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Nanotechnology and Its Effects in Architectural Design

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Abstract

Nanoarchitecture as the new contemporary architectural style of the 21st century that will revolutionize the architecture world in every way either the way architects think or how they inspire their ideas, the used materials in building, finishing materials, or the way we demonstrate to the world and building users. It is not a secret that the teaching of a nanotechnology course will soon be required in most engineering and architecture curricula. The intent of this paper is therefore to connect science and technology under the umbrella of nanotechnology in order to design and build practical and innovative materials and devices from the nanoscale upward. The findings of this paper are expected to benefit nanotechnology in architecture and building materials which will directly or indirectly contribute to its suitability and modern materials use.

Keywords: Nanotechnology, Architecture, Building materials, Nanoarchitecture.

1. Introduction

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. Carbon nanotubes are a great example of how useful materials are being developed. This material 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 material 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 switchable conduit, a light source, a generator of energy and even a conveyor of matter". 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. For instance, structures will be constructed from the bottom-up because materials like carbon nanotubes can self-assemble. 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 inhabitants live.[1] Windows with variable transparency, walls with variable transparency and mood/context sensitive clothing are all included. Nanotechnology will give architecture superior interactive functions as occupants select and communicate what transient states they would like to experience. As new materials and construction methods emerge, the advent of everyday use of nanotechnology will unleash the designer's imagination. The biggest plans for the future of our built environment are actually very small. So, Nanoarchitecture [Nanotechnology + Architecture = Nanoarchitecture] [2]
So, It will have a brief review of the meaning of Nanotechnology and how it is developing and affecting our life, and especially its influence in shaping a new architectural style.

2. Objectives

Nanotechnologies are developed at the scale of nanometres, [Figure.1] or billionths of a meter $[10]^{-9}$. The advent of nanoscience launches an entirely new age, our age, where atoms become domesticated. As nanoscience is concerned with the design of molecular and atomic phenomena, it is an integral part of many disciplines, including physics, chemistry, biology, computer science, and materials science. Given their glorious history of movements and monuments, it is a challenge for architects to think small; however, as in previous epochs, architecture will inevitably find the new science of our age unavoidable. Small is big. [2]

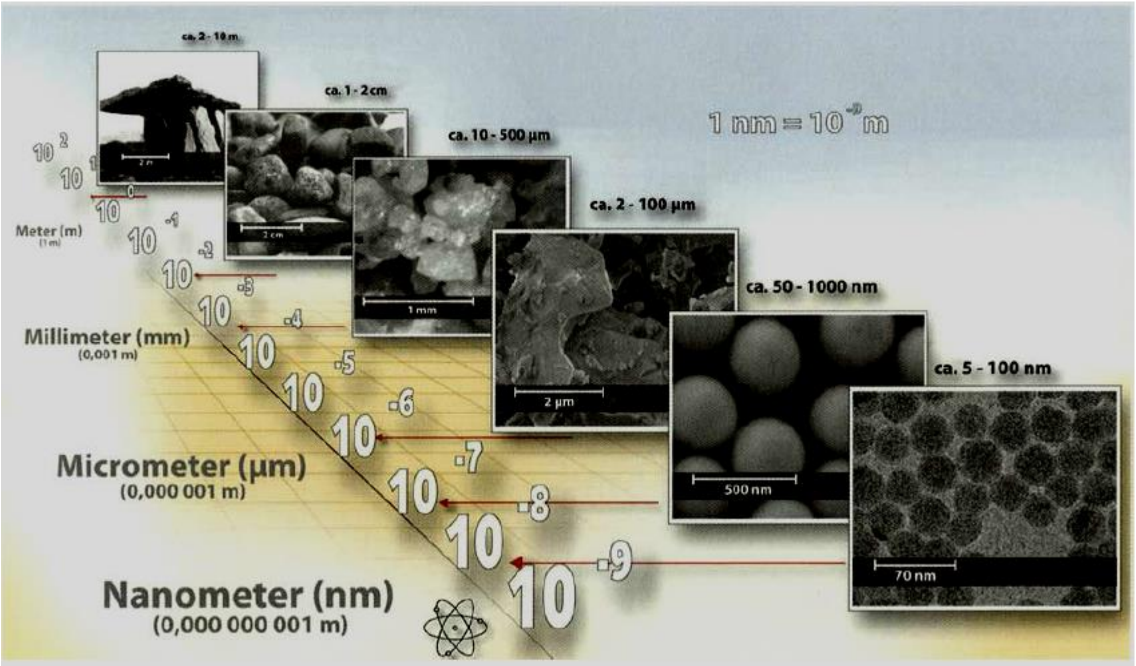

Figure.1 Nanotechnologies are developed at the scale of nanometres or billionths of a meter [10]-9

