Fraunhofer
ADAPTRONIK

# FRAUNHOFER ADAPTRONICS ALLIANCE

# WHAT IS ADAPTRONICS?

Adaptronics is an active structure technology based on integrating sensory and actuatory functions into mechanical structures. In English, we call this smart structure technology. It aims to optimise products by specifically influencing mechanical structural properties, focusing on active vibration and noise control, as well as monitoring the health of mechanical structures. Multifunctional material systems (e.g. electromechanical transducers such as piezoceramics and voice coil engines) are often used in system design. This enables the development of sensory and actuatory material systems, which – when integrated in mechanical components – enable control structural disturbance.

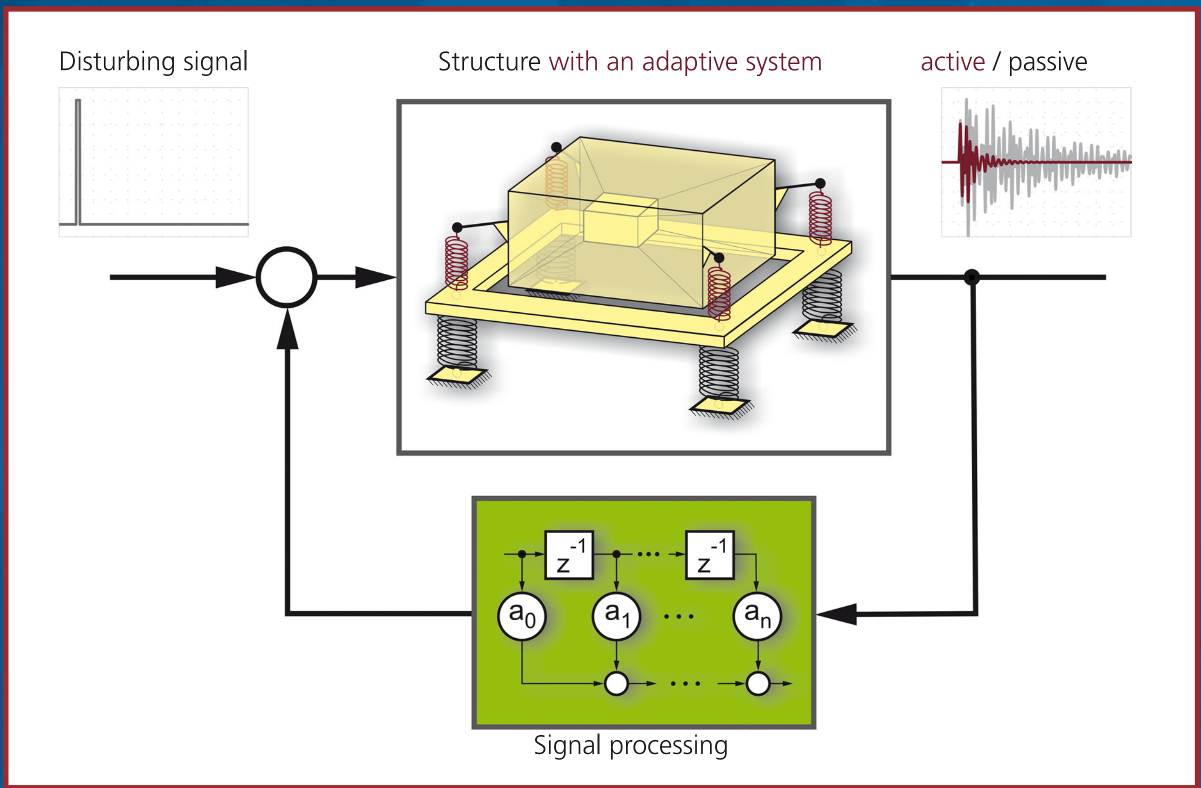



*Image 1: Schematic representation of an adaptronic system, taking the example of a active suspension (black: passive components, red: active components)*

Adaptronics is used to create structures that enable structural properties to adapt to changing operating conditions. Structures such as these satisfy product improvement requirements with respect to performance, service life, lightweight construction and function. In this way, for instance, safety characteristics can be optimised through component monitoring or load control, and comfort properties and precision can be optimised through improved lightweight construction, whilst mechanical system functions can be simplified.

