIMIZATION

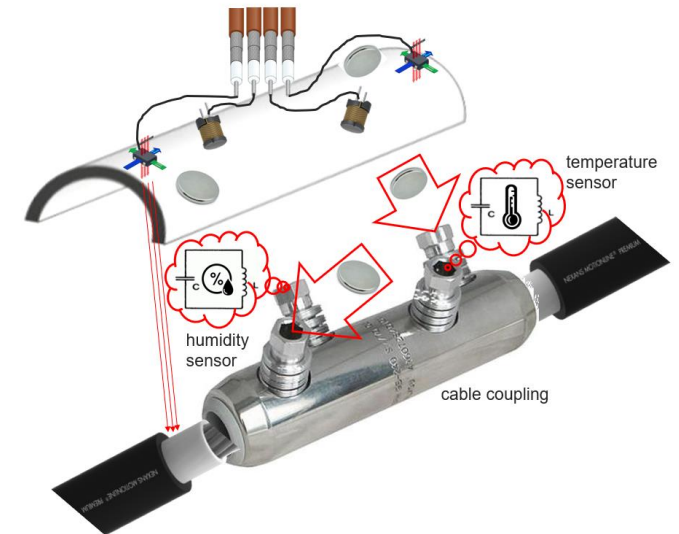
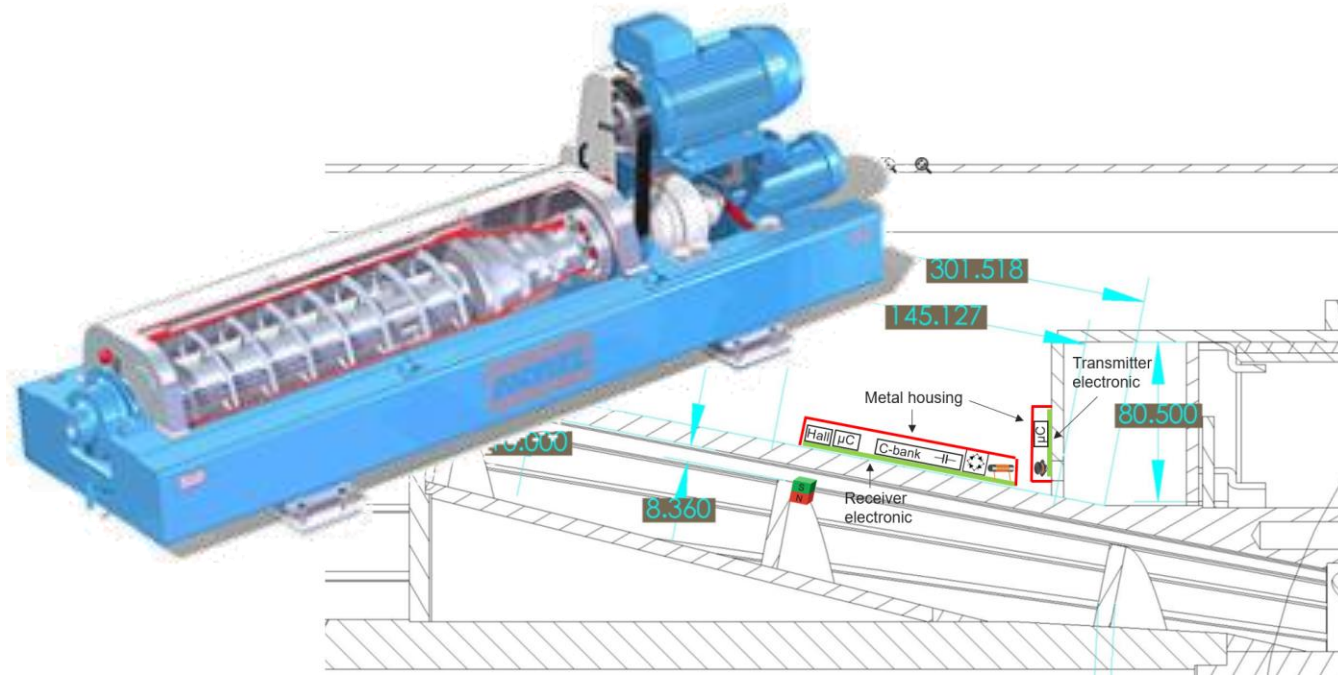
- ≡ Integration of sensor systems directly into the product and/or material to verify the impact of machine process parameter settings to analyze and increase quality.



- ≡ Project partners: Hasslacher, Knauf Insulation

# CONDITION MONITORING

- ≡ Development of customized sensor solutions to monitor the health state of parts, which is not possible to realize with systems available on the market.



