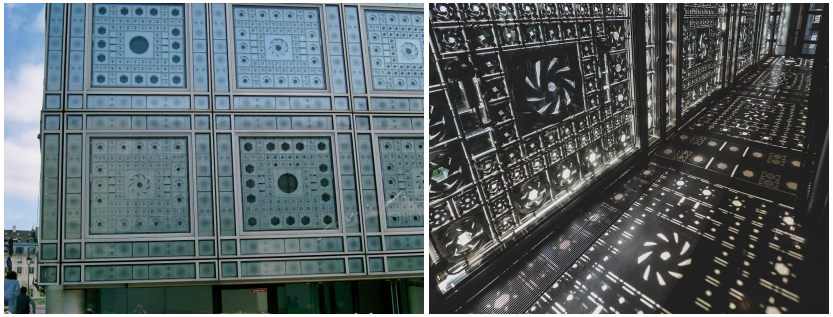


Smart Building Technologies

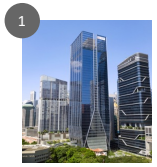
Hello everyone, welcome to class. Today, we're covering Smart Building Technologies. So 'What makes a building smart?' Well, it's about using advanced materials and technologies to make buildings safer, more comfortable, and more energy-efficient.

Remember the Institut du Monde Arabe in Paris? That building is a great example of smart technology in action. We covered much about the facade and how it adjusts to the sunlight. They open and close like camera shutters, controlling how much light and heat enter the building.

Today we will look at how buildings are becoming smarter

Use Cases and Best Practices Implementation

1



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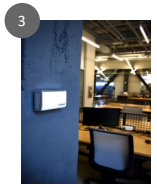


4

1. Digital Twin for Future Workplaces: Microsoft in collaboration with Bentley Systems and Schneider Electric rolled out a digital twin of its new regional headquarters at Frasers Tower in Singapore in March 2020. The sensor network collected data from 179 Bluetooth beacons in meeting rooms and 900 sensors for lighting, air quality and temperature by Schneider Electric. The platform generates nearly 2,100 data points that are connected to the cloud on Microsoft Azure, enabling the holistic management of the environment.

2. Post-COVID-19 Applications: A UAE-based start-up company, Meta Touch has developed a touch-less gesture recognition technology known as touch-less Keypad. In June 2020, Abu Dhabi International Airport deployed this solution in 53 elevators. Other measures to contain COVID-19 include thermal imaging, facial recognition and motion sensors to track movement of people.

3. IAQ-based Ventilation: Air quality monitoring company, Airthinx and facilities management company Gilbane partnered to provide air quality solution to one of its clients. Airthinx sensors installed in office buildings monitor CO2, VOCs, CH2O, and particulate matter that affects employee productivity. Gilbane recommended an increase in airflow in areas where the particulate matter spikes were found.

4. IAQ-based Ventilation: An international architect-engineering firm with office space of 50,000 square foot headquartered in the New York city is pursuing WELL platinum standard certification prioritizing health and well-being of employees. IAQ-based ventilation control provider, Aircuity collaborated with the occupants, project engineers, and sustainability consultants to pioneer a ventilation strategy that provided 9 WELL points and attained platinum certification. The solution included a multi-parameter demand control ventilation sequence that is integrated with the building management system to control ventilation not only based on CO_2, but also VOCs and particulate matter.

2 Source: CABA Intelligent Buildings and COVID-19 Report 2021

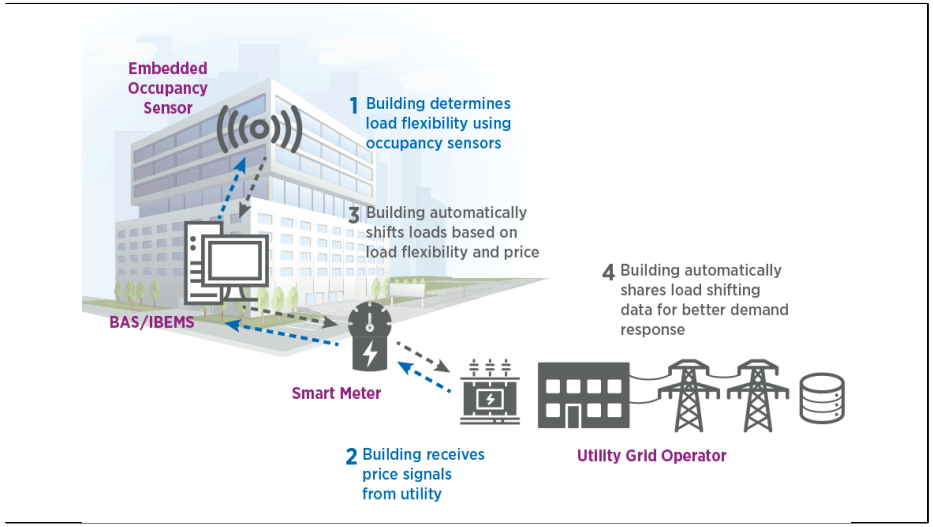
Now let look a few real-world examples to see how all this smart building tech in action. We've got four case studies here that show us different angles of what smart buildings can do.

