CBCS SCHEME

USN 2VD22MF008

BME306B

Third Semester B.E./B.Tech. Degree Examination, Dec.2023/Jan.2024

Smart Materials and System

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

			M	L	C
		Module – 1			
Q.1	**a.**	What is the structure of a smart material? Why are smart materials used?	**10**	**L1**	**CO1**
	b.	What are the functions of smart systems, and application area of smart systems?	**10**	**L1**	**CO1**
		OR			
Q.2	**a.**	What are the components of a smart structures briefly explain?	**10**	**L1**	**CO2**
	b.	What are stimulus responsive smart materials? What are examples of stimuli-responsive materials?	**10**	**L2**	**CO2**
		Module – 2			
Q.3	**a.**	What are electroactive elements? Mention the different types of electroactive polymers.	**10**	**L3**	**CO3**
	b.	What do you mean by piezoelectricity? What causes piezoelectricity?	**10**	**L3**	**CO3**
		OR			
Q.4	**a.**	What is the principle of piezoelectricity and give an example?	**10**	**L3**	**CO3**
	b.	What are the properties of piezoceramics and give an example?	**10**	**L3**	**CO3**
		Module – 3			
Q.5	**a.**	What does it mean to be thermally active? And causes of thermal activity.	**10**	**L3**	**CO3**
	b.	What is shape memory alloys? Write the properties and applications shape memory alloys.	**10**	**L3**	**CO3**
		OR			
Q.6	**a.**	Explain the static shape memory effect and its behavior.	**10**	**L4**	**CO3**
	b.	What is the phase transformation of NiTi and transformation temperature?	**10**	**L4**	**CO3**
		Module – 4			
Q.7	**a.**	Define the thermoresponsive polymers. Write the advantages.	**10**	**L4**	**CO4**
	b.	Briefly explain an electroactive polymer and user of electroactive polymers.	**10**	**L4**	**CO4**

		OR			
Q.8	**a.**	Explain protein based smart polymers with examples.	**10**	**L3**	**CO4**
	b.	Describe the PH-responsive and photoresponsive polymers.	**10**	**L4**	**CO4**
		Module – 5			
Q.9	**a.**	Define the chemical activation. What activates a chemical reaction?	**10**	**L4**	**CO5**
	b.	Define chemical gel, write the difference between physical gel and chemical gel.	**10**	**L4**	**CO5**
		OR			
Q.10	**a.**	Explain optical polymers and properties of optical polymers.	**10**	**L5**	**CO5**
	b.	Briefly explain the smart materials for aerospace application, write which material suitable for space.	**10**	**L5**	**CO5**

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Smart Materials & Systems (BME306B)
Dec 2023 | Jan 2024 Solved Paper

1.) a) What is the structure of material? Why are smart materials used

The structure of smart materials is integral to their ability to respond dynamically to external stimuli such as temperature, pressure, light, magnetic fields or pH. The term structure in this context refers to the arrangement of atoms, molecules or phases within the material, which governs how the material behaves under different conditions.

1. Atomic and Molecular Structures

* Crystal structure: Many smart materials rely on specific crystal structures that enable them to exhibit unique properties. For example, piezoelectric materials like quartz have a non-centrosymmetric crystal structure, meaning that the positive and negative charge centres in the crystal lattice do not coincide. This asymmetry is crucial for their ability to generate an electric charge when mechanically deformed.

* Phase structure: Some smart materials like shape memory alloys (SMAs), depend on the existence of different phases. SMAs have martensite phase at low temperature which is soft and easily deformed and an austenitic phase at higher temperatures which is more rigid. The reversible transformation between these phases enables SMAs to remember and return to their original shape when heated.

2. Layered Structures

* Electrochromic Materials: These materials typically have a layered structure. For instance, in an electrochromic device there might be a transparent conductive layer, an electrochromic layer (such as tungsten oxide) an ion conductor (electrolyte) and a counter electrode.

when a voltage is applied, ions move between the layers causing a change in the optical properties of electrochromic layer, such as color or transparency.

- Thermoelectric Materials : These materials convert temperature differences into electric voltage. They often consist of multiple layers or phases that allow electrons and holes to move differently, creating voltage across the material

3. Composite Structures

- Magneto ~~et~~ rheological (MR) and Electrorheological (ER) Fluids These smart fluids consists of a suspension of micron sized particles in a carrier fluid.

- Fiber Reinforced Composites : Some smart materials are composite structures with embedded sensors or actuators. For example smart textiles

4. Polymer Networks

- Hydrogels : pH sensitive hydrogels are an example of smart materials that have a network of crosslinked polymer chains.

- Shape Memory Polymers : These polymers have a molecular structure that allows them to return to a predetermined shape. when exposed to a specific trigger, such as heat. The polymer chains are arranged in a way that allows them to remember their original configuration.