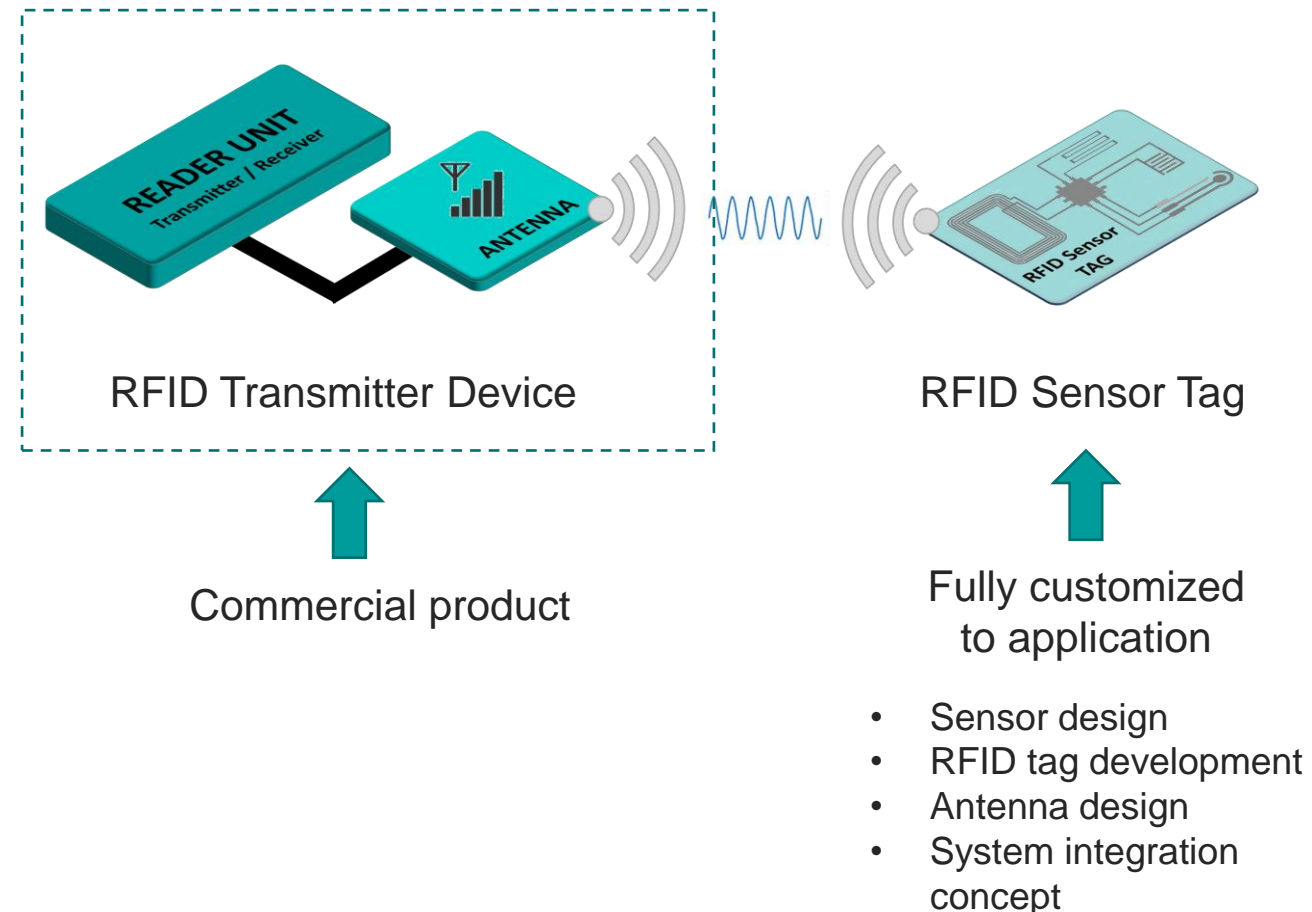
- ≡ Project partners: List AG, Andritz, KELAG

# PASSIVE WIRELESS SENSOR SYSTEMS

Implementation of well-established RFID transmitter devices, such as handheld reader units, cell phones or computer-controlled reader units, as wireless read-out system.

- ≡ Development of transponder devices based on printing or standard PCB technology focused on fully passive solutions with lowest possible component count for the desired use-case.
- ≡ Solutions are based on different standards, radio frequencies, read ranges and technologies e.g., NFC < 10 cm, UHF < 3 m, ...
- ≡ Applications:  
temperature, thermocouple, strain gages, piezo resistive sensors, pressure, voltage, accelerometer, humidity, permittivity, capacitance, bending, transmission torque, extension, compression, weigh scale, current (Hall sensor), chemical sensors, gas sensors, potentiostat, ...