1.First up is Microsoft, who teamed up with Bentley Systems and Schneider Electric to create a digital twin of their regional HQ in Singapore. What's a digital twin, you ask? It's like a virtual replica of the building that helps manage it better. They used sensors all over the place, even Bluetooth beacons in meeting rooms. All these sensors feed data to the cloud, making it easier to manage lighting, air quality, and temperature. So, imagine you're sitting in a room, and the building 'knows' how to make you comfortable.

2.Now, let's talk about how smart tech is helping with health and safety, p**ost-COVID-19** . A company in the UAE called Meta Touch came up with a touch-less keypad. Abu Dhabi Airport put this in 53 elevators. This tech is useful for keeping things clean and limiting the spread of germs. Plus, they've got thermal imaging and facial recognition to track people's movements.

3.We will talk more aobut indoor air quality in future lecture. Smart buildings can have a very positive impact on air quality. Airthinx and Gilbane teamed up to monitor stuff like CO2 levels and even tiny particles in the air that can affect how well you work. If the sensors notice something's off, they can adjust the airflow.

4. Last but not least, we have an architect-engineering firm in New York City aiming for top-level health and wellness standards. They worked with Aircuity to create a ventilation strategy that not only keeps the air fresh but also helped them earn a platinum certification for building health

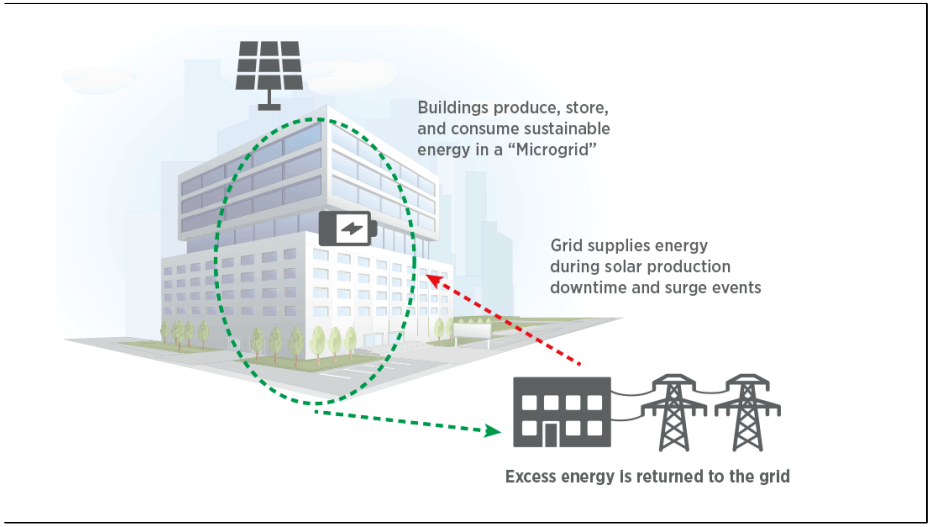


Now , let's take a look at this diagram here. It's showing us how a smart building can be super connected, not just inside but also with the world outside.
First, the building is embedded with occupancy sensors! They're like the building's eyes and ears, picking up on how many people are in a room, or how often a space is used. All that info goes into what's called a Building Automated System. Think of it like the building's brain—it takes all that data and makes decisions, like turning off lights in empty rooms or bumping up the air conditioning when it gets crowded.

But wait, there's more! See that connection to the smart meter? That's the building talking to the power company. The utility can send over info like energy prices, and the building can adjust its energy use to save money. It's like your building is a smart shopper, always looking for the best deals!

