Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 04

Types of Thermotropic materials

Dear students, in our last class we saw about thermotropic materials and slightly dwelt into smart glass with its intervention into thermotropic material usage. Today we will continue with the types of thermotropic materials. So, the second type of thermotropic material that has an application in smart glass is what we will see today. So, the working mechanism of smart glasses is that smart glass, also known as switchable glass or dynamic glass, is a type of glass that can change its light transmission properties in response to external stimuli, especially electrical voltage, heat, or light. The most common types of smart glass include electrochromic, photochromic, thermochromic, and liquid crystal-based systems. In this picture, you can see the amount of transparency or translucency that thermotropic material can bring in when used in smart glass.

So, when it comes to smart glass types, we have the electrochromic glass. What is the working mechanism? When applied voltage induces a reversible electrochemical reaction, causing the glass to change colour and thus control light transmission. When it comes to its energy efficiency, electrochromic glass can dynamically adjust to external conditions, optimizing natural light entry and reducing the need for artificial lighting and air conditioning. Whereas the liquid crystal-based smart glass Its working principle is that the liquid crystals align in response to an applied electric field controlling light passage through the glass.

In terms of energy efficiency, liquid crystal-based smart glass allows dynamic control of light and privacy by contributing to energy savings by minimizing the use of artificial lighting and shading devices. So, what it does is basically The layers, the inside they start to organize themselves in the presence of light. What are its energy-efficient features? First is daylight harvesting. So, smart glass optimizes natural light utilization, reducing the need for artificial lighting during day and saving energy. Second is solar heat gain control.

By dynamically adjusting its properties, smart glass can help regulate solar heat gain and minimize the demand for air conditioning in warmer weather. Third is the privacy control. Some types of smart glass can switch between transparent and opaque states offering privacy when needed without the use of blinds or curtains. And fourth, users can manually adjust the properties of smart glass to meet their preferences, contributing to personalized, customizable, and energy-efficient building envelopes. Examples of use in construction industry.

Smart windows. So, integration of smart glass in windows allows for the control of light and heat entering the building contributing to energy savings and occupant comfort. Second are skylights and roofs. Smart glass can be used in skylights and roofing materials to regulate natural light and heat, reducing the need for artificial lighting and cooling. The third is glass partitions.

Smart glass partitions in offices or residential spaces offer adjustable transparency, providing privacy or an open environment as desired. Fourth is curtain walls. Smart glass incorporated into curtain walls allows for energy efficient lighting and thermal control in large building facades. Fifth is spaces such as conference rooms. Smart glass partitions in meeting rooms can be controlled to provide privacy during discussions and presentations.

There are many roles of a modern window. One main important role is the thermal comfort combined with the visual comfort. But in order to do that, the window has to necessarily reduce energy use in order to be sustainable. The window has to be resilient to extreme weather condition and that must also lead to an energy efficient window. In that context use of smart windows can be very useful.

Let us now look at the working principle of shape memory alloy as a thermotropic material. Shape memory alloys or SMAs are a unique class of materials that can remember and recover their original shape after being deformed. The key working principle is based on the reversible phase transformation between a low-temperature martinistic, easily deformable phase and a high-temperature austenitic phase, which is rigid and recoverable. When the SMA is deformed at a low temperature, it retains the deformed shape. Upon heating, the material undergoes a phase transformation and returns to its original pre-deformed shape.

What are the advantages of SMAs? Now, shape memory effect. SMAs exhibit a significant shape memory effect, allowing them to recover their original shape with high precision. They are super elastic. SMAs often display superelastic behavior, meaning they can undergo substantial deformations and still return to their original shape when heated. They have high damping capacities.

SMAs possess excellent damping properties, absorbing and dissipating mechanical vibrations. They have repeatable deformation. The shape memory effect in SMAs is repeatable over numerous cycles without significant degradation. In terms of adaptability, SMAs can be designed to respond to different stimuli, including temperature, stress, or magnetic fields, providing versatility in their applications. Let us now look at the limitations.

Now narrow temperature range. The shape memory effect in many SMAs occurs within a specific temperature range, limiting their application in extreme temperature conditions. There is creep deformation over time SMAs may exhibit gradual deformations under constant stress known as creep deformation. When it comes to cost, some SMAs, particularly those containing elements like nickel and titanium, can be expensive compared to traditional construction materials. Let us look at its application in the construction industry.

