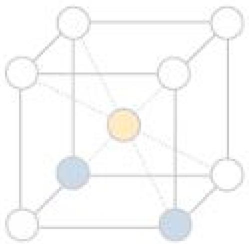
Smart Materials

Efficient Use of Material Resources



Since time immemorial, man has worked with materials like stone, wood and iron to create the basic building blocks and tools for life as we know it. Today, in an age when naturally occurring material resources are being fast depleted, intelligent deployment of materials has never been more important.

A Fraunhofer Institute for Systems and Innovation Research ISI study ("Material Efficiency in Production") conducted on behalf of the Federal Ministry of Economic Affairs and Energy (BMWi) found that annual cost savings of EUR 48 billion could be realized in industry. This is equivalent to a 75 percent increase on return on sales (this forecast increase is higher still in the clothing and textiles sectors and rubber and plastics production).

The material sciences and the resulting smart materials being developed in the field are the lifeblood driving innovation in a time of global megatrends of globalization, urbanization, demographic change, and energy change.

So-called "smart" materials (also known as "adaptive" or "intelligent" materials) are materials whose properties (e.g. mechanical, optical, and electromagnetic) can be altered in order to achieve a specific wished-for functional effect.

Material Sciences - Driving Industry Innovation

The material sciences are a broad cross-sector technology field of major importance to all manner of industry sectors including the automotive, aircraft manufacturing, industry and consumer goods, manufacturing, mechanical engineering and plant construction, medical technology sectors and many more besides.

"Conventional" and "New" Materials

All manner of different materials and technologies are called into play in order to meet the demands of industry. Materials can be divided into "conventional material" (e.g. metals, ceramics, glass, and polymers/plastics) and "new material" (composite materials, semiconductors, natural substances, and smart materials) classification categories.

Smart Materials - Building Blocks for a Sustainable Future

Smart materials are materials, materials systems and products which, in contrast to conventional materials, are dynamic in nature. At its simplest, smart materials respond to and interact with their immediate environments to exhibit adaptive characteristics that fulfill previously impossible functions. Smart materials make the products, services, and not least, public and private spaces of tomorrow’s world possible.

Today it is possible to specially create materials for a specific purpose. The smart materials successes made in the material sciences sector often go unheralded in the background as the market-ready product basks in the plaudits. Yet, the technological foundation or competitive advantage of the product developed would not exist were it not for smart materials. Around 70 percent of all technological innovations have a direct or indirect dependence on characteristics and functionality of applied materials.

Whether we know it or not, smart materials already play an important role in ordinary daily life. Chances are that you already wear smart materials when doing sports (e.g. lycra ® in light, stretchy but comfortable clothing) or pursuing outdoor activities (e.g. Gore-Tex ® in waterproof but breathable all-weather clothing).

Smart materials can work at very basic functional levels (e.g. temperature-responsive cups and plates for small children) or be used to simplify complex technical systems by integrating new properties and functionality (e.g. independent energy supply systems for microelectronic components).

The development of advanced materials for industry and new substances in the chemicals sector provide a solid basis for technological innovation and sustainable economic growth.

Germany is taking the lead in promoting advanced materials research and development. Materials and substances generate annual turnover in the billion euro region and provide indirect or direct employment to around five million people.

Selection of Smart Material Types	Smart Material Properties
Shape Memory Alloys	Shape memory alloys (SMAs) are metal alloys that "remember" their original, cold-forged shape. Changes to form can be induced and recovered via temperature or stress changes. SMAs can display "one-way memory" or "two-way memory" effects where the material can remember either one or two forms according to low or high temperature. Shape memory alloys, for example, are used as triggers in sprinkler fire alarm systems.
Shape Memory Polymers	Like shape memory alloys, shape memory polymers (SMPs) can return to their original state from a temporary, deformed state by applying an external stimulus (e.g. temperature change). SMPs differ from SMAs in terms of their "melting transition" from hard to soft phase responsible for the shape-memory effect. Shape memory foams, for example, are widely used in the construction sector.
Piezoelectric Materials	Piezoelectric materials produce a small electrical voltage when stress is applied. Conversely, applying a voltage to the material results in a stress change. This allows materials which bend, expand or contract when a voltage is applied to be made. Piezoelectric materials are used as contact sensors in a number of application contexts.
Quantum Tunneling Composites (QTC)	QTCs are composite materials of metals and highly elastic non-conducting polymers. They make use of "quantum tunneling" to allow the conductive elements to tunnel through the insulator when pressure is applied (i.e. the material becomes a conductor when squeezed). QTCs can typically be found in membrane switches of the kind found in mobile phones, pressure sensors, and speed controllers.
Electroluminescent Materials	Electroluminescent materials emit brilliant light in response to an electric current or field. No heat is produced as a by-product. Areas of application include safety signs and clothing.
Color Change Materials	Thermocromic materials change color according to temperature change. Photochromic materials change color according to differing light conditions.

