SAL
SILICON AUSTRIA LABS

SILICON AUSTRIA LABS

Bundesministerium
Klimaschutz, Umwelt,
Energie, Mobilität,
Innovation und Technologie

FEEI

Das Land
Steiermark

SFG

ZUKUNFTSFONDS STEIERMARK

LAND KÄRNTEN

ober österreich

Member of UAR INNOVATION NETWORK

KEY FACTS & FIGURES*

3

LOCATIONS
- Graz (HQ)
- Villach
- Linz

5

SHAREHOLDER
- 50.1 % Republic of Austria
- 10 % Styria (SFG)
- 10 % State of Carinthia
- 4.95 % Upper Austria (UAR)
- 24.95 % Industrial Association FEEI

> 250

EXPERTS
- Experiented team
- 40 nations
- Multidisciplinary

> 32

MIO €
PROJECT VOLUME

> 90

PARTNER NETWORK
- From Industry & Research

15

RESEARCH UNITS
in 5 DIVISIONS:
- Sensor Systems
- Microsystems Technologies
- Power Electronics
- Embedded Systems
- Intelligent Wireless Systems

*Figures of 2021

SAL BENEFITS FOR INDUSTRY

What do we offer?

- **Industry oriented research**
  Our competences and our equipment are aligned with industrial needs

- **We build the bridge between fundamental research and product development**
  We convert the findings of fundamental research into industrially usable results - right up to a functional demonstrator

- **We multiply your effort**
  The SAL finance model for cooperative research extends the radius of your research activities

OUR BUSINESS MODELS

How to work together

SAL Cooperative Research

Purpose:
- Easy accessible cofinancing for R&D projects with SAL
- Long term R&D cooperations (>1year)

Organisational Framework:
- Project Evaluation by SAL
- SAL General Contract Terms
- SAL Project Agreement

Advantages:
- 50% co-financing by SAL
- Bi/multilateral cooperation possible
- No application/proposal process necessary

SAL Contract Research

Purpose:
- Technology Concepts
- Test & Measurement Campaings
- Feasibility Studies
- Proof of Concept Studies
- (Rapid) Prototyping

Organisational Framework:
- Quote – Order Process

Advantages:
- Fast project start
- No further contractual framework necessary
- Fixed price
- Clearly defined deliverables

SAL Funded Research

FFG Forschung wirkt.

ECSEL Joint Undertaking

Horizon 2020 European Union Funding for Research & Innovation

Europäische Union EFRE Investitionen in Wachstum & Beschäftigung. Österreich.

OUR BUSINESS MODELS

Collaboration on a higher level

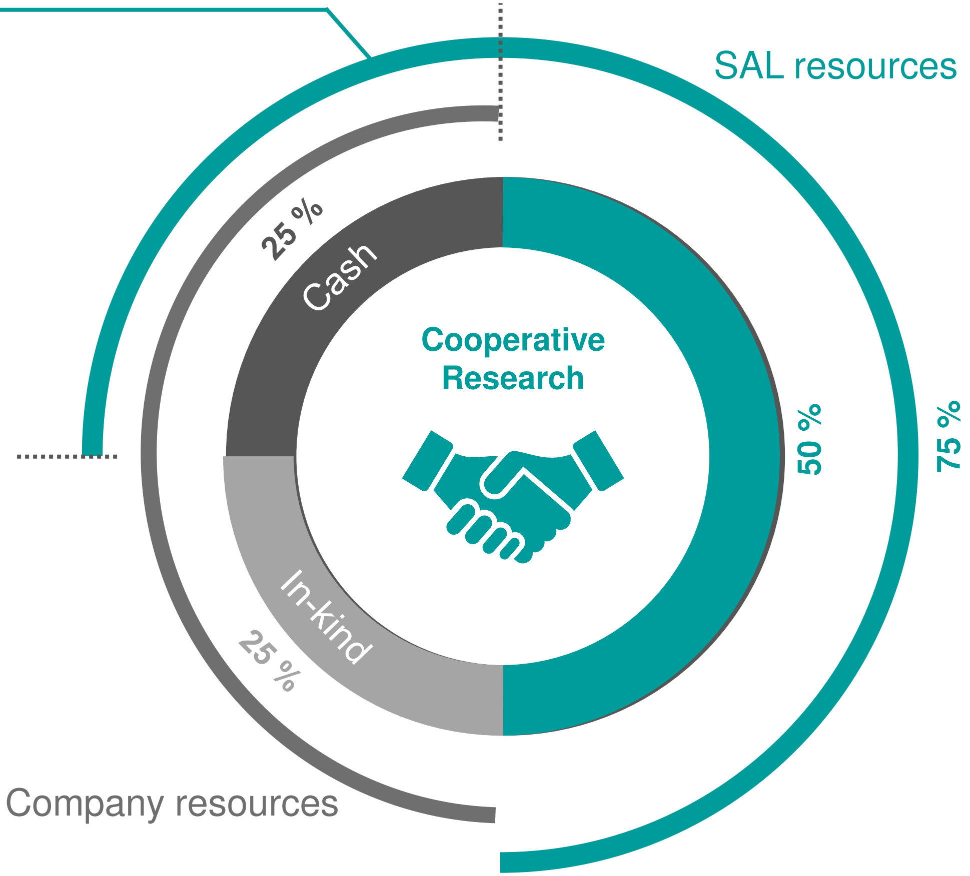
SAL Cooperative Research

- Applied Research (TRL 3 - 6)
- Multi-firm or single-firm projects customized to company needs
- Optional participations of universities as scientific partners
- 50/50 co-financing
- No funding application needed, no waiting time
- IPR rules compliant to state-aid-laws

TO PUT IT IN NUMBERS*:

€	100 k	In-kind contributions by company
€	100 k	Cash by the company
€	200 k	Co-financing by SAL (in-kind contributions)
€	**400 k**	**Project Volume**

€ 300 k expenses on SAL's side amounts to approx. 2,720 personnel hours* at actual costs and € 21,000 direct material costs etc.**



*400 k project volume as example

SAL VISION

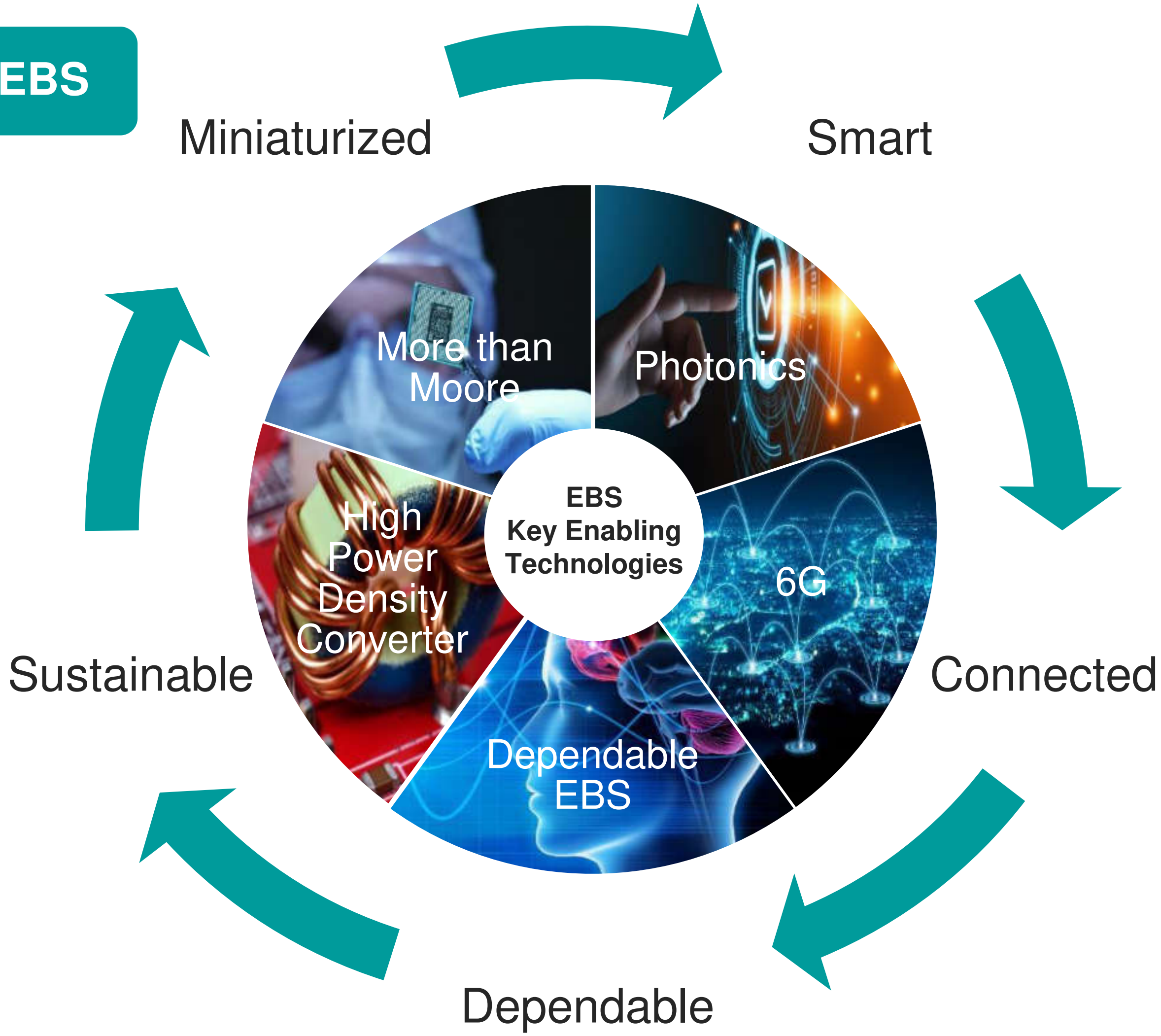
What do we envision for SAL?

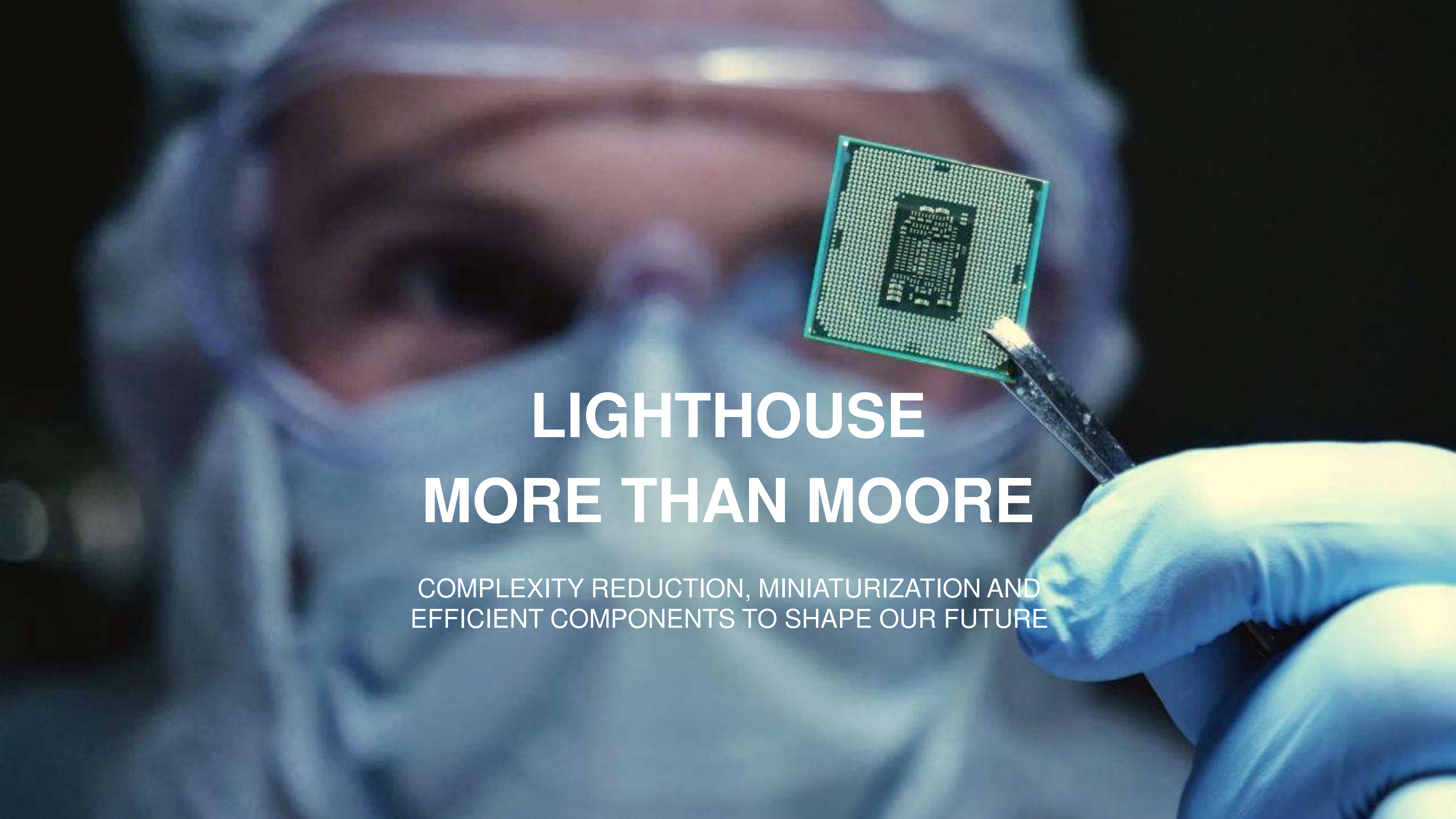
SAL is a world-class research center and pioneer in EBS

