

Smart Materials ,Shape memory alloys and their Applications in Engineering

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INTRODUCTION

SMART MATERIALS

Smart or intelligent materials are materials that have to respond to stimuli and environmental changes and to activate their functions according to these changes.

The stimuli like temperature, pressure, electric flow, magnetic flow, light, mechanical, etc can originate internally or externally.

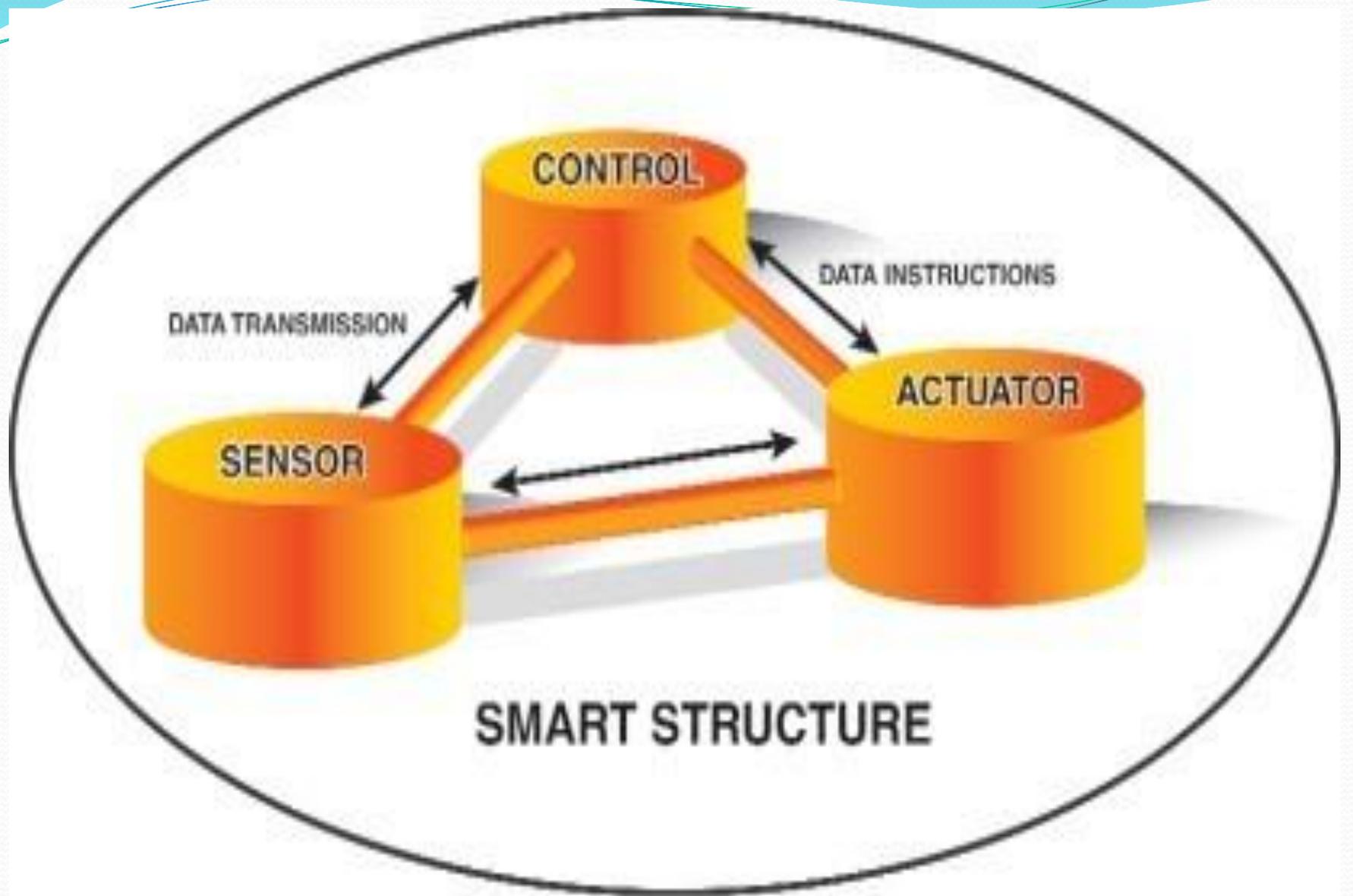
PROPERTIES OF SMART MATERIALS

- Sensing materials and devices
- Actuation materials and devices
- Control devices and techniques
- Self-detection, self-diagnostic
- Self-corrective, self-controlled, self-healing
- Shock-absorbers, damage arrest

SMART SYSTEM

- Data Acquisition (tactile sensing): The aim of this component is to collect the required raw data needed for an appropriate sensing and monitoring of the structure. E.g. Fibre optic sensing.
 - Data Transmission (sensory nerves): The purpose of this part is to forward the raw data to the local and/or central command and control units.
- Command and Control Unit (brain): The role of this unit is to manage and control the whole system by analyzing the data, reaching the appropriate conclusion, and determining

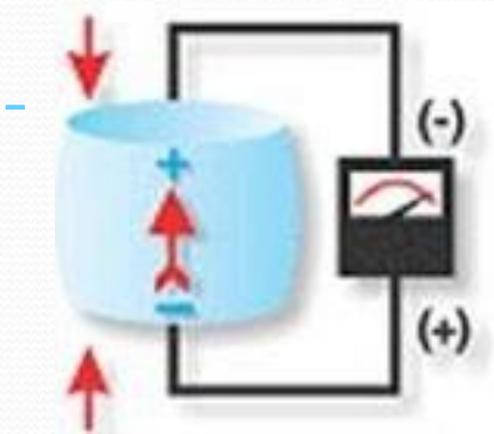
- Data Instructions (motor nerves): The function of this part is to transmit the decisions and the associated instructions back to the members of the structure.
- Action Devices (muscles): The purpose of this part is to take action by triggering the controlling devices/ units.



