Integration of Nanotechnology Materials for Green Building

(I) Impacting Design and Construction

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CONVERGENCE OF NANOTECHNOLOGY AND GREEN BUILDING

Nanotechnology Impacting Architectural Design and Building Construction

NANOTECHNOLOGY, a science that works on the molecular scale is set to transform the way we build.

Nanotechnology, the design and fabrication at the molecular scale, is opening new possibilities in green building through products like solar energy collecting paints, nanogel, high-insulating translucent panels, and heat-absorbing windows.

Even more dramatic breakthroughs are now in development such as paint-on lasers that could one day allow materials to send information to each other, windows that shift from transparent to opaque with the flip of a switch, and environmentally friendly biocides for preserving wood.

Ubiquitous sending is likely to bring a host of benefits including customized temperature settings in buildings, light-sensitive photochromic windows, and user-aware appliances.

These breakthrough materials are opening new frontiers in green building, offering unprecedented performance in energy efficiency, durability, economy and sustainability.

The nanotechnology application for green building have an emphasis on the energy conservation capabilities of architectural nanomaterials and the role of nanosensors in green building:

Nanotechnology revolution is bringing dramatic improvements in building performance, energy efficiency, environmental sensing, and sustainability, leading the way to greener buildings.

The nanotech and building sector have to yet to get to know each other a lot better in order to realize the dramatic benefits awaiting each of them.

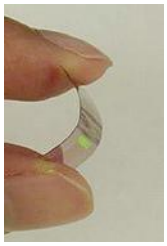
The nanotech community needs to be explored and explained the enormous economic opportunities in Green Building Design, Construction and Operation; and demonstrate to Architects, Building Owners, Contractors, Engineers and others in the $1 trillion per year global building industry that nanotech is at this moment beginning to fulfill its promise of healthful benefits for people and the environment.

The demand for Green Building is at an all time high.

According to the 2009 Green Building Market & Impact Report, the green building sector has maintained constant growth throughout 2009 despite a coarse year for the construction market.

And, many cities have adopted stringent green building requirements for new construction, and developers must find new ways to meet them.

Nanomaterials offer a whole new frontier for green builders.



It is predicted that nanotech's many environmental performance benefits will be led by current improvements in solar insulation and coatings, followed by advances in water and air infiltration, solar technology and, more distant, in lighting and structural components.

As an example, we can point to available improvements in nanocoatings for insulating, self-cleaning, UV protection, corrosion resistance and waterproofing. Some available coatings are considered "healers", in that they remove and render benign pollutants from a building's surrounding atmosphere.

While there are the obstacles to widespread adoption of nanotech in the building industry, there are news of the many nano-enhanced products currently on the market that have been demonstrated to outperform conventional products.

We can take advantage of some of the many uses of nanotechnologies,, from solar energies to structural materials to insulation, help make green buildings more cost-effective, more energy-efficient and more in tune with their environments.

Product costs continue to fall, making nanotech's promise of reduced waste and toxicity, lower energy and raw material consumption, greater safety and security, cleaner and healthier buildings and other human health and environmental benefits far more accessible.

Nanotechnology for Smart, Sustainable Green Buildings

With one in three new US construction projects registered for LEED certification, there's a bigger need for new green building technologies.

One such next-generation technology is nanotechnology, and it's utilizing new materials that defy conventional thinking.

Spray-on Solar cells, volatile organic compounds VOC-eating Nanocoatings, and windows that change color at the flip of a switch; they are here today and they promise to change the future of Green Building.

We will need to learn to identify nanotechnology products that meet our specific green building needs, compare their costs and benefits, and evaluate their environmental, health and safety impacts.

Nanotechnology, the understanding and control of matter at a scale of one to one hundred-billionths of a meter, is bringing incredible changes to the materials and processes of building.

How ready we are to embrace them could make a big difference in the future of architectural practice and construction.

Already, this new science of the small has brought to market self-cleaning windows, smog-eating concrete, and toxin-sniffing nanosensors.

But these off-the-shelf advances offer only a taste of what's incubating in the world's nanotech labs today.

There, work is underway on nanocomposites thin as glass, yet capable of supporting entire buildings, and photosynthetic coatings that can make building surface a source of free energy.