5. Nano structures

- Nanocomposites : Some smart materials incorporate nanoscale structures such as nanoparticles or nanotubes which can enhance their properties.

- Quantum Dots : In opto electronic smart materials, quantum dots (nanoscale semiconductor particles) can be used to create materials that change color or emit light in response to electric fields, light or other stimuli

Smart materials are used because of their ability to respond dynamically and reversibly to external stimuli, making them highly versatile and valuable in a various applications. The following are the key reasons.

1. Adaptive Functionality
2. Improved Efficiency
3. Enhanced Performance
4. Safety and Reliability
5. Innovation and Functionality
6. Customization and Adaptability
7. Sustainability
8. Comfort and Convenience.
9. Miniaturization and Integration.

1.) b.) What are the functions of smart systems and applications area of smart material :

The functions of smart systems are

1. Sensing : Smart systems often include sensors that detect changes in the environment such as temperature, pressure light, motion or chemical composition.
   Example : Smart Thermostat

2. Actuation : Actuators in smart systems respond to sensor inputs by performing a physical action such as moving a component, changing the shape of a material or altering electrical properties Example : Antilock Brake System.

3. Processing and Control : Smart systems process the data received from sensors make decisions based on predefined algorithms or machine learning and control the actuators to perform the desired function. Example : Smart home system.

4. Adaptation: Smart systems can adapt their behaviour based on changing conditions, learning from past interactions or optimizing performance over time.
Example: Smart grid

5. Feedback: Smart systems have feedback mechanisms that allow smart systems to continuously monitor their performance and make adjustments to achieve optimal operation. Example: Robotics

6. Self Healing: Some smart materials have the ability to detect and repair damage or malfunctions automatically improving reliability and extending the systems lifespan.
Example: Electronic circuits.

7. Communication: Smart systems often include communication capabilities allowing them to exchange data with other systems or devices either wirelessly or through wired connections. Example: Internet of Things (IoT)

Applications

1. Aerospace
2. Medical and Healthcare
3. Automotive
4. Civil Engineering and Construction
5. Consumer Electronics.
6. Textiles and Fashion
7. Energy Harvesting
8. Robotics
9. Environmental Monitoring
10. Military Defence
11. Optics and Displays
12. Sports and Recreation
13. Agriculture

2) a. What are the components of Smart Structures explain briefly

Smart structure is a component or a system that incorporates particular functions of sensing and actuation to perform smart actions. The basic five components of a smart structure are

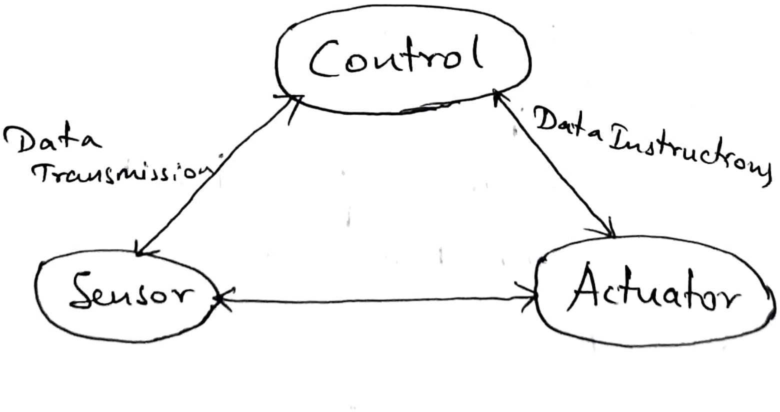
- Data Acquisition (Tactile Sensing): The aim of this component is to collect the required raw data needed for an appropriate sensing and monitoring of the structure.

- 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 conclusions and determining the actions required

- 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.



2) b. What are stimulus responsive smart materials? What are examples of stimulus-responsive materials.

Stimulus-responsive smart materials are a class of materials that can undergo significant changes in their properties or behaviour in response to specific external stimuli. These changes can include alterations in shape, color, electrical conductivity, magnetization or mechanical properties and they can be reversible when the stimulus is removed. The ability to respond dynamically makes these materials 'smart' because they can adapt to their environment or the conditions in which they are placed.

Here are some key types of stimulus responsive smart materials and the stimuli they respond to:

1. Thermo-responsive Materials
   Stimulus: Temperature
   Examples: Shape Memory Alloys (SMAs), Thermochromic Materials, Phase change Materials (PCMs)
2. Photo-responsive Materials
   Stimulus: Light (UV, visible or Infrared)
   Examples: Photochromic Materials, Photostrictive Materials, Photovoltaic Materials.
3. Magneto-responsive Materials
   Stimulus: Magnetic field
   Examples: Magnetorheological fluids (MR) fluids, Magneto elastic Materials.
4. Electro-responsive Materials
   Stimulus: Electric field or voltage
   Examples: Electroactive polymers (EAPs)
   Electrochromic Materials
   Dielectric elastomers.