# Scientific fields

The following topics are especially significant for developing adaptronic structure systems:

- Intelligent material systems for actuators and sensors
- Design and development of components and systems
- Manufacturing and system integration
- Proof of functionality and system reliability

According to these focal points, R&D projects for structure optimisation, expanding know-how and solving application-specific problems are continually being implemented. A key topic is the development and use of new intelligent material systems, in order to utilise components with improved, coupled (e.g. electromechanical, magnetomechanical, thermomechanical) functional properties. Furthermore, the relevant system components such as the actuator elements, sensor system, electronics, control technology and software are being further developed with a view to enhancing reliability and cutting costs. To enable cost-efficient implementation of robust adaptive systems in both small and large quantities, new procedures and tools for designing and manufacturing adaptive components and systems are being developed. These include production technology, design regulations, system analysis and simulation. The aforementioned fields are combined and implemented under the key word 'system integration'. The operational reliability of these fields must be determined and ensured at all times under all of the relevant framework conditions.

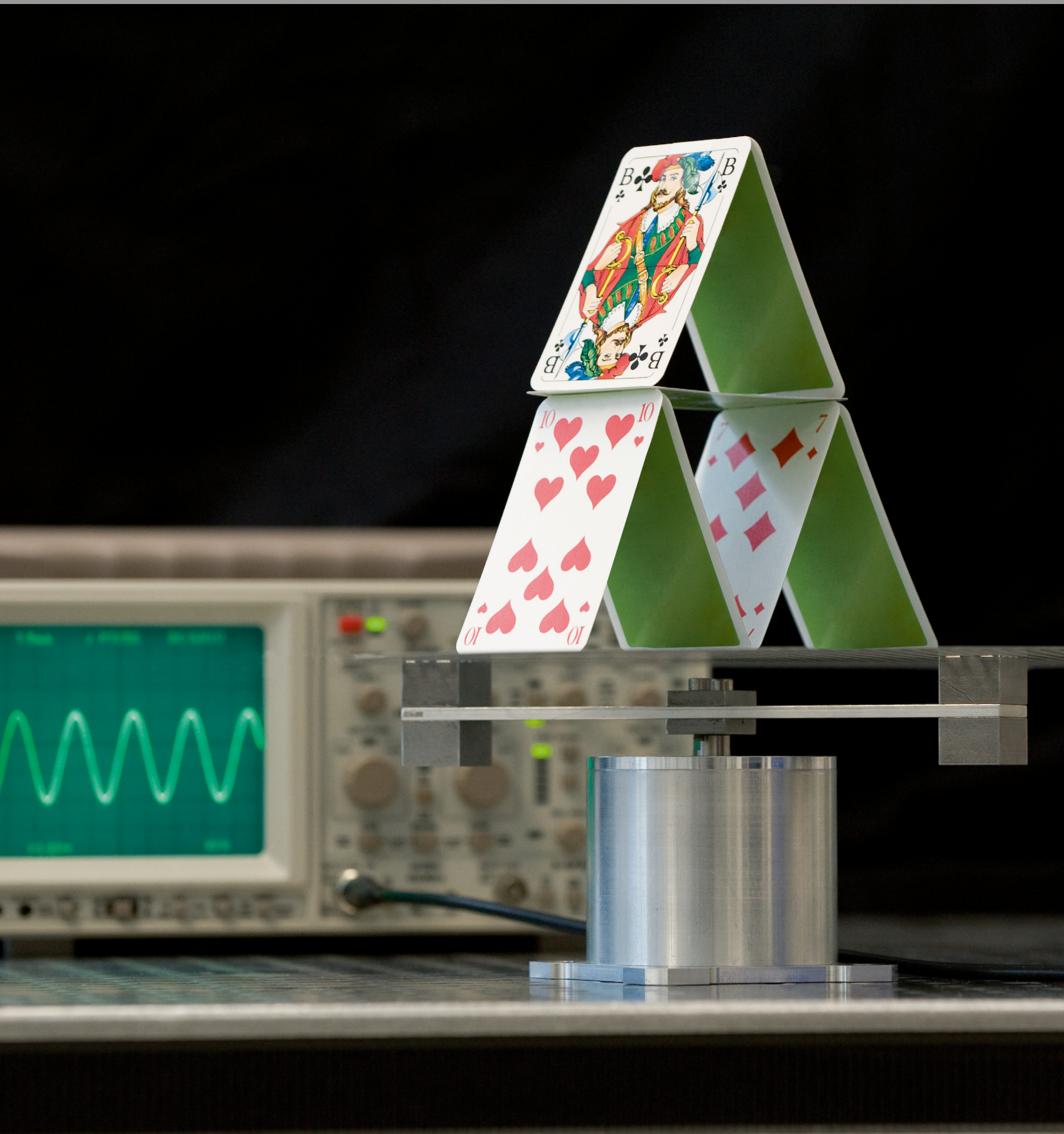
*Image 2:*
*Alliance Spokesperson*
*Prof. Dr.-Ing. Tobias Melz*