Now, here's were it gets really interesting. The building can also send info back to the utility company. Why? Well, the more the utility knows about how and when energy is being used, the better they can manage the whole power grid. So, in a way, your smart building is not just looking out for you; it's also helping the whole community be more energy-efficient.
So, you see, it's a full circle of smartness! Energy gets used wisely, money gets saved,

and the footprint is reduced.



Alright, now take a look at the same building, but instead we look at it from a energy efficeny point of view. Here we have solar panels and batteries. Let's break it down.

Adding solar panels means the building isn't just a consumer of energy; it's also a producer. On sunny days, the building can generate its own electricity. And what about when the sun's not shining? That's where the batteries come in. They store any extra energy produced so it can be used later.

Now, remember the smart meter and the grid? With these additions, the building isn't just adjusting its energy use; it can also feed energy back into the grid.

Okay, so we've been talking a lot about smart buildings, but what happens when you take that idea and apply it to a whole city? Well, you get a smart city! Take a look at this diagram.

See, it's not just about one building being smart. Imagine traffic lights that change according to traffic flow, or trash cans that tell the garbage trucks when they're full. It's all these little things talking to each other, creating a sort of smart network across the city.

Now, think back to our building with its smart meter and solar panels. What if that building was part of a whole city of smart buildings? And what if all those buildings could talk to the traffic lights, the trash cans, and even the buses and trains? You get a smart ecosystem where everything's connected.

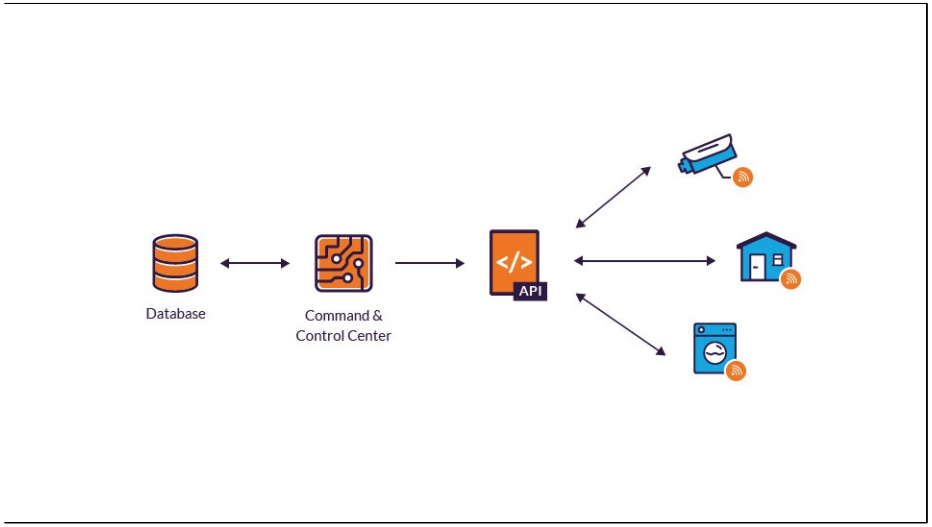
So, instead of just one building saving energy and being efficient, you have an entire city working together to be more sustainable and efficient.

Alright, now let's switch gears a little and talk about something you've probably heard of but might not fully understand: the Internet of Things, or IoT for short. Check out this image of a house filled with gadgets and devices.

Now, what is the Internet of Things? It's basically all the everyday stuff around us—like fridges, lights, or even your car—connected to the internet. Why would a fridge need to be online, you ask? Imagine your fridge telling you when you're out of milk or even ordering it for you. That's IoT in action!

But it's not just in our homes. Remember our smart buildings and smart cities? Well, they're packed with IoT devices, too. Sensors in the building, smart meters, traffic lights—all these are part of the Internet of Things. They're like the unsung heroes making everything smart and connected.

So, you see, IoT isn't some far-off future. It's here, right now. When you use a fitness tracker, or when your phone tells you the quickest route to avoid traffic, that's the Internet of Things making your life a bit easier.



Okay, so we've talked about all these smart gadgets and sensors, but how do they all work together? Let's take a look at this diagram to find out.

First up, see that database symbol? That's like the building's memory. It's where all your preferences and settings are stored. Like how warm you like your office, or which lights should be on when you walk in.