5. pH-responsive Materials
   Stimulus : pH level
   Examples : pH sensitive Hydrogels
   pH responsive Polymers

6. Chemical-responsive Materials
   Stimulus : Specific chemical or gels
   Examples : Chemochromic Materials
   Ion sensitive Polymers.

7. Moisture-responsive Materials
   Stimulus : Humidity or water
   Examples : Hydrogels
   Hygroscopic Materials.

8. Pressure-responsive Materials
   Stimulus : Mechanical stress or pressure.
   Examples : Piezoelectric Materials
   Pressure sensitive adhesive.

Module 2

3.) a. What are electroactive elements? Mention the different types of electroactive polymers

Electroactive elements refer to materials or components within a system that exhibits changes in their physical or chemical properties when subjected to an electric field or voltage. These changes can include alterations in shape, size, electrical conductivity, color, or mechanical properties. Electroactive elements are crucial in various applications particularly in sensors, actuators, displays and smart systems.

The different types of electroactive polymers are

1. Diaelectric Elastomers:

Mechanism: These polymers deform when subjected to an electric field due to electrostatic forces between the electrodes placed on either side of the polymer.

Characteristics: They offer large strains, high energy density and fast response times.

Applications: Actuators, artifical muscles

2. Ionic Polymer Metal Composites

Mechanism: These composites bend or change shape when a voltage is applied across them. The motion is driven by the migration of ions within the polymer.

Characteristics: They require low voltage to operate and have good bending capabilities

Applications: Soft actuators, biomimetic devices, sensors artificial muscles.

3. Conductive Polymers

Mechanism: These polymers change their electrical conductivity in response to an applied electric field.

Characteristics: They are typically used in applications where a change in electrical properties is needed.

Examples: Aniline, Polyaniline, Polypyrole

Applications: Flexible electronics, sensors, organic solar cells corrosion protection.

4. Electrostrictive Polymers

Mechanism: These polymers undergo deformation in response to an electric field, with the strain being proportional to the square of the electric field.

Characteristics: They offer more significant strain than piezoelectric materials but are less efficient.

Applications: Precision actuators, micro positioning systems.

5. Ferroelectric Polymers

Mechanism: These polymers exhibit spontaneous polarization that can be reversed by an electric field.

Characteristics: They have high dielectric constants and can store electrical energy.

Applications: Sensors, actuators, non volatile memory, energy harvesting.

3.) b. What do you mean by piezoelectricity? What causes piezoelectricity?

Piezoelectricity is the process of using crystals to convert mechanical energy into electrical energy or vice versa.

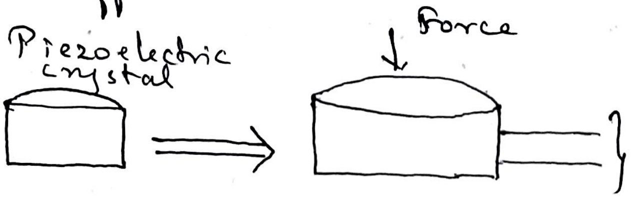
Regular crystals are defined by their organized and repeating structure of atoms that are held together by bonds called unit cell. Most crystals such as Iron, have a symmetrical unit cell. This makes them useless for piezoelectric purposes. There are other crystals that get lumped together as piezoelectric materials. The structure in these crystals is not symmetrical, but they still exist in an electrically neutral balance. However, if you apply mechanical pressure to a piezoelectric crystal, the structure deforms atoms push around and you have crystal that conducts an electrical current. If you take the same piezoelectric crystal and apply an electric current to it, the crystal will expand and contract, converting electrical energy into mechanical energy.

4.) a. What is principle of piezoelectricity and give an example

Piezoelectricity is the ability of certain materials to generate an electric charge in response to applied mechanical stress. The word piezoelectricity comes from the Greek word 'piezin', meaning to press or squeeze and 'electricity', which refers to electric charge.

Basic Principle

- Crystalline Structure: Certain materials, such as quartz, ceramics and some polymers have a crystalline structure that lacks a center of symmetry. When mechanical stress (like pressure or vibration) is applied to these materials, it distorts the crystal lattice, causing a separation of positive and negative charge centers.
- Electric Dipole Formation: This distortion creates dipoles within the material. The cumulative effect of these dipoles generates an electric potential, leading to voltage across the material.
- Reversible Effect: The piezoelectric effect is reversible. When an electric field is applied to a piezoelectrical material, it causes mechanical deformation in the material. This is known as the inverse piezoelectric effect. The figure below shows direct piezoelectric effect.



An example of piezoelectricity in action is the use of quartz crystals in watches.