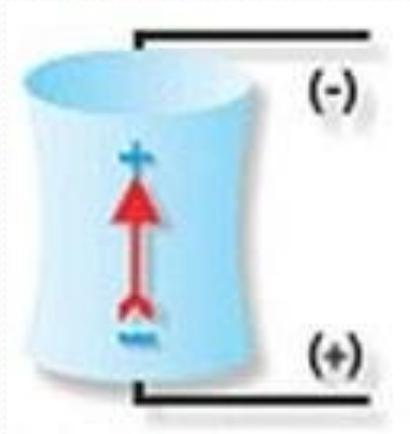
CLASSIFICATION OF SMART MATERIALS

- Piezoelectric materials
- Electrostrictive materials
- Magnetostrictive materials
- Rheological materials
- Thermoresponsive materials
- Electrochromic materials
- Fullerenes
- Biomimetic materials
- Smart gels

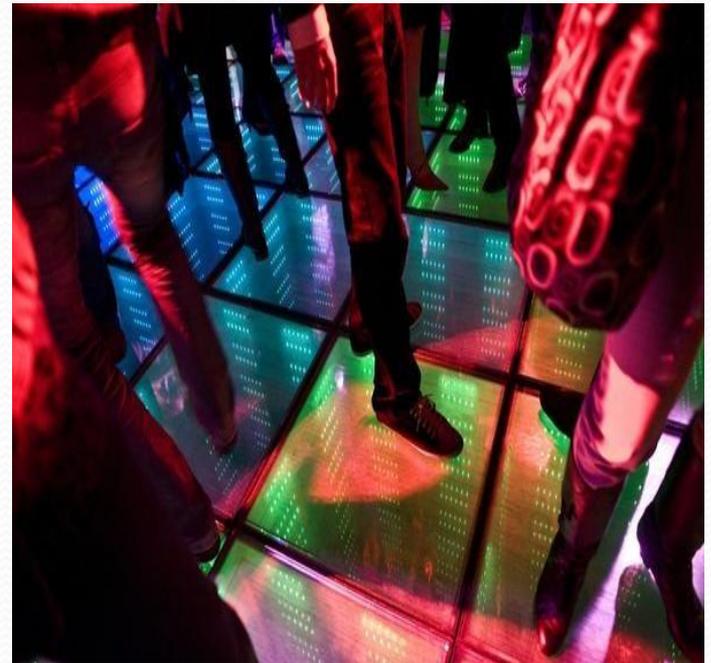
- Piezoelectric Materials: When subjected to an electric charge or a variation in voltage, piezoelectric material will undergo some mechanical change, and vice versa. These events are called the direct and converse effects