It is already influencing the way we live, and our aspirations for the future. This paper uses digital images to introduce the fundamental concerns of nanoscience and will survey a new class of materials and products that nanotechnology [applied nanoscience] has made possible. The second half of the paper presents three significant research areas of nanoscience that will have tremendous consequences for the discipline of architecture and the evolution of our cities: molecular self-assembly, artificial self-replication, and programmable matter. potential becomes reality, it could transform our world in ways undreamed of. Nanotechnology has the potential to radically alter our built environment and how we live. It is potentially the most transformative technology we have ever faced, generating more research and debate than nuclear weapons, space travel, computers or any of the other technologies that have shaped our lives. It brings with it enormous questions, concerns and consequences. It raises hopes and fears in every aspect of our lives social, economic, cultural, political, and spiritual. Yet its potential to transform our built environment remains largely unexplored. What, for instance, is the future of building if each of us possesses thermos protectant skins that shelter us from the elements? How do we interact with our environment, and with each other, if walls and roofs become paper-thin, permeable, or even invisible? So, the objectives of this paper are:

1. Highlight the fundamental changes that nanotechnology will do to our society and its reflection on architecture.
2. Create a basic knowledge for architects about Nanotechnology in order to pay their attention to the enormous transformation it promises.

3. Methods

3.1 The role of nanotechnology to play today in architecture and Built Environment:

Many nano engineered materials are already available to architects and builders, and are beginning to transform our buildings, what we can do in them, and what they can do for us. Looking further ahead, new nanotechnologies now in research and development will likely have a huge impact on building within the next twenty to fifty years. Carbon nanotubes, for example, could bring unprecedented strength and flexibility to our buildings, leading to new forms, new functions, and new relationship between people, building and environment. On the far horizon, the full impact of nanotechnology on our lives and our environment into the next century and beyond is almost unimaginable. Perhaps this is the promise and the peril of nanotechnology, that its consequences are so extreme and yet so near, as billions of dollars pour into new research and development every year and new advances pour out. The real danger in nanotechnology is not rampant self-replicating viruses or nanobots overrunning the planet; the real danger is that, as most of us experienced wit cloning, we will awake one day to find that a technological revolution has already occurred, without our knowledge or our consent, and without us even taking time to determine what we think about it, how we feel about it, or to share those thoughts and feelings in the discourse critical to a reasoned advance in technology. That day is coming sooner than we think. Today is the day to reflect and to discuss what those new challenges and relationships could be. Winston Churchill was not thinking about nanotechnology when he said we shape our buildings and our buildings shape us, but its power to transform us and our buildings brings new urgency to the shaping. Nanotechnology gives unprecedented power to the architects and engineers shaping our world, and the result could be buildings that shape us, as well as our relationships with each other and our environment, in ways that Churchill never could have envisioned. The aim of this paper is to kick-start your thinking about nanotechnology and its potential impact on the buildings that shape you, not by forecasting the future, this technology is much too unpredictable for that , but by laying out a realm of possibilities for nanotechnology, architecture and the future of the built environment. These possibilities become almost infinite as we try to extrapolate the impact if nanotechnology fifty or one hundred years from now, so these long-range scenarios are tempered by a closer look at the more immediate impact of nanotechnology and the potential impact of technologies now in research and development. At each stage the personal, social, ethical and environmental consequences are explored because these are the real and significant questions that nanotechnology raises. Nanotechnology will transform our built environment; it is essential that we use it to shape one that is healthier, more comfortable and more humane. Without forethought, dialogue and debate we may awake one day to find that we have already been shaped by it. [1]