# The Fraunhofer Adaptronics Alliance

With the Fraunhofer Society's application-oriented research mandate, adaptronics institutes with complementary technological competencies are cooperating in the Fraunhofer Adaptronics Alliance (FAA). Depending on the application requirements, the partners are working together in both scientific and industrial research cooperations, enabling interdisciplinary-based solutions from a single source.
The partners' expertise lies in the fields of:

- Materials and components
- Numerical and experimental simulation
- Electronics and regulation technology
- Manufacturing and processing
- Evaluation, applications and technology transfer

# ACTIVE
# VIBRATION CONTROL



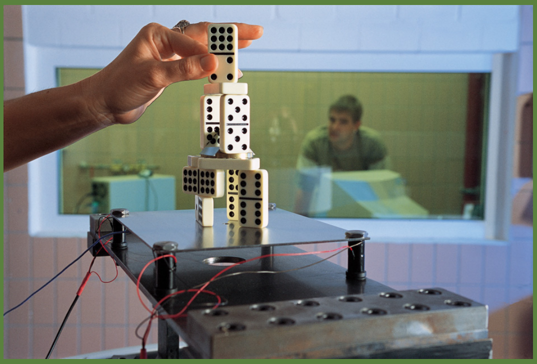
**Functionality:**

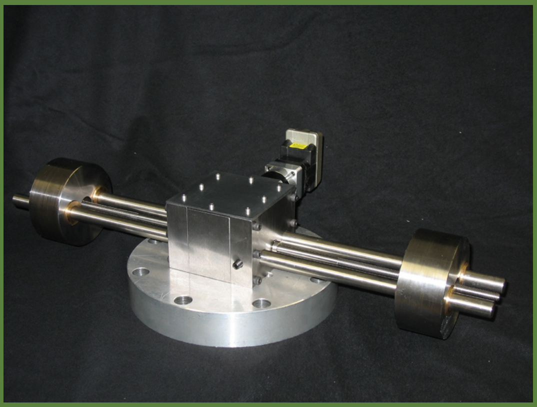
The task of active vibration control is often to reduce vibration. Approaches often aim at actively suspending the disturbing source (e.g. a motor) or the disturbed system (e.g. a sensor unit). Alternatively, spring-mass-damper systems based on inertial mass (such as adaptive absorbers and neutralizers or inertial mass actuators that are mounted on the structure) can help to reduce disturbing and damaging vibrations. We call this active vibration control (AVC).

**Sample application:**
**Vibration reduction using adaptive spring-mass-damper systems**

The sensitivity to vibrations increases with lightweight construction. One approach is to use adaptive neutralizers, whos resonance frequecy automatically follows the excitation frequency during operation or adaptive absorbesrs whose resonance frequency can follow a structural resonance of a structure for changing operation conditions, such that there is an optimum compensation at all times. An optimum proof mass absorber system offers minimum system damping, thus representing a sprin-mass system. To adjust the resonance frequency of a spring-mass-damper system, in most cases it is preferable to change the spring stiffness. It is also possible to change the mass, but this is generally more costly and therefore only interesting in the case of very large spring-mass-damper system for ships or civil engineering structures.

Adaptive neutralizers can be used to adapt to speed changes during system start-ups and load changes during operation cycles. Adaptive absorbers can adapt to variations in natural frequencies due to changing optration conditions, temperature chnages, fatigue and effects due to non linear material behaviour. Due to these measures higher rotational speeds can be achieved while at the same time ensuring quite and smooth mashine operation. Adaptive spring-mass-damper systems are suitable for applications in many mechanical engineering fields, such as vehicle technology, aviation or industrial plant design.





