



# Microsystems

*Novel solutions for MEMS devices.*

The Microsystems Research Division aims to develop beyond state-of-the-art technologies for novel MEMS devices. In close collaboration with our industrial and scientific partners we develop cutting-edge technology from design and proof-of-concept to product prototypes. In addition to our long-standing experience in MEMS, the Microsystems Division also relies on cross-border and interdisciplinary skills. These capabilities enable the team to push the boundaries of current technologies, promoting innovative and groundbreaking ideas in various directions and for diverse applications, with a strong focus on partners' and markets' interests.



*"Microsystems make products not only smaller and more powerful, but also more efficient, smarter & multifunctional. In the Microsystems Division, we create the basis for novel technologies and processes on the verge of market trends and at the highest global level. With our expertise in MEMS design, modelling, microfabrication and characterization, we support our partners in strengthening their products and accelerate innovation."*

*Mohssen Moridi, Head of Division Microsystems*



# Thin Film Technologies

## Deposition

- » Physical and chemical vapor deposition of thin film/stacks for piezoelectric, photonic, magnetic, and other applications
- » Up to 200 mm wafers in ISO 5 infrastructure
- » **Examples:** high quality piezo stacks for piezoMEMS; novel PECVD process for low density materials; new material compositions by co-sputtering; enhanced grain size metals by HiPIMS

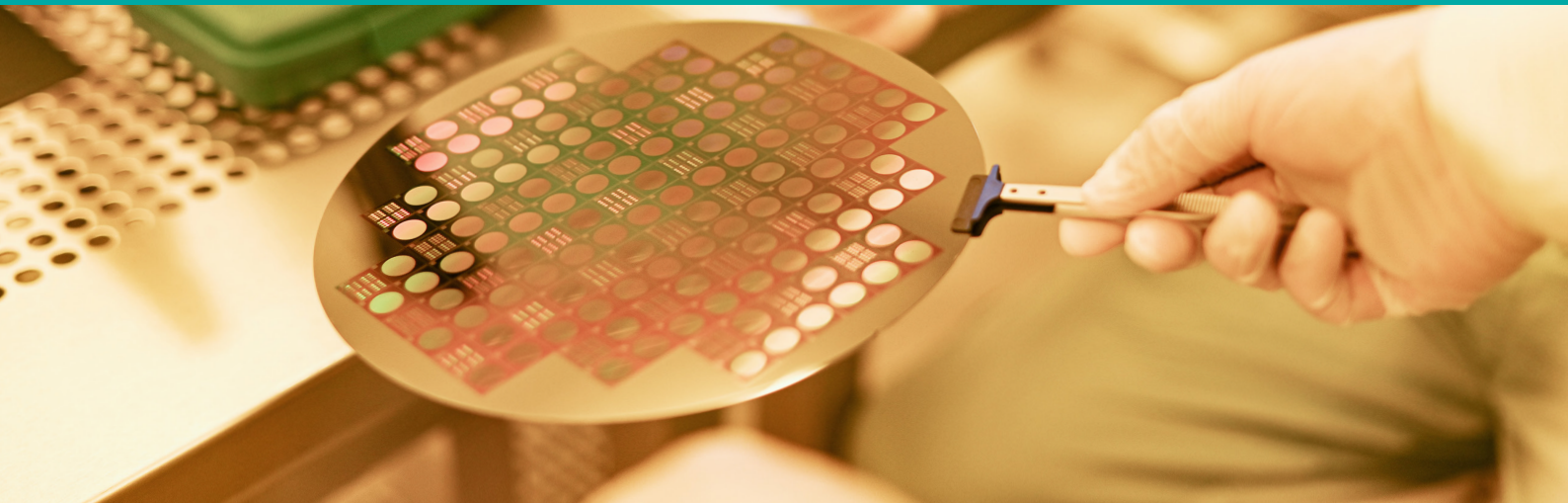
## Characterization & Testing

- » Understanding the structure of thin films and surfaces from atomic to macroscopic scale
- » Techniques for obtaining material properties such as dielectric function, crystallinity, stress, roughness and many more
- » Non-atmospheric and mapping possibilities for many tools
- » **Examples:** mimicking annealing processes with hot stage environment; surface analysis of process steps; mapping of crystallinity, thickness, refractive index
- » Testing of application relevant properties such as the piezoelectric coefficient
- » Device test structures to test the thin films in action
- » **Examples:** measurement of piezoelectric properties; cyclic testing

## Key Equipment

- » Magnetron sputtering – Evatec Clusterline 200E: 2 multisource modules for oxides/nitrides (+ HiPIMS generator), PZT module, single target nitride module with hot chuck, soft etch module, PEALD (2023)
- » Plasma-enhanced chemical vapor deposition – Oxford Instruments PlasmaPro 100
- » Evaporation – Leybold Univex 900
- » Rapid Thermal Annealing – Jivelec Jetfirst 200C
- » X-ray diffraction and reflectivity – Panalytical MRD XL + Anton Paar domed hotstage
- » Spectroscopic Ellipsometry – Semilab SE-2000IR + heating stage
- » Atomic Force Microscopy – Park Systems NX20
- » Resistivity Mapping – Filmetrics R50
- » Stress measurement – Toho FLX-2320
- » Double-beam laser interferometry – aixACCT aixDBLI with TF2000 for piezo testing; sample holders for thin film and bulk samples
- » Raman microscope – Renishaw Qontor





# Integrated Photonics Technologies

## Design & Simulation

- » Photonic integrated circuits (PICs)
  - o Passive and active integrated photonic components and systems for sensing and datacom applications.
  - o Definition and optimization of photonic platforms based on various materials (Si, SiN, LN, AlN, plasmonic and emergent materials)
- » Nano-optics and meta-optics
  - o Nano- and micro-optics, optical antennas, metasurfaces, photonic crystals from components to systems.
  - o Theory and concepts for meta-optics, non-classical optics and quantum-optics devices
- » Multi-physics and advanced simulations
  - o Nano- and micro-opto-electro-mechanical systems (MOEMS), nano-photo-thermal systems.
  - o Inverse photonic design