Providing EBS Key Enabling Technologies for **Smart, Connected, Dependable, Sustainable** and **Miniaturized** Solutions

Offering cost-effective solutions through the lighthouses. **More-than-Moore, Photonics, 6G, High Power Density Converter** and **Dependable EBS**

EBS one-stop-shop for high-tech industries, innovative SMEs and start-ups enabling **research along the value chain**





LIGHTHOUSE
MORE THAN MOORE

COMPLEXITY REDUCTION, MINIATURIZATION AND
EFFICIENT COMPONENTS TO SHAPE OUR FUTURE

MORE-THAN-MOORE LIGHTHOUSE

SAL SILICON AUSTRIA LABS

While Moore‘s law reaches its saturation (due to its massive capital intensity and ultimately semi-conductor physical limits), a new functional diversification, mixing and matching best suited EBS technologies for the good of ever more compact and performant systems becomes paramount. MEMS and MOEMS devices, RF filters, CMOS, magnetic and sustainable sensors combined with heterogeneous integration will be the new growth drivers in the EBS sector.

Flagship Research Topics

Piezo MEMS advanced piezo thin-film development and innovative piezo MEMS devices for emerging applications

Photonic MEMS integrated silicon photonic MEMS for applications such as miniature sensors, telecommunication, …

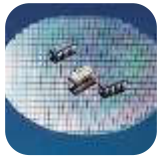
Magnetic Sensors material characterization and system & application design for micromagnetic sensor systems

Sustainable Sensorics biodegradable and regenerative materials, resource efficient fabrication methods for flexible and conformable devices

Applicative Packaging dedicated leading edge packaging solutions driven by customer applications

Infrastructure & Services

Complete **process chain for 200 mm** wafers with a focus **high performance thin film tech.**



Bridging **Research** and **prototyping** to **small series** production

Cleanroom access for SAL VIP partners and their **strategic research**

Target Customers / Partners and Value Propositions

Semicon & Microelectr. Ind.

Material, telecom., Automotive, Helathcare,…

Industrial Users

Sustainable electronics and applicative packaging taking solutions a step further

Cleanroom Equipment Vendors

Driving beyond stat-of the-art manufacturing technologies

LIGHTHOUSE PHOTONICS

THE AGE OF LIGHT IS STARTING

PHOTONICS LIGHTHOUSE

SAL SILICON AUSTRIA LABS

The **technology of light** will make it possible to overcome the physical limits of micro- and nano-electronics. Defined as a "European Key Enabling Technology", Photonics pushes the limits of a wide range of applications from sensing and metrology to (quantum-)communication, lighting and photovoltaics. SAL's comprehensive capabilities from photonic devices to systems, backed by an advanced research infrastructure and long-term experience, is unique in Austria and amongst few in Europe.

Flagship Research Topics

Next Generation Photonic Systems for sensor and metrology solutions.

Advanced Photonic Assembly, key enabling technology for miniaturization, robustness and reliability.

Non-Linear & Quantum Photonics: Bring novel technologies of non-linear spectroscopy and quantum sensing to industrial application.

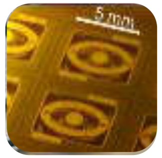
Infrastructure & Services

Simulate

Multiphysics simulation tool chain with Zemax, Virtual Lab, Comsol

Photonics Lab

400 m² class 4 laser-lab space for fabrication, testing, assembly



Cleanroom

Cleanroom facilities for Photonic MEMS customized for system requirements

Target Customers / Partners and Value Propositions

Semiconductor and Photonic component industry

RD&I for Photonic Components and Systems

Optical System Providers

Holistic Photonic system simulation and optimization including advanced photonic assembly

Application Industry

RD&I from simulation to custom photonic-component based application prototypes

LIGHTHOUSE
HIGH POWER DENSITY CONVERTERS

HIGH POWER-DENSITY LIGHTHOUSE

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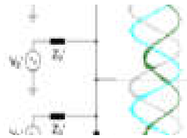
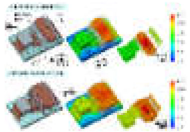
The climate change demands an energy turn-around along with stronger electrification. Modern efficient power converters with highest power density and efficiency are key enablers for that, with an immense range of target applications, replacement markets and hence impact potential.

Flagship Research Topics

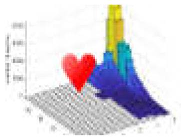
Highly efficient power converters & inverters with focus on resonant topologies aiming for compact hardware designs with high switching frequency exploiting wide-bandgap devices.



Emerging control engineering theory supported by signal processing, AI and high bandwidth controller hardware to enable full system/component utilization and lifetime optimized control.



Multiphysics simulation for power electronics optimization & design. Multi-rate, multi-domain simulation for multi-objective, efficiency/lifetime/volume system optimization including EMC.



Power system health monitoring with minimal sensing effort via novel embedded multi-domain state estimators e.g. WBG device junction temperature sensing for lifetime aware systems.

Infrastructure & Services

Simulation

"SALamander" multi-domain simulation framework for multi-objective efficiency/lifetime/volume system optimization and design.

Characterization, Test & Prototyping

Rapid Prototyping and Test Infrastructure for precise component & system measurements as well as hardware design.

Target Customers / Partners and Value Propositions

Power semiconductor component and module industry

Multi-physical, component-level measurements and characterization for holistic multi-physics simulation approaches, workflows and methodologies

System integrators and industrial user of power electronics:

Advanced topology, modulation and control aiming for full utilization of power electronic devices, components, and systems


TRUSTWORTHY, RESILIENT, SAFE & SECURE
DEPENDABLE
ELECTRONIC BASED SYSTEMS

DEPENDABLE EBS LIGHTHOUSE

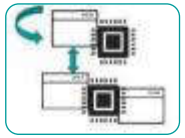
SAL
SILICON AUSTRIA LABS

Our research strives to make your systems dependable –
„trustworthy, resilient, safe and secure“

Flagship Research Topics

Advanced Signal Processing
for integrated digital- & virtual sensors

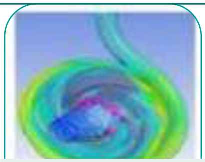
Trustworthy AI
for secure, explainable and verified AI at the edge



Efficient Computation
Dependable HW/SW-codesign and distributed algorithms up to middleware

Testing complex and connected EBS under application relevant conditions

Infrastructure & Services



Simulation & Modeling

Edge Computing Dev. Platforms

EBS Reliability Tests Lab

Edge AI System Test Lab

Target Customers / Partners and Value Propositions

Semiconductor industry
From formal methods to real-world testing on component and system level

Life Sciences & Medical electronics
Trustworthiness for wearables and point-of-care testing

Automotive & CPS
Combining safety, security, reliability into trustworthiness


LIGHTHOUSE
6G
PROPEL RESEARCH IN WIRELESS COMMUNICATIONS INTO
SUSTAINABLE CONVERGED NETWORK SERVICES

6G LIGHTHOUSE

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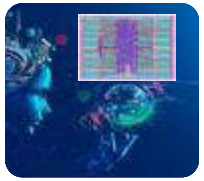
6G will enable a "hyper-reality" blurring the boundaries of physical and digital worlds. It will enable ubiquitous connectivity for people, billions of "hyper-connected" machines and services beyond pure communication. 6G will drive the convergence of communication, radar, localization and sensing.

Flagship Research Topics

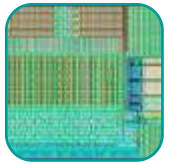
RF- & Analog IC design from mmWave to sub-THz frequency spectrum for convergence of communication, radar, localization and sensing.



Embedded AI for hybrid signal processing and machine learning in hardware.

Wireless time-sensitive networking facilitating real-time and secure wireless communications

Infrastructure & Services



IC Design

Digital-, RF-, Analog- & Neural Network Integrated Circuits Design

RF Test & Measurements

mmWave test- & measurement equipment (up to 500 GHz)

5G Use Case Prototyping

5G/6G research & experimentation testbed for industrial applications

Target Customers / Partners and Value Propositions

Semiconductor and ICT industry

RD&I for Integrated Circuits and Systems for RF, BB & ML for wireless communication and sensing

Industrial user of wireless systems and networks

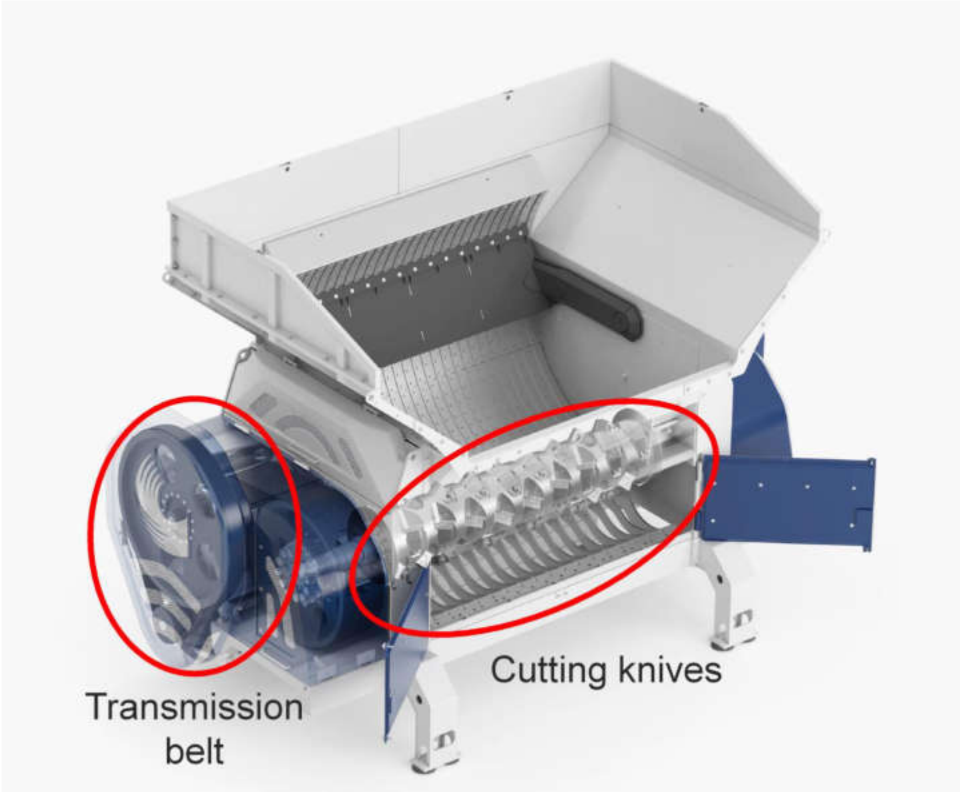
RD&I for industrial applications of wireless communication and sensing