Type of Smart Material	Input	Output
Type 1 Property-changing		
Thermomochromics	Temperature difference	Color change
Photochromics	Radiation (Light)	Color change
Mechanochromics	Deformation	Color change
Chemochromics	Chemcial concentration	Color change
Electrochromics	Electric potential difference	Color change
Liquid crystals	Electric potential difference	Color change
Suspended particle	Electric potential difference	Color change
Electrorheological	Electric potential difference	Stiffness/viscosity change
Magnetorheological	Electric potential difference	Stiffness/viscosity change
Type 2 Energy-exchanging		
Electroluminescents	Electric potential difference	Light
Photoluminescents	Radiation	Light
Chemoluminescents	Chemical concentration	Light
Thermoluminescents	Temperature difference	Light
Light-emitting diodes	Electric potential difference	Light
Photovoltaics	Radiation (Light)	Electric potential difference
Type 2 Energy-exchanging (reversible)		
Piezoelectric	Deformation	Electric potential difference
Pyroelectric	Temperature difference	Electric potential difference
Thermoelectric	Temperature difference	Electric potential difference
Electrorestrictive	Electric potential difference	Deformation
Magnetorestrictive	Magnetic field	Deformation

Promoting Smart Materials

A number of major smart materials funding programs and initiatives have been set up in Europe and Germany to promote smart materials innovation in industry and society at large. These dovetail at the European and domestic level to reflect the highly interdisciplinary nature of this exciting sector.

More

Supporting SME Innovation - Federal Institute for Materials Research and Testing (BAM)

Central to safeguarding the country's innovation advantage is the presence of excellent technology infrastructure which is put in the service of the market. The Federal Institute for Materials Research and Testing (BAM) is of particular significance in a smart materials context.

As part of the Unterstützung kleiner und mittlerer Unternehmen bei der Umsetzung von Innovationen in den Bereichen Messen, Normen, Prüfen und Qualitätssicherung ("Supporting Small and Medium-sized Enterprises in the Implementation of Innovations in Measurement, Norms, Testing, and Quality Assurance program") the BMWi promotes ambitious innovation projects between small and medium-sized enterprises in partnership with BAM in the areas of measurement, norms, testing, and quality assurance ("MNPQ") and projects which build on the research and development work conducted by BAM.

The aim of the initiative is to make the R&D results of the various technology and science federal agencies (including BAM) with high commercial potential available in partnership with small and medium-sized enterprises in order to create market-conform products, processes, and services through optimized technology transfer.

Smart Materials Projects

M A I Carbon: Carbon Composites - A Key Technology for Germany

The "M A I Carbon" cluster in the Munich-Augsburg-Ingolstadt region has been selected as one of the 15 winners of the Leading-Edge Cluster Competition (itself a component of the High-Tech Strategy) to identify "leading-edge clusters" that bring together excellent R&D and interdisciplinary competences in a specific geographical region. The winning cluster regions conduct innovative research and development work according to common strategic goals promoting international partnership for long-term growth and prosperity.

THE M A I Carbon cluster has set itself the ambitious goal of establishing carbon-fiber reinforced polymers (CFRP) as the materials group of the 21st century. It is intended that CFRP’s unique lightweight properties should be utilized in an industrial scale by 2020

Existing materials, like steel and aluminum, have reached the limits of their lightweight potential. According to M A I Carbon, new CFRP-based materials and components require a major rethinking of extant manufacturing and production paradigms. Springboard innovations across the entire component life cycle (from material production and manufacturing to recycling) are needed in order to realize CFRP deployment for mass production application purposes.

Seventy-two partners including renowned German companies and technology leaders in the automotive engineering, aerospace, and mechanical engineering and plant construction as well as fiber and semi-finished product manufacturing sectors are cluster members. Their collective aim is to develop and display M A I Carbon’s technology leadership in mass production-deployed CFRP components.

Promoted by Federal Ministry for Economic Affairs and Energy in accordance with a German Parliament resolution.