Nanotechnology works by tweaking matter from the bottom up. Recent advances in scanning electron microscopes and other technologies now make it possible to see and manipulate matter at the molecular scale more economically than ever before.

Using these tools, nanoscientists are creating revolutionary materials like coatings a single atom thick, carbon nanotubes up to 50 times stronger than steel yet 10 times lighter, and quantum dots that could enable us to change the color of almost any object instantaneously.

These remarkable effects are achievable because matter behaves differently at the nano-scale, where the laws of quantum physics take hold.

In this quantum world, objects can change color, shape, and phase much more easily that at the macro scale.

Fundamental properties like strength, surface-to-mass ratio, conductivity, and elasticity can be engineered to create dramatically different materials.

The building products currently using nanotechnology and look ahead at the Next Generation Green Building technologies:

I. We live in an age where scientific progress continues to transform human lifestyle.

This is even more true when it comes to the progress being made in the field of nanotechnology. This science stands to change and advance the practice of design in a multitude of ways – where architectural progress is being made at the molecular level.

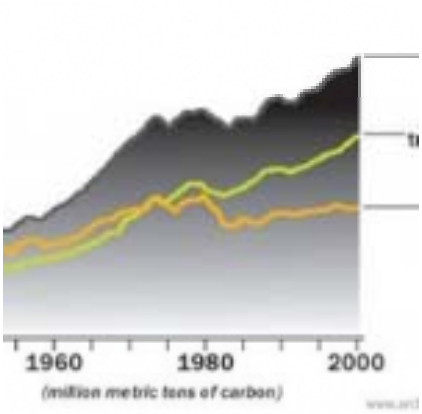
A design area that will be influenced by nanotechnology is the smart environment.

Here, tiny embedded nanosensors will make architectural features responsive. Communication will occur between object and object, between occupant and object, between object and environment and between occupant and environment.

As new materials gain more transient properties, objects and architectural features will impact the process of design by making 'fields of interaction' a major focus.

By working on 'fields of interaction' architecture professionals will have some framework by which to design for dynamic environments.

Since smart architecture will be changing states and communicating heavily, architects will likely focus on relationships as much as they focus on design forms during the design stage. It is likely that both forms and their relationships will make up rule-based systems by which smart architectural spaces can function.



The science of nanotechnology continues to progress and the design field stands to benefit.

As nanotechnology develops, new architectural techniques will surface.

Design creativity will reach new heights as innovative nanomaterials and nanosensors come together to give designers a renewed palette.

Nanotechnology is here.

Nanotechnology will have profound effects on the way we live. Already, developments are underway for newfound uses.

For the architecture profession, nanotechnology will greatly impact construction materials and their properties. Materials will behave in many different ways as we are able to more precisely control their properties at the nano-scale.

Impacting Both Design & Construction.

As materials gain such transient features, architectural design and construction will evolve. By transforming the essential properties of matter, nanotechnology will be able to change the way we build.

Nanotechnology will profoundly affect the industry of architecture at all scales; and, interior design, building design and city design will all benefit.

Architecture will have the ability to function at more optimum levels - revolutionizing the way we live.

Nano Architecture.

Nanotechnology will impact environments. Nanotechnology will give architecture superior interactive functions – allowing occupants to better 'communicate' with their surroundings.

Windows and walls with variable transparency and mood/context sensitive clothing are just a few ways this will become possible. As new materials and construction methods emerge, "Nano Architecture" will definitely unleash the designer's imagination.

Nanotech Wonder Materials

Nanotech's 'wonder materials' have the potential to revolutionize how and what we build.

One day, carbon nanotubes and other nanomaterials could so radically transform our material palette that paper-thin sheets might hold up entire building, forcing us to completely rethink the relationship between structure and skin.

Carbon nanotubes, sheets of graphite just one atom thick, formed into a cylinder, are not only 50 times stronger than steel and 10 times lighter, they are transparent and electrically conductive to boot.

Nanotubes are already the building blocks for hundreds of applications, used to reinforce concrete and deliver medication to individual cells.