Now, moving on to the command and control center—that's the building's brain. It's the place where all the decisions are made. It takes the info from the sensors—remember, the building's eyes and ears—and checks it against the database.

So, let's say it's a hot day, and more people are coming into the building. The sensors pick that up, and the control center says, 'Hey, we need more air conditioning here!' And just like that, the building adjusts itself to keep everyone comfortable.

What makes it even cooler is that the control center uses something called APIs to talk to all these different devices. Think of APIs as the building's language, helping it chat with the lights, the AC, and even the elevators.

So you see, that's what makes a building smart. It's not just sensing what's happening; it's about making real-time decisions to make our lives better.

So, let's bring it back home for a moment. How many of you have seen one of these? Yep, it's a Google Nest Thermostat, and it's a great example of smart tech that many of us might already have in our homes.

First, this isn't just a dial on your wall that controls the temperature. it's way smarter than that! You see, it's connected to the Google Cloud. What does that mean? Well, all your preferences, like what temperature you like when you wake up or when you're away, are stored in the cloud.

Now, here's where it gets really interesting. Google uses machine learning or AI to make this device even smarter. So let's say you usually turn up the heat around 6 PM when you get home. The Nest starts to learn this pattern. After a while, it'll start warming up the house just before you arrive. And because it's connected to the cloud, you can even control it from your phone. Imagine turning up the heat while you're still on your way home.

Going back to the Nexushaus I we used smart systems to control the humidity and temperature of the interiors. Here is a short video showing the systems.

How Innovation takes place in Architecture

- Advancements in Architecture take certain steps:
  - first demonstrative
  - then performative
  - finally normative

Alright, so we've talked about a lot of cool gadgets and smart systems, but let's zoom out a bit and look at the big picture. When it comes to advancements in architecture and tech, there's a sort of evolution that happens. It goes like this: first, we have something that's 'demonstrative,' then it becomes 'performative,' and finally, it ends up being 'normative.' W Let's break it down.

1.Demonstrative: This is like the 'show and tell' stage. We're proving that something is possible, but it's not widespread yet. It's like a science fair project, showing off what could be. This is where Univeristies come in.

2.Performative: At this stage, the tech is not just for show; it's actually doing something useful. Take the Nexushaus, for instance. Back in 2010, it was a big deal because it was more than just a concept; it was a working model of a sustainable, smart home.

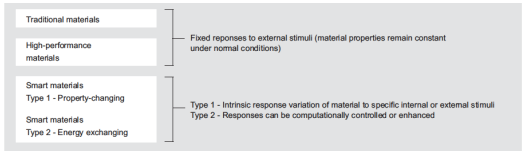
3.Normative: This is when the tech becomes so common, it's almost expected. Like smart thermostats today. They were a novelty not too long ago, but now they're becoming the norm.

So you see, once we show off what's possible, like with the Nexushaus, it opens the door for more practical, everyday tools, like the Google Nest Thermostat. And before you know it, what was once a 'wow, that's cool!' becomes a 'yeah, everyone has one.'

So now lets look at some tech out there, we can call them smart materials for our next projects.

Smart Materials

- Smart materials are transformative
  - The transformation may be within the material itself, as in one of its properties or its physical state (Type 1)
  - The material could be the vehicle to transform other things, such as energy forms or the surrounding environment. (Type 2)



So how can we think about smart matierlas. Check out this diagram that breaks them down into two main types.

1.Type 1: These are the materials that change themselves. Imagine a material that can change its shape, color, or even its strength based on conditions around it. It's like a chameleon, adapting to its surroundings!
2.Type 2: Now, these are the materials that act as transformers for other things. Let's say you have a material that can take sunlight and turn it into electricity. It's not changing itself, but it's changing the energy around it.

So what's the point of understanding these two types? Well, when you're designing a smart building or a smart city, knowing what your materials can do is key. Some materials are perfect for self-adjusting, like windows that tint themselves when it gets too sunny. Others are great for transforming the environment, like roofing materials that can capture and store rainwater for later use.