It works as follows

- Quartz Crystal Oscillator: In a quartz watch, a small quartz crystal is cut in a specific shape and size to create an oscillator. When an electric field is applied to the quartz crystal (using a small battery), it deforms slightly due to the inverse piezoelectric effect.
- Vibration: This deformation causes the crystal to vibrate at a precise frequency (usually 32,768 times per second)
- Timekeeping: The watch's electronics count these vibrations and use them to keep time accurately. The consistency of the quartz crystal's vibrations makes quartz watches incredibly precise.

This is a practical and widely used application of piezoelectric effect. Another common example is piezoelectric lighters.

4) b What are the properties of piezoceramics and give an example

Piezoceramics are a type of ceramic material that exhibits piezoelectric properties, meaning they can generate an electric charge when subjected to mechanical stress and vice-versa. These materials are widely used in various applications due to their unique properties

Properties of Piezoceramics

1. Piezoelectric Effect:

Piezoceramics can convert mechanical energy into electrical energy and electrical energy into mechanical energy.

2. High Dielectric Constant

Piezoceramics have a high dielectric constant, which enhances their ability to store electrical energy. This makes them useful in capacitors and other energy storing devices.

3. High Curie Temperature

Piezoceramics have a high Curie temperature (the temperature above which they lose their piezoelectric properties), allowing them to be used in high-temperatures environments.

4. Mechanical Strength and Durability

These materials are mechanically robust and can withstand significant stress and deformation without losing their piezoelectric properties

5. Thermal Stability

Piezoceramics maintain their properties over a wide range of temperatures, making them suitable for various applications in different environmental conditions.

6. Versatility is shape and size

Piezoceramics can be manufactured in various shapes and sizes including thin films, bulk materials and complex geometries to suit specific applications.

Examples

- Lead Zirconate Titanate (PZT)

PZT is one of the most commonly used piezoceramic materials. It is a solid solution of lead zirconate ($PbZrO_3$) and lead titanate ($PbTiO_3$)

Applications

- Ultrasound Transducers
- Actuators
- Sensors

Module 3

5.) a. What does it mean to be thermally active? and causes of thermal activity.

To be thermally active means that a material or system exhibits a significant response to changes in temperature. This response can include changes in physical properties, chemical reactions or the generation of energy due to temperature variations.

Causes of Thermal Activity

1. Thermal Expansion

Description: Most materials expand when heated and contract when cooled. This change in dimensions with temperature is known as thermal expansion

Cause: The increase in temperature causes the atoms in the material to vibrate more vigorously, increasing the average distance between them.

2. Phase Transition

Description: Certain materials undergo phase transitions when heated or cooled, such as melting, boiling, or transitioning between different crystalline structures.

Cause: At specific temperatures, the thermal energy overcomes the bonds holding atoms or molecules in a particular arrangement, leading to a change in the material's state (e.g from solid to liquid) or structure.

3. Thermoelectric Effect

Description: Some materials generate an electric voltage in response to a temperature gradient known as the thermoelectric effect.

- Cause : The movement of charge carriers (electrons or holes) in the material is influenced by temperature differences, leading to a voltage across the material.

4. Chemical Reactions

- Description : Certain chemical reactions are thermally active, meaning they only occur or significantly accelerate at certain temperatures

- Cause : The kinetic energy of molecules increases with temperatures, leading to more frequent and energetic collisions which can overcome activation energy barriers and trigger chemical reactions.

5. ~~Pyroelet~~ Pyroelectric Effect

Description: Some materials generate electric charge in response

Cause : The materials asymmetry in the crystal structure of pyroelectric materials leads to a change in polarization as the temperature changes, generating an electric charge.

Examples of Thermal Activity

- Bimetallic Strips : Used in thermostats where two metals with different co-efficients of thermal expansion are bonded together when heated, the strip bends due to the different rates of expansion, which can activate a switch.

- Thermocouples : Devices that generate a voltage when exposed to a temperature gradient used in temperature sensing

- Smart Materials : Some materials change their properties (like shape memory alloys) in response to temperature changes, which can be harnessed in various applications.

5.) b What is shape memory alloys? Write the properties and applications of shape memory alloys.

Shape Memory Alloys (SMAs) are a unique class of metal alloys that can "remember" and return to a pre-defined shape when subjected to appropriate thermal or mechanical conditions. This distinctive property arises from a reversible phase transformations between two different crystal structures: martensite (low temperature phase) and austenite (high-temperature phase)

Properties of Shape Memory Alloys.

1. Shape Memory Effect:

- Description: SMAs can be deformed into a temporary shape at a low temperature and when heated above a specific transition temperature, they return to their original, pre-set shape.

- Mechanism: The phase transfomation between martensite & austenite allows the alloy to 'memorize' the orignal shape and revert to it upon heating.