Nanocomposites, which combine new nanomaterials with more traditional ones such as steel, concrete, glass and plastics, can be many times stronger than standard materials.

Already on the market is a nanocomposite steel that is three times stronger than conventional steel.

In the near term, **nanocomposite reinforcement of steel, concrete, glass, and plastics** will dramatically improve the performance, durability, and strength-to-weight ratio of these materials.

Before long, nano-reinforced glass might be used for both structure and enclosure.

As threats from terrorism and even from natural forces like hurricanes rise, we will utilize the strength of nanotubes to make our buildings more secure.

Research that is now underway to make Army vehicle windshields bomb-proof, using polycarbonate-reinforced nanofibers, may soon be applicable to building glass.

Nanocoatings nanomaterials stand to revolutionize insulating methods because they are structured at the molecular level to trap air between particles. They are far more efficient than traditional insulators like fiberglass and polystyrene which work at the macro level, without the environmental harm associated with those materials. And because it traps air at the molecular level, an insulating nanocoating even a few thousandths of an inch thick can have a dramatic effect.

Nanogel insulation, made by the Cabot Corp, is a form of aerogel, the lightest-weight solid known as 'frozen smoke', nanogel is 5% solid and 95% air. The high air content means that a translucent panel 3.5 inches thick can offer a high insulating value.

Another company, Nanoseal, makes **insulating paint** for buildings. Its insulating coating, applied in a layer only seven-thousandths of an inch thick, is being used on beer tanks in Mexico by Corona, resulting in a temperature differential of 36 degrees Fehrenheit.

Nanocoatings are used to insulate both new and existing materials, and to protect wood, metal, and masonry, without the hazardous off-gassing of many other coatings.

Nanoengineered ultraviolet curable protective coatings by Ecology Coatings won 2006's Silver Award for Innovation in The Wall Street Journal's Technology Innovation Awards competition. Garbage, paper, and other renewable can be formed into products, but they have a tendency to dissolve in water. A very light coating of the nanocoating product can be used to waterproof these, and they can be used as a substitute for plastic.

Good for the environment, this nano technology may be good for our health, too.

The Hong Kong subway system has coated its cars' interiors with **titanium and silver dioxide coatings that kill most of the airborne bacteria and viruses** they come into contact with.

And in cleansers and interior paints used around the world, Behr Premium Plus Kitchen & Bath Paint is one example, **nanoparticles fight mildew**.

Nanocoatings can break down dirt as well.

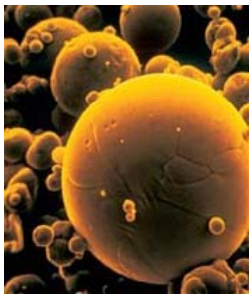
PPG Industries and Pilkington Glass both offer **self-cleaning window glass** that harnesses nanotechnology.

The Jubilee Church in Rome features **self-cleaning concrete**: Photocatalytic titanium dioxide nanoparticles in the precast panels, manufactured by Italcementi, make them shed dirt. The panels trap airborne pollutants in a nanoparticle matrix on their surface, then decompose them.

Similar **depolluting nanocoatings can be applied to almost any surface, making it a smog-eating machine**. In the near future, road surfaces, bridges, and tunnels may be able to counter act pollution.

The Swedish construction co Skanska has been involved in a Swedish-Finnish project to develop **catalytic cement and concrete products coated with depolluting titanium dioxide**.

Smart Environments



In the future, the environment will interact with occupants in way hardly imaginable today, creating what a 2005 United Nations report calls “An internet of things”.

Tiny nanosensors embedded in building materials will soon be able to track movement and detect termperature changes, humidity, toxins, weapons, even money.

Sensors will pick up on users’ preferences and attributes, which will then trigger responses in the intelligent objects around them, dimming the lights, altering the temperature, or as is already happing with “push” technology that marketers use to blitz cell phones, alerting them to nearby sales and events.

Soon, the design and construction of buildings will incorporate a rich network of interacting, intelligent objects, from light-sensitive, photochromic windows to user-aware appliances.

Buildings will not be static but will change constantly as their components continuously interact with users and each other.

These dynamic environments will be almost organic in their ability to respond to changes, so architects will need to learn to design for change.