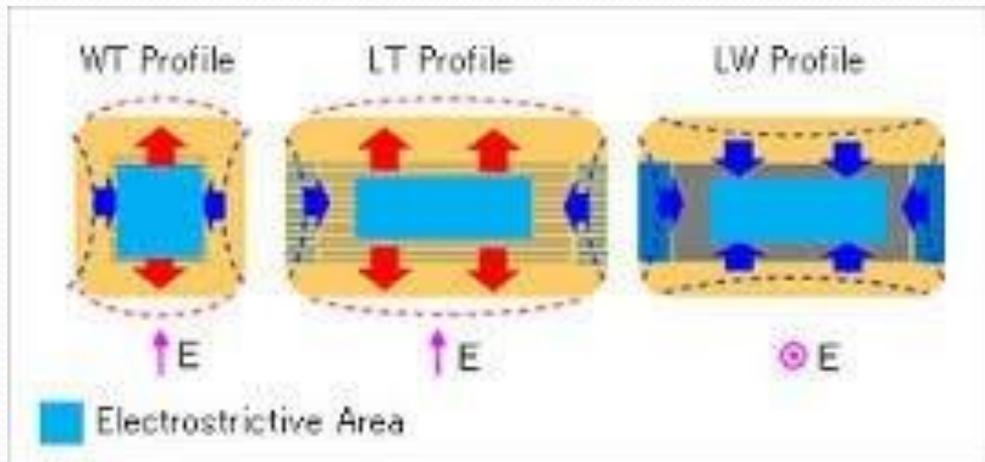
The Direct Effect



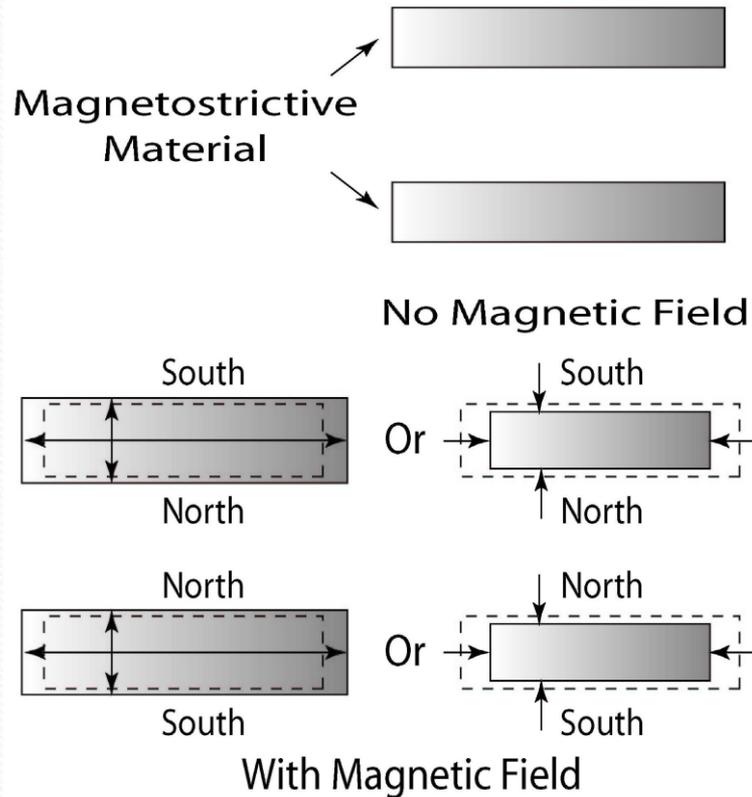
The Reverse Effect



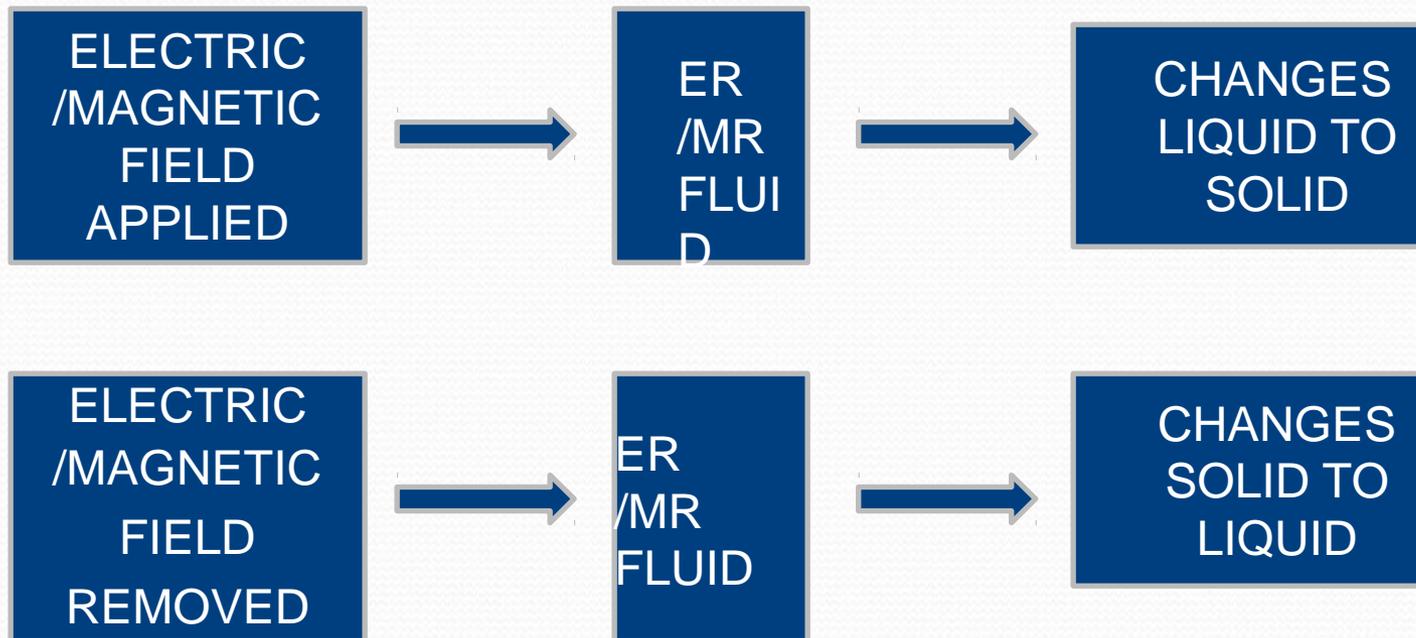
- Electrostrictive Materials: This material has the same properties as piezoelectric material, but the mechanical change is proportional to the square of the electric field. This characteristic will always produce displacements in the same direction.



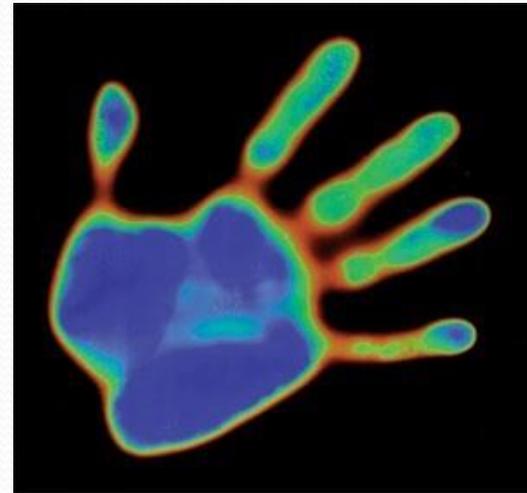
- Magnetostrictive Materials: When subjected to a magnetic field, and vice versa (direct and converse effects), this material will undergo an induced mechanical strain. Consequently, it can be used as sensors and/or actuators. (Example: Terfenol-D.)



