

Course Name: Building Materials as a Cornerstone to Sustainability

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Lecture 03

Thermotropic

materials

Hello everybody. So, last class we saw the various ways of controlling solar radiation in buildings, and as part of that we saw what are thermotropic, thermochromic materials, and thermotropic materials. We had just touched a little bit on thermotropic materials, and we had not gone into the details or depths of them. Today's class is a continuation of the previous class, and we will focus on thermotropic materials. I expect this to be a shorter class considering our previous class was a little longer. So, today we will see what are thermotropic materials.

So, thermotropic materials are also known as liquid crystal materials. These are a class of substances that exhibit changes in their physical properties in response to variations in temperature. These materials often undergo phase transitions between different ordered states as the temperature changes. The term thermotropic is derived from the Greek words- thermo meaning heat and tropos meaning turn.

The incorporation of thermotropic materials in the construction industry contributes to energy efficiency, sustainability, and improved occupant comfort. As the construction sector continues to prioritize environmentally friendly and smart building solutions, thermotropic materials offer versatile options for achieving these goals. Here you can see the structure of various forms. This is a crystalline solid which is arranged very clear manner. The liquid crystal becomes a little more organic, and the isotropic liquid is completely random.

So, what is thermotropism? It is a change of transparency with respect to temperature change, and the parameters of light scattering in thermotropic systems vary with the temperature. The materials are suitable for use in solar control if the enhanced scattering is correlated with a significant degree of backscattering that is dependent on temperature growth. So, in thermotropism we have primarily hydrogels which are used in windows which have to react based on thermotropic characters. So, thermoresponsive materials that modulate optical transmittance via a tunable light scattering behavior are denoted as

thermotropic materials. Thermotropic materials present an intriguing option for the adaptive control of solar heat and visible light entering buildings when utilized in windows.

Put another way, the diurnal and seasonal fluctuations in meteorological conditions such as ambient air temperature and sun irradiation level affect the visible light transmittance and solar transmittance of thermotropic windows. Without significantly compromising solar radiation for room heating and day lighting in the winter, this feature can aid in lowering the energy consumption for space cooling in the summer. Additionally, thermotropic windows can lessen the dangers of overheating and direct light glare more successfully than chromogenic smart windows since they function on the basis of reflecting and scattering effects. However, because thermotropic windows' untunable scattering behavior is dependent on the surrounding environment and cannot be actively controlled, they are not appropriate for use in construction regions where it is necessary to have persistent interior views. thermotropic system exhibits a temperature-dependent change of the light scattering properties.

If the increased scattering is linked with a substantial degree of backscattering dependent on the temperature increase, the materials are suited for an application in solar control. Thermotropic effects investigated in this field can be caused by a phase separation process, by a phase transition between an isotropic and an anisotropic liquid crystalline state, and by strongly differing temperature dependencies of the refractive indices of domains and matrixes. Polymer blends and polymeric hydrogels have been studied intensively. Thermotropic materials are substances that undergo reversible changes in their physical properties, such as phase transitions or changes in molecular organization, in response to variations in temperature. These materials are often used in various applications where precise control over their properties is needed based on temperature adjustments.

Let us look at the other properties of thermotropic materials. First is the optical properties. Thermotropic materials often have unique optical properties such as birefringence. This makes them suitable for applications in smart windows where they can modulate light transmission based on temperature contributing to energy efficiency and occupant comfort. Second is structural flexibility.

Some thermotropic materials exhibit structural flexibility, allowing them to change the physical state in response to external stimuli. This flexibility can be exploited in adaptive building components that respond dynamically to environmental changes. Third is responsive facades and building envelopes. Thermotropic materials can be integrated into the design of building facades and envelopes to create responsive surfaces. This

adaptability allows for the regulation of heat and light penetration contributing to energy efficient and sustainable building design.

Because based on what can be done to prevent indoor heat. And therefore, to prevent excess load on HVAC, these building envelopes can react. And therefore, responsive facades are facades that respond to any stimuli that will increase indoor heat through the building envelope. Such kinds of facades, which are also called smart facades, can drastically reduce the load on heating, ventilation, and air conditioning systems, and they can reduce the consumption of electricity drastically. Next is the aesthetic innovation.

The unique visual effects and dynamic changes in appearance associated with some thermotropic materials can be leveraged for aesthetic innovation in architecture and construction. Creating visually engaging and responsive structures that can even cause some kind of visual drama is possible. Next is thermal responsiveness. The ability of thermotropic materials to respond to changes in temperature makes them useful in applications where thermal regulation is important. For example, they can be integrated into building materials to enhance the insulation and energy efficiency.

They can even be used for smart insulation. Incorporating thermotropic materials into insulation systems can result in smart insulating materials that adjust their thermal properties based on temperature, enhancing the overall energy efficiency of buildings. Let us have a brief look at the types of thermotropic materials. First are liquid crystalline polymers, or LCPs. Liquid crystalline polymers, or LCPs, are a type of polymer that exhibits both the characteristics of liquid crystals and polymers.

They have unique molecular structures that allow them to form liquid crystal faces even in the solid state. What are their properties and advantages? So, liquid crystal polymers can be main chain, side chain, partially cross-linked, or network. Since we are not getting into the physical structure of any of the material, we are not discussing this, but just for perspective, there are different kinds of liquid crystalline polymers. Their advantages are they offer high strength and stiffness. They are thermally very stable.

They have strong chemical resistance. They melt processability. They are high performing and are lightweight in construction. When we look at applications in the construction industries, LCPs find applications in the construction industry due to their unique combination of properties. Some specific uses include high-performance composites.

LCPs can be used as reinforcing fibers or additives in composite materials, contributing to enhanced mechanical properties of construction materials. Second is the structural

components. The high strength and stiffness of LCPs make them suitable for structural components in constructions such as beams and panels. Insulation materials. LCPs can be incorporated into insulation materials to improve thermal resistance and provide better energy efficiency in buildings.

When it comes to reinforcement in concrete, LCP fibers can be added to concrete to enhance its tensile strength and toughness, reducing the risk of cracking and improving overall durability. What are the challenges? in using LCPs. There are challenges associated with the use of LCPs in construction. First is the cost. LCPs can be more expensive than traditional construction materials, limiting their widespread adoption.

Second is processing difficulty. Some LCPs may be challenging to process, which can impact the ease of manufacturing and construction. Third is its limited availability. The variety of commercially available LCPs may be limited compared to other polymers affecting material options. Fourth are recycling challenges.

The recycling of LCPs can be challenging due to their complex molecular structure. If we look at smart glass, then smart glass, which is 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, typically electrical voltage, heat, or light. And the most common types of smart glass include thermotropic glass, many times electrochromic, photochromic, thermochromic and liquid crystal based systems. Now these smart glasses help or aid energy efficiency. But when they come with these challenges, it becomes important for us as architects to reduce these challenges wherever possible.

If this glass is used in large quantities then over a period of time its challenges such as cost or construction will get resolved. Of course, we also have to think of circularity and recycling along with the use of this glass or this material. So, I will close this class with this thought. In the next class, we will continue with this thermotropic material and we will look at the types of thermotropic materials. Thank you.