3.2 Nanotechnology and Nanoarchitecture:

the ability to manipulate matter at the scale of less than one billionth of a meter, has the potential to transform the built environment in ways almost unimaginable today. Nanotechnology is already employed in the manufacture of everyday items from sunscreen to clothing, and its introduction to architecture is not far behind. On the near horizon, it may take building enclosure materials [coatings, panels and insulation] to dramatic new levels of performance in terms of energy, light, security and intelligence. Even these first steps into the world of nanotechnology could dramatically alter the nature of building enclosure and the way our buildings relate to environment and user. At mid-horizon, the development of carbon nanotubes and other breakthrough materials could radically alter building design and performance. The entire distinction between structure and skin, for example, could disappear as ultralight, super-strong materials functioning as both structural skeleton and enclosing skin are developed. [3]

When introducing a new technology to a field such as the construction industry, one should always first examine the benefits it can bring. In case of the application of nanotechnology, we are talking about added value, additional functionality, as well as market demand regarding product development. Good design in principle is always based on demand, and in this way contributes to the evolution of both nanomaterials and the resulting nanoproduct – in the long term the materials and products for which there is a demand will become established whereas others will disappear from the market. The use of nanotechnology is therefore not an end but follows an ongoing demand for innovation because of the growing cooperation between scientific global entities of each country of the world. Where, Nanotechnology can make a concrete contribution to the following areas:

- Optimization of existing products
- Damage Protection
- Reduction in weight and/or volume
- Reduction in the number of production stages
- A more efficient use of materials
- Reduced need for maintenance [easy to clean, longer cleaning intervals] and/or operational upkeep

And as a direct result:

- Reduction in the consumption of raw materials and energy and reduced CO_2 emissions
- Conservation of resources
- Greater economy
- Comfort

3.3 Nanoarchitecture

Nanoarchitecture is the conversion of architecture in the new nano revolution in the 21st century. The use of nanotechnology in architecture varies from materials, equipment, to forms and design theories. In architecture two fundamentally different design approaches prevail when dealing with materials and surfaces, Where

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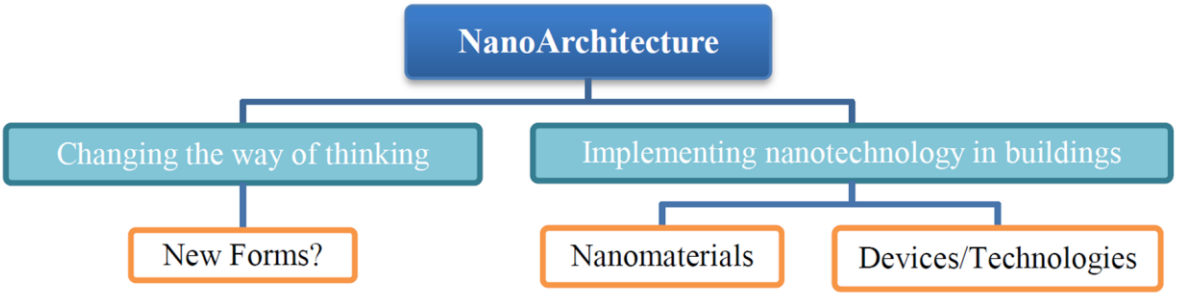

Figure.2 Nanoarchitecture: Nanotechnology in buildings.

3.4 Nanomaterials:

In architecture two fundamentally different design approaches prevail when dealing with materials and surfaces.

A] Honesty of Materials :

This approach is favored by those architects for whom authenticity is a priority and who value high-quality materials such as natural stone or solid woods.

B] Fakes Materials:

artificial surfaces that imitate natural materials: For the most part, -fake- materials are chosen for cost reasons. Wood, whether in the form of veneer or synthetic wood-effect plastics, is considerably cheaper than solid wood. Even concrete or venerable walls can be had en plastique.

Artificial surfaces are - brought to perfection - the grain can be tailored to appear exactly as desired, the color matches the sample precisely and does not change over the course of time.

More and more -patinated- surfaces are being created that exhibit artificial aging: instant patinas precisely controllable. Certain design approaches prefer the provocation of deliberate artificiality.

C-Functional Nano surfaces, emancipated from underlying materials:

The properties of such ultra-thin surfaces can differ entirely from the material they enclose and can be transparent and completely invisible. Also possible are nanocomposites with new properties: nano particles or other nanomaterials are integrated into conventional materials so that the characteristics of the original material are not only improved but can be accorded new functional properties or even be made multifunctional. Surface materials that are customized to have specific functional properties are set to become the norm, heralding a switch from catalogue materials to made-to-measure materials with definable combination of properties – a perfectly modular system.