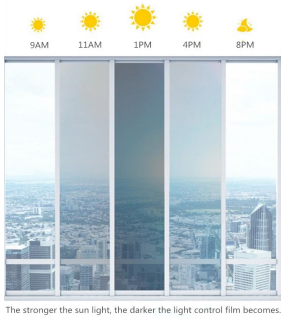
Basically, these smart materials are the unsung heroes in our journey toward making everything smarter and more efficient. Whether they're changing themselves or changing the world around them, they're what make all this smart tech possible.

Type 1 – Smart materials

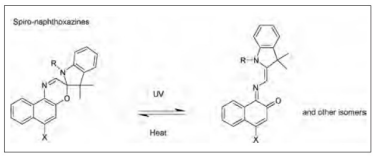
Property Changing Materials

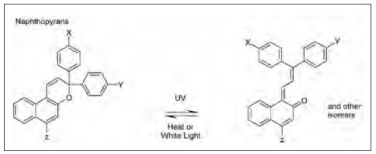
Now let's looks at Type 1 materials example, these are ones that change properties.

Photochromic ‘Smart’ Glass



The stronger the sun light, the darker the light control film becomes.





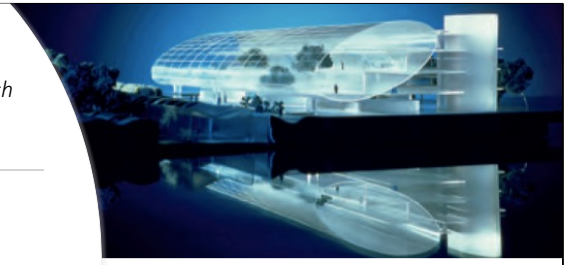
Alright, let's dive into a real-world example of a Type 1 smart material: Photochromic 'Smart' Glass. Take a look at this diagram here, showing how these windows can change color based on the time of day.
So, how does it work? Well, it's all thanks to some nifty chemistry. When the glass is exposed to light, a chemical reaction takes place that changes its color.

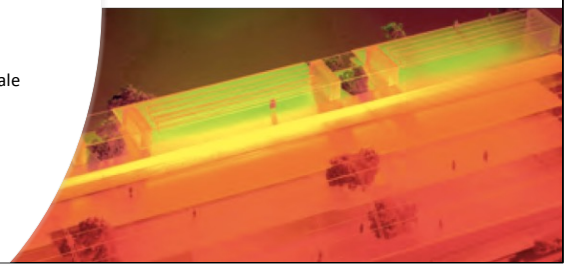
Now, check out this chemistry diagram. It shows the phase changes in the glass. Don't worry, you don't need to be a chemist to get it. All you need to know is that the glass transforms when light hits it. This isn't just for show; it's super practical. Imagine your windows automatically tinting when the sun's out, keeping your home cool without you having to lift a finger.

So, this Photochromic glass is more than just a cool trick; it's a perfect example of how smart materials can change themselves to make our lives better.

Museum of Modern Art – Munich
Design concept

- Architects: Kuhn & Kuhn
- Submitted Deisgn Plan for MOMA – Munich
- Photochromic glazing on the building envelope
- Technology is unsound for this large scale
- Plan rejected





Okay, so now that we've got our heads wrapped around what photochromic glass can do, let's talk about a time when architects aimed for the stars but couldn't quite get there.

Meet the unbuilt design concept for the Museum of Modern Art in Munich. The architects, from the firm of Kuhn & Kuhn, had big dreams for this one!

They wanted to use photochromic glazing on the entire building. Imagine a museum that changes color from morning to night, creating this amazing light show for everyone around.

But here's the catch: the plan was rejected. Why? Well, using this kind of smart material on such a large scale raised some big questions. The cost was high, and there were concerns about how long this fancy glass would actually last.

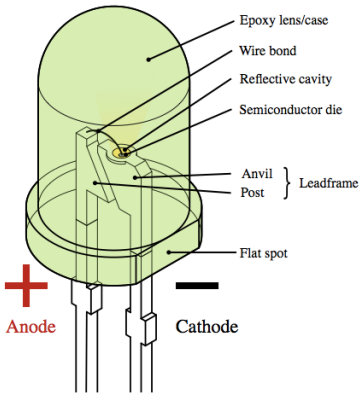
Even though the building was never made, it opened the door for more architects to think about using smart materials like photochromic glass. Sure, it hasn't been fully realized yet due to feasibility issues, but who knows? As technology advances, we might see these kinds of dream projects come to life.

