

SMART MATERIALS

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What are Smart Materials???

Definition:-

- **Smart materials** are designed materials that have one or more properties that can be significantly changed in a controlled fashion by external stimuli, such as :-
 - *Stress;*
 - *Temperature;*
 - *Moisture;*
 - *pH;*
 - *Electric Fields;*
 - *Magnetic Fields.....*

Smart materials:-

S  **SIGNIFICANT**

M  **MEASURABLE**

A  **APPROPRIATE**

R  **RESULT-ORIENTED**

T  **TIME-ORIENTED**

A smart fluid developed in labs at the Michigan Institute of Technology



Major Types:-

CLASSIFICATION OF SMART MATERIALS

Type of SMART Material	Input	Output
Piezoelectric	Deformation	Potential Difference
Electrostrictive	Potential Difference	Deformation
Magnetostrictive	Magnetic Field	Deformation
Thermoelectric	Temperature	Potential Difference
Shape Memory Alloys	Temperature	Deformation
Photochromic	Radiation	Color Change
Thermochromics	Temperature	Color Change

Smart Materials

- Piezoelectric
- Electrostrictive
- Magnetostrictive
- Shape memory alloys
- Magnetocaloric
- Fullerene

Piezoelectric:-

❑ When subjected to an electric charge or a variation in voltage, piezoelectric material will undergo some mechanical changes.

❑ The best known example is electric cigarette lighter. Eg Bugger,

❑ Materials Used: Quartz, Rochelle Salt, Topaz, Bismuth Ferrite

DISCOVERY OF PIEZOELECTRIC MATERIALS



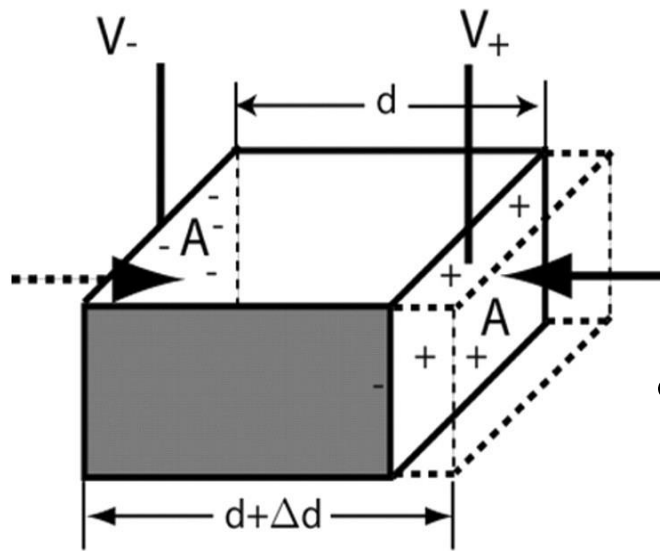
Jacques Curie



Pierre Curie

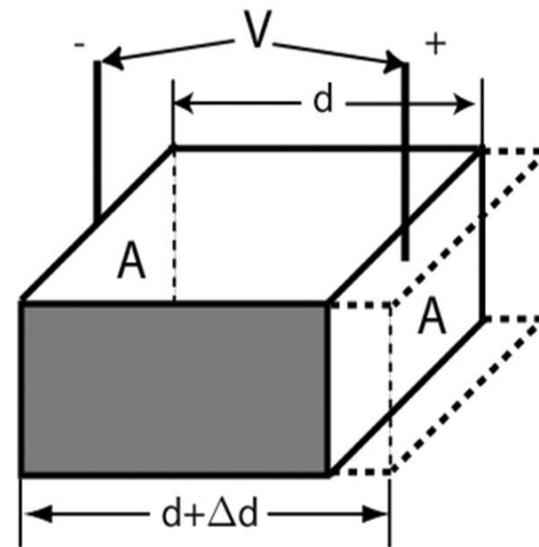
A select group of materials, was discovered in **1880** by Jacques and Pierre Curie during their systematic study of :
The effect of pressure on the generation of electrical charge by materials and materials which generated electrical charge were called Piezoelectric materials