## Principle setup of a passive RFID-based wireless sensor system



# PASSIVE WIRELESS SENSOR SYSTEMS

## Example – Smart Shirt

- ≡ Printed strain sensor on T-shirt
- ≡ Measurement of shirt tension
- ≡ Wireless (UHF-based)
- ≡ Battery free
- ≡ Removable electronics







**SAL**

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**COMPONENT SOLUTIONS  
PRINTED ELECTRONICS**

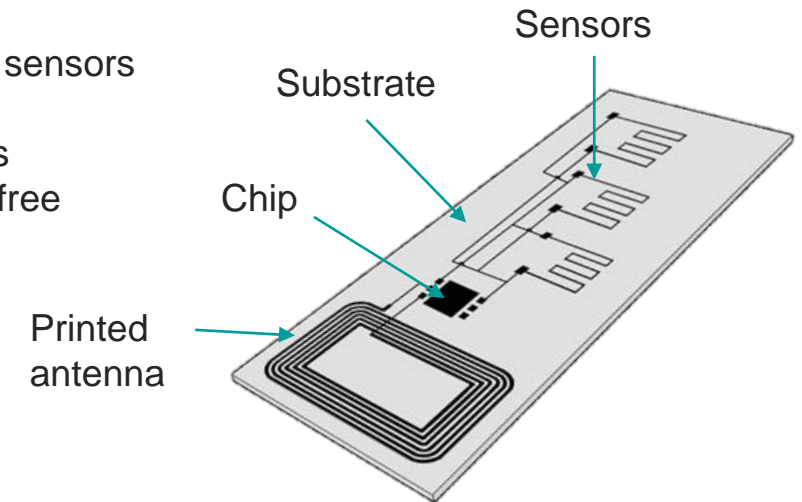
# PRINTED ELECTRONICS - A NEW ERA

## Why Printed Electronics?

- ≡ **Electronics on Everything**
- ≡ Efficient Manufacturing
- ≡ Sustainable Products
- ≡ Affordable already at small-scale needs
- ≡ Lightweight, non-obtrusive, ultra-thin electronics
- ≡ Flexible, bendable, conformable electronics
- ≡ Wide range of manufacturing technologies
- ≡ Wide range of substrates, printing materials and coatings
- ≡ Hybrid integration
- ≡ Wired or wireless readout with NFC, UHF, inductive methods, BLE,...
- ≡ Wholistic system design (concept, simulation, fabrication, testing,)

## Example:

- Multiple sensors
- Chip
- Wireless
- Battery-free



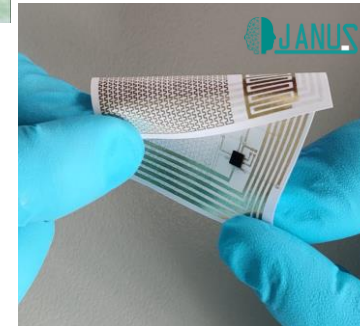
# ONGOING PROJECTS

- ≡ Humidity, Proximity, Temperature, Pressure, Force, Strain Sensors
- ≡ Chemical sensors (Acetone, tobacco virus,...)
- ≡ Displays (Electrochromic, Electroluminescent, OLED,...)
- ≡ Batteries, organic PV, energy harvesting
- ≡ Electronics on Metals, Polymers,...
- ≡ Sensors for quality monitoring of Timber Products, Composite Materials, Ceramic Parts, and Harsh Environments, Filter Monitoring
- ≡ Flexible and Stretchable Sensors for Biomedical Application
- ≡ Structural Electronics

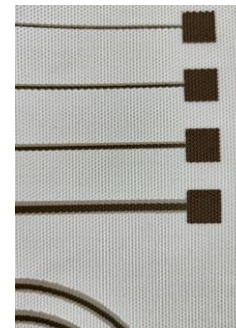
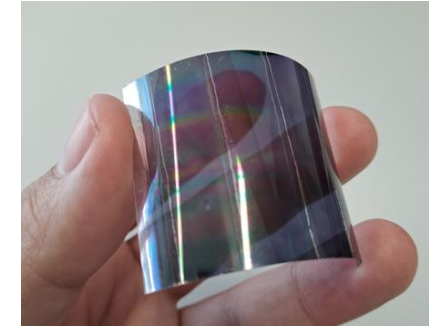
Temperature sensor embedded in flax composite material



Double-side printed, wireless sensor for temperature, humidity and strain. Best electronics product Award at 5E Contest (2021).