So, it's a lesson and a challenge for us all. How do we take these amazing materials and technologies from the drawing board to the real world, without breaking the bank or compromising durability?

Type 2 - Smart Materials

Energy Exchanging Materials

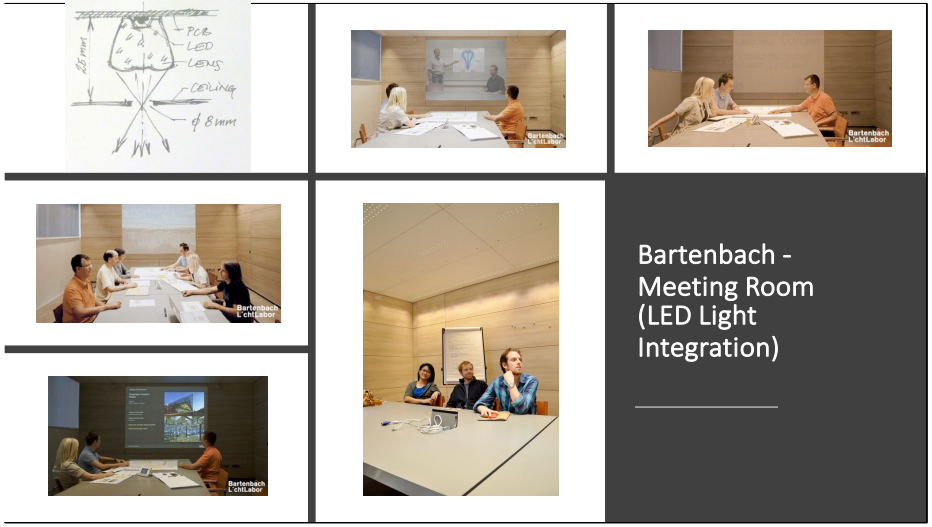
Now let's talk about a type 2 smart material, energy exchanging material.



Light-Emitting Diode (LED)

- Injection electroluminescence
- Long replacement life
- Low power consumption
- Versatile

You see this diagram here with an anode and a cathode? That's the inner working of an LED light.
Now, the magic happens through a process called 'Injection Electroluminescence.' Big words, but let's break it down. Electroluminescence is just a fancy way of saying a material emits light when an electric current passes through it. So, in an LED, the electric current flows from the anode to the cathode, and voila! We get light.
Unlike traditional bulbs, which use a filament that can burn out, LEDs are super-efficient. They have a long replacement life and consume less power, making them perfect for all sorts of uses, from your home to big buildings.



now let's talk about a place I've had the pleasure of visiting—Bartenbach's meeting room in Germany. For those of you who aren't familiar with Bartenbach, they're a company that specializes in lighting design and technology. They're pretty much the wizards of the lighting world.

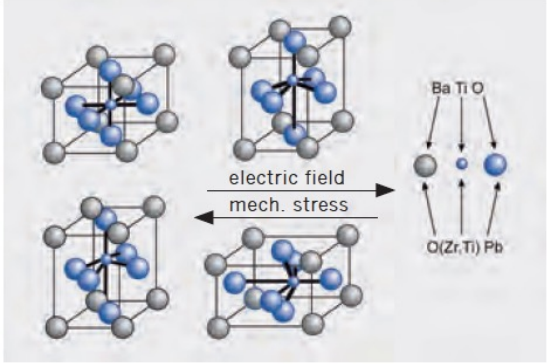
So, what's so special about this meeting room? Well, it's not just any room; it's a smart room, decked out with LED lights connected to a control system. You can see some images here that give you an idea of how it looks.

Now, here's the cool part: the control system lets you set various lighting conditions depending on what the room is being used for. Having a brainstorming session and need bright lights to keep everyone awake? No problem. Need softer lighting for a more relaxed meeting? You got it. The control system adjusts the LED lights to create the perfect ambiance.

When I was there, it was incredible to see how lighting could have such a big impact on the mood and functionality of a room. It's like the room itself was adapting to what we needed, all thanks to smart lighting technology.

Piezoelectric Materials

Are able to generate electricity when deformed by mechanical stress



Now lets talk about Piezoelectric Materials. Now, don't let that long name scare you off; it's just a fancy term for materials that can turn mechanical stress into electricity. Imagine you step on a floor tile and it generates electricity. No, it's not magic; it's piezoelectricity! These materials are super sensitive to changes in shape, like being squeezed or stretched. When that happens, they generate an electric charge.