Piezoelectric :-



Forces change thickness
and create charge

B



Applied voltage
causes thickness
changes

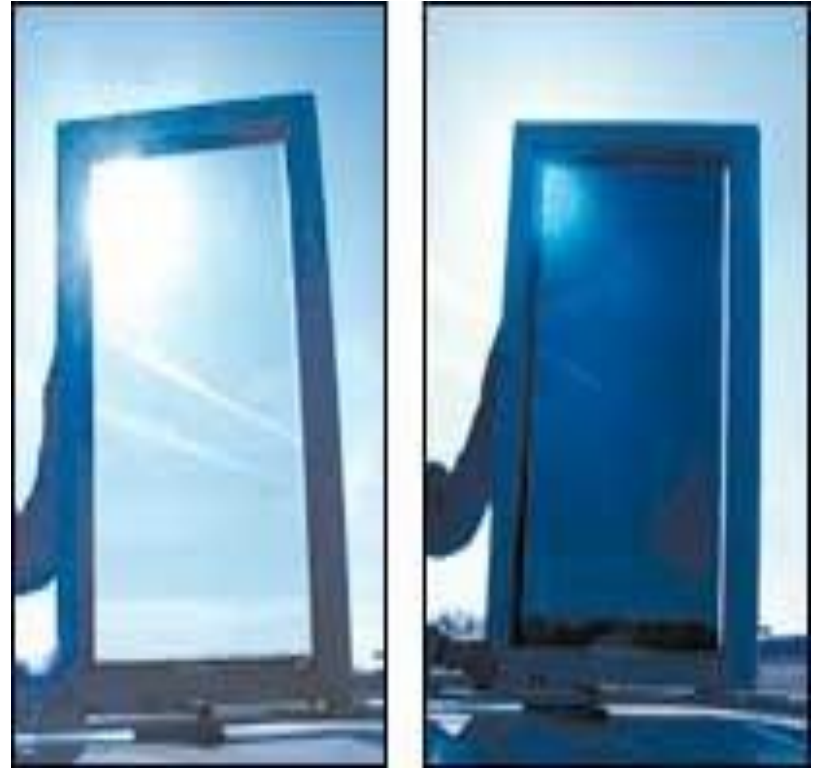
Electrostrictive:-

- This material has the same properties as piezoelectric material, but the mechanical change is proportional to the square of the electric field.
- Lead Magnesium Niobate (PMN) and its doped derivatives are classical electrostrictive materials.

Electrostrictive:-

The action of an electric field signals the change in the window's optical and thermal properties. Once the field is reversed, the process is also reversed. The windows operate on a very low voltage -- one to three volts -- and only use energy to change their condition, not to maintain any particular state.

LEAD LANTHANUM
ZIRCONATE
TITANATE(PLZT)



Magnetostrictive:-

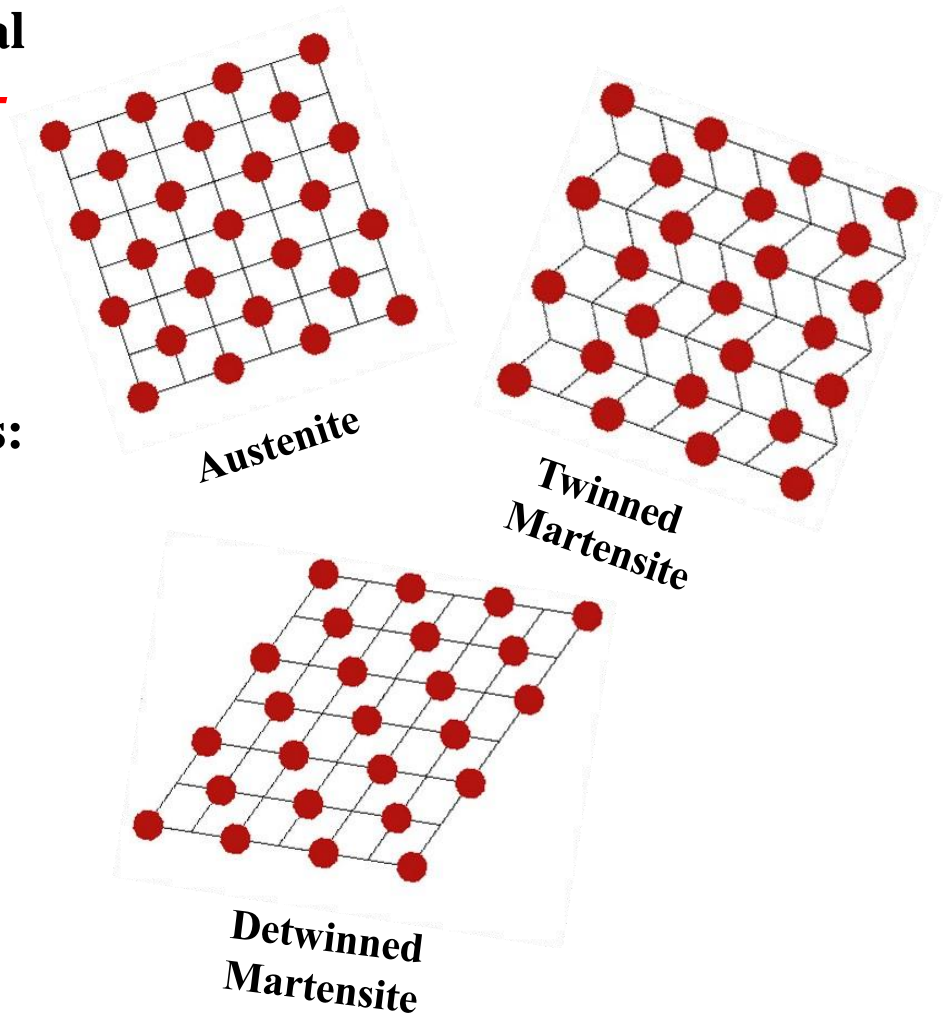
- When subjected to a magnetic field and vice versa (direct and converse effects), this material will undergo an induced mechanical strain. Consequently, it can be used as sensors and/or actuators.
- When subjected to a magnetic field, this material will undergo an induced mechanical change.
- Consequently, it can be used as sensors.
- Eg: **TERFENOL-D** (alloy of Terbium, iron(Fe))
- Rarest of the rare earth material. and hence very expensive
- □