2. Superelasticity (Pseudoplasticity)

- Description: SMAs exhibit superelastic behaviour when deformed at a temperature above the transition temperature. They can undergo large strains and recover their original shape immediately upon unloading without the need for heating.

- Mechanism: This is due to the stress-induced phase transformation from austenite to martensite which is fully reversible upon removal of the applied stress.

3. High Damping Capacity
   - Description: SMAs have a high ability to absorb and dissipate mechanical energy, making them useful in vibration damping applications.

4. Biocompatibility
   - Description: Some SMAs like Nitinol (an alloy on nickel and titanium) are biocompatible making them suitable for medical implants and devices.

Applications

- Medical: SMAs are extensively used in medical applications such as stents that expand at temperature or surgical tools that require precise movement and control
- Aerospace: SMAs are used in aircraft and spacecraft components for adaptive structures and morphing wings.
- Consumer Products: Items like eyeglass frames, which benefit from their ability to return to shape after being deformed.
- Robotics and Actuation: SMAs are used as actuators in robots.

6) a Explain the static shape memory effect and its behaviour

The Static Shape Memory Effect (SSME) refers to the ability of a Shape Memory Alloy to recover its original shape when heated after being deformed at a lower temperature. This effect is called 'static' because the deformation and subsequent shape recovery happen without any dynamic or ongoing force being applied the shape change occurs purely due to a thermal trigger.

Behaviour of the Static Shape Memory Effect

1. Initial Shape setting (Austenite Phase):
   The SMA is first shaped into its 'memorized' or original form while in the austenite phase (high temperature phase). This is typically done by heating the material above its transition temperature and then cooling it while holding the desired shape.

2. Cooling to Martensite Phase
   - The material is then cooled down to enter the martensite phase (low-temperature phase). In this phase the alloy becomes more malleable and can be easily deformed.

3. Deformation (Martensite Phase)
   While in the Martensite phase, the SMA can be mechanically deformed into a different shape. The deformation happens without causing permanent damage to the material's internal structure.

4. Heating to trigger Shape Recovery
When the deformed SMA is heated back above its transition temperature, it undergoes a phase transformation from martensitic to austenitic. During this transformation, the material 'remembers' and returns to its original shape, regardless of the deformation it experienced in the martensite phase.

5. Final Shape Recovery
The alloy fully recovers its original shape when it reaches the austenite phase, demonstrating the shape memory effect. The recovery is typically complete and the material returns to its exact pre-deformed shape.

6) b What is phase transformation of NiTi and transformation temperature:

Nitinol, a nickel-titanium alloy exhibits a unique property known as the shape memory effect and superelasticity due to its ability to undergo reversible phase transformations between two different crystalline structures: Martensite and Austenite

1. Austenite Phase

- High Temperature Phase: This phase is more rigid and stronger phase of NiTi. It has cubic crystal structure

- Stable above Transition Temperature: Austenite is stable at material's transformation temperature also known as austenite finish temperature, A_f

- Shape Memory: The original or "memorized" shape of the NiTi alloy is set in the austenite phase.

2. Martensite Phase
   - Low Temperature Phase : This phase of NiTi is low temperature phase, where the crystal structure is monoclinic. This phase is more ductile and easily deformed.
   - Stable below Transition Temperature : Martensite is stable below the transformation temperature below the martensite finish temperature, M_f
   - Deformable : In the martensitic phase, the material can be easily deformed. However, this deformation is reversible if the material is heated back to the austenite phase.