Nanomaterials can extend our design possibilities. The aging process becomes a question of time frame – it can set in earlier or later according to the material chosen. Likewise, aesthetic, functional and emotional qualities can be expressed more easily – it is simply a matter of choice. As such, ―Form Follows Function‖ applies more than ever and for all kinds of building tasks. [4]

However, the developments outlined are not without their hurdles. In the building sector, a large proportion of work concerns renovation, conservation work and building in existing fabric. In this field nano high-tech materials meet old, conventional materials and methods with which they should be compatible. The use of new materials derived from nanotechnology is not just a financial risk for those involved but also a legal risk. Many builders often do not like to offer guarantees in areas they do not know well, which explains why it is sometimes difficult to find a suitable firm for certain services. Likewise, a good product can be compromised by poor installation or the difficulty involved in installing it. Finally building products need to be certified by the building inspectorate, a hurdle that needs to be overcome for nanoproducts as well. [4]

The question of authenticity also arises in the way that nanomaterials themselves are presented. In many cases the producing companies do not communicate well whether nanotechnology plays a role in the products they sell or not. A number of different phenomena can be observed in this context:

"Nano-Fake": It is not unknown for products to be marketed as "nano" [because "nano's always good..."] even when the product has nothing to do with it - which is sometimes determined through laboratory analysis.

"Nano-Proof": There are also situations where companies are unwilling to provide detailed information about the individual products. Studies are not always freely available. Other producers, on the other hand, market products with a variety of quality marks or certificates. Some regard quality marks without a statutory basis as lacking impartiality - the commissioning client can influence the testing method and therefore the results and their assessment. Nevertheless, quality marks do offer consumers a degree of purchasing confidence that is better than none. Ideally, statutory prescribed testing methods should be established that are independent and precisely defined. [3]

"No-Nano": Occasionally products appear in the "nano" context whose producers, when asked, assert that their products have been produced without the use of nanotechnology. Sometimes the confusion results from differences in the definition of "nano", although as mentioned previously no precise definition exists. It can also happen that "nano" is an aspect of a particular product but that this is not mentioned in the company's publicity communications or marketing for fear of negative publicity ["nano risk"], for example when the licensee of a nano patent intentionally declines to mention "nano" in its communications. It can at times be difficult for architectural offices and designers to find appropriate partners for information on nano-based products and technology. Without such partners, the danger is that important details regarding the application of nanotechnology products are omitted, for example that hydrophilic glass is incompatible with silicone and should be used with alternative sealants. Interesting and competent partners are often to be found in the product development and technical departments of the producing companies, or even in their laboratories. [3]

3.5 Nanomaterials and Architecture/Functions and Applications

Not least for this reason, the following selection of representative case studies complements the description of the different nano-functions, providing concrete examples of innovative applications so that all participants have a better idea of how they can be employed. The built examples from architects around the world are intended to help recognize new developments in the field. The selection features forward-looking projects from a variety of countries, all of which were completed in recent years and incorporate nanomaterials or nano surfaces. Together they represent a solid and tangible foundation for future developments, providing a promising outlook on an exciting field. Also, architecture, interior design and related disciplines are concerned with real and visible applications:

3.5.1 Self-cleaning materials:

3.5.1.1 Lotus-Effect: [3]

-Microscopically rough, not smooth. -Hydrophobic – water trickles off. This is one of the best-known means of designing surfaces with nonmaterials. The name -Lotus- Effect‖ is evocative, conjuring up associations of beads of water droplets, The contact angle of the solid–liquid–gas phase can be categorized as static when the droplet is stationary and as dynamic when the droplet moves. The dynamic contact angle is commonly evaluated by contact angle hysteresis, in which the forward contact angle at the front end of the droplet and the receding contact angle at the rear end of the droplet are different [Figure.3] From the perspective of fluid dynamics, the slippery solid–fluid surface is allowed to slide across the solid surface following the Navier slip law: [11]