No longer will we call the work of design done when construction is complete. That will be only the beginning of the design process, thanks to nanotechnology.

II. Nanotech is already providing environmental benefits for buildings.

The market for nano-enhanced building materials in the US is expected to grow to $400 million by 2016.

$4 billion a year is known to being pumped into Nanotech R&D worldwide, resulting in a pipeline of materials and products that will transform the way future buildings are constructed.

Nano has the potential to greatly reduce emissions from buildings, reduce construction waste, while providing cleaner air and water inside buildings.

In the first wave, nanotech is making its way into insulation, coatings and solar PV.

The next wave, currently in the development stage, will bring advances in lighting technology, air and water purification.

In about seven years we will begin to see changes in structural components like concrete and steel, adhesives, and batteries.

III. Nano being used today in green building:

Using Nano to improve the performance of existing buildings is one of the great opportunities.

- **Nano Insulation is one of the most commercialized nano products.**

It gets around the problem of insulating existing buildings, which is hard to do with bulky conventional materials like fiberglass.

You literally paint or spray the insulation on – it's invisible and non-toxic. The insulating coatings are so thin and clear that you don't k now they're there.

With demand for energy efficient buildings rising, insulation is the most cost effective way to reduce carbon emissions from buildings; it lowers a building's energy consumptions while maintain a comfortable indoor environment.

Nano insulating materials are more efficient than conventional materials like fiberglass or cellulose.

Industrial Nanotech, for example, has signed many thermal insulation contracts. Its Nansulate, patented nanocomposite insulate made with Hydro-NM-Oxide, a product of nanotechnology and documented as one of the highest quality insulation as having one of the lowest measured thermal conductivity values, when fully cured, contains approximately 70% hydro-NM-oxide and 30% acrylic resin and performance additive.

A liquid applied coating, it dries to a thin layer and provides exception insulation, corrosion protection, prevents mold, and prevents rust, and has proven to provide energy savings in a variety of insulation application. They also insulate pipelines – the coating insulates them from the weather, saving huge amounts of energy.

Case study:

It's applied to aluminum ceiling panels in the new Suvarnabhumi International Airport in Bangkok, Thailand, one of the world's largest airport.

Need: Long-term protection of aluminium panels which are to be used in a ceiling of the air link bridge at the Airport,.

Solution: Nansulate PT was used to coat the aluminum sandwich panels, providing them with long-term corrosion protection and offering added insulating ability.

In an example of another application, they just assigned a contract with the large textile company in Turkey to coat some of their machinery. When you insulate machinery, the building's cooling costs drop dramatically.

The company is also developing the first prototype for insulation that actually generates electricity.

The thin sheets of insulation – just a few thousands of an inch thick – use the temperature differential that insulation creates to generate electricity.

In the future, they will be able to tap the difference in day and night time temperature between the inside and outside of a building, an almost constant source of energy.

Cabot Corp is a midcap company that manufactures Nanogel aerogel, flexible insulation, for a range of applications including thermal insulation, architectural daylighting, subsea piping, coating, and apparel.

Aerogel, dubbed 'frozen smoke', is also the lightest weight solid in the world. The gel is filled with gas rather than liquid and is 95% air and 5% solid. Yet, it can support over 2000 times its own weight. A 3.5 inch thick aerogel panel provides an R-value of R-28, previously unheard of in a translucent panel. It doubles the insulation and light transmission values of skylights and other daylighting technologies, enabling architects to design buildings with more natural light, reducing energy consumption.

Aerogel is currently being used for its unique characteristics like hydrophobicity and ultra-low thermal conductivity in products ranging from architectural daylighting systems to oil and gas pipeline insulation.

As energy-efficiency standards for buildings become increasingly stringent, using a traditional insulation material often means having to accept increasingly thick layers of insulation in walls, floors, and roofs.

This consumes valuable floor space in new construction. In renovation project, significant aesthetic and functional compromises are often required to retrofit more insulation on the inside or outside of the building envelope.

