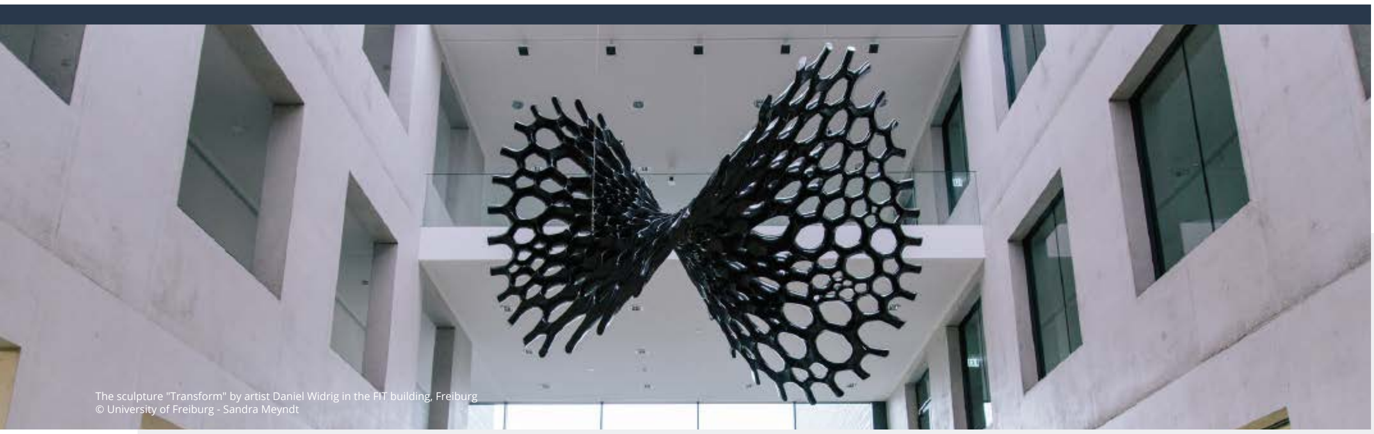
livMatS Living, Adaptive and Energy-autonomous Materials Systems

UNI FREIBURG



The sculpture "Transform" by artist Daniel Widrig in the FIT building, Freiburg

The Cluster of Excellence develops novel, bioinspired materials systems that adapt autonomously to their environment and harvest clean energy from it. The purely technical, but behaviorally quasi-living materials systems meet people's demands for future-oriented environmental and energy technologies.

livMatS follows the vision to combine the best of two worlds: nature and technology

livMatS turns this vision into reality by

- bringing together researchers from biomimetics, chemistry, physics, mathematics, materials sciences, microsystems engineering, sustainability research, psychology and philosophy,
- combining cutting-edge research from faculties and research centers at the University of Freiburg with the expertise of the Fraunhofer Institutes and the Freiburg Öko Institute,
- offering young researchers an interconnecting environment with interdisciplinary Shared Labs and a training program, and
- forging international research partnerships.

Find out more about *liv*MatS and your career opportunities with us on our website:
www.livmats.uni-freiburg.de

University of Freiburg | Cluster of Excellence *liv*MatS
Georges-Köhler-Allee 105 | 79110 Freiburg, Germany

Gefördert durch
DFG Deutsche Forschungsgemeinschaft
Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy – EXC-2193/1 – 390951807.

Creating novel materials systems

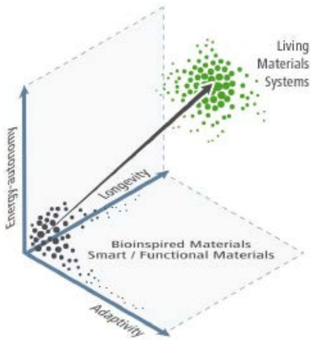
Today's technological materials have largely static properties. Apart from inevitable ageing and wear, their mechanical, optical, and thermal properties hardly change over time. In nature, on the contrary, everything from cells to tissues and whole organisms undergoes constant change. In fact, a key to survival for all living beings is having the utmost flexibility.

While it is their static set of properties that allows some synthetic materials to be used even under extreme conditions – such as in the deep sea, the desert, or outer space – natural structures overcome the obstacles of a hostile environment through their ability to adapt to changes. However, this ability comes at a price: adaptation intrinsically costs energy, which in nature needs to be provided through food or sunlight.

The vision of *liv*MatS is to combine the best of both worlds, the biological and the technological realm, to develop **living, adaptive, energy-autonomous Materials Systems**. These innovative materials systems will respond to changes in their environment by complex adaptive behaviors, and harvest the necessary energy without the need for an external power supply.

© Adobe Stock / kessudap

© Adobe Stock / zorgens



Vital, but not alive

To achieve such unprecedented properties, we will integrate several material components that work in concert. Nature, especially plants, will be an important source of inspiration – however, to go beyond biology, the materials systems envisioned by livMatS do not contain biological cells. This frees us from the limiting preconditions that are required to keep cells alive, such as moderate temperatures and the presence of water.