Shape Memory Alloys

Shape Memory Alloys are metal alloys which can undergo *solid-to-solid* phase transformation and can recover completely when heated to a specific temperature.

These materials has two phases:

- **Austenite**- high temperature phase;
- **Martensite**- low temperature phase.



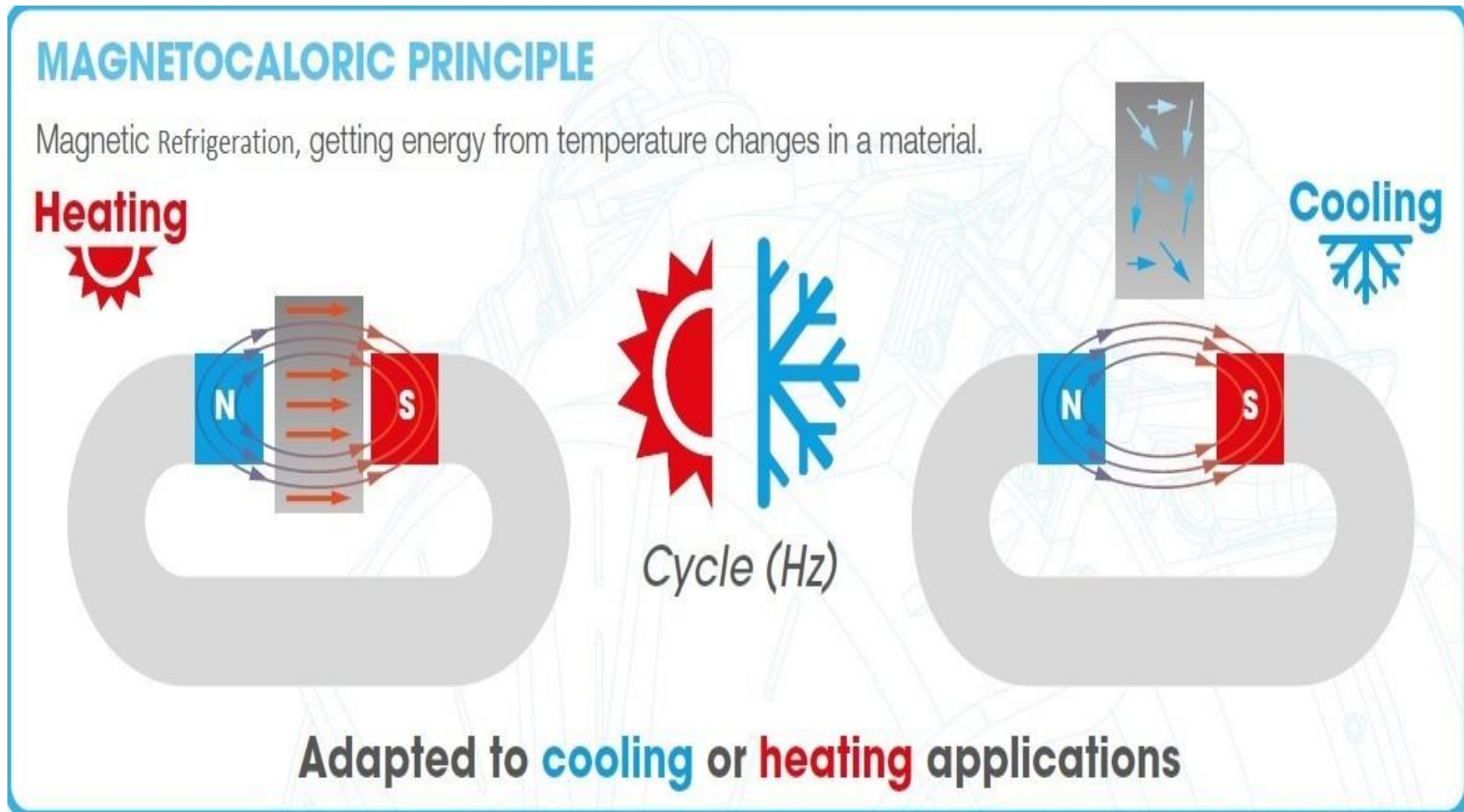
Shape Memory alloy:-



Magnetocaloric materials:-

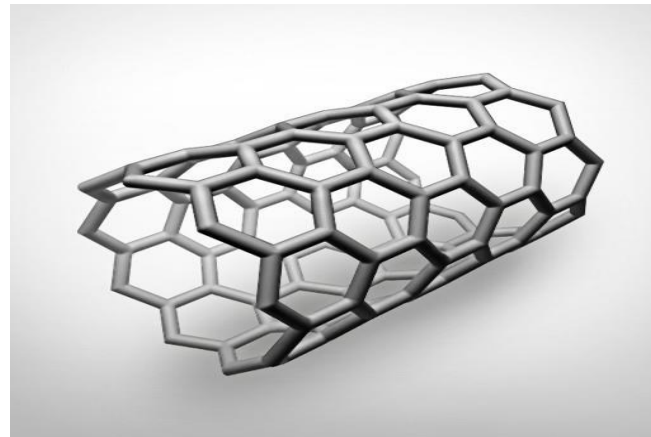
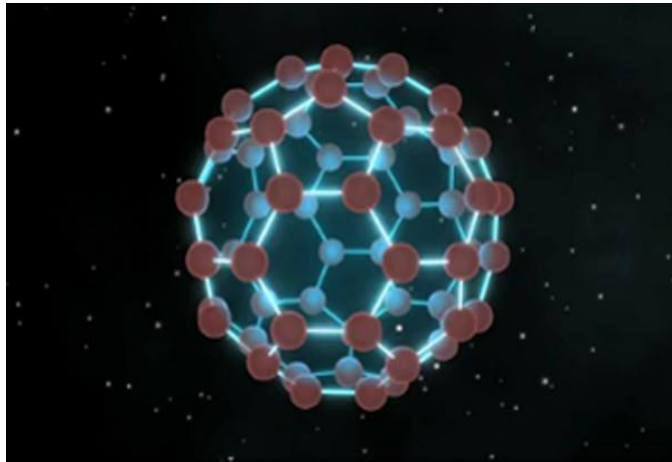
- ❑ Magnetocaloric materials are compounds that undergo a reversible change in temperature upon exposure to a changing magnetic field.
- ❑ These materials have applications in refrigeration.

Magnetocaloric materials:-



Fullerine:-

❓ 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.



Applications of fullerenes:-

❑ Superconductors

❑ By doping fullerenes with three variable atoms, a superconducting state can be achieved.

❑ Medical

❑ Atoms can be trapped in a buckyball, in order to create a biological sponge.

❑ HIV protease inhibitor

❑ A buckyball can be inserted in the HIV protease active site in order to stop replication.