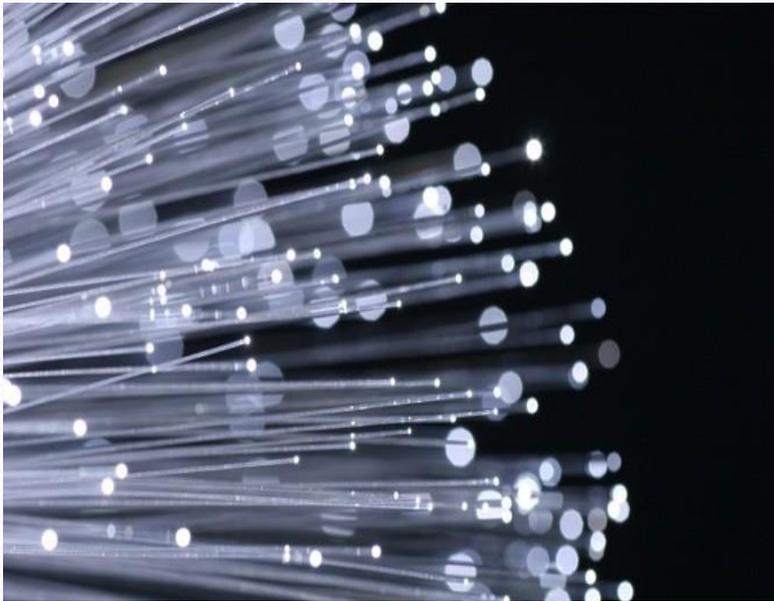
- Rheological Materials: These are in liquid phase which can change state instantly through the application of an electric or magnetic charge. These fluids may find applications in brakes, shock absorbers and dampers for vehicle seats.



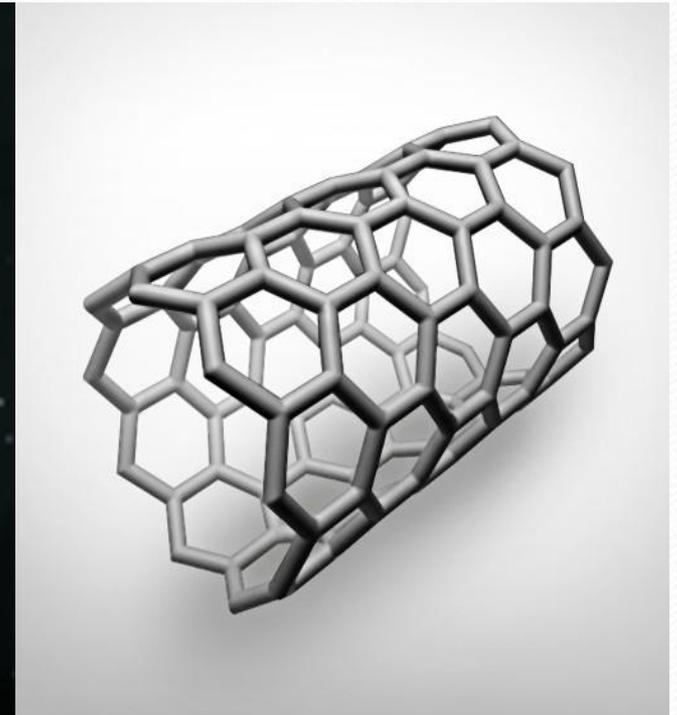
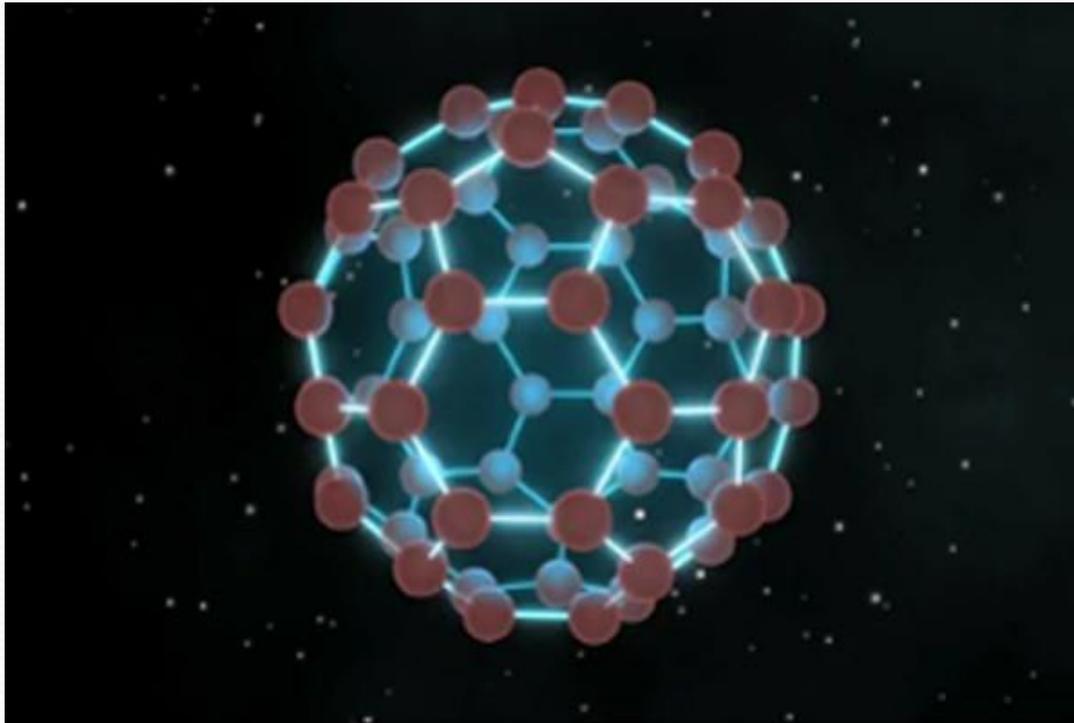
- Thermoresponsive Materials: Thermoresponsive is the ability of a material to change properties in response to changes in temperature. They are useful in thermostats and in parts of automotive and air vehicles.