PREDICTIVE MAINTENANCE OF INDUSTRIAL SHREDDERS: EFFICIENT OPERATION THROUGH REAL-TIME MONITORING USING STATISTICAL MACHINE LEARNING

FEDERICO PITTINO, DOMINIK HOLZMANN, KRITHIKA SAYAR-CHAND, STEFAN MOSER, SEBASTIAN PLIESSNIG AND THOMAS ARNOLD

INTRODUCTION

- The objective was to develop models for predictive maintenance on an industrial waste shredder.
  - Harsh environment
  - Frequent and critical maintenance
- Main focuses:
  - Cutting knives, need replacement every few months
  - Transmission belt, needs periodic re-tensioning and is replaced every 1-2 years
- Models need to work in real-world conditions
  - Data acquisition using custom data-loggers
  - Continuous monitoring of one shredder at a recycling plant (in Austria)
  - Data acquired for almost a year



KNIVES SHARPNESS MEASUREMENT

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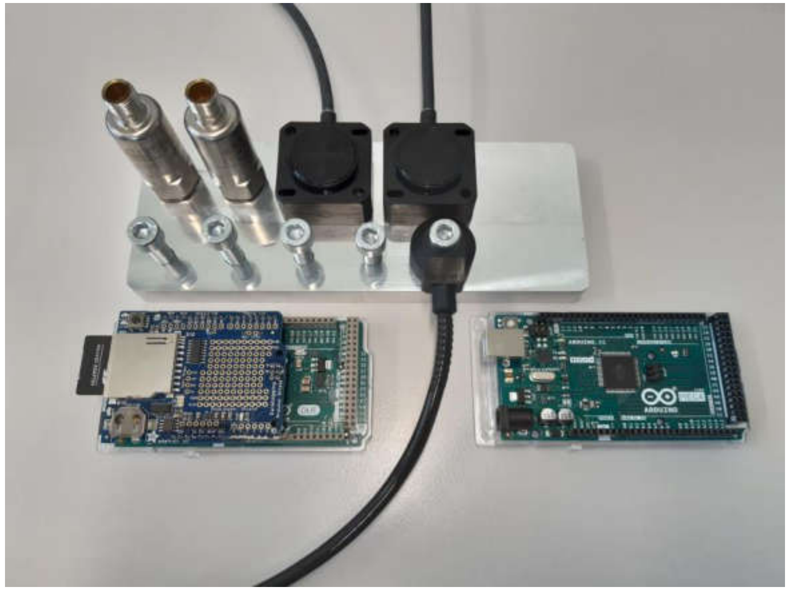
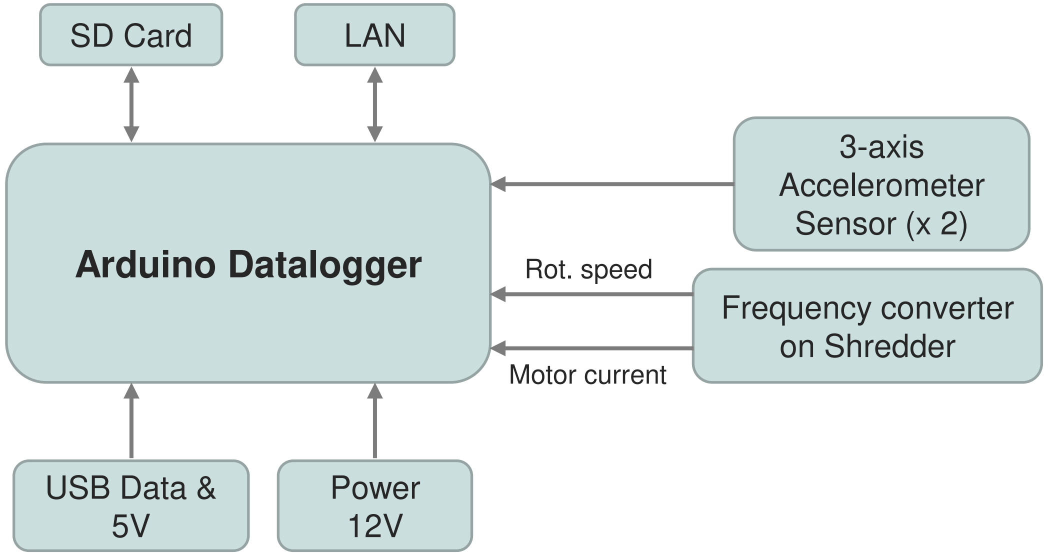
- Data for determining knives sharpness has been acquired through an Arduino Datalogger
  - Features 2 accelerometers and reads the motor current and rotation speed
  - Acquires continuously during each working day
  - Sampling rate 10ms
  - Data is stored internally and periodically transferred via LAN interface





DATA ACQUISITION
KNIVES CONDITION

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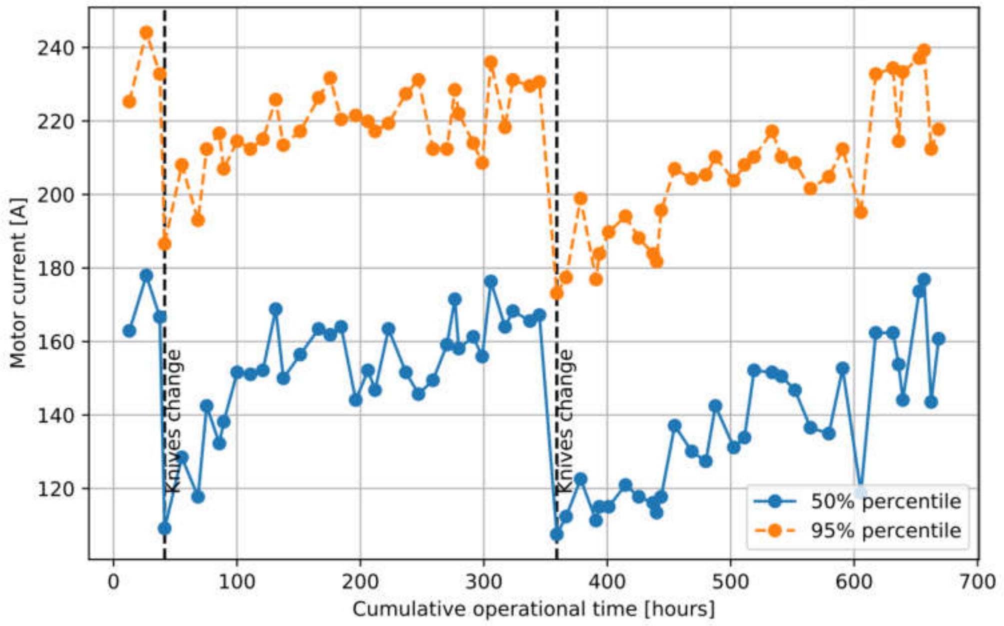
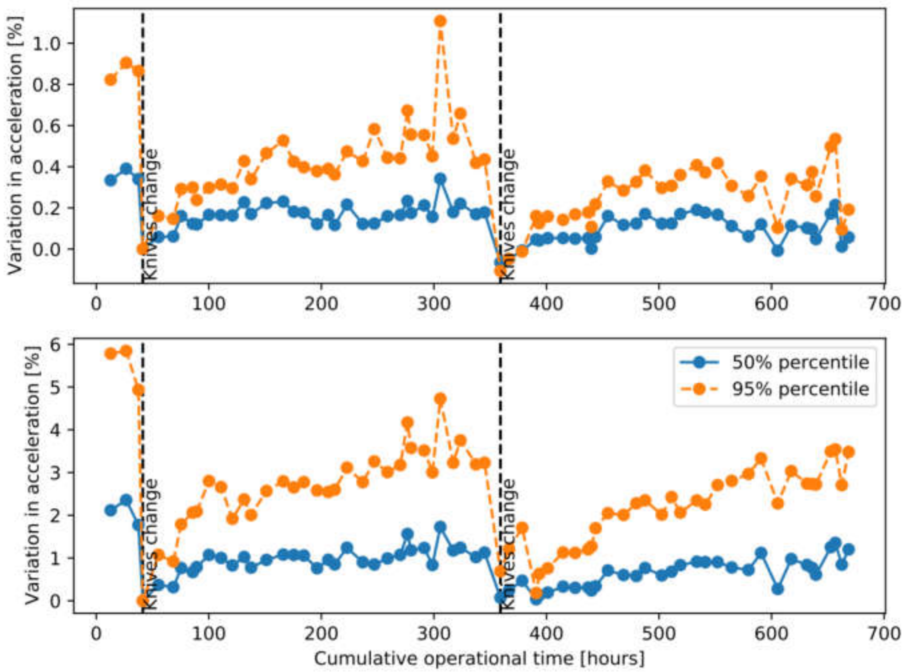
- The operational time of the machine has been extracted:
  - identifies the time instants in which the motor speed rises above a set threshold (1000 rpm)
  - retains only the intervals in which speed > threshold for at least 1 minute

- The motor current and accelerations are preprocessed:
  - The 50% and 95% daily percentiles are calculated
  - The average current up to the 95% percentile is derived
  - Done to discard large outliers caused by occasional tough material

- The knives were changed twice during the acquisition
  - Training set consists of data between the two knives changes
  - Test set consists of data after the second knives change

RESULTS – PERCENTILES
KNIVES CONDITION

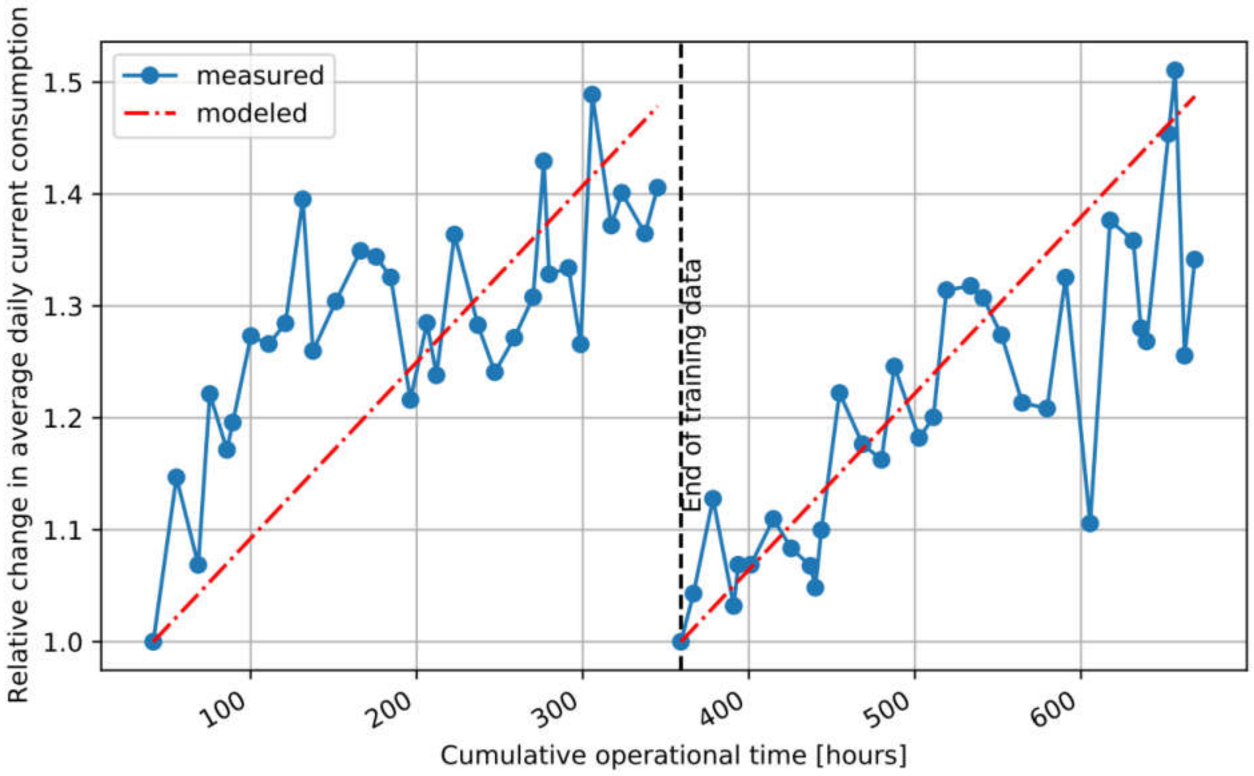




- Motor current:
  - Clear drops after the knives change
  - Around 50% increase between maximum and minimum
- Accelerations 1 and 2:
  - Clear effect after the knives change
  - Signal clearer on accelerometer 2, very dependent on position