Organic, semitransparent and flexible PV



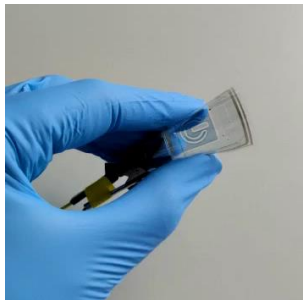
Printed sensors on industrial filter



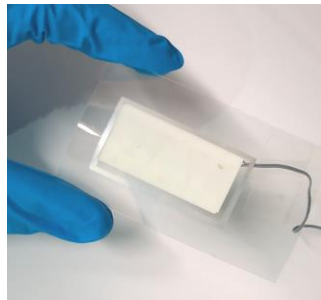
Printed humidity sensor on wood



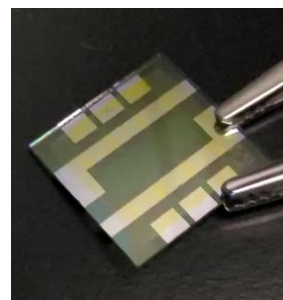
Printed Zinc-Manganese Dioxide battery (1.6 V)



Electrochromic display printed on PET



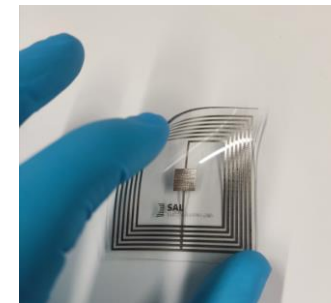
Electroluminescent display printed on PET



Printed OLED

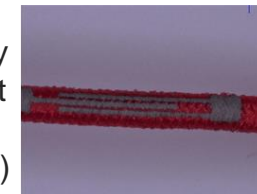


Printed pressure sensors in shoe inlay



Flexible pressure sensor on biocompatible transparent TPU film

Printed humidity sensor and light (EL) on thread (patent pending)



# EXAMPLE - PRINTED HUMIDITY SENSORS

(Wireless) printed humidity sensors can be applied on a wide range of substrates by use of different inks or pastes offering several benefits:

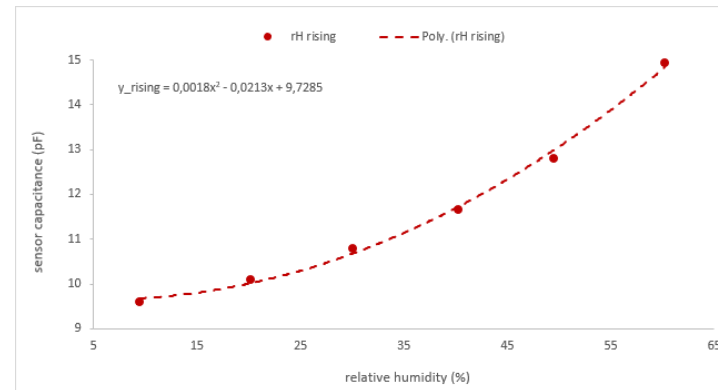
- ≡ Fast and cost-efficient fabrication
- ≡ Flexible and lightweight
- ≡ Scalable fabrication
- ≡ Passive wireless with single chip solution (RFID-based)
- ≡ Passive wireless with inductive readout
- ≡ Achieve high level of sustainability

Example of wireless, inductive read-out of paper-based printed and flexible sensor.

Sensor specs:

- Dimensions: 50 x 50 mm
- Thickness: 80  $\mu$ m
- Weight: 300 mg

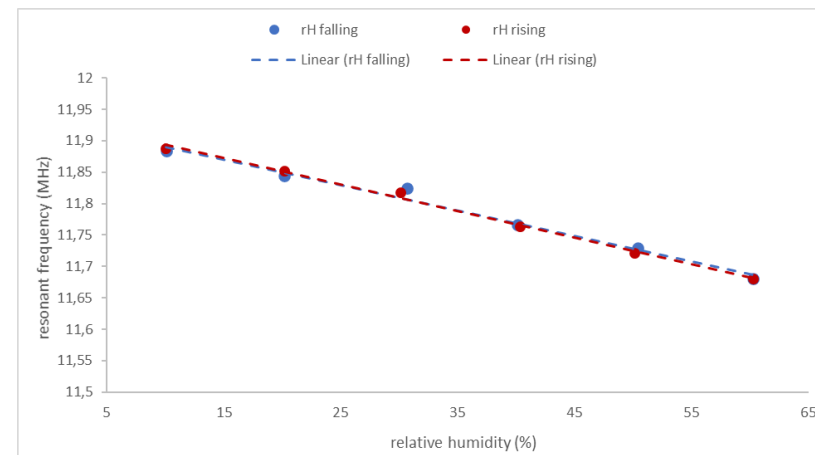
Example of wired readout:



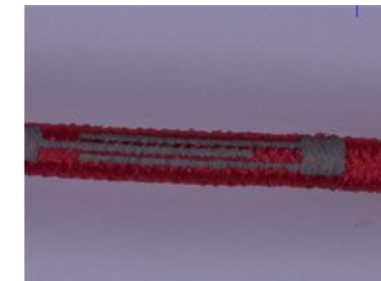
Double-sided printing humidity sensor with minimal material consumption.



