Germany Trade and Investment

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	Chemical 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

2016