Aerogel can help building owners and architects break away from these compromises. With a thermal efficiency that is 2-4 times greater than traditional materials such as polystyrene, mineral wool, and cellulose, aerogel delivers more insulation performance with less thickness. Along with high efficiency windows and daylighting systems, the use of aerogel in walls, floors and roofs can help a building meet even Aerogel particles, or granules, are especially useful in loose-fill cavity wall applications. Aerogel granules may also be added to plasters and other coatings systems to provide thermal insulation.

Aerogel Thermal Wrap blanket is especially useful in applications where a thermal product is required that can be easily cut, rolled, and/or shaped on the jobsite. Thermal wrap is useful for insulating facades, roofs, and interior walls. Because it delivers high insulation performance even when compressed, it is especially useful as a thermal break in places that otherwise conduct a lot of heat such a s over studs and around windows. In addition to it value as a thermal insulator, the excellent acoustic properties of the thermal wrap help attenuate noise from outside the building.

Case study:

60,000 sqft, four-story glass structure enclosed by a transparent building envelope at the Yale University Sculpture Building

Need: Maintain a predominantly glazed envelope, without compromising the building's high level of energy performance

Solution: High performance curtainwall that combines glass and aerogel surround the 14ft high studios of the Yale University Scupture Building and Gallery on the upper levels, and the shops and teaching space on the first floor.

To maintain a predominantly glazed envelope, without compromising the building's high level of energy performance, the project installed a triple-glazed curtainwall of insulated glass and super insulated R-20 aerogel-insulated translucent panels.

This high performance curtainwall provides significant reductions in both heat gain and loss year round. The warm air trapped in the curtainwall cavity is retained by the aerogel insulation and is either used internally in the winter months or vented to the exterior during the warm months.

This creates an effective thermal management barrier than increases energy performance while simultaneously allowing the entire façade to admit natural light into the interior, thereby reducing artificial lighting costs.

The building's transparent, lightweight façade system transmits soft, glowing light through 8ft operable windows, triple-glazed low-E vision panels, and a translucent double-cavity spandrel panel using aerogel.

❑ Nano used for Coatings is the other most established sector.

Nanocoatings can be used to self-clean surfaces, and in the process they de-pollute; they actually remove air pollutants and dissolve them into relatively benign elements.

De-polluting nanocoatings break down toxins that come in contact with surfaces. When painted onto a road, bridge or building they not only protect the surface and reduce the need for cleaning - they eliminate some of the pollution that cars emit. It's invisible and non-toxic.

Self-cleaning windows were one of the first architectural applications of nanotech.

The coating causes water to sheet off the surface, leaving a clean exterior with minimal spotting or streaking.

They also have the potential to clean indoor air.

Nanotec's coatings are on many buildings around the world now. Its nano treatments self-clean concrete and stone, glass and ceramics, textiles, wood, stainless steel, aluminum, and plastic.

A building stays clean much longer, especially the windows, reducing the need for toxic chemical cleaners which emit volatile organic compounds VOCs.

Kohler and other plumbing fixture manufacturers are starting to **paint anti-microbial coatings on sinks and toilets, which means less maintenance and lower costs.**

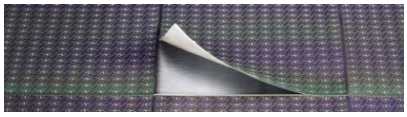
Microban International manufactures an anti-bacterial chemical compounds for incorporation into molecular plastics and synthetic fibers, imparting resistance to the growth of bacteria, molds and mildew that can cause stains, odors and deterioration of a product. Built into products during the manufacturing process, its antimicrobial product protection is used in over 450 products including cleaning supplies, paints, caulking and plumbing fixtures, provide an added level of defense against damaging microbes for the useful lifetime of the product.

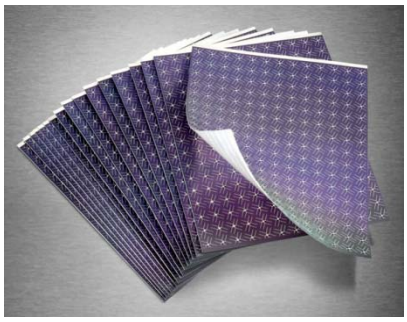
In the future, the technology could make pipes so smooth and slippery that they can't plug up, wear out, and can carry much more water in a smaller pipe.