- Electrochromic materials: Electrochromic is the ability of a material to change its optical properties (e.g. Color) when a voltage is applied across it. They are used in LCDs and cathodes in lithium batteries.

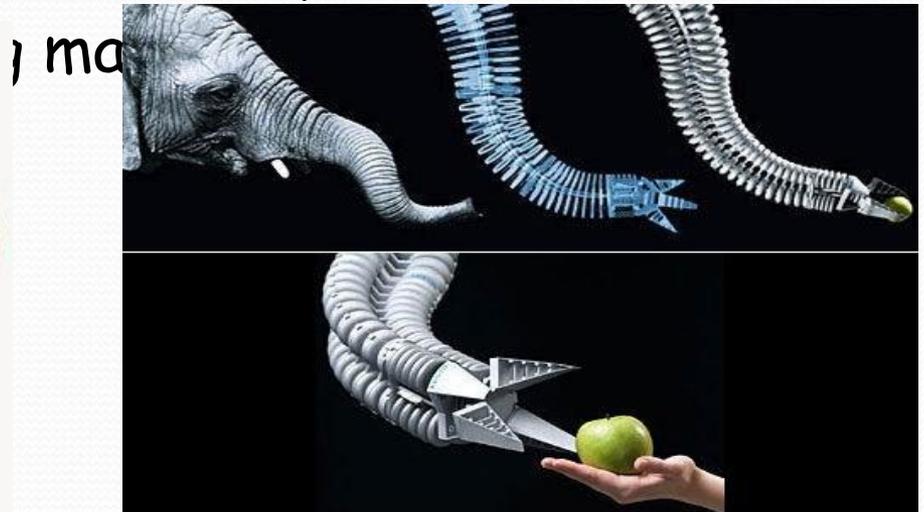


- Fullerences: These are spherically caged molecules with carbon atoms at the corner of a polyhedral structure consisting of pentagons and hexagons. These are usually used in polymeric matrices for use in smart systems. They are used in electronic and microelectronic devices, super-conductors, optical devices, etc.



- *Biomimetic Materials*: The materials and structures involved in natural systems have the capability to sense their environment, process the data and respond instantly. For example: to allow leaf surfaces to follow the direction of sunlight and essentially a real-time change in the load path through the structure to avoid overload of a damaged region.

The field of biomimetic materials explores the



- Smart gels: These are gels that can shrink or swell by several orders of magnitude. Some of these can also be programmed to absorb or release fluids in response to a chemical or physical stimulus. These gels are used in areas such as food, drug delivery, organ replacement and chemical processing.



SHAPE MEMORY ALLOYS

In 1930s, Arne Olander was first observed the shape memory effect while working with an alloy of gold and cadmium.

This Au-Cd alloy was plastically deformed when cold but returns to its original configuration when heated.

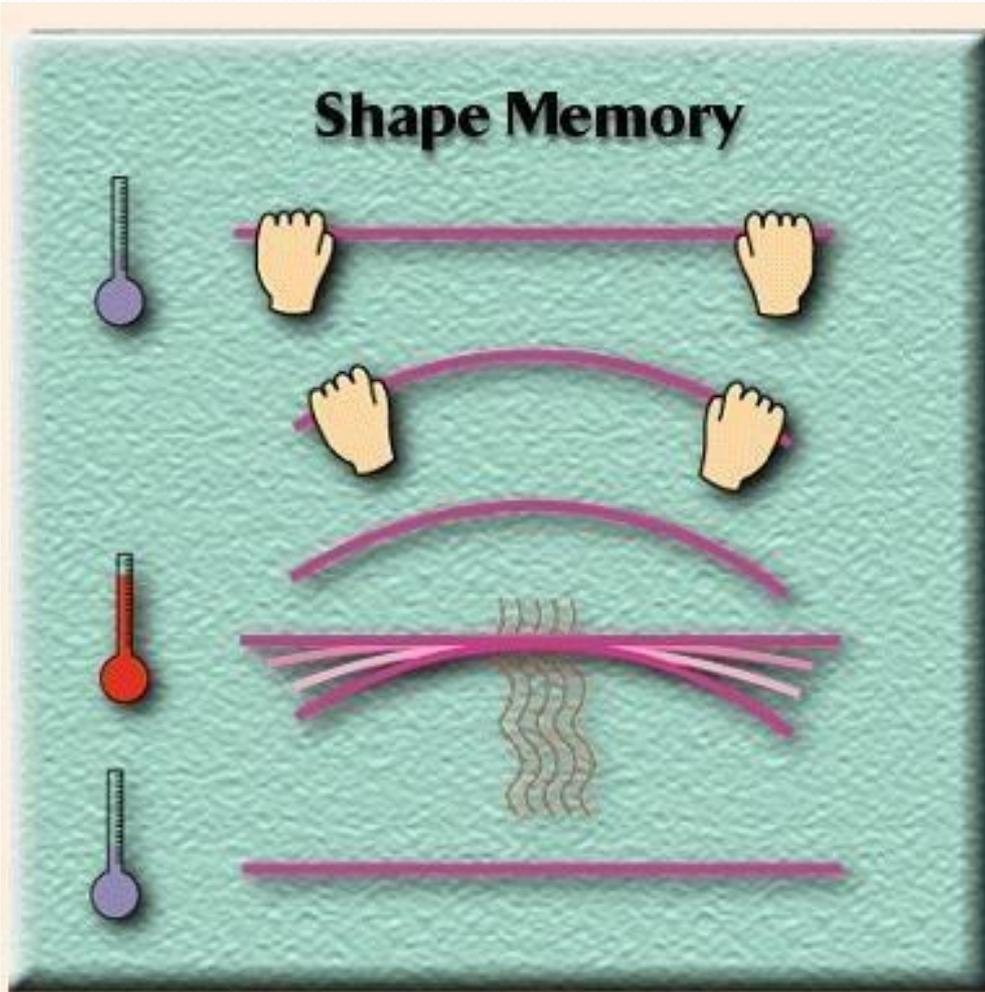
The shape memory properties of nickel-titanium alloys were discovered in the early 1960s. Although pure nickel-titanium has very low ductility in the martensitic phase, the properties can be modified by the addition of a small amount of a third element.