## Key Equipment

- » CM300xi-SiPh 300-mm-wafer probe for PIC characterizations
- » Santec 1500-1600 nm tunable laser and multi-port power meter
- » A PIC testbed compatible with DC electro-optical testing with vacuum sample holder and active temperature controller

### SOFTWARE

- Ansys Lumerical (FDTD, MODE): comprehensive component design
- Comsol: simulations requiring multi-physics
- Lucedo IPKISS: complex circuit layout and modelling.
- Synopsys' RSoft (FullWAVE FDTD, RCWA, BandSOLVE, ...)
- Matlab and Python: customized simulations and postprocessing

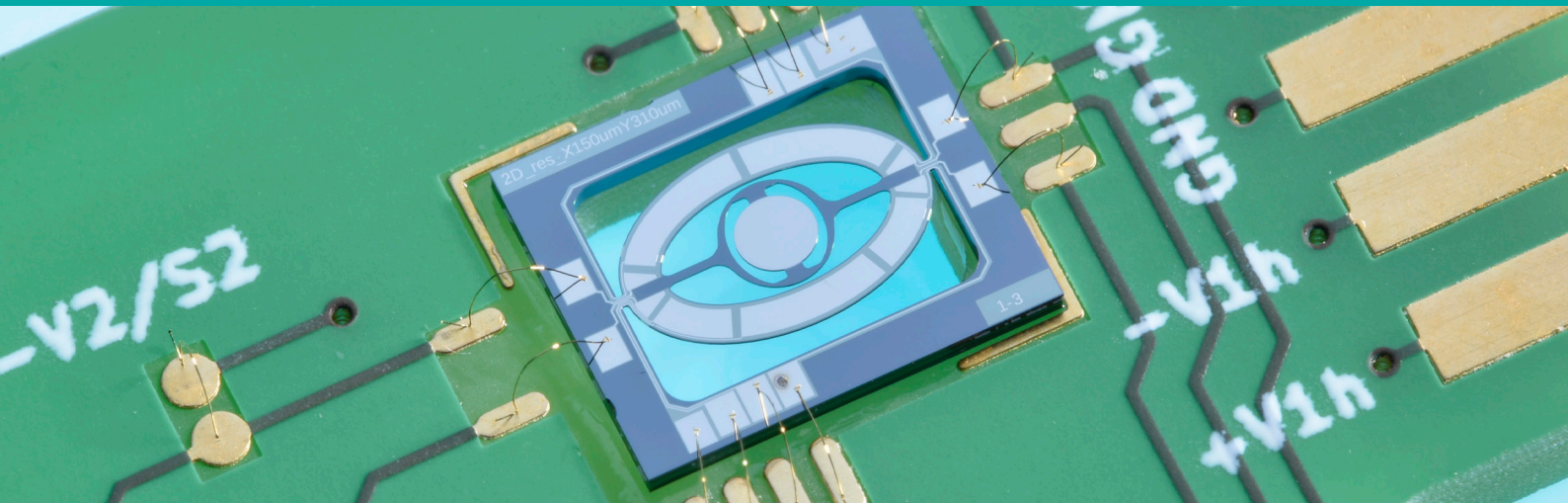
## Measurement, Characterization & Testing

ISO-7 cleanroom-based photonics lab for characterization and demonstration.

- » Photonic integrated circuits
  - o Sample testing: horizontal & vertical alignment, C+L band covered, component performance (loss and bandwidth), electro-optical characteristics, complete circuit characterization
  - o Wafer testing: automated testing and characterization by customizable routines, wafer size up to 12", NIR and MIR available
  - o Lab-based environmental (gas) sensing and monitoring systems.
- » Opto-electronics, opto-mechanics, thermo-optics characterization
  - o Opto-electronics sensors, thermal sensors and bolometers
  - o Optical emission spectroscopy and plasma diagnostics

## Fabrication

- » Photonic integrated circuits
  - o Passive components based on SiNOI, SOI, Al(Sc)NOI platforms.
  - o Post-processing of active components.
- » Wafer-level optics, meta-optics, photonic MEMS
  - o Low-loss optical thin-films and optical filters (oxides, nitrides, carbides, ... and plasmonics).
- » Molding and nanoimprint technologies for wafer-level optics (microlens, metalens, freeform optics), metasurfaces.



# Piezoelectric Microsystem Technologies

## Design & Simulation

- » Design of piezoelectric MEMS such as piezoelectric MEMS microphone, PMUT, piezoelectric micromirror, SAW and BAW
- » Simulations of MEMS devices at the die, package, system levels using methods including FEM, LEM, and analytical calculations
- » Co-design and co-simulation of MEMS and IC or electronics for system-level optimization
- » Process flow design and optimization taking into account our microfabrication platform capabilities