RESULTS – PREDICTIVE MODEL
KNIVES CONDITION

- Showing the change in average daily current consumption up to the 95% percentile relative to the day when the knives were changed
- A linear model has been trained to predict the average motor current
  - Independent variable is the cumulative operational time since the last knives change
  - The model on the test data is very accurate -> good reproducibility between different periods
  - The linear model is capable of satisfactory accuracy
  - Again shown an increase of 50% on the average current before the knives change



BELT TENSION MEASUREMENT

- It is assumed that, when the belt tension decreases:
  - Slipping events between motor and rotor occur
  - Using encoders to detect slipping

- Incremental encoder sensors have been mounted on motor and rotor wheels
  - A Logic Analyzer used for the acquisition
  - Acquires continuously during each working day
  - Run-length encoded data is obtained from both encoders, providing a square signal
    - Sampling rate 1 MHz
  - Outliers (unusually small values) need to be rejected
  - The total speed per full rotation of the encoder is then calculated, and compensated for the gearing ratio

RESULTS
BELT CONDITION

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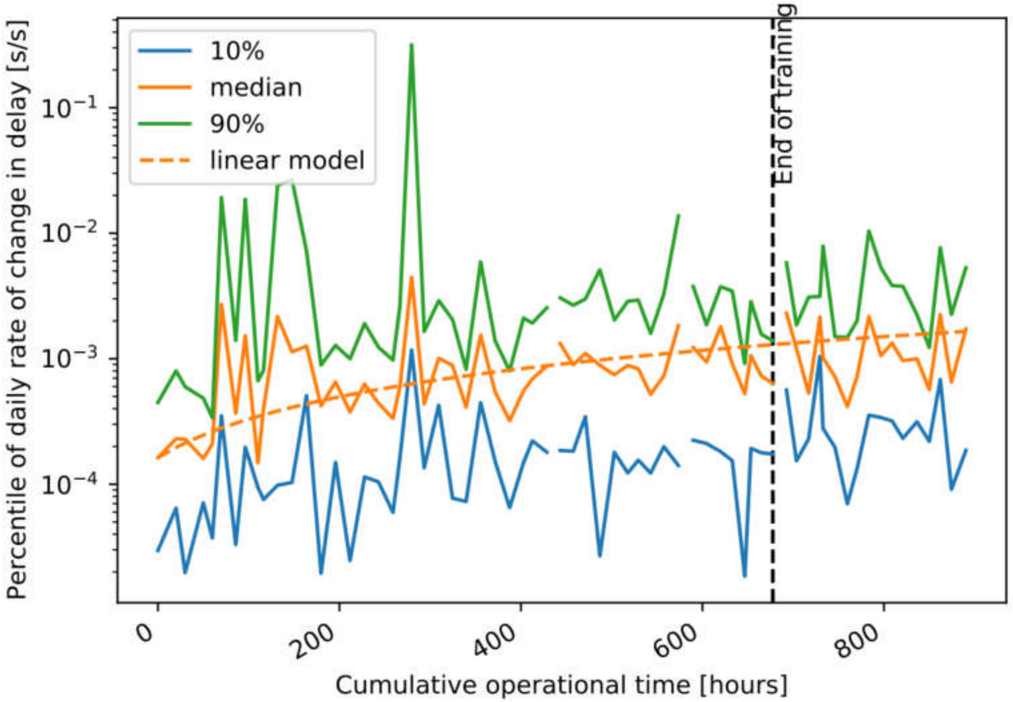
- The delay rates of variation are calculated on the whole data
- Another linear model is trained to predict the increase of this delay rate over time:
  - It is predicted the daily median of the rate
  - For training, the first 75% of the data is used, the rest used for test
  - The model uses as independent variable the cumulative operational time of the machine
- The results show:
  - Clear increasing trend of the delay rate over time, due to progressive wear in the belt
  - Very good accuracy of the linear model, also on the test set



CONCLUSIONS

- We have presented a system for data collection and processing on an industrial shredder:
  - Working in real-time during normal operation
  - Performing predictive maintenance on two key components

- Simple data-driven models can provide very good predictions as soon as the machine is monitored :
  - for a long enough time
  - with sufficient accuracy to observe all its states of wear

- Such prediction models should be used in a predictive and preventive maintenance strategy:
  - to optimize the cost of operation
  - to prevent any downtime

TINY POWER BOX

How to develop the smallest, lightest, & most efficient bidirectional onboard charger for e-cars?

Thomas Langbauer

Power Electronics
Architectures & Topologies

TINY POWER BOX

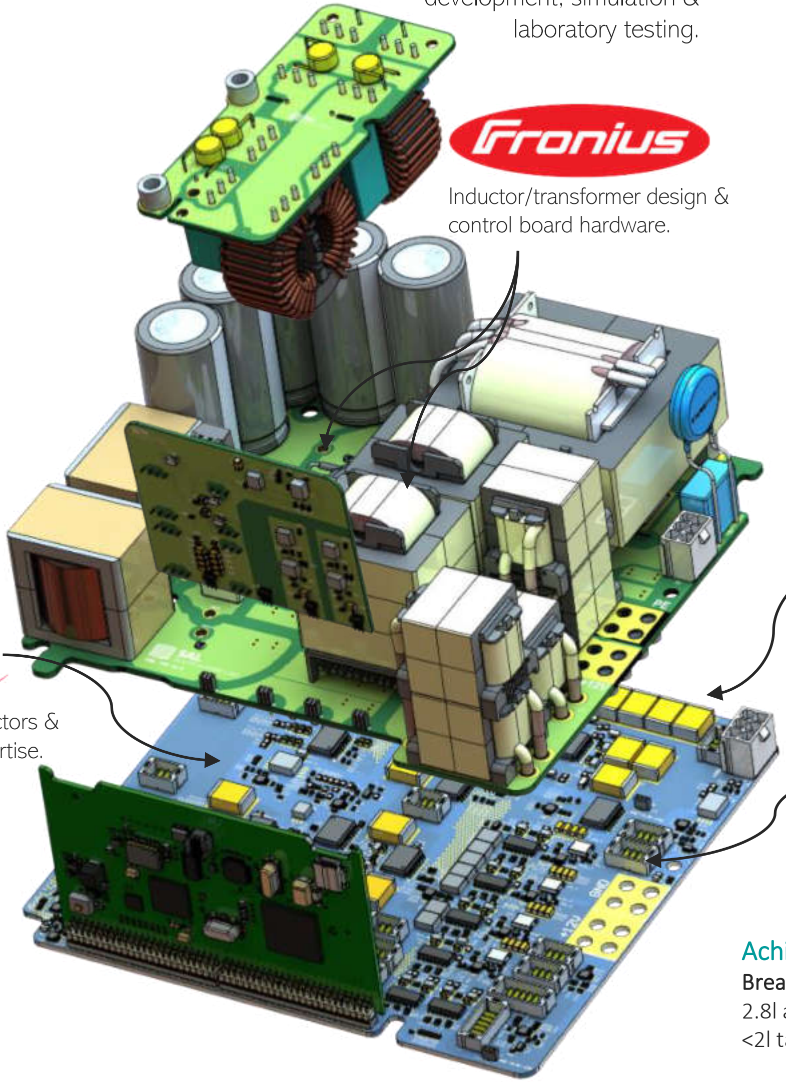
ROLE MODEL FOR CO-OP PROJECTS

1) Beyond state-of-the-art power density

Bi-directional Onboard Charger for…

Variant A: **Automotive** (7kW)
Variant B: **Industrial Forklift** (11kW)

With integrated LVDC output



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Topology optimization, system design, EMC design, control development, simulation & laboratory testing.

Fronius
Inductor/transformer design & control board hardware.

Infineon
Power semiconductors & circuit design expertise.

TDK
Ceralink™ modelling, capacitor expertise & potting assembly.

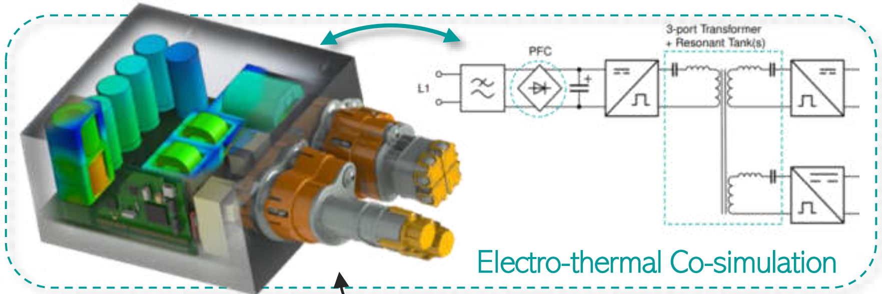
AT&S
Embedded MOSFET benchmarking & simulation.

TINY POWER BOX — **SAL** SILICON AUSTRIA LABS

Project Volume TOTAL: 3.5MIL €

Budget		Duration		SAL Tiny Box Team		
SAL	5 Partners	3 Years		Currently 10 persons involved		
1.75 MIL	**1.75 MIL**	2019	2022	6 Post-Doc	2 PhDs	2 Engineers

2) Holistic simulation workflow



+ develop path for:
System
Lifetime

AVL
Thermal, system & reliability simulation expertise.

PhD & Master Students

TU Graz — KÄRNTEN University of Applied Sciences

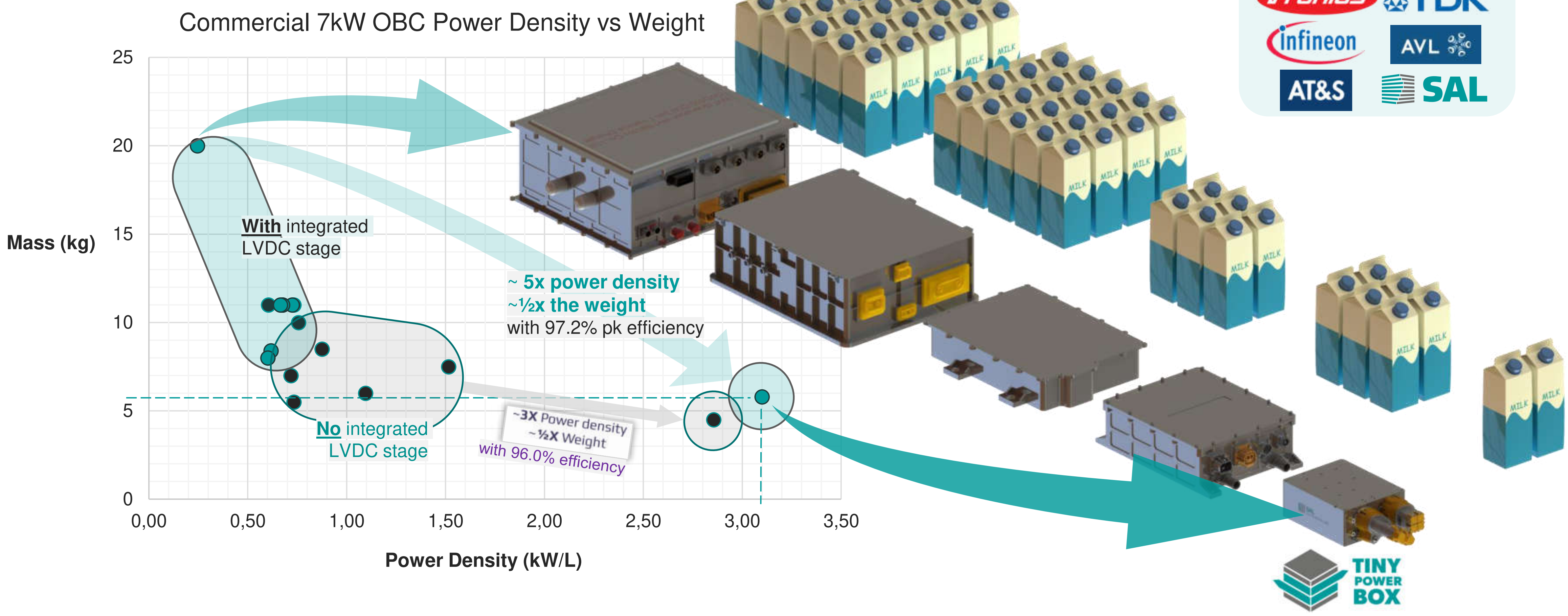
Achievements

Breaking state-of-the-art OBC power density
2.8l actual total volume with case
<2l target volume for re-design step