Printed humidity sensor on paper substrate connected to printed antenna for wireless read-out.

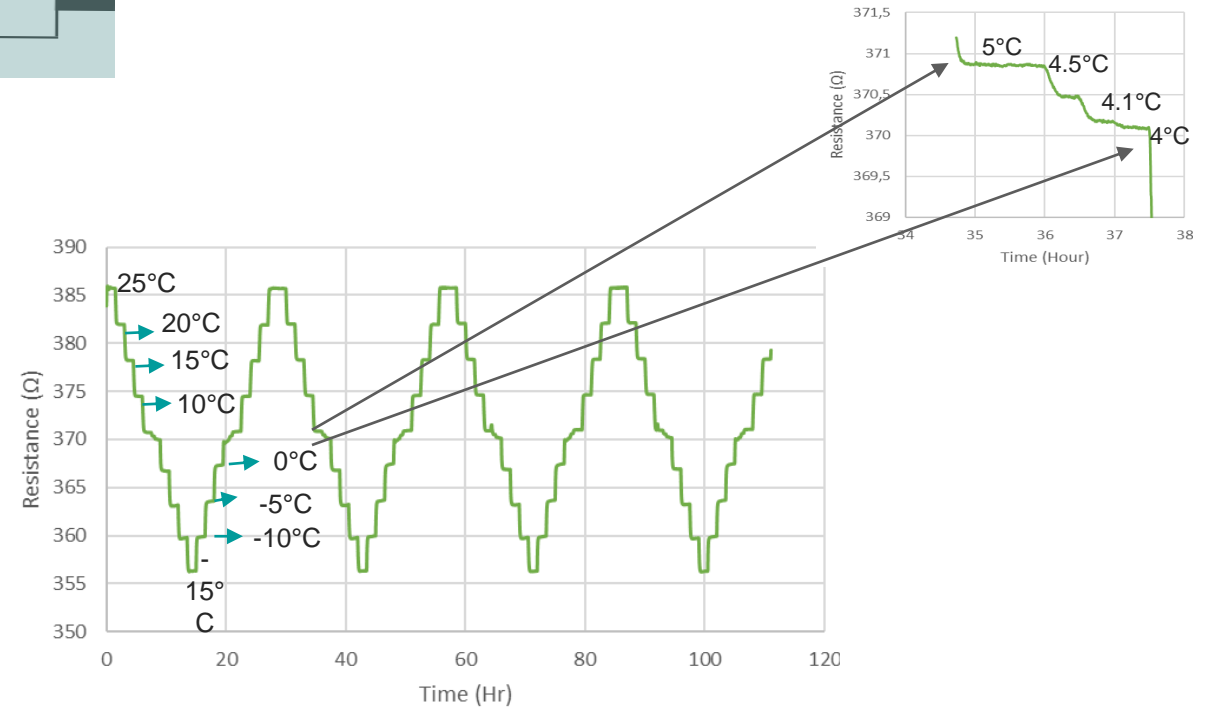
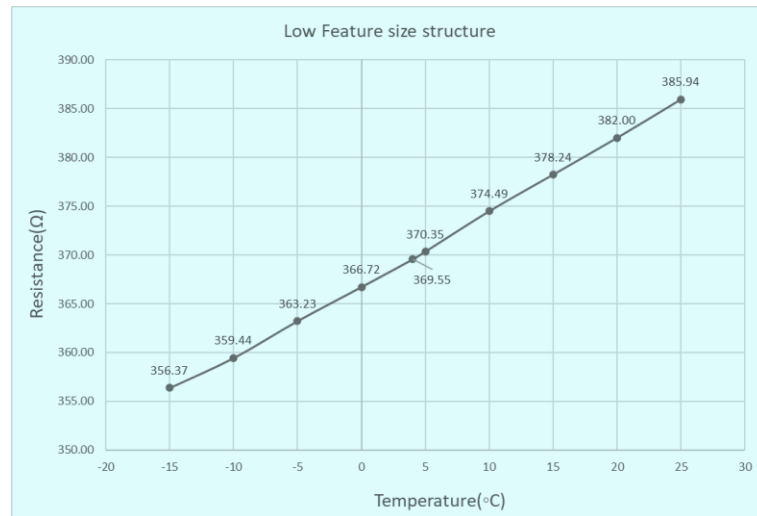
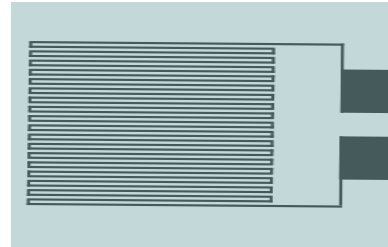