Examples

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List of Smart Materials (I)

Material	Input/Stimulus	Output/Response	Application
Polymeric gel	pH change	Swelling or contracting	Artificial muscle
Electro-rheological fluid	Electric signal	Viscosity change	Torsional steering system damper
Pyroelectric material	Temperature	Electric signal	Personnel sensor (open super-market door)
Polymer (eg thin film cellulose), ceramic	Humidity change	Capacity/resistance change	Humidity sensors
Self-Healing Materials	Force	Force	Smartphone chassis
Smart metal alloys	Temperature	Shape	Motor actuators
Dielectric Elastomers	Voltage	Strain	Robotics

EXAMPLES

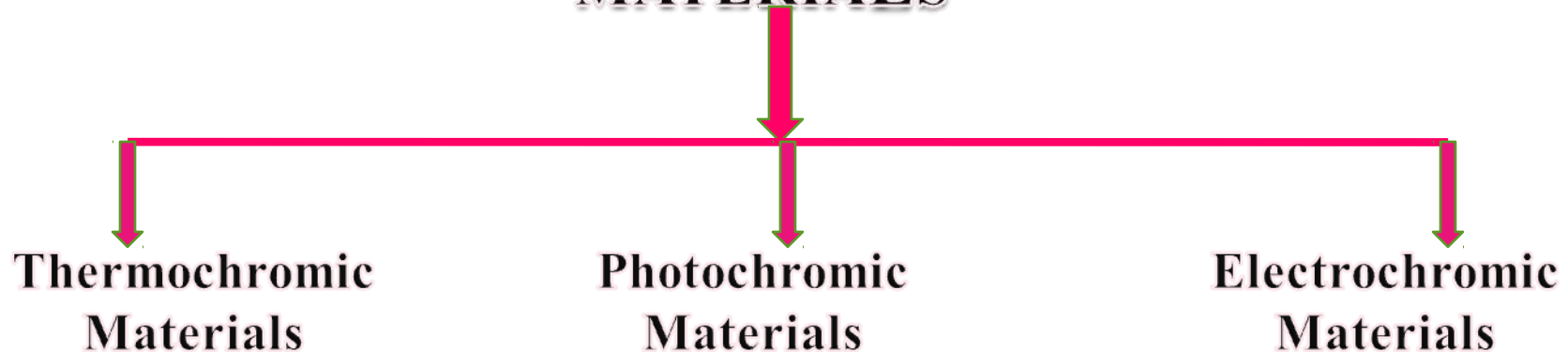
- ❑ Treated Paper
- ❑ Thermo color Sheet
- ❑ Precious Metal Clay (PMC)
- ❑ Paper foam
- ❑ Footwear
- ❑ Etc.



Chromogenic Materials

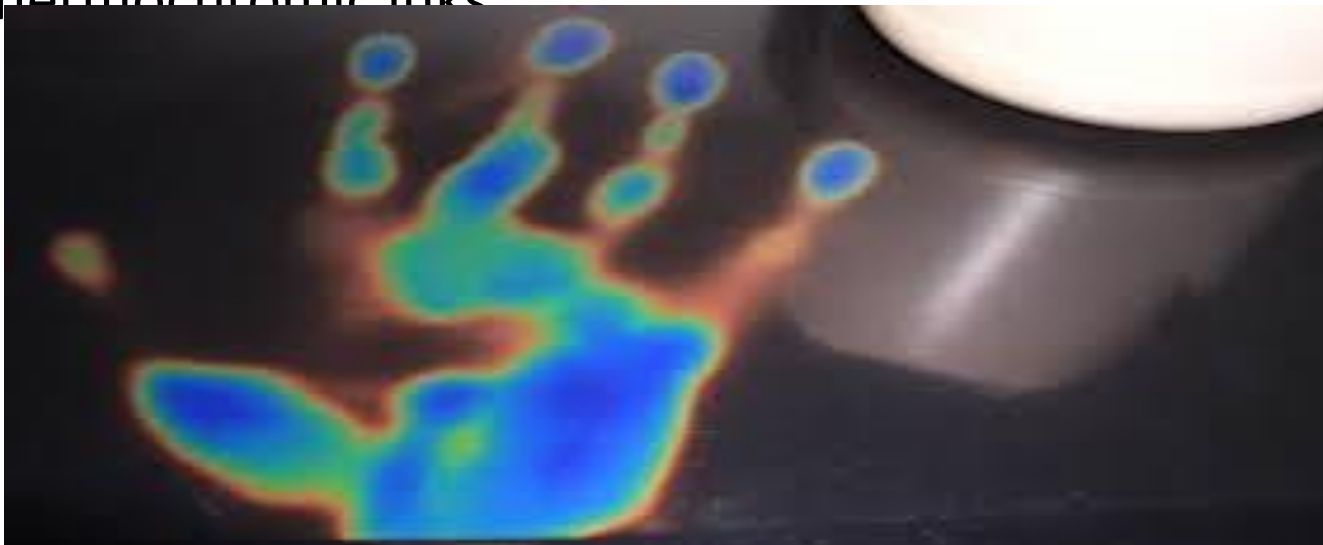
Chromogenic materials change their color in accordance to electrical, thermal or radiative stimuli.