Breaking state-of-the-art OBC efficiency
>98% in PFC stage
>98% in DCDC stage

TINY POWER BOX vs MARKET
AUTOMOTIVE

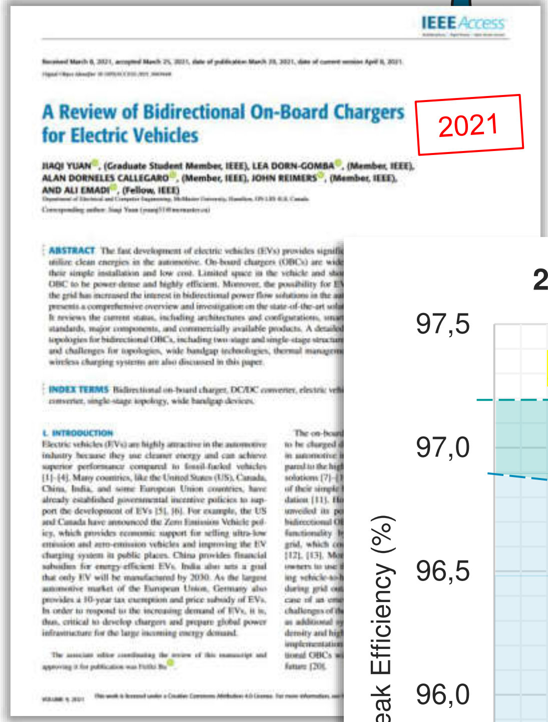
Tiny Power Box



TINY POWER BOX vs SoA
AUTOMOTIVE

Without housing/casing!!

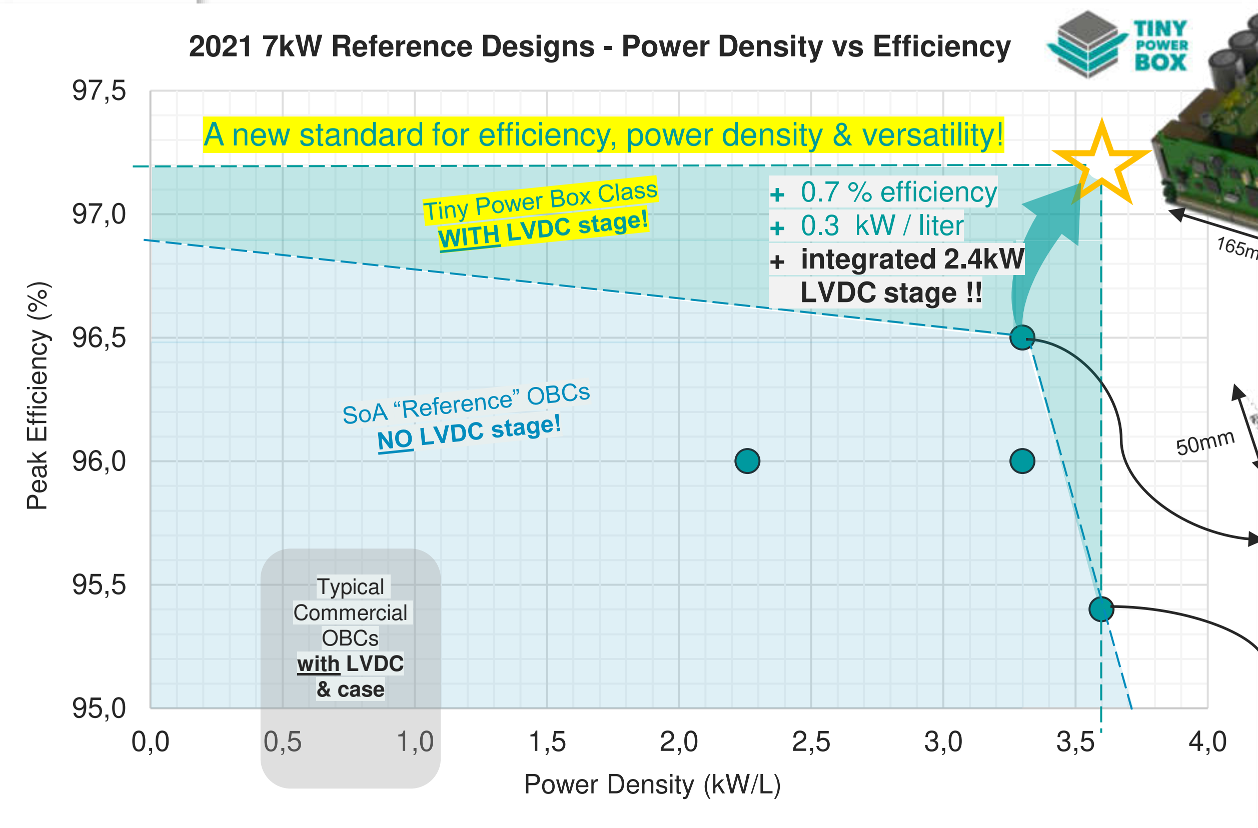
Manufacturer	PFC Topology	DC/DC Topology	Input Voltage (V)	Output Voltage (V)	Power (kW)	Efficiency (%)	Power Density (kW/L)	Switching Devices	Cooling Method	Aux. LVDC Stage
Texas Instruments	Totem pole	CLLC	208-240	250-450	6.6	97	-	SiC	-	no
Delta-q	Totem pole	CLLC	85-265	250-450	6.6	96	2.26	SiC/GaN	Liquid	no
Wolfspeed	Totem pole	CLLC	-	250-450	6.6	96.50	3.3	SiC	-	no
Current Ways	Three-phase full-bridge	DAB	97-265	250-425	6.6	96	3.3	SiC	Liquid	no
Silicon Austria Labs	**Totem pole**	**CLLC**	**85-265**	**250-450**	**7.0**	**97.2 ★**	**3.6 ★**	**SiC/Si**	**Liquid**	**YES – 2.4kW ★**