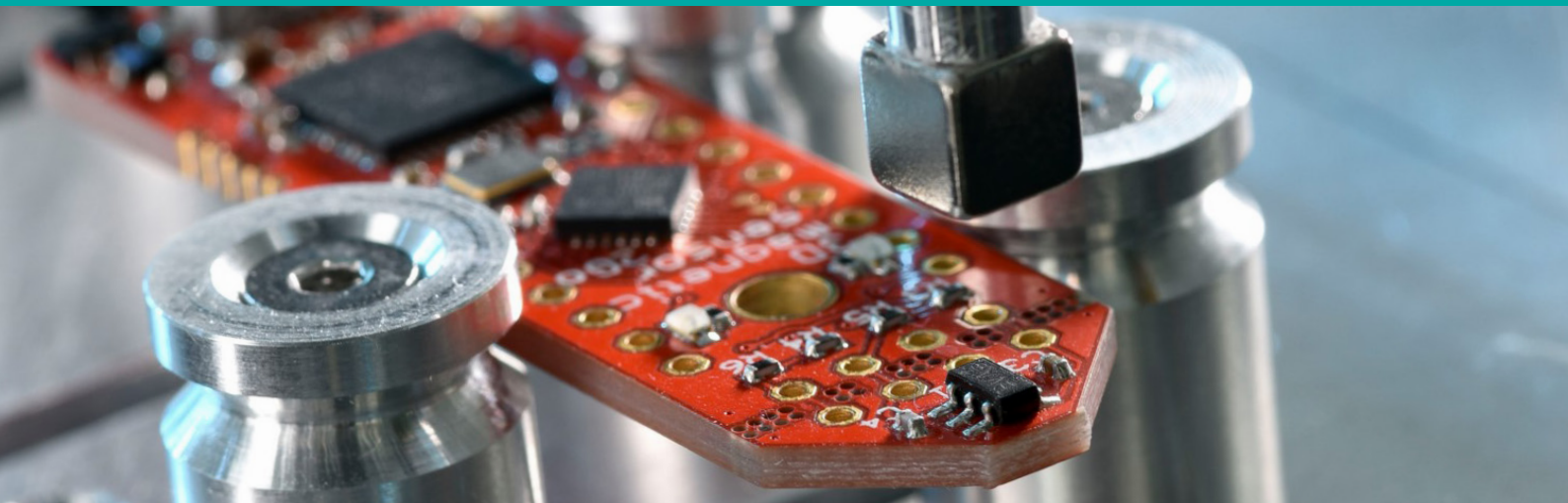
## Measurement, Characterization & Testing

- » Acoustic Lab (Wind Tunnel, Anechoic chamber, Impedance Analyses)
- » Mechanical MEMS characterization (White Light Interferometry, Digital Holographic Microscopy, Laser Doppler Vibrometry)
- » Characterization bench for optical scan angle of micromirrors
- » Characterization of piezoelectric materials at the wafer level (polarization curve, piezoelectric coefficients, leakage current, dielectric losses)

## Key Equipment

- » Thin film deposition
  - Magnetron sputtering and co-sputtering: Evatec Clusterline 200 II
  - E-beam Evaporation: Leybold Univex 9000
  - PECVD: Oxford Plasmatherm
- » Lithography
  - Mask Aligner: EVG 610
  - Direct Laser Lithography: Heidelberg DWL 66+, EVG Lithoscale
  - Nanolprint Lithography: EVG 7300
- » Dry Etching / Wet etching:
  - Ion Beam Etching: Veeco
  - ICP-RIE: Oxford Cobra
  - RIE dedicated to Bosh process: Oxford Cobra
  - HF Vapor: SPTS
- » Metrology:
  - SEM, EDX, XRD, AFM, Resistivity, Stress





# Magnetic Microsystem Technologies

## Magnetic Microsystems and MEMS

- » Deposition and patterning of magnetic thin film materials for the microfabrication of magnetic sensors
- » Design of magnetic sensors for custom applications via micromagnetic simulations
- » Characterization and testing of micromagnetic sensor devices
- » Integration of magnetic parts into MEMS devices and structures

## Magnetic position and orientation systems

- » Custom magnetic position system development for automotive and industrial applications fulfilling respective norms and standards
- » High-end system simulations (magnetic field, magnetic position, current, magnetization process, stray fields, sensor simulations, tolerances ...) with standard tools (ANSYS, COMSOL) and custom environments
- » Magnetic position system construction, testing and prototyping

## Key Equipment

- » Thin Film deposition (Sputtering, E-beam evaporation), Patterning (Mask aligner, Laser lithography, E-beam lithography), Etching (wet, dry), Metrology (SEM, EDX, XRD, AFM, MFM)
- » Industrial simulation environments (ANSYS, COMSOL) and custom simulation tools for magnetic position systems.
- » Custom testbenches for magnetic position systems



# Heterogeneous Integration Technologies

## Package Design and Multi-Domain Simulation

- » Multi-domain Simulation (ANSYS Tools, ANSYS Twinbuilder)
- » Evaluation of thermal stress
- » Evaluation of coupled electric, thermal, thermomechanical behavior in packages
- » FEM and Reduced Order Models
- » Computational Fluid Dynamics Simulations

## Heterogeneous Integration Technologies

- » Waferlevel Packages (MEMS Encapsulation, W2W/C2W Bonding)
- » Interconnect Technologies (Adhesive, Solder, Sinterpaste, Thermocompression, various material systems)
- » Applicative Packaging development for MEMS, sensor, flexible/sustainable electronics, power device, optical assembly ...

## Measurement, Characterization & Testing

- » Shear/pull testing
- » Nanoindentation
- » Surface acoustic microscopy
- » Functional, lifetime, aging and reliability testing
- » In-situ characterization of devices at wide temperature range (-180 °C – +1000°C)
- » Cross-section analysis
- » Shear and dynamic bending test
- » Scanning Acoustic Microscopy
- » Helium leakage test
- » Infrared Inspection of bonded wafers

## Key Equipment

- » Waferbonder EVG 520
- » Waferaligner SmartView
- » Finetec Lambda, Sigma
- » Häcker Ourplant D1
- » Manual wirebonders for thin wire and thick wire
- » Bruker TI Premier Nanoindenter
- » EVG I20 Infrared Inspection
- » DAGE Optima+ Shear/Pull tester





## ABOUT SAL

Silicon Austria Labs (SAL) is a top European research center for Electronics and Software Based Systems (ESBS). The application-oriented center offers cooperative research & services at three locations – Graz, Linz and Villach – in the pioneering research areas of Sensor Systems, Microsystems, Intelligent Wireless Systems, Power Electronics and Embedded Systems.