$$\mathbf{U}_w = \lambda\left(\frac{\partial \mathbf{U}}{\partial z}\right)_w$$

Self-cleaning surfaces were investigated back in the 1970s by the botanist Wilhelm Barthlott. He examined a self-cleaning effect that can be observed not only in Lotus leaves. They exhibit a microscopically rough water-repellent [hydrophobic] surface, which is covered with tiny knobbles or spikes so that there is little contact surface for water to settle on. Due to this microstructure, surfaces that are already hydrophobic are even less wettable. The effect of the rough surface is strengthened still further by a combination of wax [which is also hydrophobic] on the tips of the knobbles on the Lotus leaves and self-healing mechanisms, which results in a perfect, super-hydrophobic serf-cleaning surface. Therefore, the effect is often confused with -Easy-to-clean‖ surfaces or with photocatalysis, which is also self-cleaning. [5]

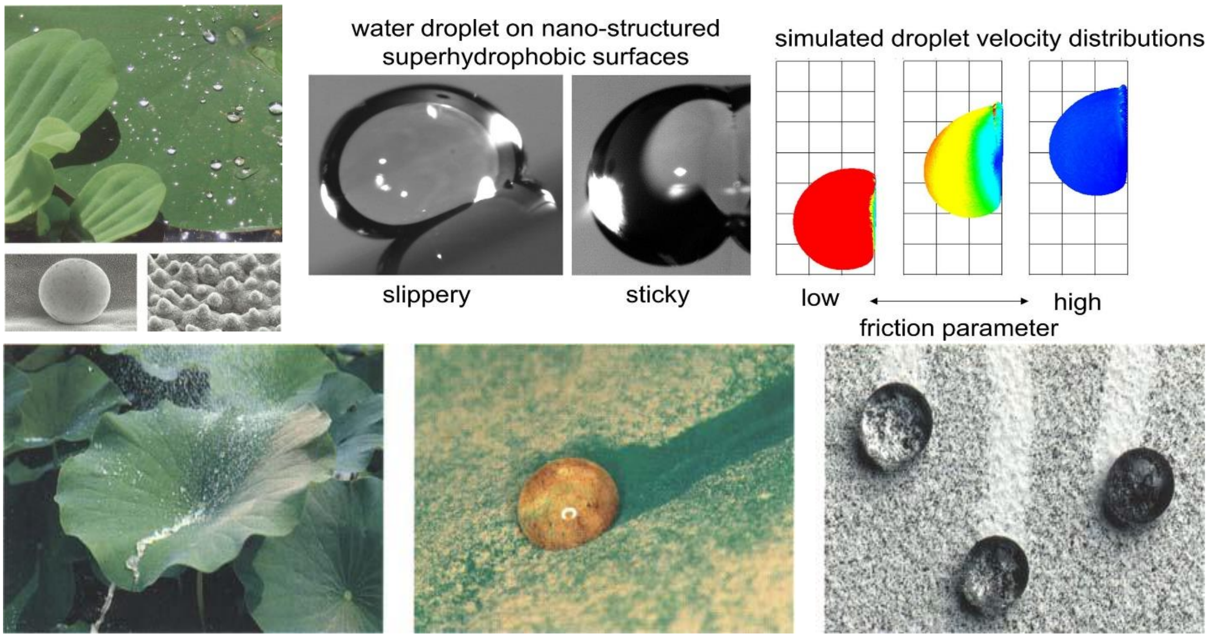

Figure 3. Dynamics of a water droplet on a hydrophobic inclined surface [5]

In architecture, Wood can be given an extremely water-repellent self-cleaning surface. By creating nanostructures similar to those of the Louts plant on the surface of the wood, [Figure 4,5] the contact area between water & wood is minimized and surface adhesion reduced. Water rolls off instead of penetrating the wood. [3]