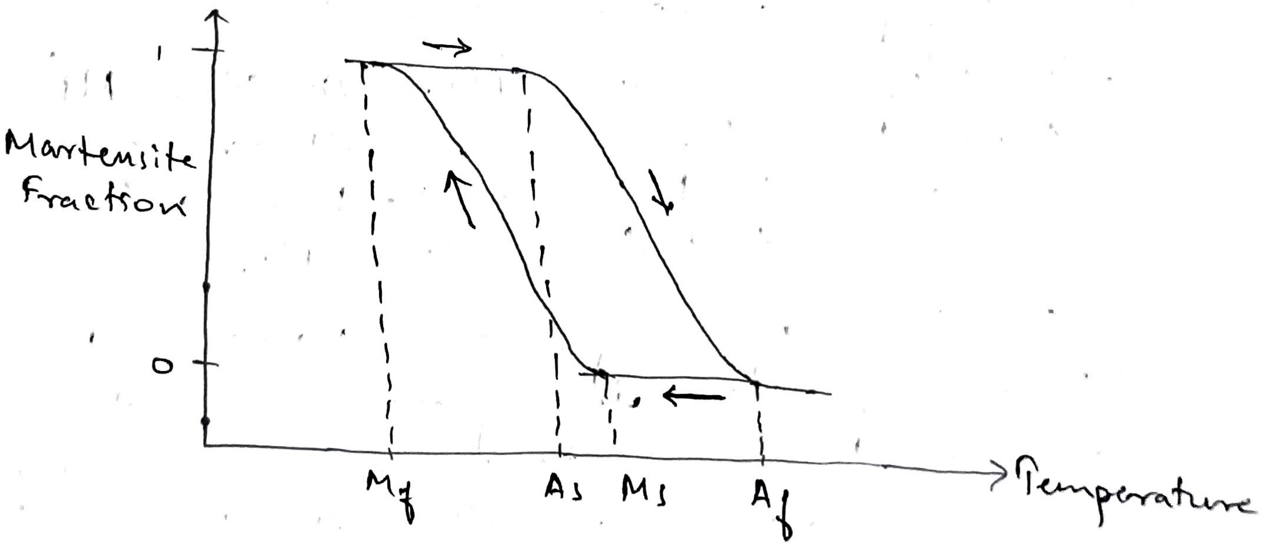
Phase Transformation Sequence

1. Cooling from Austenite to Martensite
   - Start of Transformation (Martensite Start M_s)
     As the temperature decreases, the transformation from austenite to martensite begins at the martensite start temperature M_s.
   - Completion of Transformation (Martensite Finish, M_f)
     The transformation is complete when the temperature drops to the martensite finish temperature M_f. Below this temperature, the NiTi alloy is fully in the martensite phase and can be deformed.
2. Heating from Martensite to Austenite
   - Start of Transformation (Austenite Start, A_s) : Upon heating, the transformation from martensite back to austenite begins at the austenite start temperature A_s.
   - Completion of Transformation (Austenite Finish, A_f)
     The transformation is complete when the temperature reaches the austenite finish temperature A_f.

Above this temperature, the NiTi alloy is fully in the austenite phase and regains its original, predeformed shape.

Transformation Temperatures

- Ms (Martensite Start Temperature): Range from -50° C to 20° C
- Mf (Martensite Finish Temperature): Range from -70° C to 0° C
- As (Austenite Start Temperature): Range from -30° C to 40° C
- Af (Austenite Finish Temperature): Range from -10° C to 60° C



Module 4

7) a. Define thermo responsive polymers. Write the advantages.

Thermo-responsive polymers are a class of smart materials that undergo a reversible change in their physical or chemical properties in response to temperature changes. These changes can include alterations in solubility, shape, volume, mechanical strength or other characteristics depending on the specific type of polymer and its application.

Characteristics.

1. Critical temperature
2. Reversible phase transition
3. Hydrophilicity & Hydrophobicity.

Thermo-responsive polymers offer several advantages

1. Controlled Drug Delivery
2. Reversability
3. Biocompatibility
4. Tunable propertses
5. Environmental Applications
6. Applications is Smart Materials
7. Minimally Invasive Medical Procedures
8. Cost-Effective Production

Thermo responsive polymers are versatile materials that offer significant advantages in a wide range of applications particularly in the biomedical, environmental and materials fields. Their ability to respond to temperature changes in a controlled and reversible manner makes them highly valuable for developing smart, adaptive systems and devices.

7.) b. Brefly explain electroactive polymer and uses of electroactive polymer

Electroactive Polymers (EAPs) are a class of polymers that exhibit a change in size, shape, or mechanical properties in response to an applied electric field This unique property makes them useful in various applications, including actuators, sensors and artificial muscles.

When an electric field is applied (EAPs) can undergo significant deformation, such as bending stetching or contracting. This mechanical response ~~is~~ is typically reversible and can be precisely controlled by adjusting the electric field.

Types of Electroactive Polymers

- Ionic EAPs: These polymers rely on the movement of ions within the material to produce deformation. Examples include ionic polymer metal composites (IPMCs) and conductive polymers They usually operate at low voltages but require an electrolyte.

- Electronic EAPs: These polymers deform in response to the movement of electrons rather than ions. Dielectric elastomers and electrostrictive polymers are examples. They can generate larger forces and strains but often require higher operating voltages.

Uses of EAPs:

1. Artificial Muscles
   - Robotics
   - Prosthetics
2. Sensors and Actuators
   - Pressure sensors
   - Actuators

3. Tactile Feedback Devices
    - Haptic Interfaces
    - Wearable Devices
4. Medical Devices
    - Implants
    - Rehabilitation
5. Adaptive Structures
    - Adaptive Optics
    - Shape Morphing Materials
6. Energy Harvesting
7. Smart Textiles
8. Biodegradable Electronics
9. Micro & Nano Scale devices
10. Entertainment and Consumer Electronics.

8.) a Explain protein based smart polymers with examples

Protein-based smart polymers are a type of smart material derived from proteins that exhibit responsive behaviour to external stimuli. These polymers combine the unique properties of proteins with versatility of synthetic polymer systems, leading to materials with specialized functionalities

Characteristics of Protein based Smart Polymers

1. Stimuli - Responsiveness
    - Thermal Response - Protein based polymers can undergo conformational changes or sol gel transitions in response to temperature changes.
    - pH Sensitivity - The charge state of proteins can change with pH, affecting solubility and interaction with other molecules. This makes protein based polymers useful in applications where pH-induced changes are beneficial.