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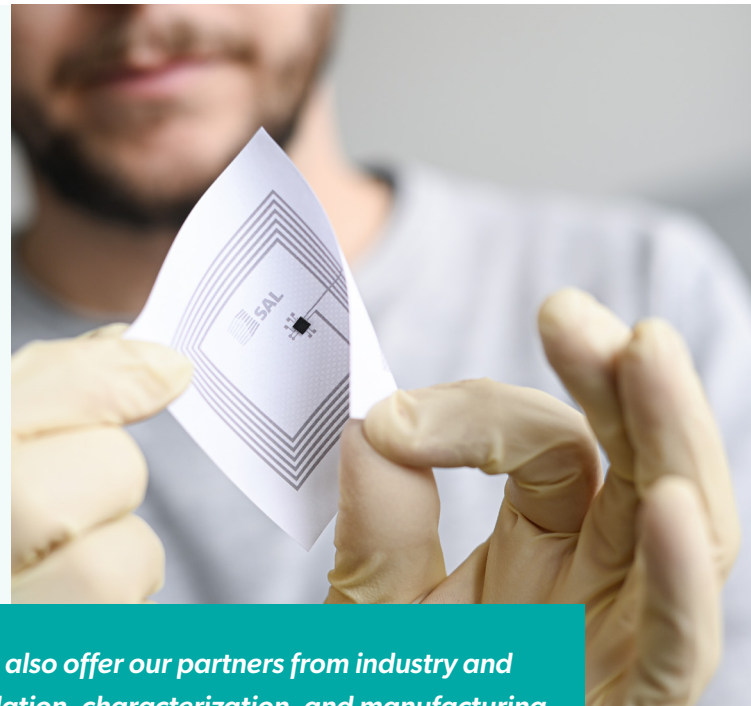


# Sensor Systems

*Sensory organs of digital life.*

In the Sensor Systems division, our teams use the basis of state-of-the-art technologies to work on different sensors that collect information from the environment, inspired by all five senses.

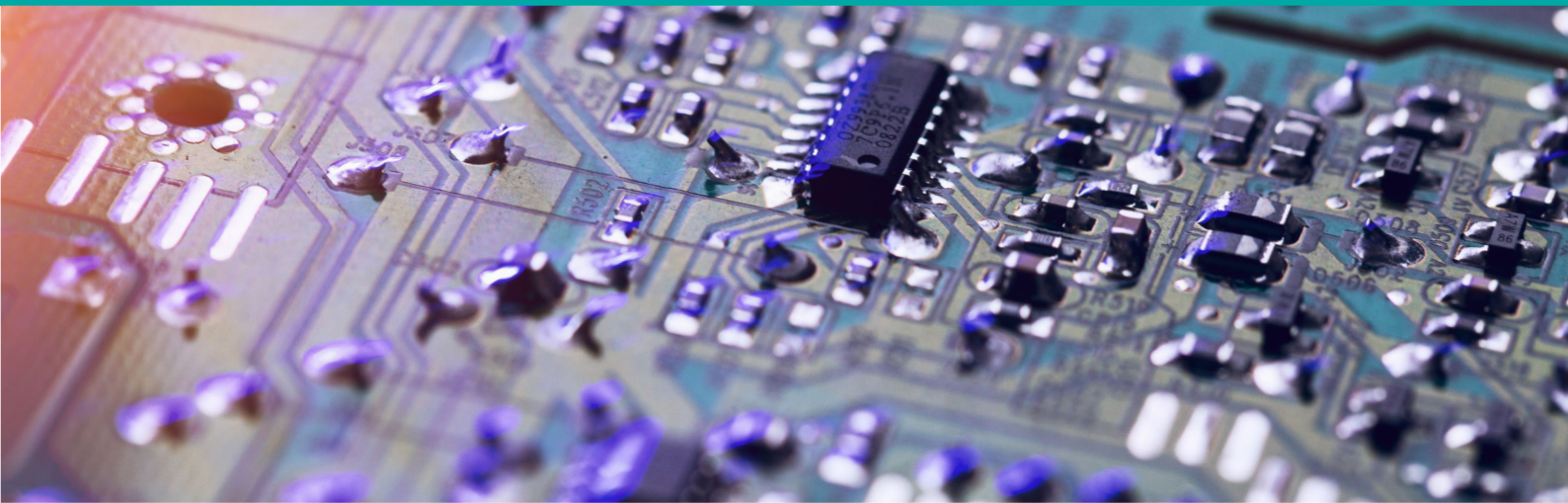
It is important to find the optimum combination of the multitude of sensors to expand the heterogeneous integration of smart sensor systems for various applications. This can be achieved with the help of intelligent algorithms and the latest developments in this field.



*"In addition to high-end research, we also offer our partners from industry and research services in the areas of simulation, characterization, and manufacturing. Our customers benefit from our extensive know-how, flexibility, and state-of-the-art infrastructure. It is essential for us to support them in a highly competitive environment so that they reach market maturity as quickly as possible."*