Humidity Sensor on wire (patent pending)



# EXAMPLE – PRINTED RESISTIVE TEMPERATURE SENSOR

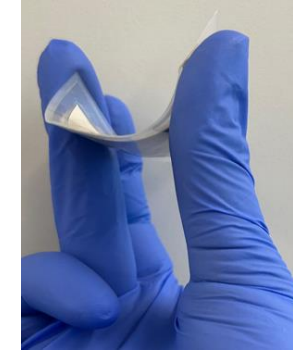
- ≡ Temperature sensor on PET
- ≡ Printed silver
- ≡ Sensitivity 0.21%/ °C
- ≡ Resolution 0.1°C



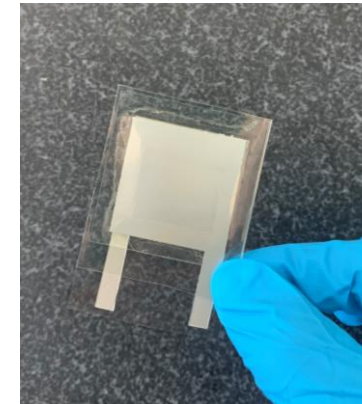
# EXAMPLE – PRINTED BATTERIES

Printed batteries create new opportunities for powering devices by departing from the limitations of traditional batteries in terms of rigidity, size, shape or energy:

- ≡ Fully customizable
- ≡ Flexible, thin and in any kind of shape and design
- ≡ More sustainable, less waste
- ≡ Efficient fabrication by inkjet or screen printing
- ≡ Non-rechargeable: Zinc-manganese dioxide
- ≡ Rechargeable: Zinc-silver oxide



Single cell architecture

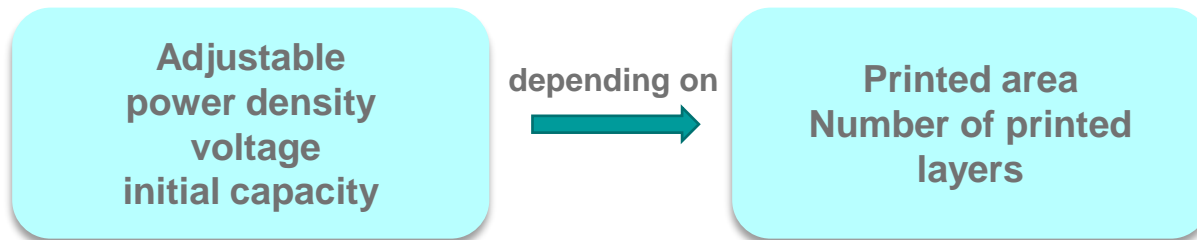


- ≡ Open circuit voltage: ~1.6 V
- ≡ Capacity: 1-2 mAh

Two cell architecture



- ≡ Open circuit voltage: ~2.0 V
- ≡ Capacity: 1-2 mAh



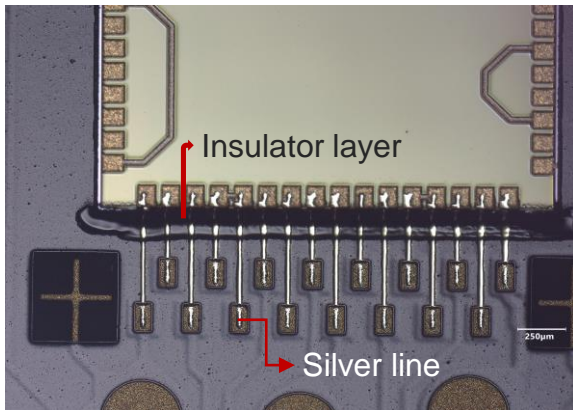
# CENTER OF EXCELLENCE – ADDITIVE MANUFACTURING OF INTEGRATED SYSTEMS (AMIS)

- ≡ The best results in additive manufacturing by merging the excellence of the tool manufacturer and the research center.
- ≡ Development of novel and application-oriented solutions and processes for the semiconductor and electronic device industries using OPTOMECC's proprietary Aerosol Jet printing technology combined with the expertise of SAL on electronic systems.
- ≡ Aerosol Jet printing as a key technology enables conformal printing of high-resolution features onto three-dimensional surfaces, allowing the additive manufacturing of interconnects and electronic components with a wide variety of inks and substrates.