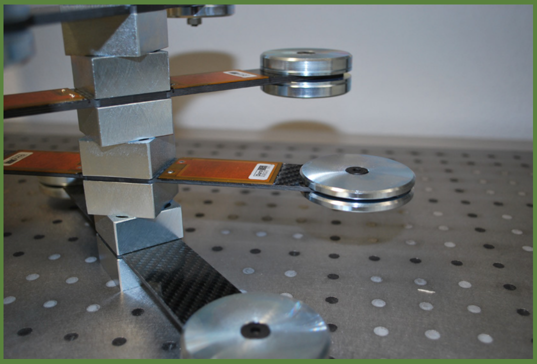


*Image 1: Active vibration isolation with piezoceramic transducers*
*Image 2: Adaptive mass damper with motor drive for low and medium frequencies and medium and high forces*
*Image 3: Adaptive mass damper with piezoceramic actuators for higher frequencies and smaller and medium forces*

# ACTIVE
# NOISE CONTROL

**Functionality:**

As with the aforementioned AVC, adaptronic measures can be imbedded in structures with a view to monitoring components' which is then called active structural acoustic control (ASAC). Unlike active noise control (ANC) approaches ASAC ais to achtively control the vibrations of structural components, in order to prevent the resulting sound radiation.

**Sample application:**
**Active aggregate suspension to reduce structural vibrations and structure-borne sound transmission**

Active mounts for vibration isolation have been developed to effectively reduce the noise and vibrations on board ships. Piezoceramic transducers, are used as actuators. The vibrations caused by the engine are measured, and compensation forces adapted to phase, frequency and amplitude are introduced into the structure. In this way, it is possible to actively influence mechanical properties, such as damping behaviour or engine mount stiffness resulting in a vibration reduction. This solution can be used in a wealth of further applications to control vibration within suspensions of mechanical systems.

The active suspension concept developed allows actuatory intervention in frequency ranges from 30 to 350 Hz, in a range where passive, conventional elastomer mounts have a reduced efficiency. Active aggregate suspension takes effect directly in the engine mount's force flow and thereby reduces transmission far better than passive solutions. A great deal of economic and technological significance is attached to vibration- and noise-reduced aggregates in the shipbuilding industry and other sectors, such as the automotive, rail and aircraft construction sectors.

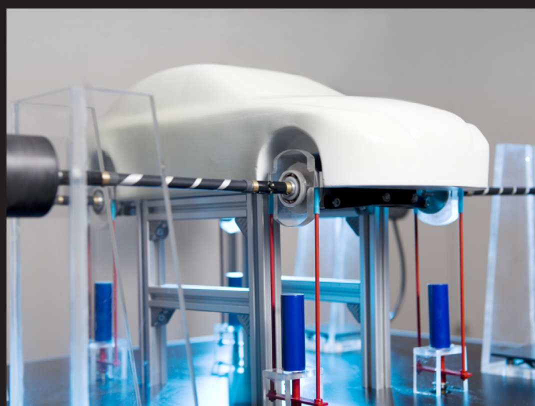



*Image 1: Examining sound propagation in cars*
*Image 2: Test bench model for developing active systems in automotive construction*
*Image 3: Testing active aggregate suspension in the North Sea*

# ACTIVE SHAPE CONTROL / SPECIAL ACTUATOR SYSTEMS

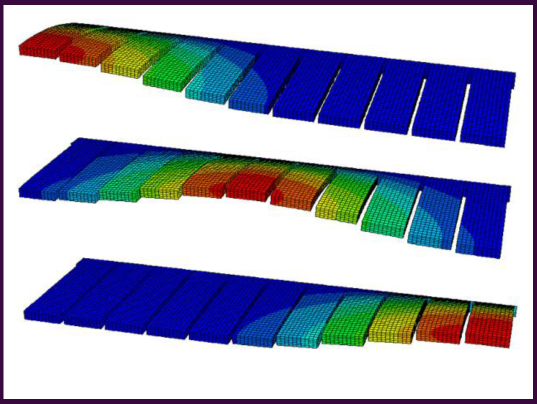
**Functionality:**

By integrating and controlling suitable multifunctional materials in structural components (e.g. reflectors), it is possible to actively control their shape or properties. Compared with conventional approaches, this enables continuous control of the elastic shape state, as well as compact lightweight construction and the implementation of new actuator approaches to optimally extend the functionality at the same time.