*Christina Hirschl, CEO Silicon Austria Labs*





# Electronic Sensors

## Design & Simulation

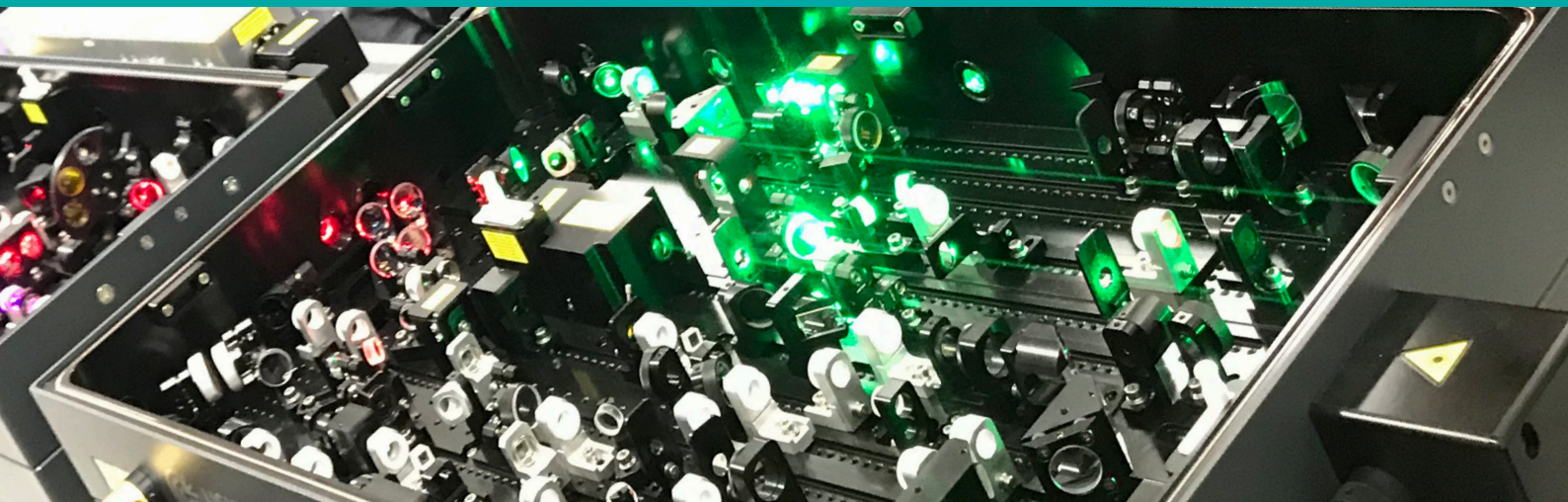
- » Electronic read out circuits for custom made sensors
- » Optimization of ultra-low-signal level and ultra-high-resolution signal processing with respect to wireless energy and data transfer
- » Electrical analysis from DC to the GHz level
- » Development of the whole sensor read out-, data processing- and data displaying system
  - System on Chip programming (ARM/FPGA, Xilinx, Vivado, Vitis)
  - SPICE circuit simulation
  - Altium PCB design

## Measurement, Characterization & Testing

- » Prototyping and testing of electronic based systems
- » Programming and testing of novel, AI-based, signal analysis algorithms
- » Functional, lifetime, aging and reliability testing
- » In-operation characterization of EBS under varying environmental conditions (-70°C – +180°C, controlled humidity)
- » Gas sensor testing

## Key Equipment

- » Weiss Umwelttechnik ShakeEvent C/600/70/15/V
- » Schwingprüfanlage TIRA TV 51110



# Photonic Systems

## Design & Simulation

- » Optical Simulation & System Design
  - Including Optical Raytracing and Full Wave Simulation (Zemax/Optics Studio, Lighttrans-Virtual Lab, Comsol, Rsoft, OptiLayer)
- Custom Simulation Development and Assessment
- Bulk Optical Systems, Filter- & Coating Design, Anisotropic Media, Fiber Optics, Nonlinear Optics, Laser

## Measurement, Characterization & Testing

- » FT-IR Spectroscopy on solid and liquid samples
- » Raman Spectroscopy of macroscopic and microscopic samples
- » Hyper-spectral imaging in the spectral range of 400nm-2500nm
- » UV-VIS spectroscopy of transparent samples in the range of 190nm-1100nm
- » Optical measurement & data analysis
- » Ultrafast time resolved and non-linear spectroscopy
- » Quantum sensing based on color centers

## Key Equipment

- » Raman microscope, Renishaw inViaTM Qontor
  - In combination with Tip Enhanced Raman option, Bruker, Innova SPM
- » FT-IR microscope, Bruker, Lumos
- » UV-VIS spectrometer, Agilent Cary60
- » Fiber coupled spectrometers UV-VIS-NIR
- » Fs-Laser system for non-linear spectroscopy
- » Digital holographic microscope, LynceeTec, DHM
- » Scientific and industrial imaging systems
- » High power laser for material processing, Lightconversion, Pharos
- » Microsystem analyzer, Polytec, MSA-500
- » Fiber processing equipment
- » Profilometer, Keisleigh
- » Photonic Probe station, Formfactor
- » Photonic assembly station, Ficontec





# Advanced Sensors & Electronics Technologies

## Sensor Design & Application Support

- » Application specific sensors
- » Printed sensors
- » Sustainable sensors
- » Flexible and conformable sensors

## Surface Modification & Functionalization

- » Targeted deposition and assembly of (conducting and insulating) polymers
- » Electrode surface functionalization
- » Metal nanoparticle deposition on electrodes

## Fabrication & Rapid Prototyping

- » Inkjet printing of functional inks
- » Photonic curing and sintering of printed layers
- » Stencil and Screen printing of functional inks and coatings
- » Ultrasonic spray coating of functional inks (2D and 3D)
- » Slot die printing for extremely thin film coatings ~80 nm
- » Aerosoljet printing for high-resolution (~10  $\mu\text{m}$ ) printing of functional inks (2D and 3D)
- » Laser-induced Graphene