CHROMOGENIC MATERIALS



Thermochromism:-

- **Thermochromism** is the property of substances to change color due to a change in temperature.
- Smart materials are used in all types of thermochromatic liquid crystals, leuco dyes, thermochromic papers, thermochromic polymers and thermochromic inks



Photochromic Lens:-

- ❑ **Smart materials** are also used in photochromic lens.
- ❑ **Photochromic lenses** are lenses that darken on exposure to specific types of light, most commonly ultraviolet (UV) radiation.
- ❑ Once the light source is removed (for example by walking indoors), the lenses will gradually return to their clear state.



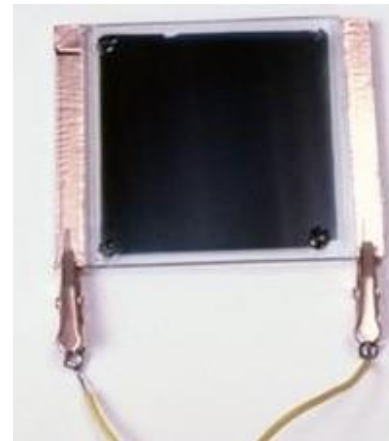
Electrochromic Materials

These materials change their optical behavior with application of electrical voltage.

Their behavior is basically characterized by the amount of light they allow to pass through them.



Transparent and looks like ordinary glass



Application of small voltage turns it opaque (blueish and dark)

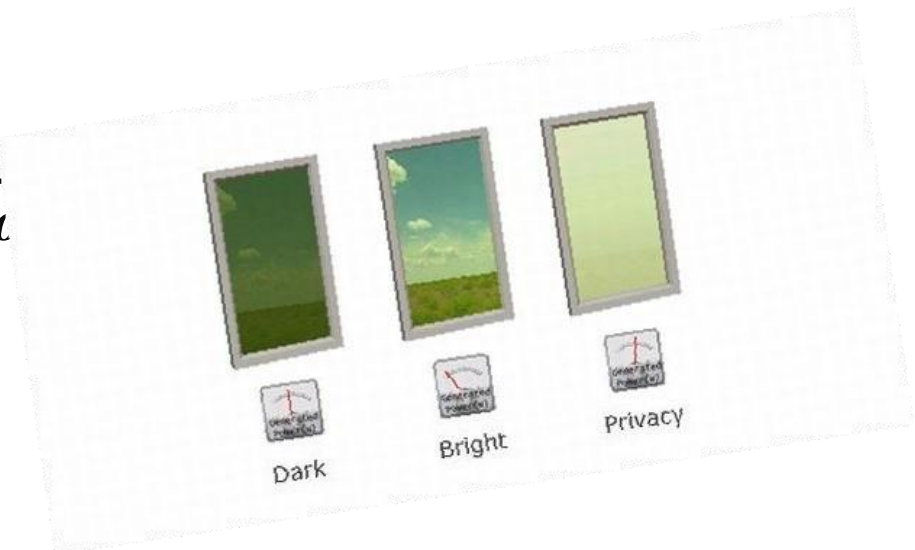
Electrochromic Materials

General materials used are:

- ❑ NiO ;
- ❑ WO_3 ;
- ❑ TiO_2 ;
- ❑ *Polyaniline*;
- ❑ *Polythiophene*.

Major applications:

- ❑ *Smart Glass*;
- ❑ *Light-transmissive devices for optical information storage*;
- ❑ *Rear-view mirrors*;
- ❑ *Protective eyewear*.



Shape-memory polymers

Shape-memory polymers (SMPs) are polymeric smart materials that have the ability to return from a deformed state (temporary shape) to their original (permanent) shape induced by an external stimulus (trigger), such as temperature change.