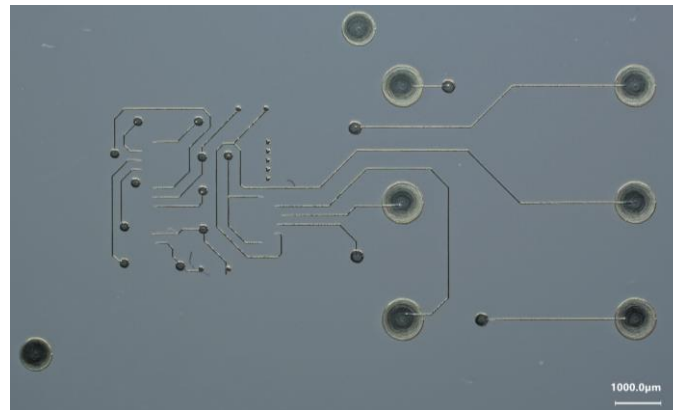


OPTOMECC FLEX 5X Aerosol Jet printing system at SAL

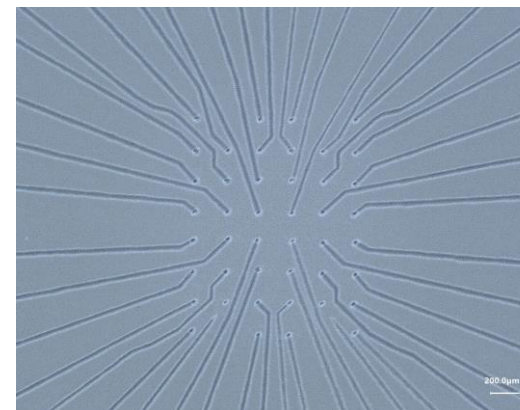
## EXAMPLES



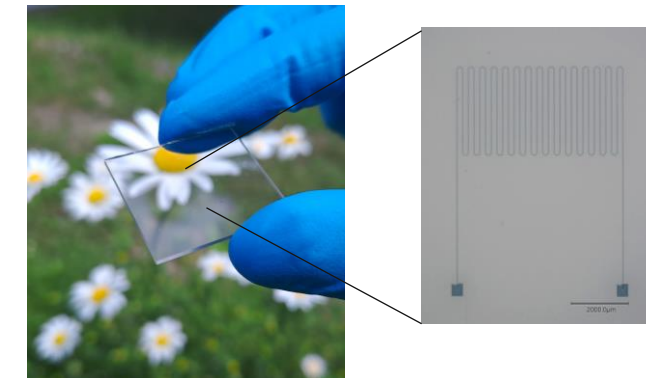
Chip interconnects



Micro Interposer



Biocompatible and semi-transparent Microelectrode Array (MEA).



Invisible humidity PDOT:PSS sensor on glass

≡ Test before Invest – **Gedruckte Elektronik Services für KMUs kostenfrei bis EUR 40k**  
(darüber hinaus mit Selbstbehalt)

≡ EU/FFG - gefördertes Projekt zur Unterstützung von KMUs

≡ Zusammenschluss von Unternehmen, aus mehreren forschungs(nahen) Organisationen

≡ Zweck: Vorantreiben der digitalen Transformation

≡ Erhöhung des Digitalisierungsgrads

≡ von KMU

≡ Betrieben bis zu 2.999 Mitarbeiter:innen

≡ und des öffentlichen Sektors



# PRINTED & FLEXIBLE ELECTRONICS LAB

- ≡ 150 m<sup>2</sup> dedicated space for printed electronics R&D
- ≡ 40 m<sup>2</sup> ISO 7 clean room
- ≡ **Inkjet-Printer: Meyer Burger PixDro LP50**
  - ≡ Different print head assemblies (Fujifilm Spectra, Dimatix DMC)
  - ≡ Resolution down to ~100 μm features
- ≡ **PulseForge 1200: advanced R&D photonic curing tool**
  - ≡ No substrate limitations and short curing times: ~ ms
  - ≡ Peak radiant power delivered: 5.9 kW/cm<sup>2</sup>
- ≡ **3D- filament printer: N2 Plus Dual Extruder (Raise3D)**
  - ≡ Material: PLA, ABS, PC, PETG, HIPS, NinjaFlex
  - ≡ Resolution 0.01 mm - 0.25 mm and print speed 10 ~ 150 mm/s
- ≡ **Electrohydrodynamic Printer: Scrona Prototype**
  - ≡ Resolution down to ~1 μm features
  - ≡ 40 nozzles
- ≡ **Screen Printer: Eickmeyer SCF 300**
  - ≡ Semi-automatic
  - ≡ Max. print size 200 x 300 mm at 800 cycles/h