❑ Solar

Nanotech Solar is starting to offer real competition to conventional silicon-based solar manufacturing.

It isn't as efficient as conventional solar, but is steadily improving. It could replace silicon technology in 3-7 years. The Department of Energy estimates that nearly 50% of the electrical needs of buildings in the US can be met by BIPV systems.



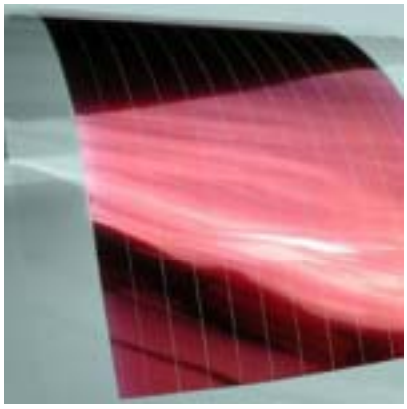


NanoSolar has received investments from some of the venture capital powerhouses, along with individual investors like the founders of Google.

The company has the potential to transform the solar market with its 'roll to roll' process, where thin film, nanotech solar cells are literally printed onto plastic or metal.

It makes integrating solar into a building more like printing a newspaper, a major advance from glass plates that are installed on rooftops. Solar sheets can be made for less than a tenth of what current panels cost at a rate of several hundred feet per minute.

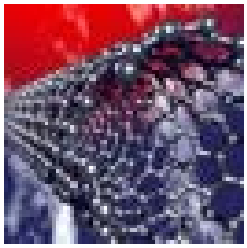
Its SolarPly BIPV panels, made from semiconductor quantum dots and other nanoparticles, will create solar-electric "carpet" to be integrated into commercial roofing membranes.



Spire Corp integrates solar into façade elements like windows and awnings. Its nanostructured materials make fabricating solar cells more efficient and enables solar to be available in various colors, giving architects options for improved aesthetics.

Innovalight is developing silicon ink-based printed solar cells. By processing silicon with liquids, the company believes it can reduce the cost of solar by substantial percentage.

❑ Carbon Nanotubes



This materials is said to be one hundred times stronger than steel because of its 'molecular perfection'.

In addition, because carbon atoms can bond with other matter; such materials can be an 'insulator, semi-conductor or conductor of electricity'.

As a result, carbon nanotubes will have significant influence on the architecture industry as such materials can act as a 'a switchable conduit, a light source, a generator of energy and even a conveyor of matter'.

❑ Lighting

LED lighting is already an over $4 billion market, and organic LED (OLED) are coming.

It's a potentially huge market with a lot of money going into research. In the long run, 5-7 years off, we are looking at exciting development that will change the relationship between lighting and building.

OLEDs are like thin film solar in that they are printed onto substrates. When activated by electricity, they provide brighter, crisper displays on electronic devices and use far less energy than LEDs. TVs will be less than ¼ inch thick and will be able to be rolled up when not in use. OLEDs can be applied to any surface, flat or curved, to turn it into light source.

In the future, light panels will replace light bulbs – walls, floors, ceilings, curtains, cabinets and tables could all become sources of light.

They have appeared in small consumer devices like cell phone screens and have entered architectural lighting market.

Universal Display Corp is an important company here; and Philips and GE are picking up the technologies.

❑ Some of the areas that are further in the future

Think about all the applications that can benefit from greater efficiency and you will find a role for nanotech.

It will make **batteries** more efficient; create new super capacitors, lead to advances in thermovoltaics for turning waste heat into electricity; create improved materials to store hydrogen, as well as more efficient hydrocarbon based fuel cells.

Altair Nanotechnologies is one of the most established companies that's developing batteries; their NanoSafe product has been used in the new line of electric motorcars. AlwaysReady, a subsidiary of mPhase Technologies, is bringing its Smart Nanobattery to market.

Nanotechnologies for **water and air filtration**, which are widely available as consumer products, will increasingly penetrate the market for built-in filtration systems. NanoH2O is creating advanced membrane materials for the desalination and water reuse industries.

Research is also underway to use nano for **fire protection** and **to enhance structural materials** including steel, concrete and wood.

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