Here's a simple way to think about it: let's say you have a sponge that's full of water. If you press down on the sponge, water comes out, right? Well, piezoelectric materials work the same way, but instead of water, they release electric charge when you apply pressure.

So, why is this so awesome? Well, think about all the places where mechanical stress happens: footsteps on a floor, cars driving over a road, even the vibrations from a building. All of that could be turned into useful energy, powering everything from lights to sensors.

In a way, piezoelectric materials give us a new lens to look at the world. They make us see not just structures but also potential sources of energy.

Piezoelectric polymers

- Piezoelectric polymers (PEP) can generate electric charges when mechanical loads or deformations are applied to it.
- By working on the Nanoscale, natural vibrations is enough pressure to generate current

Imagine blending these electric charge-generating materials into the everyday stuff we build with, like polymers. That's right, we're talking about Piezoelectric Polymers, or PEP for short.

Now, what's fantastic about PEP is that it's super sensitive. You don't need a lot of pressure to get it to work. Thanks to advances in nanotechnology, even natural vibrations can generate electric charges. Imagine a building swaying slightly in the wind and that movement generating electricity. It's like the building is breathing and creating energy at the same time!

So, why does working on the nanoscale make a difference? Well, at such a tiny scale, even small amounts of mechanical stress can generate useful amounts of electricity. That means your building isn't just standing there; it's actively helping to power itself. The possibilities are endless. We could make self-powering sensors, energy-efficient lighting, or even entire smart buildings that generate their own electricity.

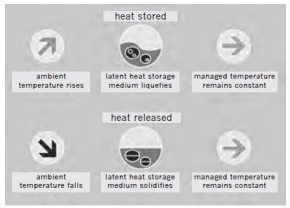
This tech is still in in the demonstrative mode, will be interesting to see how they are integrated into future buildings.

AVIVA München Lighten Control System

the AVIVA Munich building, a place where they've nailed the use of piezoelectric polymers.
Now, imagine you're in an office in this building, and you want to adjust the blinds. No problem! The building uses remote-controlled, batteryless, piezo radio sensors to do just that. And here's the kicker: these sensors are powered by the building's own vibrations, thanks to piezoelectric polymers.

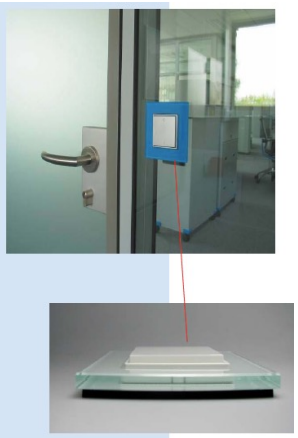
Phase Change Materials

- These materials are able to store energy in the form of heat and cold (negative heat) as latent energy.
- Mostly used as temperature-regulating media

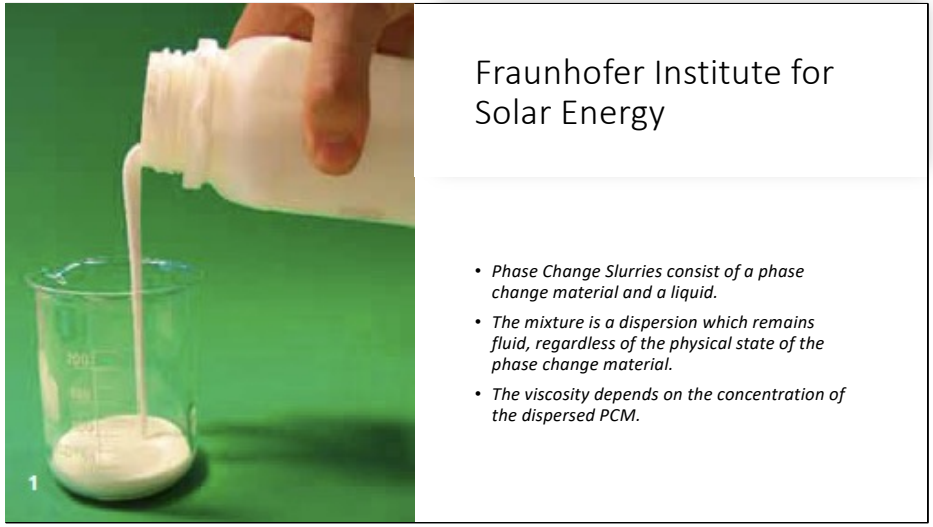


Enocean Alliance
Wireless Switches

- Very high flexibility for spatial planning
- "No Wires, No Batteries, No Limits"



Because they don't need an external power source, the sensors are tucked away in flush-mounted boxes. That means no messy cables or connections showing, which adds a clean, sleek look to the architecture.