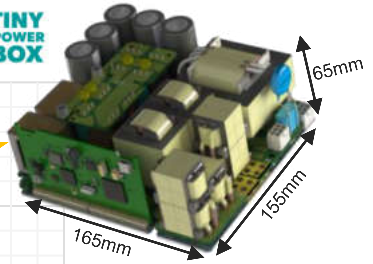

IEEE Access

A Review of Bidirectional On-Board Chargers for Electric Vehicles

JIAQI YUAN, LEA DORN-GOMBA, ALAN DORNELES CALLEGARO, JOHN REIMERS, AND ALI EMADI

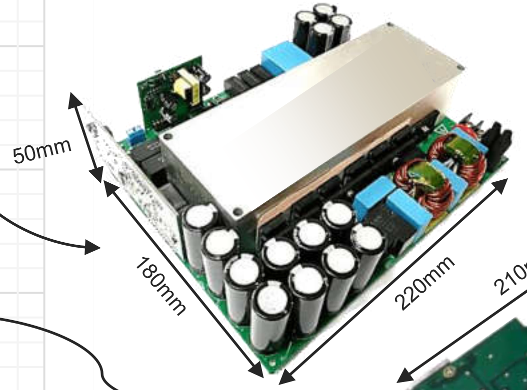
2021

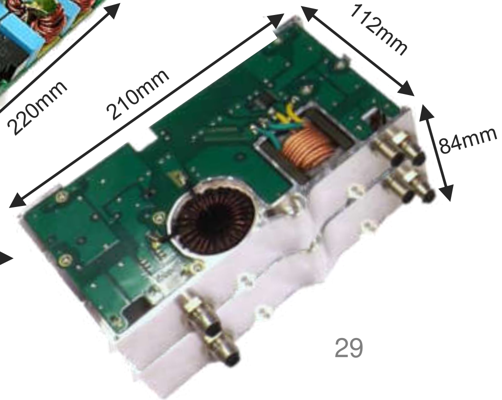




Tiny Power Box

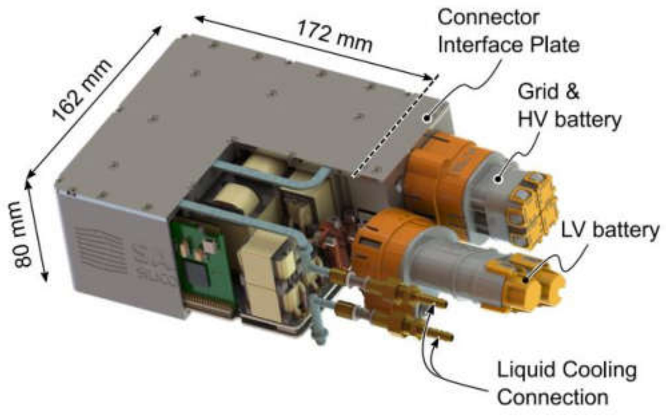
Fronius, TDK, Infineon, AVL, AT&S, SAL

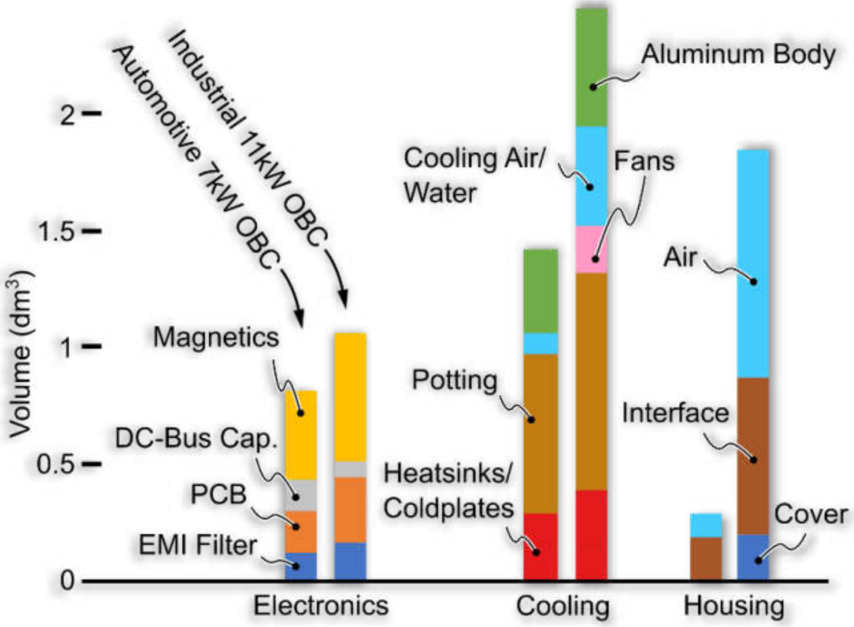




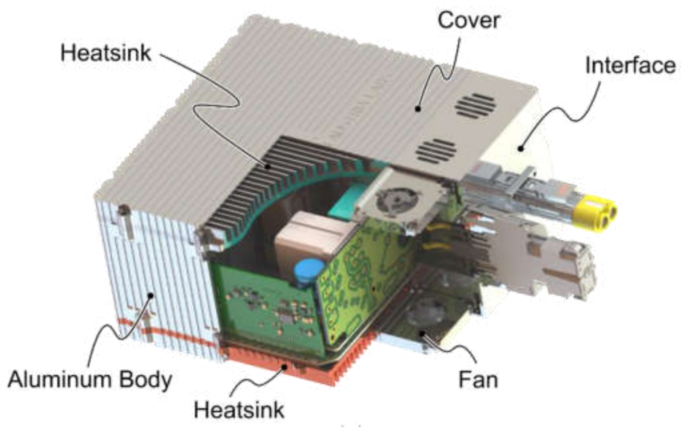
TINY POWER BOX HARDWARE
COMPARISON

Automotive 7kW OBC





Industrial 11kW OBC

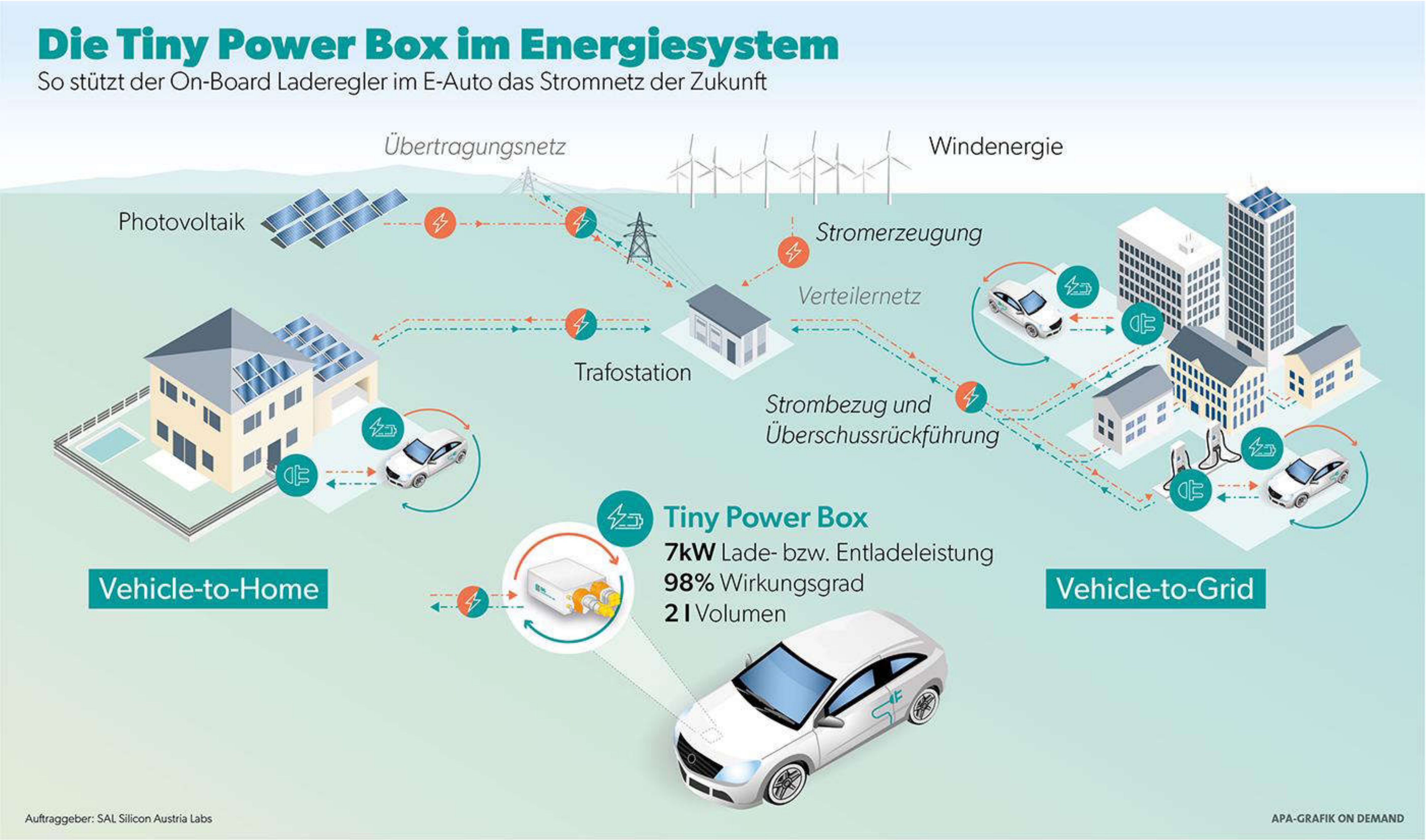


Automotive 7kW 1 Phase Onboard Charger,
Isolated, Bi-directional & Integrated 2.4kW LV

3.6 kW/dm³ excl. cooling system
3.1 kW/dm³ **incl. cooling system**

Industrial 11kW 3 Phase Onboard Charger,
Isolated, Bi-directional & Integrated 775W LV

4.0 kW/dm³ excl. cooling system
2.1 kW/dm³ **incl. cooling system**



Die Tiny Power Box im Energiesystem
So stützt der On-Board Laderegler im E-Auto das Stromnetz der Zukunft
Übertragungsnetz
Windenergie
Photovoltaik
Stromerzeugung
Verteilernetz
Trafostation
Strombezug und
Überschussrückführung
Tiny Power Box
7kW Lade- bzw. Entladeleistung
98% Wirkungsgrad
2 l Volumen
Vehicle-to-Home
Vehicle-to-Grid
Auftraggeber: SAL Silicon Austria Labs
APA-GRAFIK ON DEMAND

SMARTER LEICHTBAU

How to develop printed sensors to use them
in production / composites industry?

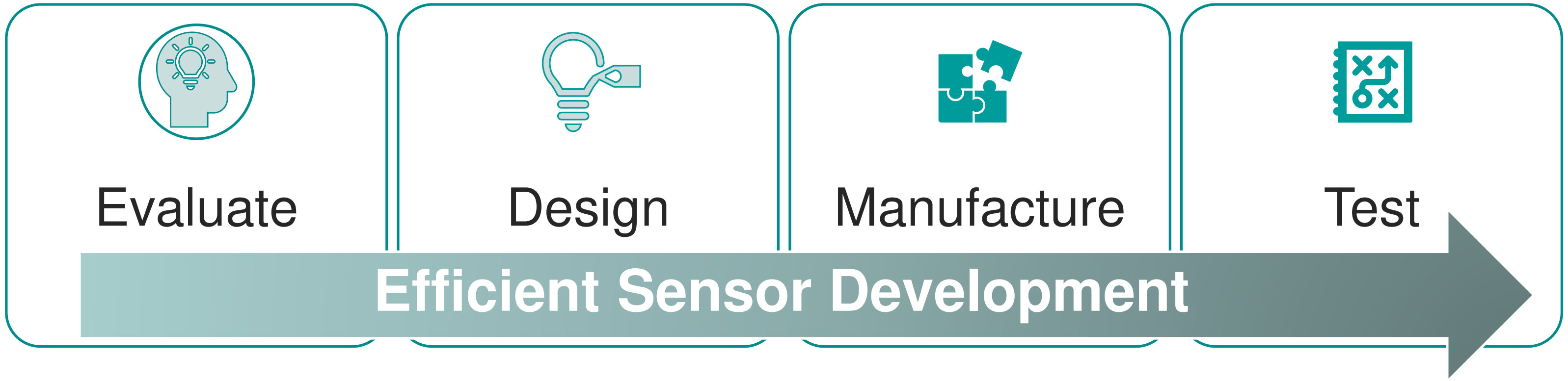
Lukas Rauter

Sensor Systems
Sensor Applications

WHAT WE OFFER

SAL SILICON AUSTRIA LABS

APPLICATION SPECIFIC SENSORS – THE FAST TRACK TO A PRODUCT



Methods

- Consider and adapt existing solutions
- Focus on commercially available of-the-shelf components
- Include component and/or system manufacturers
- Utilize wired, inductive or non-contact (NFC, UHF, BLE) communication for sensor signal read-out
- Integration of sensors with hard- and software
- Enable fast translation to product

Examples

- Sensing inside of rotating machines (inductive readout,…)
- Wear or damage detection (Eddy Currents, Ultrasound,…)
- Harsh environment sensing (high temperature, high pressure,…)
- Customized sensors for medical devices (passive, non-contact readout)

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- Two subprojects:
  - Smarter Leichtbau 4.0 (01.12.2017 – 31.12.2020)
  - Smarter Leichtbau 4.1 (01.02.2021 – 31.12.2022)
- EFRE funded
- Partners:
  - Wood K Plus – Wood Competence Center
  - Carinthia University of Applied Sciences
  - Silicon Austra Labs
- Project aims:
  - Lightweight construction with fibre composites to increase efficiency and improve sustainability for a wide range of applications
  - Further development of fibre materials, especially in the direction of renewable raw materials
  - Integration of sensor technology for smart functionality and efficient process control
  - Non-destructive materials testing and process analytics technology

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Background

Increased requirements on the performance of construction parts and their sustainability have resulted in:

- Increased use of lightweight composites
- Synthetic fibers replaced by natural fibers

Problem(s)

- Humidity absorption and temperature changes lead to fiber swelling and material degradation, resulting in integrity loss, mechanical weakening, etc.
- This can happen during both fabrication and application

Objectives/ Targets

- Monitoring of moisture and temperature inside of natural fiber composite materials
- Wireless readout
- Thin and planar sensor
- Eco-friendly/green sensor solution for integration (biodegradable sensor substrates)
- Resource-efficient production

Solution

- Printed sensors and printed antenna on paper embedded inside the composite material
- Inductive, wireless readout

Sustainable, wireless humidity sensor patch — ***Integration in composites*** — ***Lamination process and wireless communication***

Advantages

- Wireless readout
- Resource-efficient sensor fabrication
- Paper as substrate and sensing material
- Minimal effect on mechanical properties of composite material

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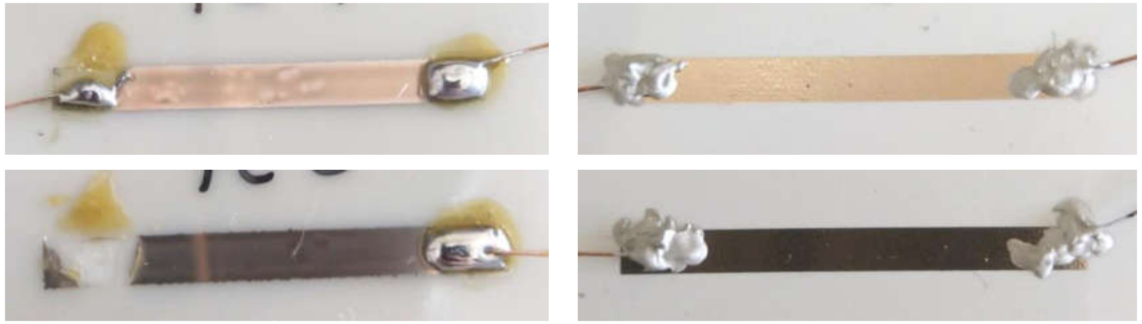
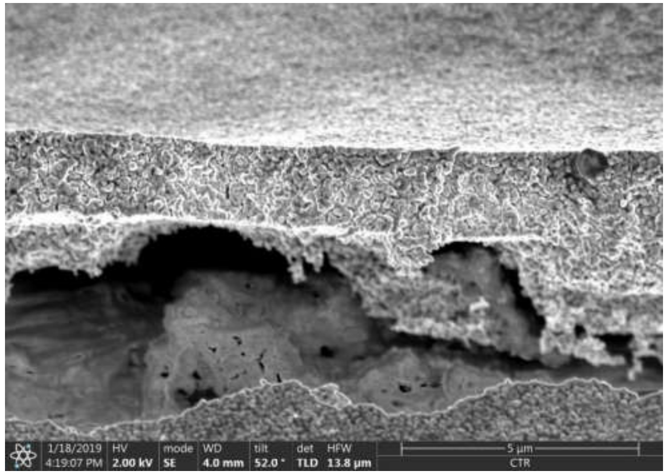
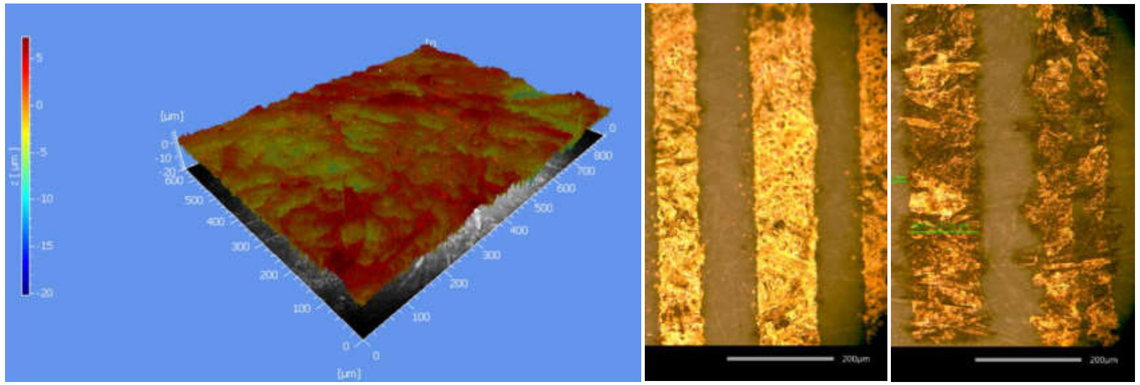
- Evaluation of electrical bonding strategies for inkjet-printed electronics
  - Soldering
  - Soldering on screen printed pads
  - Adhesive bonding
  - Mechanical crimping
- Substrate evaluation and investigation of substrate-ink compatibility