This means that the aspired systems are not alive in a biological sense. However, apart from that, they will exhibit many features of living entities. They are "vital" in the sense that they are energy self-sufficient, durable, adaptive, self-regulating and self-protecting, and they can function even under adverse conditions without encountering system failure.

Creating novel concepts

The vitality of these materials systems and the look and feel of living structures breaks with current paradigms in materials research. So-called "smart" or "intelligent" materials developed so far typically respond to changes in the environment only in a fixed and pre-programmed way, and usually rely on motors, controllers, and energy supply. *liv*MatS will develop truly new concepts of materials systems generation by simultaneously integrating features such as energy harvesting, sensing, simple decision making, adaptation and self-improvement into a single system.

Research in *liv*MatS will be carried out in constant, concurrent reflection of the sustainability of the applied approaches and on the societal challenges related to materials systems with lifelike features. Instead of first completing the technological development and then analyzing the implications for society, we will closely interweave technology development, sustainability assessments, behavioral analyses, acceptance, and the philosophical discourse on the interplay between human control and autonomy of systems.

Our partners

Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Fraunhofer ISE

Fraunhofer IWM

Our research program

Research Area A

Energy Autonomy

Research Area A will develop materials-integrated concepts for energy harvesting, storage, management and distribution. An unprecedented combination of functional principles, materials and fabrication technologies will be applied to address a seamless and non-interfering integration of multiple functionalities into one materials system.

We will harvest from three energy forms:
• optical (solar radiation)
• thermal (heat sources and fluxes)
• mechanical (vibration, sound, shock/acceleration)

The harvesters will operate in static or adaptive modes. The energy they gain will be converted primarily into electrical energy. In addition, harvested ambient energy will be directly fed into a materials system, to be used there without intermediate conversion. The energy provided will power functions like the system's adaptivity and longevity.

Research Area B

Adaptivity

Research Area B will investigate adaptive soft macromolecular materials systems, integrating distributive networks when needed. Central design strategies will focus on methods to form hierarchical systems through merging top-down additive manufacturing with bottom-up self-assembly, and combining this with programmable interactions on a molecular, structural and systems level (Integrated Multimaterials Additive Manufacturing).

We will break with present concepts of responsive materials, which mostly shift passively between equilibrium states. We will focus on complex adaptation mechanisms, including
• adaptation to non-trivial functional states (encountered in metamaterials or shape morphing),
• linear and non-linear signal strength-dependent adaptation,
• and exposure-frequency-dependent adaptation (reinforced "learning").

Research Area C

Longevity

Research Area C will develop concepts to increase the longevity of materials, ensuring functionality for their defined lifetime. By integrating and compiling numerous components at various (hierarchical) levels, a system will be created that warrants functionality under changing environmental conditions without a battery or external wiring. The resulting long-lived materials systems will be able to adapt to loading conditions (training), intrinsically detect systemic demands and (incipient) damage, autonomously respond with restoring and repairing functions, and efficiently use the resources of energy and systems components.

A central task will be to identify the most efficient approaches for "training-", "repair-" and "detour-routes", selected from a panoply of options. We aim to assure the longevity of functions like mechanical stability, (rapid) sensing and reflection of light as well as efficient ways of harvesting, converting and storing energy.

Research Area D

Societal Implications and Sustainability

The development of living materials systems will be part of the scientific and technical progress in the Anthropocene, the current era in the history of the Earth dominated by human impact on life and inanimate nature. Research Area D will provide guardrails through sustainability assessment and prediction of psychological acceptance during technology development. Sustainability issues, individual acceptance and traditional notions of what is considered "natural", "artificial", "living" and "inanimate" have an important impact on public perception.

Instead of first completing the technological development and then analyzing its societal implication, *liv*MatS interweaves technology development, sustainability assessments, psychological analyses, and the philosophical discourse on the interplay of human control and autonomy of systems. Experts from the natural and engineering sciences, and from sustainability analysis, psychology, and philosophy will work together to achieve this ambitious goal.

Research Areas A–D

Demonstrators

*liv*MatS will design and build technological demonstrators to integrate Research Areas A–D and focus their efforts. The demonstrators represent attractive research challenges and serve as lighthouses guiding research in the cluster. They will showcase the feasibility of the technologies developed in *liv*MatS, be the first steps towards their later implementation in collaboration with suitable industrial partners, and highlight their wide application range.

One of these demostrators deals with the development of a new generation of artificial Venus flytraps (AVTs), which are energy self-sufficient and should have all the functions of the living role model. Ultimately, our AVTs should pass a kind of Touring test, i.e. they should not be distinguishable from the living Venus flytrap in their function, but should be constructed from purely technical materials. Other demonstrators include novel materials systems with immanent sensing, controlling and decision making for soft autonomous machines e.g. for handling in work environment and medical use.