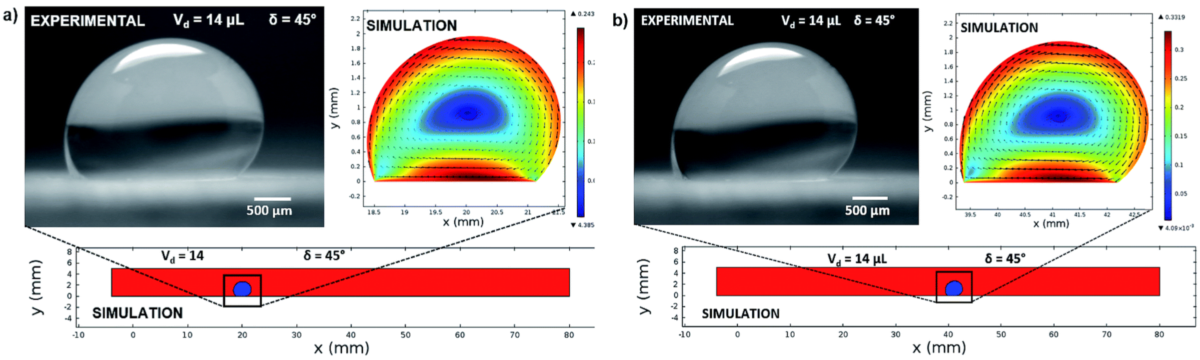

Figure 4. Droplet location on an inclined surface and velocity field predicted from the simulations. [a] Velocity field inside the droplet located 20 mm on the inclined surface. [b] Velocity field [m s^{-1}] inside the droplet located 40 mm on the inclined surface. [6]

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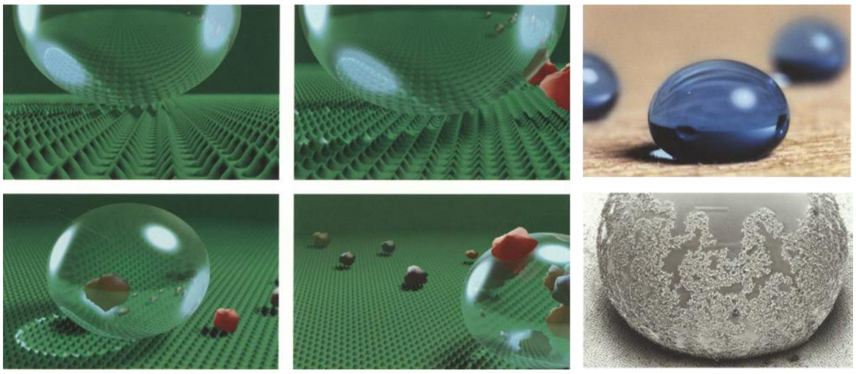


Figure 5. The visualisation illustrates how the basic principle of the Lotus-Effect works: the knobbly structure combined with reduced surface contact and low surface adhesion makes water form droplets that run off, washing away dirt deposits. [3]

3.5.1.2 Self-cleaning: Photocatalysis

-Hydrophilic surfaces.

-Deposited dirt is broken down and lies loose on the surface.

-A water film washes dirt away.

-UV light and water are required.

-Reduces maintenance requirements.

Photocatalytic self-cleaning is probably the most widely used nano-function in building construction. There are numerous buildings around the world that make use of this function. Its primary effect is that it greatly reduces the extent of dirt adhesion on surfaces. It is important to note that the term -self-cleaning‖ in this context is misleading and does not mean, as commonly assumed that a surface need not be cleaned at all. The interval between cleaning cycles can, however, be extended significantly, a fact that is particularly relevant in the context of facility management. Fewer detergents are required, resulting in less environmental pollution and less wear and tear of materials. Likewise reduced cleaning cycles lead to savings in personnel costs and the fact that the dirt adheres less means that it is also easier to remove. A further advantage is that light transmission for glazing and translucent membrane is improved as daylight is obscured less by surface dirt and grime. Energy costs for lighting can be reduced accordingly. For the function to work, UV light present in normal daylight is sufficient to activate the phot catalytic reaction. Organic dirt on the surface of a material is decomposed with the help of a catalyst – usually titanium dioxide, which has been used in all kinds of products. At a nanoscalar dimension, titanium appears no longer white but transparent, and it‘s also hydrophilic. Photocatalytic surface coatings are often applied to façade panels made of glass or ceramics or to membranes. As the self-cleaning effect doesn’t function without water, eaves should be designed so that they do not prevent rainwater or dew from reaching the façade. It is also necessary in glazing to abstain from the use of silicon-based seals because the oils they contain transfers to the glass and are incompatible with the surface coating, rendering it partially hydrophobic and resulting in unsightly streaking.. On conventional tiles and glass water forms droplets that dry leaving behind dirt deposits. On the hydrophilic surfaces of photocatalytic tiles, water forms a film that runs off taking any loose dirt deposits with it by using nano coating. Figure 6