They can be used for seismic dampers. SMAs can be incorporated into building structures as seismic dampers to absorb and dissipate energy during seismic events, reducing structural damage. They can also function as self-healing structures. SMAs can be integrated into concrete to create self-healing structures. When the SMA wires within the concrete sense cracks, they can be heated to induce crack closure.

Experiments have shown how the use of SMAs in self-healing concrete can actually heal the concrete. Smart facades. SMA actuators can be used in adaptive building facades that change shape as a response to environmental conditions, optimizing energy efficiency. In terms of structural bracing, SMAs can act as smart braces in building structures, adjusting their stiffness and damping characteristics based on dynamic loads. Expandable bridges and SMA cables can be used in bridge construction.

When heated, they contract, causing the bridge to expand and contract to accommodate temperature changes. Hence, these can be used more like an expansion joint in bridges. Thermal insulation. SMAs with shape memory properties can be used to develop smart windows that automatically adjust their insulation properties based on temperature changes. Let us now look at the advantages of thermotropic materials.

First, thermotropic materials show improved energy efficiency. They have dynamic control. Thermotropic materials can respond to changes in temperature, allowing for dynamic control of properties such as light transmission and thermal insulation. This adaptability contributes to optimized energy efficiency in buildings. The second aspect of improved energy efficiency is reduced heating and cooling loads.

By regulating heat and light transmission, thermotropic materials can help reduce the reliance on artificial heating and cooling systems, leading to energy savings. The second aspect is sustainability and environmental benefits. The first aspect of sustainability and environmental benefits is reduced resource consumption. The ability of thermotropic materials to enhance energy efficiency contributes to overall resource conservation. By minimizing the need for excessive energy consumption, these materials promote sustainability.

The second aspect of sustainability and environmental benefits is lower carbon footprint. Utilizing thermotropic materials in building design can result in lower carbon emissions, especially when their energy-efficient properties reduce the demand for fossil fuel-based energy sources. Therefore, in terms of energy efficiency in buildings, the use of thermotropic elements can greatly contribute towards optimization of energy consumption in order to maintain indoor temperature. The third aspect is enhanced comfort and functionality. The first aspect of enhanced comfort and functionality is an optimized indoor environment.

Thermotropic materials can create a more comfortable indoor environment by dynamically adjusting to external conditions. This includes controlling glare, managing solar heat gain and maximizing natural light. The second aspect is personalized spaces. The adaptability of thermotropic materials allows for the creation of personalized spaces. Users can tailor the environment to their preferences, enhancing comfort and functionality.

The fourth aspect is occupant well-being. Visual comfort. The controlled modulation of light transmission by thermotropic materials contributes to visual comfort for building occupants. It reduces glare and creates a well-lit pleasant environment. When it comes to temperature regulation, thermotropic materials can assist in maintaining a comfortable indoor temperature by adjusting their properties, enhancing occupant well-being.

Next is smart building integration. Integration with building automation system. Thermotropic materials can be seamlessly integrated into smart building systems. This integration allows for automated control based on environmental conditions, occupancy or user preferences. The second aspect is energy management.

The use of thermotropic materials in conjunction with smart building technologies contributes to effective energy management, reducing waste and optimizing overall building performance. The sixth dimension is the innovative design possibilities. Under this, let us look at the aesthetic appeal. The dynamic and responsive nature of thermotropic materials can be leveraged for innovative and aesthetically pleasing designs.

Buildings and structures incorporating these materials can stand out for their uniqueness and adaptability.

And second is the architectural flexibility. Thermotropic materials offer architects and designers more flexibility in achieving specific design goals. This includes creating responsive facades, adaptive windows, and other elements that enhance the architectural appeal. Let us quickly look at the shape-changing facade as a prototype. Now the New York-based architects focus their design efforts on how they can utilize the most cutting-edge material technologies in design applications, offering innovative solutions.

The line maze like facade consists of material that flexes and bends as an artificial muscle fighting solar heat gain by changing shape on its own. No computer program or physical adjustments are required. The system regulates a building's climate by automatically responding to environmental conditions and has an advantage over other systems because of its low power consumption and localized control. So, these are the various dimensions various aspects, advantages, limitations, uses of thermotropic materials. Thermotropic materials are important evolving materials.

Its complete application in the building industry is yet to be explored because it is a smart material and an evolving material. So, probably your generation of architects and designers will have a greater role in the use of these smart materials in buildings in order to make them more energy efficient. With this thought, we will stop the class here today and we will discuss yet another smart material in the next class. Thank you.