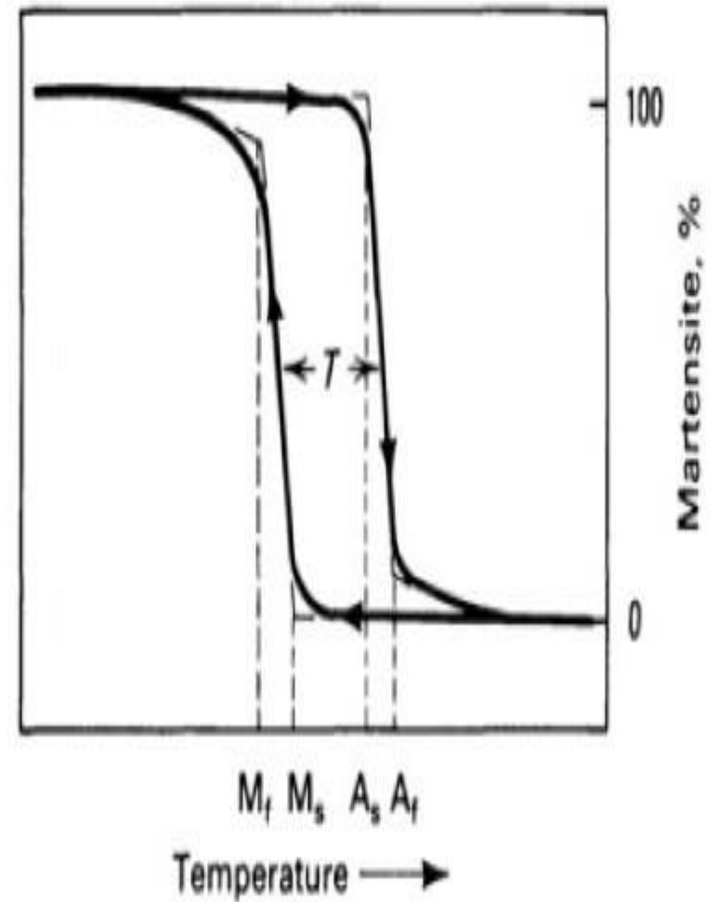


Shape Memory Polymer:-

- made by mixing nickel and titanium
- $T < T_C$, Martensitic phase-plastic state-

large strains can be applied with little stress.

- $T > T_C$, Austenitic phase-memory phase-retains its original shape.
- Actuation is caused by transforming the material from martensite to austenitic phase. This process causes enormous amount of stress, which can be used for actuation purpose.
- Slow reaction time



Advantages and Dis-Advantages

Advantages of Smart Materials:-

- ❑ High energy density (compared to pneumatic and hydraulic actuators)
- ❑ Excellent bandwidth
- ❑ Simplified packaging
- ❑ Novel functions such as the huge volume change as a function of temperature exhibited by smart gels.

Advantages:-



Disadvantages of Smart Materials:-

- ❑ Dropping people out of the labor
- ❑ Not biodegradable
- ❑ Environmental pollution
- ❑ Expensive to produce
- ❑ Long term effects unknown
- ❑ Global crisis

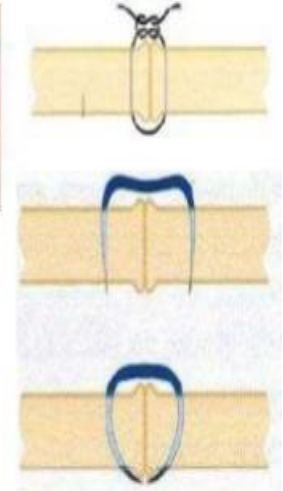
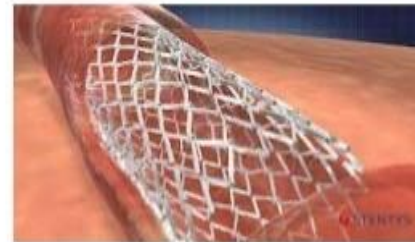
Applications

- ? Smart Fabric;
- ? Smart Aircraft;
- ? Sporting Goods;
- ? Smart Dust;
- ? Reducing vibration helicopter blades;
- ? Robotics;
- ? Medical Surgeries;
- ? Security;
- ? And many others.....

APPLICATIONS

❖ SMA have applications in industries like-

Medical: Mending bones, Stent in arteries, Eyeglass frames, Tooth clips



Military: Nitinol couplers in F-14 fighter planes

Safety: Anti-scalding devices and fire sprinklers

Robotics: As an actuator

 Thank you

 Any Queries??

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