These groups of alloys are known as Nitinol™ (Nickel-Titanium-Naval-Ordnance-Laboratories).

How SMA Works?

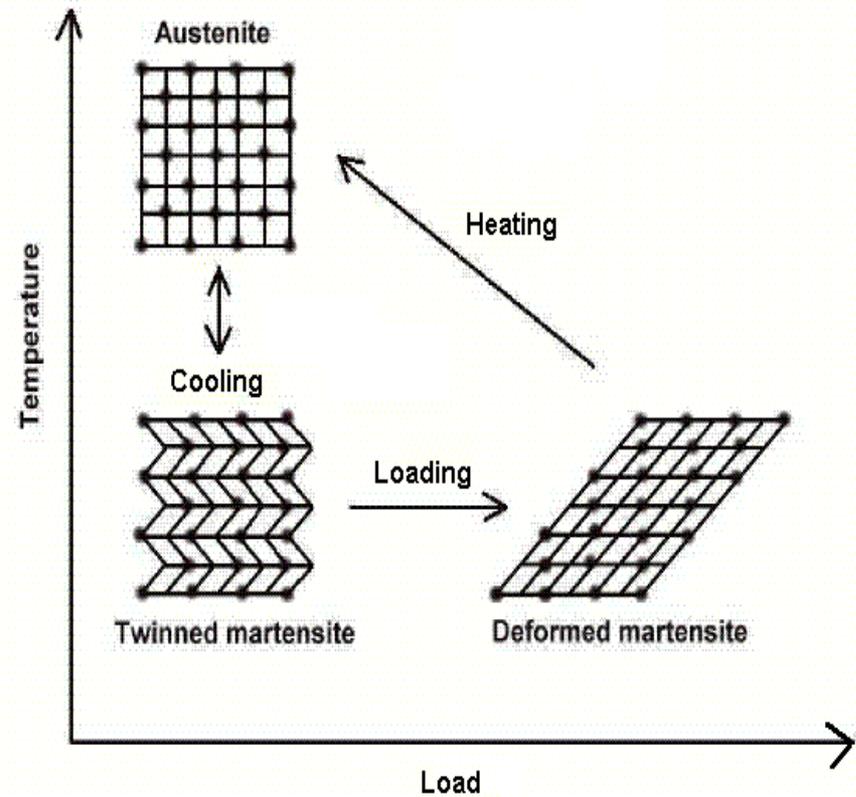
- SME occurs due to the change in the crystalline structure of materials.
- Two phases are:
 - ☐ Martensite:
 - Low temperature phase
 - Relatively weak
 - ☐ Austenite:
 - High temperature phase
 - Relatively strong

Shape Memory



- ❑ MARTENSITE
- ❑ DEFORMING
MARTENSITE
- ❑ DEFORMED
MARTENSITE
- ❑ AUSTENSITE
- ❑ MARTENSITE

- Martensite to Austenite transformation occurs by heating.
- Austenite to Martensite occurs by cooling.