# PRINTED & FLEXIBLE ELECTRONICS LAB

- ≡ **Aerosoljet Printer: OPTOMECH 5X Flex**
  - ≡ Printing on 3D structures, feature size down to 10  $\mu\text{m}$ , wide viscosity range.
- ≡ **Stamp/Pad Printer: Inkcup 2200-PS**
  - ≡ Efficient printing on curved surfaces
- ≡ **Spray Coater: Nadetech SP Ultrasonic Pro**
  - ≡ Homogenous large-area layer deposition (low viscosity)
- ≡ **Slot die Coater: InfinityPV RLC 3DPrint**
  - ≡ Homogenous large-area layer deposition (high viscosity)
- ≡ **Parylene Coater: Comolec C25S**
  - ≡ Homogenous conformal coating
- ≡ **Laser Cutter/Sinter: PLS150D**
  - ≡ Laser sintering, laser-induced graphene
- ≡ **Fume Hood**
  - ≡ Safe handling of solvents, inks,...
- ≡ **Contact Angle Analyzer: Dataphysics**
  - ≡ Surface properties

# INFRASTRUCTURE TESTING & METROLOGY

- ≡ **Climatic Chamber: VC3 4018 (Vötsch Industrietechnik) (Fig.1)**
  - ≡ Temperature ranges: -70°C (-72°C discontinuously) to +180°C
  - ≡ Humidity range from 10%RH to 98%RH
  - ≡ Automated data recording
- ≡ **Photovoltaics Sensing and Analysis Equipment:**
  - ≡ PV Module/String Characteristic Curve I-V: IV 400 (HT Instruments)
  - ≡ I-V, photoluminescence and electroluminescence measurements
  - ≡ Solar Cell Flash Tester: FCT-350 Sinton Instruments
- ≡ **Microscopy and Spectroscopy Equipment:**
  - ≡ Raman Microscope/Spectroscope inVia Qontor (Resnishaw) (Fig.2)
  - ≡ SEM/FIB Microscope Helios G4 UC (Thermo Fisher) (Fig.3)
  - ≡ Light & darkfield microscopy



*Fig.1: Climatic chamber VC3 4018*



*Fig.2: Raman  
Microscope/Spectroscope  
Renishaw inVia Qontor*



*Fig.3: SEM/FIB Microscope Helios G4 UC*

# INFRASTRUCTURE CLEANROOM, INTEGRATION AND ANALYSES

320 m<sup>2</sup> R&D CLEANROOM FACILITY *Cleanroom Classes ISO 5 & 8*

## 8" FRONT-END LINE FOR MEMS MICRO-FABRICATION



Direct Write Lithography  
Heidelberg DWL66+



Resist Coat & Develop  
Süss MicroTech RCD8



Wet Chemical Proc.  
Acid/Base/Solvent



Thin Film Deposition  
Leybold UNIVEX 900



Plasma Asher  
Diener Nano 6



ICP - RIE



PE-CVD

## 3D RAPID PROTOTYPING & MICRO-ASSEMBLY



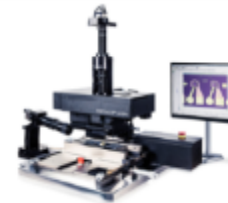
Functional Ink-Jet  
Pixdro LP50



3D HR Printer  
ProJet 3510 HD



UV Photocuring  
Pulse Forge 1200



Fineplacer  
Lambda



µ-Assembly  
Häcker OurPlant D1



Wire Bonding  
Kulicke Soffa & TPT HB16

## TESTING & ANALYSIS



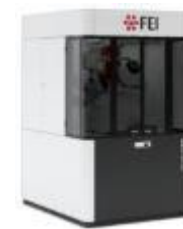
Bond Tester  
Nordson Dage



Laser Vibrometer  
Polytec MSA-500



Profilometer  
Bruker Dektak XT



SEM/EDS/FIB  
FEI Helios G4 UC



Raman Microscope  
Renishaw Quontor



FTIR Microscope  
Bruker LUMOS



Nano-Identer

# YOUR ADVANTAGES

- ≡ Fast and efficient cooperation
- ≡ Exploitation of cutting-edge knowledge and research expertise
- ≡ Complete solution provider for electronics systems
- ≡ Customized sensing components
- ≡ Simple access to co-financing
- ≡ Application of novel materials, emerging technologies and advanced concepts for the design of innovative products
- ≡ Fabrication of small sample quantities and prototype concepts

# PARTNERS



From **wood** to **wonders**.



Kneading - Mixing - Drying





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**UNFOLD THE FUTURE**

[WWW.SILICON-AUSTRIA-LABS.COM](http://WWW.SILICON-AUSTRIA-LABS.COM)