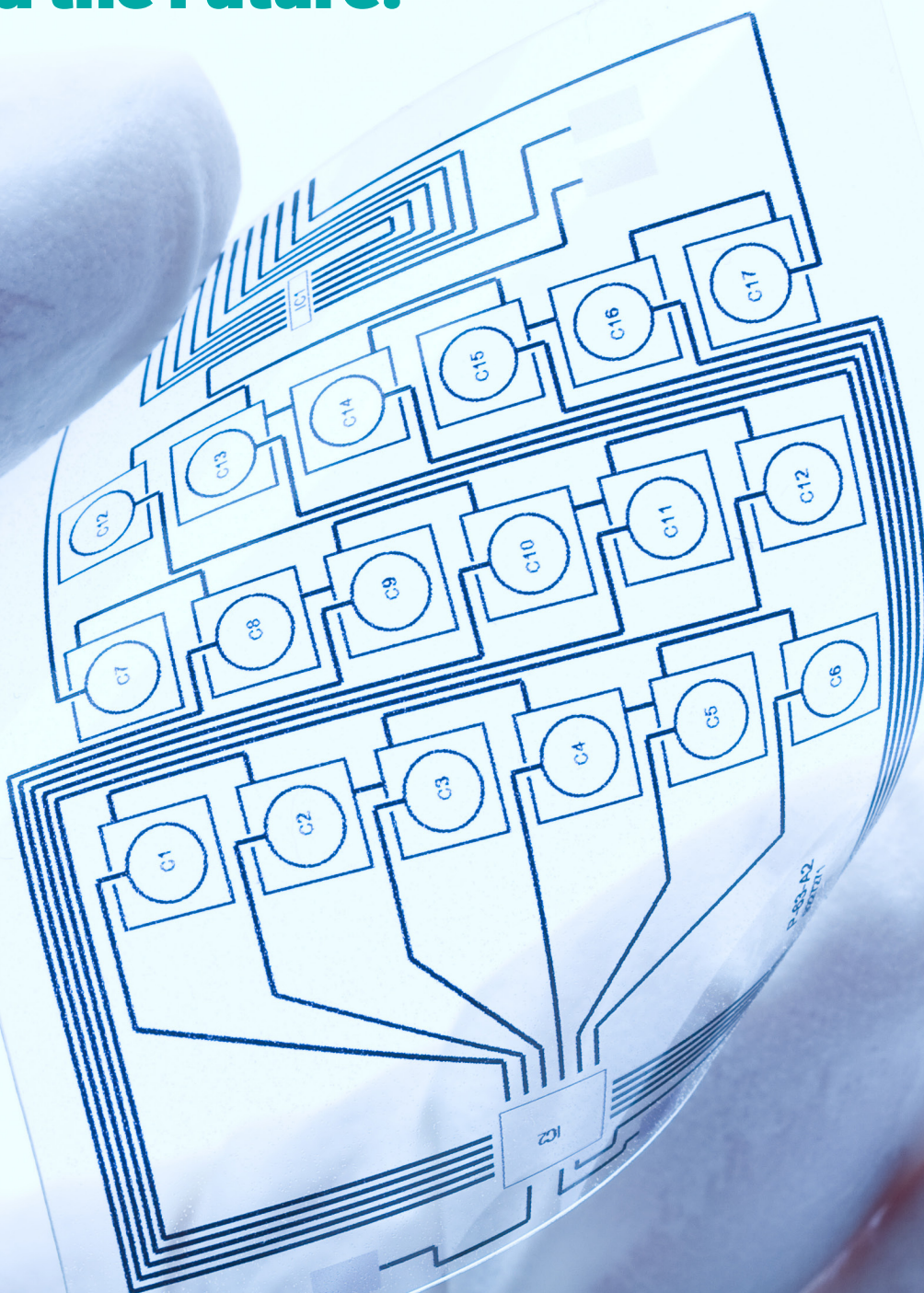
## Measurement, Characterization & Testing

- » Push- and pull testing of materials and sensors
- » Ablation and peel-off testing of coated and printed layers
- » Bending testing
- » Accelerated aging of sensors
- » Contact angle and surface energy measurements
- » Biodegradability assessments

## Key Equipment

- » Force test bench, ZwickRoell
- » Inkjet printer Pixdro LP50, Süss MicroTec
- » Photonic curing system PulseForge 1200, Novacentrix
- » Laser cutter platform, PLS150D, Universal Laser Systems
- » Semi-Automatic Universal Screen Printing Machine SCF300DE, Eickmeyer GmbH
- » Slot coater with flexographic and bar coating unit, InfinityPV RLC 3DPrint Slot
- » Ultrasonic Spray Coater ND-SP, Nadetech Innovations
- » Pad Printer, Inkcup ICN2200PS

# Unfold the Future.



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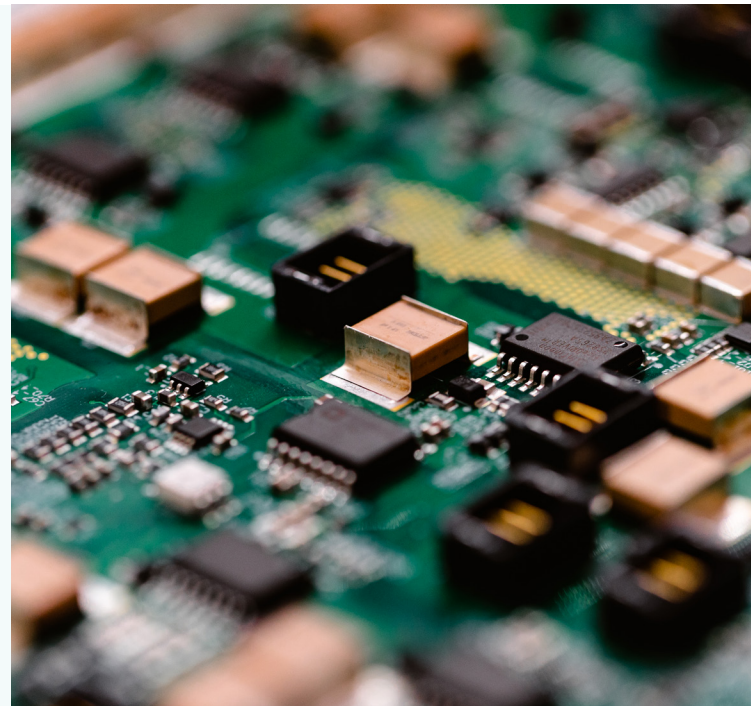