Different electrical bonding strategies have been investigated and compared on various flexible substrates (paper, PET, Polyimide etc.)



SEM image of crack in the printed Ag-layer on uncoated paper substrate.



Investigation of the surface properties and printability of substrates.

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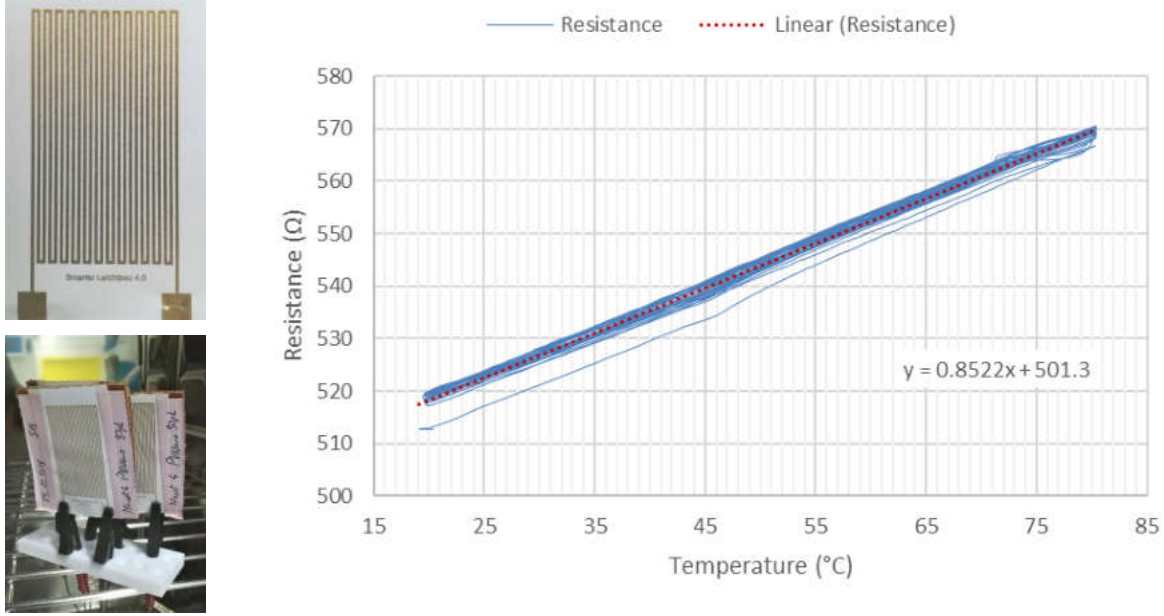
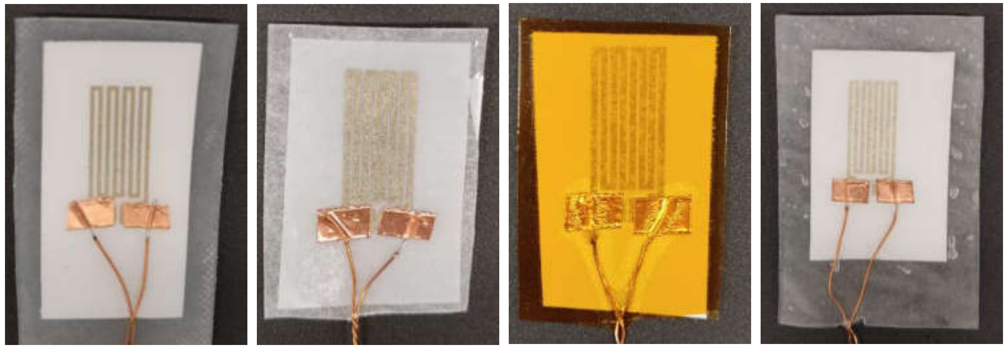
- Development, fabrication and characterization of printed temperature, strain and humidity sensors
  - Inkjet technology
  - Uncoated paper substrate
  - Physical connection
  - Good repeatability
  - Sensitivity comparable with commercial sensors

- Protective coatings for printed flexible sensors
  - EVA
  - PDMS
  - Polyimide
  - Polyolefins
  - Liquid rubber



Printed resistive temperature sensors and characterization results.



Investigation of sealing methods for protection against humidity and UV irradiation.

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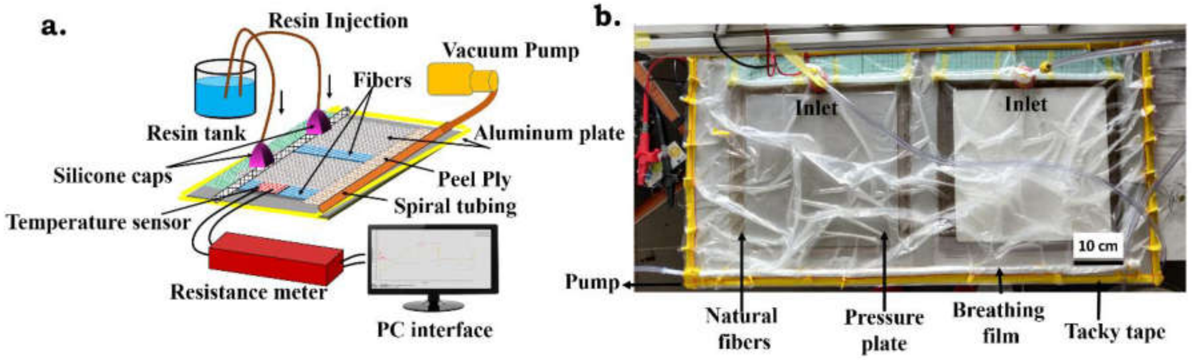
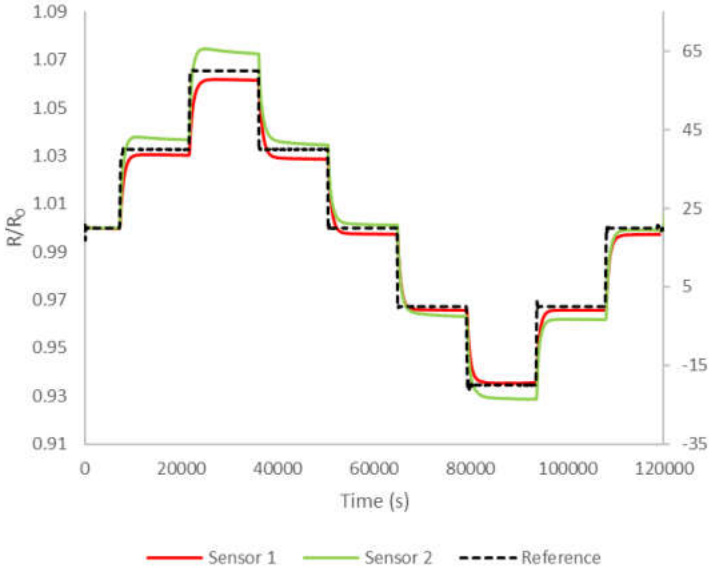
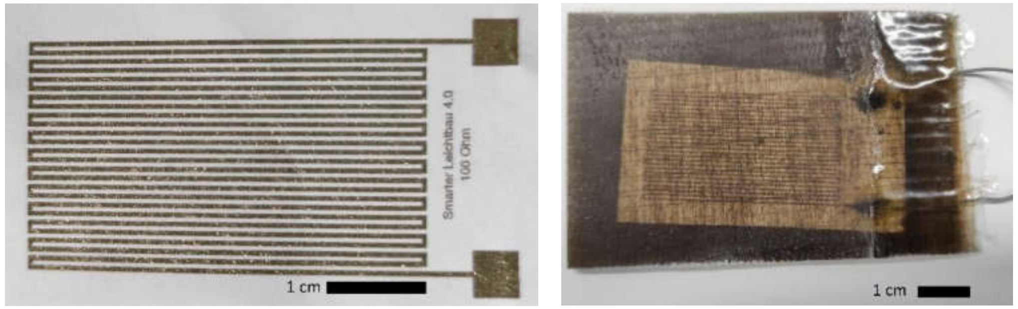
- Sensor integration
  - Embedded in natural fiber composite panels
  - Fiber composite also works as packaging
  - Good sensor response
  - Very good repeatability



Vaccum infusion process for sensor integration.



Embedded temperature sensor compared with commercial reference sensor.



Printed temperature sensor on paper substrate: bare sensor and embedded specimen.