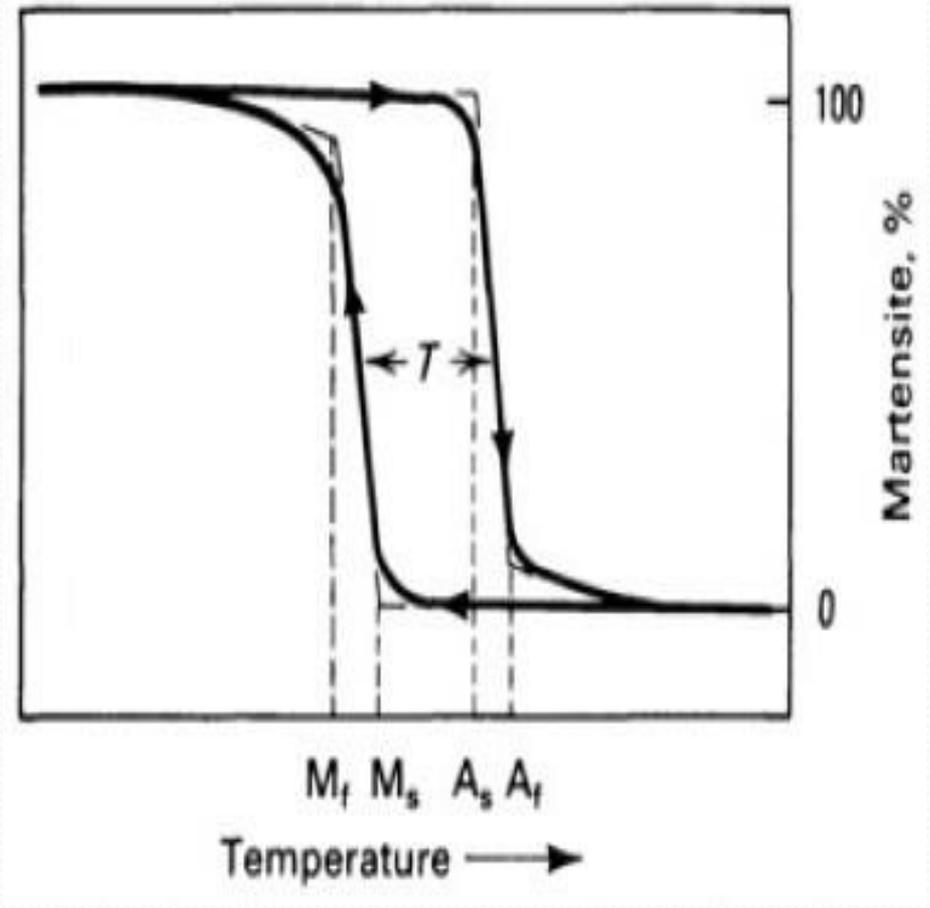


HYSTERESIS

S

where

- M_s - Martensite start
- M_f - Martensite finish
- A_s - Austenite start
- A_f - Austenite finish



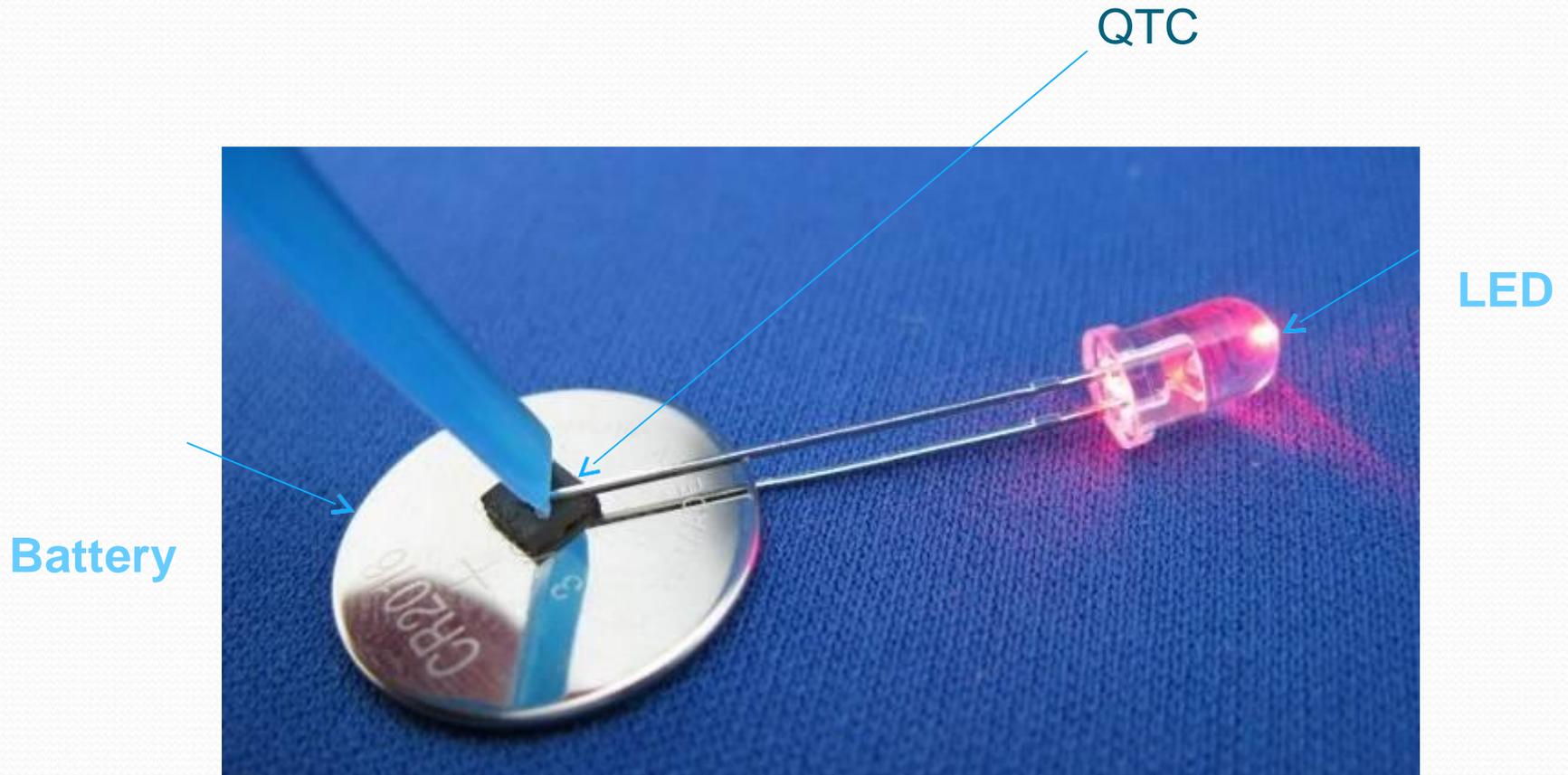
- A QTC in its normal state is a perfect insulator
- When compressed it becomes a perfect conductor
- If only lightly compressed its conductivity is proportional to the pressure applied