# Power Electronics

*Smart electronic devices for future products & applications.*

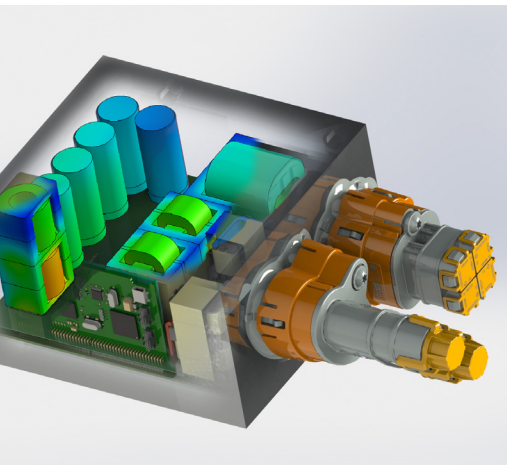
Power electronics are at the heart of the development towards ecologically compatible mobility and energy-efficient digitalization. Invisible from the outside, it is hidden in almost every electronics-based system - be it within e-mobility, used for renewable energy or in power supplies for IT and communication applications. To meet the growing demands on electronic components and the need for high performance and reliable integrated power supply, the SAL team is working on power electronics systems along the entire EBS value chain. Starting from the design and characterization of components up to the complete system design of power electronics including the control software.



***"Power electronics are the backbone of digitalization. Unseen, but embedded in almost every electronic system. We contribute to this transformation with our services in design, prototyping and characterization with our key expertise and state of the art labs."***

*Alfred Binder, Head of Division Power Electronics*

# Our Service Portfolio:



## Design & Simulation

- » Simulation and Optimization of Power Electronics Systems and Pareto Front optimization by Multidomain coupling
- » Rapid System Prototyping (software, electrical & mechanical)
- » 3D EM & PCB EM Simulations, Signal & Power Integrity Simulations
- » Accurate electrical and thermal modelling of active and passive components for EMC and power simulations.
- » E/MCAD System Co-Design process for cooling system/mechanical integration and simulation

SOFTWARE - Commercial licenses and experts available:

- Ansys Maxwell
- Ansys HFSS
- Ansys Q3D
- MATLAB
- PLECS
- Keysight Pathwave ADS
- Solidworks CAD
- Altium Designer
- SALamander Circuits



## Measurement, Characterization & Testing

- » High power prototype system testing facilities
- » Thermal and electrical characterization of power components & modules
- » High precision impedance measurements including biasing
- » Advanced probing of voltages and currents
- » RF signal generation
- » Spectral measurements and EMI analysis
- » Emission measurements with GTEM cell
- » De-embedding of measurement fixtures
- » Time Domain Reflectometry measurements



## Key Equipment

- » Precision AC/DC supplies & Sourcemeters
- » Grid simulator
- » Arbitrary Waveform Function Generators
- » Vector Network Analyzer
- » High precision Impedance Analyzer
- » GTEM cell and crawford TEM cell
- » High Power Amplifiers
- » RF Signal Generator (IQ Modulation, WLAN signals, etc.)
- » EMI Receiver
- » Rapid Control Prototyping System
- » High power loads for AC/DC applications
- » Probes: current, differential, active, optical isolated probes
- » Test fixtures for component and magnetic material characterization
- » 3D Profilometer and Microscopic measurement systems
- » Curve Tracer
- » Fast in-house PCB Prototyping (vapor phase solder, semi-manual SMT assembly & rework station)

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# Intelligent Wireless Systems

*Wireless communication and sensing for future products.*

Wireless systems are an essential part of Industry 4.0. New functions in 5G/6G networks and the use of edge computing in combination with wireless sensors are gradually improving the industry of the future and also the way systems are built and IT services are delivered. The 6<sup>th</sup> generation of wireless communications - 6G for short - enables the transmission of large amounts of data in real time while offering high reliability. This key technology thus plays an important role for wireless "machine-to-machine" communication, in radar systems but also in medical technology and materials testing. At SAL in Linz and Villach, our teams of experts are already conducting intensive research on 6G - the focus includes the targeted use of artificial intelligence with AI chips and algorithms to reduce the complexity, costs and energy consumption of future applications.

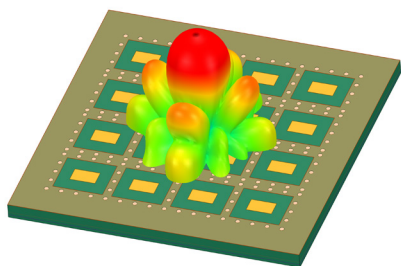


***"Wireless systems installed in buildings, machines or vehicles will continue to grow strongly. Therefore, it is necessary to further develop intelligent wireless technologies to pave the way to a wireless future."***

*Thomas Buchegger, Head of Division Intelligent Wireless Systems*



# Our Service Portfolio:



## Design & Simulation

- » VLSI IC Design: chip level development of digital and analog/RF integrated circuits
- » Machine intelligence development for data and signal processing, sorting, analysis and labeling. Analysis of problems, network topology exploration, anomaly detection
- » Wireless standards research & development of application protocols, TSN integration and positioning
- » HW-platform integration: application integration of ICs and subsystems, platform architecture and feasibility analysis, PCB-level design, impairments optimization, FW development

### SOFTWARE - licenses and experts available:

- Ansys
- Keysight
- Matlab
- Altium Designer
- Cadence
- Mentor
- Synopsys



## Measurement, Characterization & Testing

- » mmW device characterization
- » Neural network and machine intelligence deployment: Real time HW and SW solutions for applying machine learning where adequate
- » Wireless standards infrastructure services for experimental performance evaluation and configuration optimization (real life conditions)
- » Wireless standards training & support services from theoretical aspects to roll out and deployment challenges