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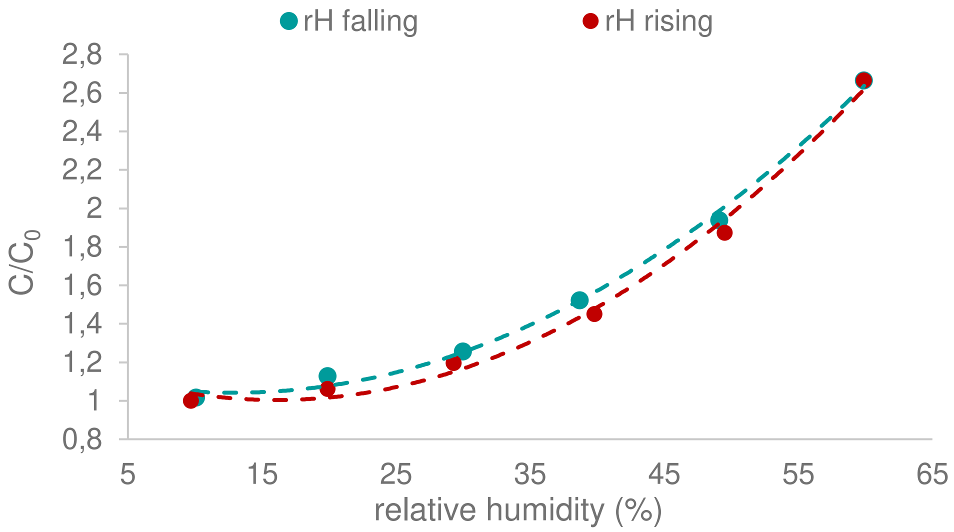
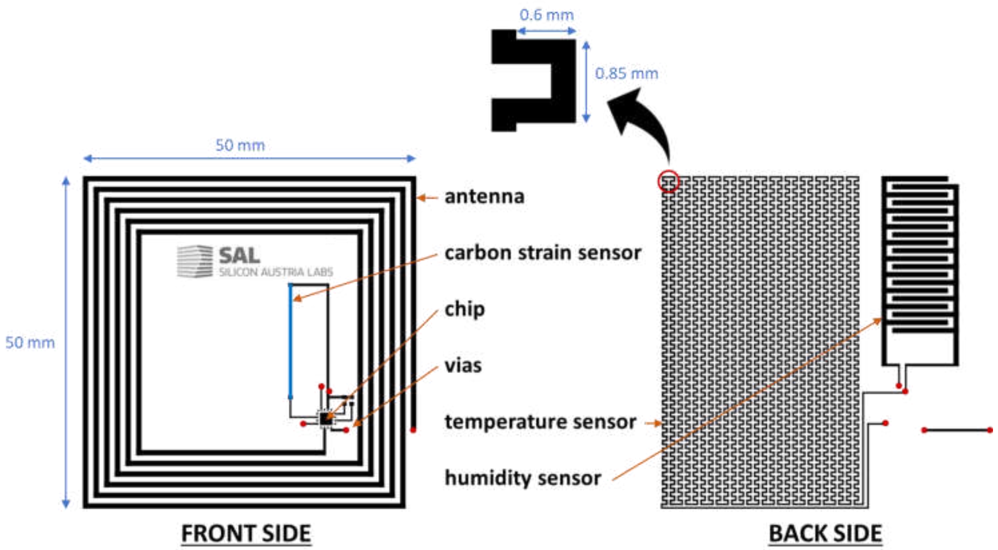
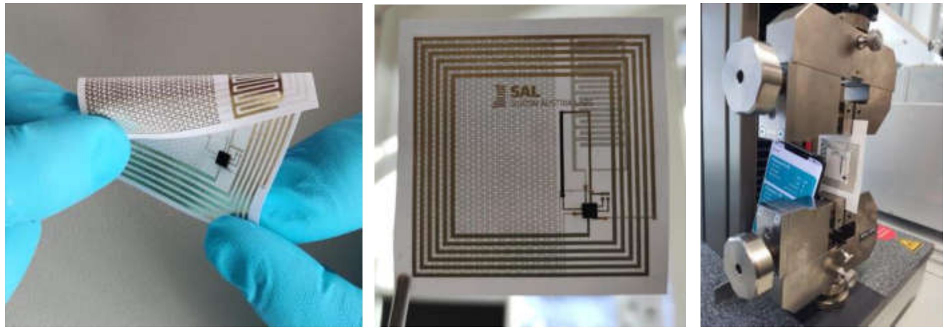
- Hybrid sensor solution
  - Inkjet and screen printing
  - Via fabrication
  - Chip bonding
  - NFC read out with smart phone



Sensor response to changing relative humidity.



Schematic of the sensor design.



Hybrid sensor system under investigation.

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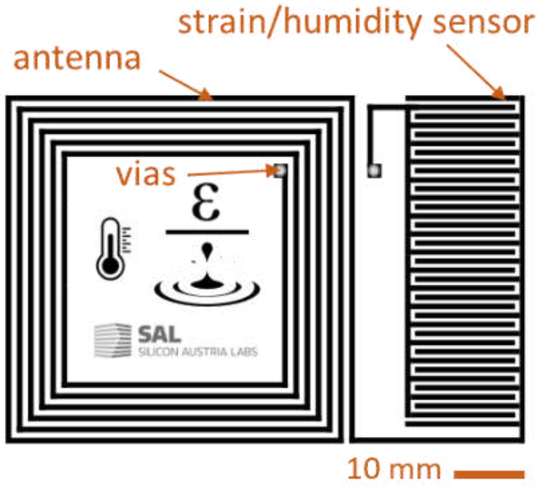
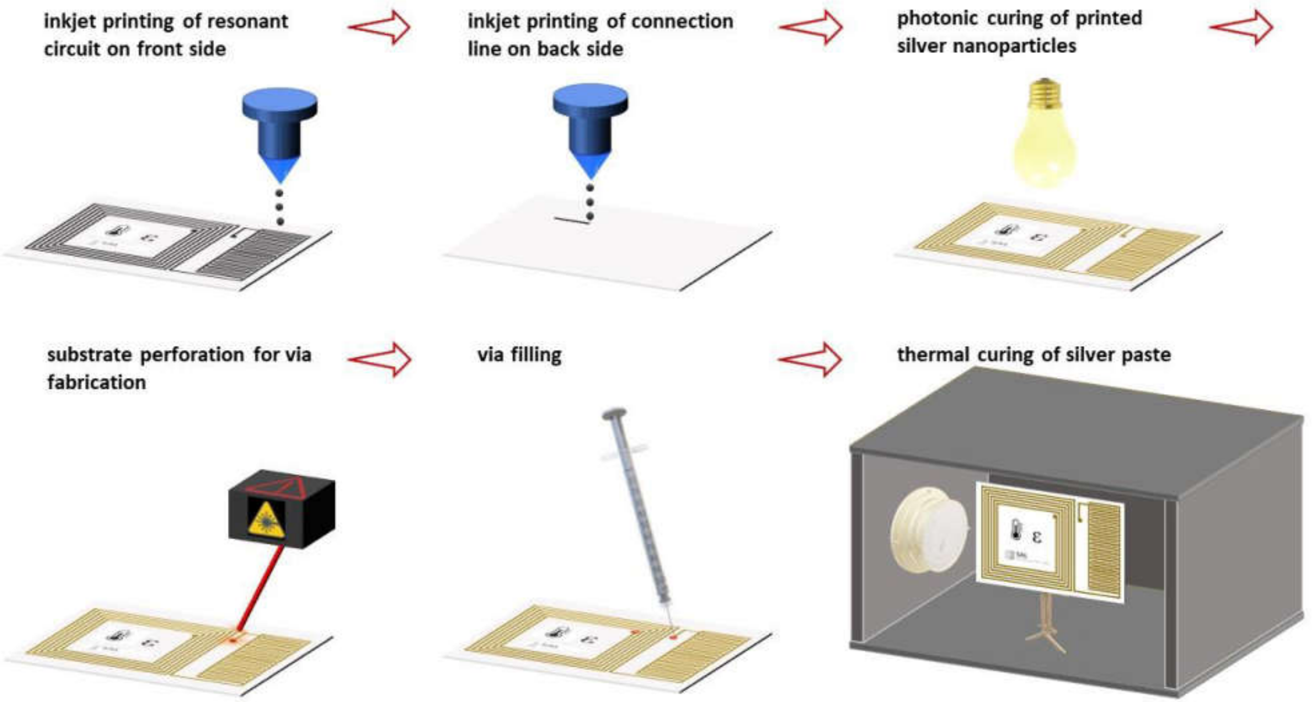
- Fully printed chipless sensor solution
  - Design: parallel resonant circuit
  - Inkjet printing
  - Photonic curing
  - Via fabrication



Schematic of the sensor design.



Schematic illustration of the sensor fabrication.

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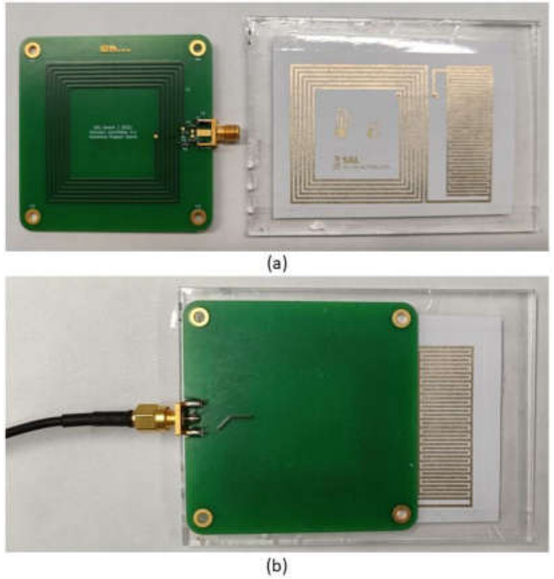
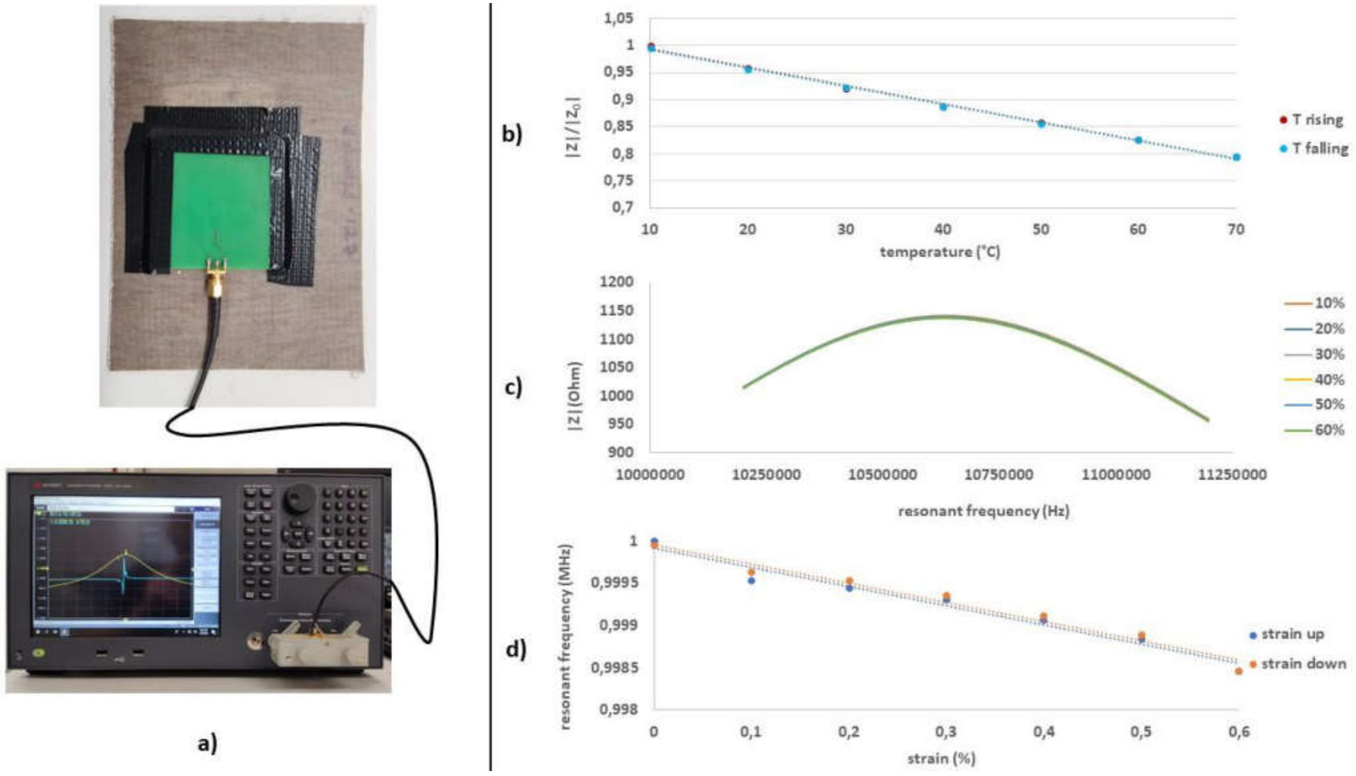
- Fully printed chipless sensor solution
  - Read out via inductive coupling with reader antenna
  - LCR meter measurements of resonance shift and changing bandwidth
  - Investigation and characterization of embedded sensor system



Fully printed sensor tag prepared for characterization measurements.



(a) Illustration of wireless measurements via reader antenna connected to impedance analyzer. b) Temperature dependent, c) humidity dependent and d) strain dependent measurement results.

CONCLUSION

- Gaining experience in field of printed electronics
- Evaluation of ink-substrate combinations for printed sensors
- Green and eco-friendly sensor solutions for structural health monitoring
- Compatibility of printed flexible sensors and natural fiber composites
- Hybrid sensor solutions
- Wireless fully printed sensor solution ➔ biodegradable

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