- Ionic strength - Changes in ionic strength can alter protein - protein interactions and polymer behaviour useful in various biological and chemical processes.

2. Biocompatibility & Biodegradability
   - Biocompatibility : Many protein - based polymers are inherently biocompatible, making them suitable for medical and biomedical applications including drug delivery, tissue engineering and implants.
   - Biodegradability : These polymers are often biodegradable, reducing environmental impact and eliminating the need for long term disposal.

3. Self Assembly and Conformational Changes
   - Self Assembly : Proteins can self - assemble into specific structures or nanostructures, which can be harnessed in creating material with desired properties
   - Conformational Changes : Proteins can undergo reversible changes in their structure in response to external stimuli, leading to changes in material properties.

Examples of Protein Based Smart Polymers.

1. Silk Fibroin :

   Source : Derived from silk produced by silkworm

   Properties : Silk fibroin can be processed into films, hydrogels and scaffolds that exhibit biocompatibility and mechanical strength.

   Application : Used in wound dressings, tissue engineering scaffolds, and drug delivery systems.

8) b. Describe the pH-responsive and photo responsive polymers.

pH-responsive polymers and photo responsive polymers are types of smart materials that exhibit changes in their properties in response to pH and light stimuli respectively. These polymers have a range of applications in fields like drug delivery, environmental monitoring and advanced materials

pH-responsive polymers

pH responsive polymers change their physical or chemical properties in response to changes in the pH of their environment. This responsiveness is primarily due to the presence of acidic or basic functional groups in the polymer structure, which can ionize or deionize depending on the pH.

Characteristics

1. Ionization & Deionization
   - Acidic Groups: Polymers with acidic functional groups (e.g. carboxyl groups) become more soluble in basic environments where these groups deionize.
   - Basic Groups: Polymers with basic functional groups (e.g. amino groups) become more Soluble in acidic environment where these groups ionize.
2. Solubility Changes.
   - The solubility of pH-responsive polymers can change significantly with pH. For example, a polymer that is soluble at low pH may become insoluble at high pH or vice versa

3. Hydration and Swelling
   - These polymers can swell or shrink in response to pH changes, leading to changes in their volume and mechanical properties.

Examples : 1) Poly Acrylic Acid (PAA)
2) Poly N-isopropylacrylamide (PNIPAM)
3) Polymers with Chitosan.

Applications
1.) Drug Delivery System.
2) Hydrogels
3) Environmental Monitoring

Photo-Responsive Polymers.

Photo-responsive polymers change their properties in response to light, typically UV or visible light. The light induced changes are due to the photo sensitive groups incorporated into the polymer which undergo chemical or physical transformations when exposed to light.

Characteristics

1. Photochemical Reactions
   - Photoisomerization: Some photo-responsive polymers contain chromophores that undergo reversible changes in the structure upon light exposure leading to changes in the polymer's properties.
   - Photo cleavage: Light can induce cleavage of specific bonds within the polymer, resulting in a change in the polymer's molecular weight or structure.

2. Light-Induced Swelling and Deformation
   - Exposure to light can cause polymers to swell, contract or change shape due to the photo induced structural changes in the polymer network.

3. Reversibility
   - Many photo responsive polymers exhibit reversible responses to light, allowing them to return to their original state upon removal of the light stimulus

Examples :
1.) Azobenzene-Based Polymers
2.) Spiropyran - Based Polymers
3.) Photo cleavable Polymers.

Applications
1.) Controlled Drug Release.
2) Optical Devices
3) Self Healing Materials:

Module 5

9) a. Define the chemical activation. What activates the chemical reaction.

Chemical activation is a process used to enhance the surface area and porosity of materials particularly in the production of activated carbon and other adsorbents. This process involves treating the raw materials (carbon rich materials like wood, Coal or biomass) with chemical agents that promote the formation of a highly porous structure.

Key aspects of Chemical Activation

1. Chemical Agent

The process typically involves the use of chemicals such as phosphoric acid (H_3PO_4), potassium hydroxide (KOH) or zinc chloride ($ZnCl_2$). These chemicals act as dehydrating agents, preventing the formation of tar and promoting the development of pores within the material.

2. Process steps

- Impregnation : The raw material is impregnated with the chemical agent, which penetrates the materials structure
- Heating : The impregnated material is then heated at elevated temperatures (usually 400°c to 900°c) in an inert atmosphere such as nitrogen to initiate the chemical reactions that create pores.
- Washing : After activation, the material is washed to remove residual chemicals, resulting in a highly porous activated material

3. Resulting Material

- The final product is a material with a surface area and well developed porous structure, which enhances its adsorptive properties.