**Sample application:**
**SMA actuators as the basis of a sensorless drive and control concept for exoprosthetics**

Actuatory use of thermal shape memory alloys (SMAs) is increasingly taking centre stage in application-oriented research due to significant improvements to material properties. In addition to the possibilities of using actuators such as these in machine tools and in the field of vehicle technology, the shape memory materials can also be used for medical applications. Thermal SMAs are currently being examined with respect to their applicability as actuators for exoprosthetics. The main objective here is to develop a sensorless drive and control concept to complement existing drive systems for external power prostheses.

A promising result of these examinations is the development of a gripping mechanism based on a self-sensing actuator that offers various possibilities for complementing existing drive systems in the field of exoprosthetics and orthotics.
In the gripping mechanism that has been developed, the actuators correspond to the natural muscle pattern: the actuator wires are tensioned in the gripping system's forearm and transmit their tractive force to the fingers via artificial tendons. To clarify the functional principle, the joint structure is limited to a total of nine rotary joints in a current test component (see image 2).



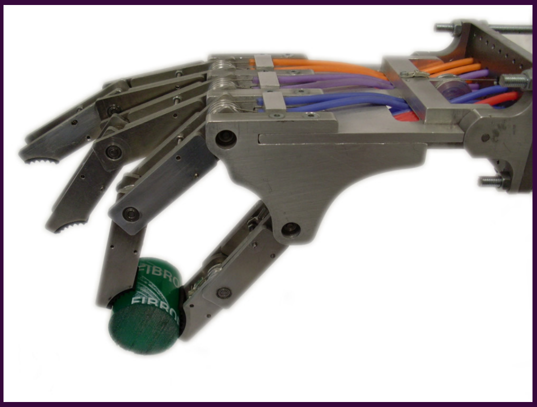


*Image 1: FEM simulation of the pump function of a micro-pump with PZT CRP bender arrays*
*Image 2: Pinch grip using an SMA self-sensing actuator*
*Image 3: MRF clutch for automotive applications in the field of electromobility*

# STRUCTURAL HEALTH MONITORING

**Functionality:**

Vibrations can be purposefully introduced into structures using adaptronic approaches. Resultant structure reactions can be evaluated with respect to their mechanical stresses or damage characteristics using suitable signal processing. This allows components to be monitored during operation and maintenance measures requested as required. Alternatively, component loads can be purposefully reduced using the aforementioned AVC measures or specially tailored actuator systems. thereby extending the service life and enhancing the reliability of structures.

**Sample application:**
**Structural health monitoring for component monitoring**

Fraunhofer Adaptronics Alliance scientists are currently working on using structural vibration introduced by ambient sources such as wind or water for automated vibration analysis and health monitoring. For example, wind excitation can be used to performe a continous analysis of the structural dynamics of a wind turbine. In a test set-up, acceleration sensors are attached to a turbine and the vibration data recorded is processed by embedded signal processing systems. In one typical system approach, one system pre-processes the signals and compresses the data, while another performs a further evaluation and determines the structural characteristics (the resonance frequencies in this case). If the resonance frequencies change during operation, this may indicate a damage within the structure.

Structural behaviour not only needs to be monitored for wind turbines; it is also important to monitor it for bridges, ships and aircraft. In the case of aircraft, electrodynamic exciters have previously been used (which are usually attached underneath the wings) to determine defects. Unlike previous test procedures such as these, the output-only modal analysis (OMA) does away with artificial structure excitation (e.g. a hammer or shaker) and uses ambient excitation that occure naturally or due to the system opperation. OMA could – to a certain extent – render lengthy and expensive hammer tests redundant.