Alright, let's dive into another category of smart materials that's making waves in the building industry—Phase Change Materials, or PCMs for short. These are special substances like paraffins or salt hydrates that can change from solid to liquid at specific temperatures. Sounds simple, right? But here's where it gets interesting.

These PCMs are not your average materials; they're engineered to switch phases at just the right temperatures, making them super useful in buildings. For instance, they can act as a heat storage body. You pump energy into them, and then you can use that stored heat later when you need it.

Now, think about insulation. PCMs can be added to walls, and just a thin layer—like 1 to 6 cm—can provide the same thermal benefits as a 20 cm thick concrete ceiling! That's a game-changer, especially for buildings where you want to keep things light but still need good insulation.
But wait, there's more! Let's talk about Phase Change Slurries. This is a mix of PCM and a liquid, staying fluid no matter the state of the PCM. Imagine the potential here; you could pump this slurry through a building to move heat around, kind of like a super-smart, energy-efficient radiator.

Senior citizens' apartments with a latent heat-storing glass facade | Domat/Ems, Switzerland (2004)

Now lets talk about a building that is using these materials in the façade. This **Senior citizens' apartments, or retirement home, has a latent heat-storing glass facade**

Used Glass that Incorporates PCM

Installed on South Façade

Triple insulation glazing unit

PCM Panel on the inside

Light-directing prism panel outside

-Blocks Summer Sun

-Allows Winter Sun to activate PCM

Polycarbonate containers filled with a salt hydrate mixture, which stores heat at +26°C to +28°C.

Swiss architect Dietrich Schwarz

The façade takes the solar energy that and stores the themeral energy in polycarbonar containers fill with salt hydrate mixture. This store heat to 26 – 28 C or about 80 F. Then that heat is reradiate out to the building at night when there is no sun. IN the summer the system is used as a shading device blocking the heat from the sun.

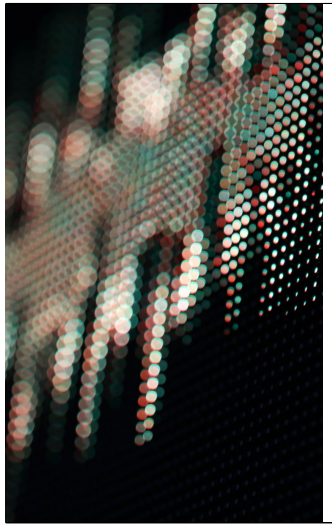
Uncharged

Charged

The materials have two different colors, showing the building occupants if the material is charged or not. When charged it store the thermal energy that can be transfer over the evening.

https://www.bloomberg.com/news/videos/2015-09-23/see-the-world-s-greenest-office-building-the-edge

I have a cool video showing an example of a smart building, it is called edge, an office park for delloite.



Advance materials, Advancing Architecture

- Smart materials are providing the ability to precisely design behaviors.
- This is the power that architecture can use to design better buildings.

So, we've talked about different types of smart materials and what they can do, right? But let's think about why this is a big deal, especially for architecture.

See, smart materials give us the power to design behaviors. That's right—behaviors, not just buildings. Imagine a building that 'knows' when to keep itself cool, or a bridge that 'senses' when it needs repair. It's like giving your building a personality! What this means for architecture is huge. We're not just talking about making a building look good; we're talking about making it act smart. So, instead of just drawing up plans for how a building should look, architects can now plan how a building should behave.

This is what sets apart the next generation of buildings and cities. They won't just be structures; they'll be smart structures that interact with people and the environment in intelligent ways. And it's all thanks to smart materials, making them the real game-changers in the world of architecture.

Discussion Questions

- Do you have confidence in Smart Homes / Offices?
- What about IT problems?
- Do you think these systems can save energy, or do they lead to more e-waste and energy usage?