Applications

1) Activated Carbon Production
2) Catalysis
3) Energy storage.

9.) b. Define chemical gel, write the difference between physical gel and chemical gel.

A chemical gel is a semi-solid material formed by the crosslinking of polymer chains through chemical bonds. This crosslinking creates a three dimensional network structure that can trap and hold large amounts of solvent giving the gel its characteristics properties of both solids and liquids.

Physical Gel	Chemical Gel
1.) The network is formed through non covalent interactions like hydrogen bonding, ionic interactions van der Waals forces. These bonds are weaker and reversible	1) The network structure is formed through covalent bonds between polymer chains. These bonds are strong and permanent
2) Less stable as compared to chemical gels	2) More stable than physical gel
3) The non covalent interactions in physical gels can be reversible	3) The covalent crosslinks in chemical gels are Irreversible under normal conditions
4) Physical gels are usually softer & more flexible with lower mechanical strength	4) chemical gels have higher mechanical strength and resistant to deformation
5) Physical gels are more sensitive to temperature changes. Heating can disrupt the non-covalent interactions causing the gel to melt	5) Chemical gels are more thermally stable due to the robustness of covalent bonds

10) a. Explain ~~optical~~ optical polymers and properties of optical polymers.

Optical polymers are specialized types of polymers (plastics) that are designed to transmit, refract or reflect light, making them useful in various optical applications. These polymers have unique properties that allow them to be used in lenses optical fibers, displays and other devices where light manipulation is crucial.

Properties of Optical Polymers

1. Transparency

Optical polymers are typically highly transparent to visible light, allowing light to pass through with minimal absorption. This property is essential for applications like lenses and optical fibers.

2. Refractive Index

The refractive index of an optical polymer determines how much light is bent or refracted as it passes through the material. Optical polymers can be engineered to have specific refractive indices to suit particular applications.

3. Low Dispersion

Dispersion refers to the spreading of light into its component colors as it passes through a material. Optical polymers with low dispersion minimize this effect, which is important for applications requiring clear and undistorted light transmission

4. Mechanical Properties

optical polymers are often lightweight and impact resistant, making them durable alternatives to glass in glass in many applications. Their flexibility and ease of processing also allow them to be molded into complex shapes.

5. UV and Weather Resistance

Many optical polymers are resistant to ultraviolet (UV) light and weathering, ensuring long term stability and performance in outdoor or high exposure environments.

6. Thermal Stability

Some optical polymers are designed to withstand high temperatures without significant degradation of their optical properties, which is crucial for applications in demanding environments.

10.) b. Briefly explain smart materials for aerospace applications write which material is suitable for space.

Smart materials are advanced materials that can respond to external stimuli such as temperature, pressure, electric or magnetic fields and mechanical stress in a controlled and reversible manner. In aerospace applications, these smart materials are crucial for enhancing the performance, safety and efficiency of aircraft and spacecraft.

Smart Materials in Aerospace applications

1. Piezoelectric Materials

Function: Convert mechanical stress into electrical energy and vice-versa

Application: Used in sensors and actuators for vibration control, structural health monitoring and energy harvesting in aircraft and spacecraft

2. Shape Memory Alloys

Function: Return to their original shape after deformation when exposed to certain temperature.

Application: Used in deployable structures, actuators for controlling wing flaps and morphing wings that change shape in response to aerodynamic conditions.

3. Electroactive Polymers (EAPs)

Function: change shape or size when exposed to an electric field.

Application: Employed in lightweight, flexible actuators and sensors, potentially used in adaptive wings or other control surfaces.

4. Magnetostrictive Materials

Function: Change shape or size in response to a magnetic field

Application: Used in actuators for precision control and damping systems in spacecraft and aircraft

5. Thermoresponsive Polymers

Function: Change their physical properties such as shape or solubility in response to temperature changes.

Applications: Used in temperature-sensitive coatings self healing materials and adaptive thermal insulation systems in spacecraft.

6. Self Healing Materials

Function: Automatically repair damage such as cracks or punctures

Application: Used in aircraft and spacecraft skins reducing the need for maintenance and enhancing safety

Suitable Material for Space Application

Shape Memory Alloys (SMAs) are particularly suitable for space applications due to their unique ability to undergo shape changes in response to temperature. In the harsh environment of space, where temperature fluctuations can be extreme, SMAs can be used to deploy and control structures like antennas, solar panels and other extendable components on spacecraft.

Advantages of SMA in space applications are

- Reliability
- Compactness
- Energy efficiency.

Dean, Academics
KLS VDIT, HALIYAL

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HOD
Mechanical Engineering
KLS Vishwanathrao Deshpande
Institute of Technology
Haliyal-581329