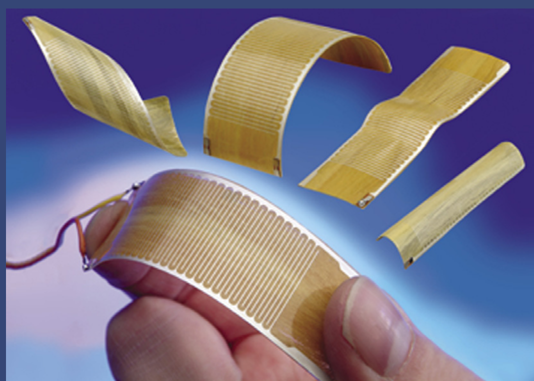


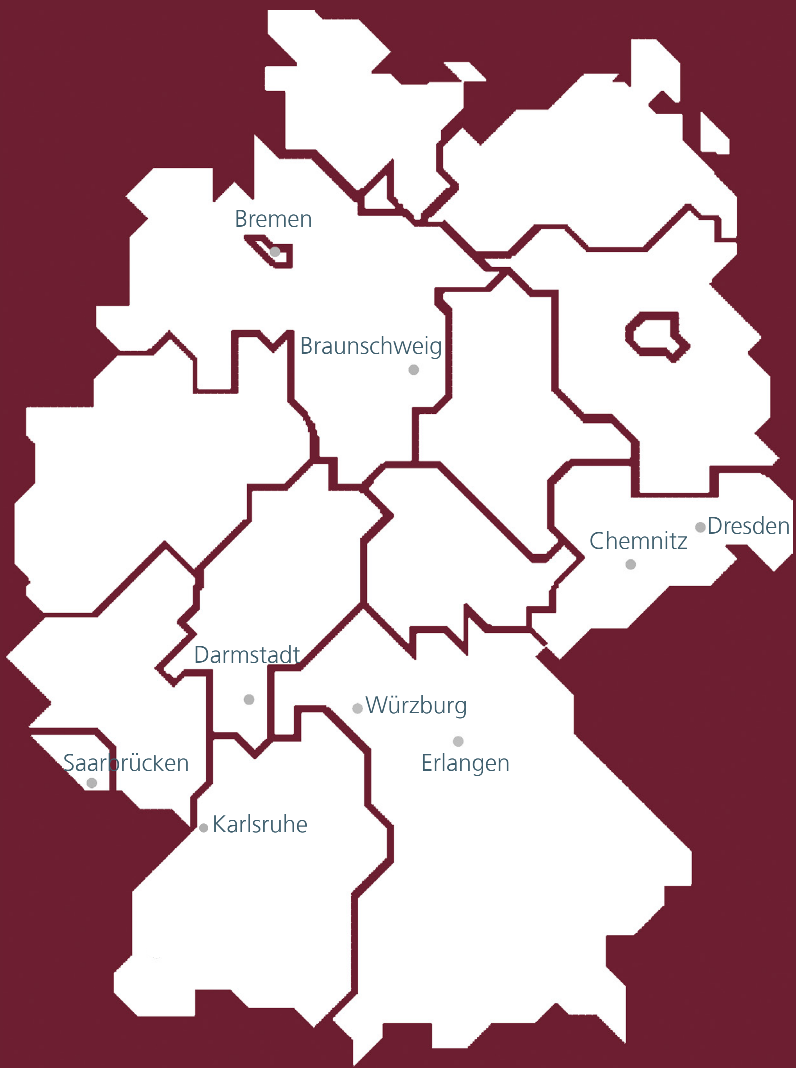

*Image 1: Aluminium foot tredle with cast-in piezoceramic transducers for determining the waste and active force during cycling*
*Image 2: Piezoceramic transducer for vibration excitation*
*Image 3: Aircraft model with integrated SHM sensors*

# ADAPTRONICS – TECHNOLOGY THAT TRANSFORMS

## The institutions involved

**Fraunhofer Institute for**

Structural Durability and System Reliability LBF, Darmstadt
Manufacturing Technology and Advanced Materials IFAM, Bremen
Integrated Circuits IIS, Erlangen
Ceramic Technologies and Systems IKTS, Dresden
Surface Engineering and Thin Films IST, Braunschweig
Silicate Research ISC, Würzburg
Optronics, System Technologies and Image Exploitation IOSB, Karlsruhe
Machine Tools and Forming Technology IWU, Dresden
Nondestructive Testing IZFP, Saarbrücken

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