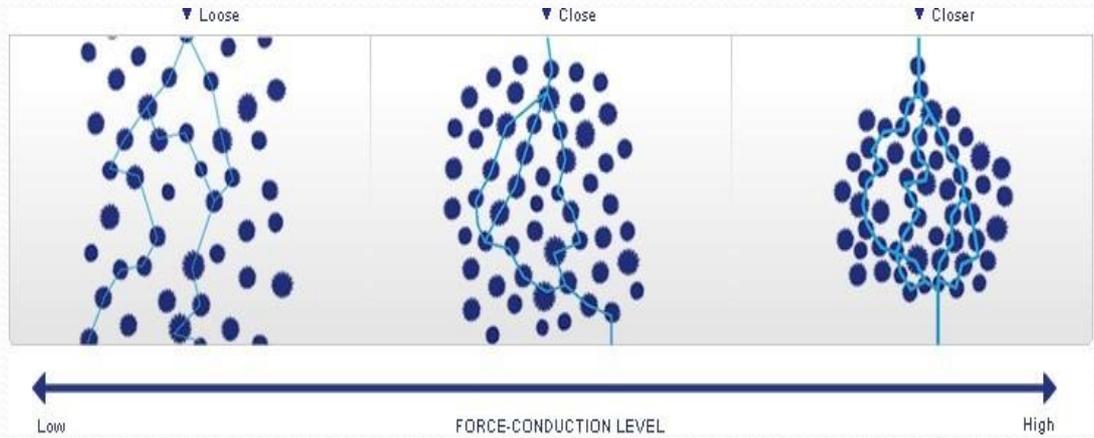
How does it work?

- In normal physics an electron cannot pass through an insulation barrier.
- In Quantum physics theory a wave of electrons can pass through an insulator - this is what is happening!

How QTC

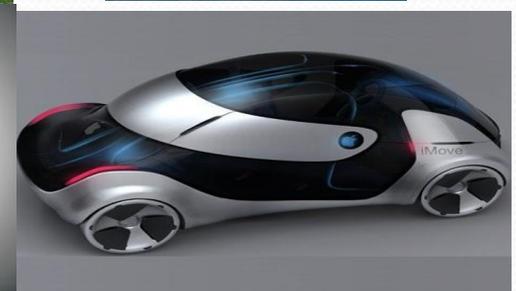
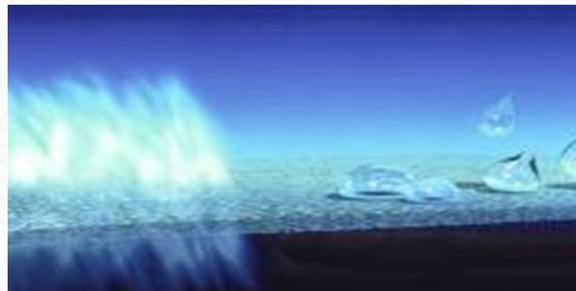
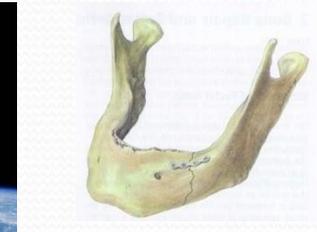
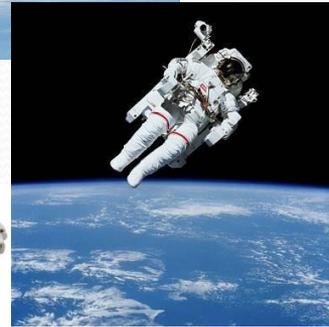
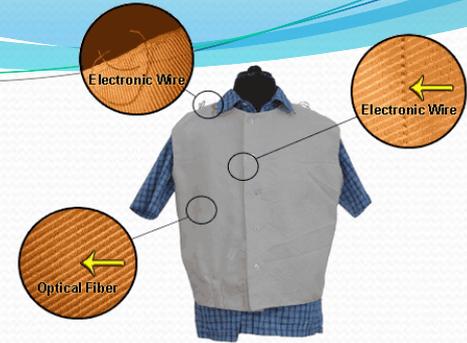
Works?





APPLICATION

- Aircrafts
- Orthopedic surgery
- Dental braces
- Robotics
- Reducing vibration of helicopter blades
- Smart fabrics
- Sporting goods



MERITS

- Bio-compatibility
- Simplicity
- Compactness
- Safety mechanism
- Good mechanical properties

DEMERITS

- More expensive
- Low energy efficiency
- Complex control
- Limited bandwidth

Conclusion

- Today, the most promising technologies for lifetime efficiency and improved reliability include the use of smart materials and structures. Understanding and controlling the composition and microstructure of any new materials are the ultimate objectives of research in this field, and is crucial to the production of good smart materials.
- New and advanced materials will definitively enhance our quality of our life.



Thank you!