## Key Equipment

- » VLSI IC design flow: Full access to EDA tools
- » 300mm Wafer Prober
  - o Automated thermal chuck -60°C to +300°C
  - o 4 RF Positioners, 10 DC Micropositioners
  - o Vibration isolated
  - o 12x Digital Microscope
  - o Laser Cutter
- » 6 GHz bandwidths Oscilloscope with 4 Channel DC – 6 GHz, 20 Gsamples/sec., DSP and digital cursor control
- » Spectrum Analyzer with 5GHz analysis bandwidths
- » Highest frequency signal generators and network analyzers
- » 5G/6G Testbed
  - o Fraunhofer FOKUS Core network
    - Software based Core functionalities
    - 3GPP Release 15 and 16
    - Integration with 5G NR SA, non-3GPP
    - Benchmarking and experimentation
    - Support for slice selection
  - o Radio area network (RAN) HW
    - Baseband unit and radio heads
    - Designed for indoor campus network
    - Operable for 5G sub-6 frequency
    - Baseband unit and remote radio units
    - GPS for network synchronization
  - o Open Air Interface (OAI) with 5G core and RAN (USRP Implementation) developed towards Open RAN specifications

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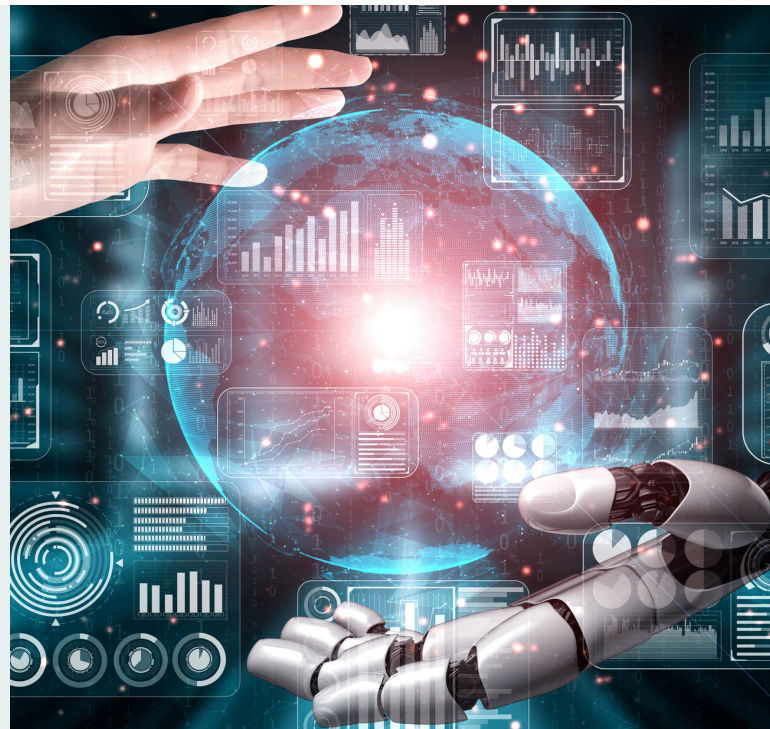
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# Embedded Systems

*At the Core of intelligent Embedded and Software Based Systems.*

Using inputs from sensors, flexible connectivity enabled by wireless technology, and relying on the energy provided by power electronics, the embedded division brings it all together: we focus on dependable software and adaptive computation covering conventional designs up to privacy-preserving distributed AI-solutions. In doing so, we design and verify custom algorithms and software and map them most efficiently to hardware, assembling custom compute accelerators if necessary. Our research is driven by topics of trustworthy AI – including advanced perception – and adaptive & secure software and computation to build the trustworthy, intelligent, and efficient systems of the future.



**“Software, algorithms and data-based approaches are the basis to all the advanced functionality offered by modern systems. We not only make this happen but ensure trustworthiness, efficiency, safety, and security.”**

*Willibald Krenn, Deputy Head of Division Embedded Systems*





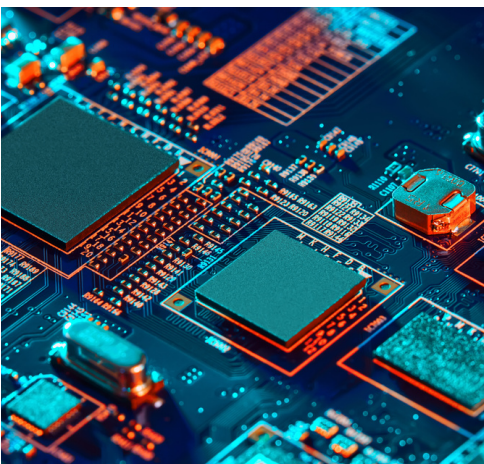
## Design, Implementation & Software-Engineering

- System modelling and analysis supported by our formal methods know-how
- Energy efficient, high-performance signal processing and FPGA programming
- AI approaches for control and prediction, virtual sensing, object recognition and tracking
- Distributed data processing in fog- /edge computing environments
- Low-code development



## Security, Verification & Testing

- Design and implementation of automated testing & verification methods
- Formal Methods-based verification, e.g., SW-Model-Checking, Modelbased Diagnosis and reasoning,
- Model-based Testing, Symbolic Execution
- Side-channel vulnerability analysis of Electronics and Software Based Systems
- Code Analysis & Reverse Engineering



## Key Equipment

- ChipSHOUTER Kit for Fault Injection
- Compute Servers (à 128 nodes, 2 TB RAM, Nvidia A100 GPUs)
- State-of-the-art Compilers, Debuggers, Development Boards

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