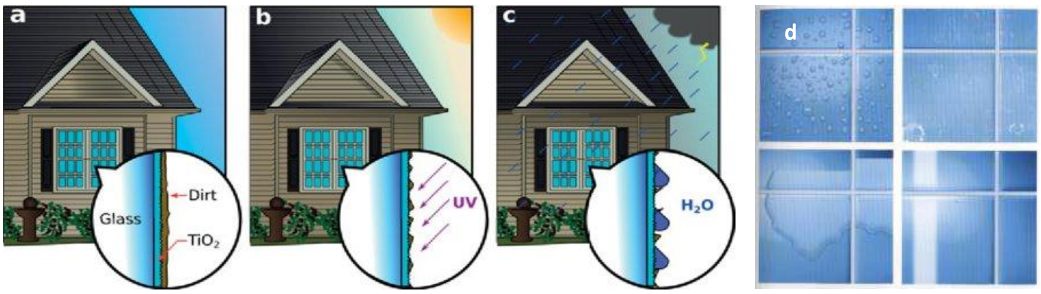


Figure 6. Mechanism of action of a self-cleaning window based on TiO 2 coating [a]. The combined effects of photocatalysis, initiated by sunlight [b], lightinduced superhydrophilicity [c], and conventional tiles [d] self-cleaning help maintain the coated surface clean of contamination.

3.5.1.3 Easy-to-clean [ETC]: [Figure 7]

-Smooth surfaces with reduced surface attraction.

-Surface repellence without using the Lotus-Effect.

Recent climate changes have initiated dust storms. Dust settlements on surfaces both during and after dust storms reduce the efficiency of solar energy harvesting devices, such as photo voltaic panels. Considerable effort is required to clean these surfaces because of the large surface area of the devices and the scarcity of clean water in urban areas. Water droplets on inclined hydrophobic surfaces can reduce the effort required to remove dust particles from the surfaces. The dynamic motion of a water droplet remains critical for removing dust particles on hydrophobic surfaces. The contact line dynamics of the droplet govern droplet behavior by either rolling off or sliding on the surface. An understanding of the dynamic motion of a water droplet is critical to reduce the effort required to remove dust particles from such surfaces. In line with self-cleaning applications, the wobbling and geometric variations of a rolling droplet were experimentally assessed for various droplet sizes. Furthermore, the internal fluidity of a rolling droplet was numerically predicted. The findings revealed that the rotational Bond number influenced the droplet wobbling due to adhesion force variations during rolling. Small-sized droplets, which were comparable to the capillary length, resulted in higher rotational speeds than those of larger-sized droplets. The ability to alter the rolling characteristics of droplets on inclined hydrophobic surfaces could address the limitations of self-cleaning surfaces and has implications for efficiency enhancements in solar energy devices by using nano technology. [6]

Figure 7. self-cleaning solar panels that use waterless cleaning technology to remove dirt and dust from the surface. These panels integrate hydrophilic coatings using nano technology that cause water to form beads and roll off the surface. This technology can help reduce water usage significantly and maintain the efficiency of panels during droughts. [6]

3.5.1.4 Anti-fogging: [Figure 8]

-Clarity for steamed-up surfaces Due to nanotechnology a permanently clear view is now possible without the use of electricity. The solution is an ultra-thin coating of nanoscalar TiO2, which exhibits a high surface energy and therefore greater moisture attraction. On hydrophilic surfaces moisture forms an ultra-thin film instead of water droplets. It still settles on the surface but remains invisible. The film is transparent, creating a fog-free clear appearance. Bathroom mirrors are obvious candidates for such coating, as are glass surfaces in airconditioned rooms in the tropics, which tend to cloud as soon as outdoor air streams into a room. Anti-fogging coatings can also be applied to plastics. Anti-fogging sprays are effective as a temporary means of making surfaces appear clear but the effect doesn‘t last long. Further application areas for anti-fogging surfaces are currently being developed but are not yet ready for the market place. Two aspects are common to all anti-fogging variants: condensation itself is not stopped. Instead, and more importantly, it remains transparent and therefore appears invisible. A clear view is possible at all times, simply and effortlessly, without the need for heating, wiping down or a hairdryer. [7]

Figure 8. glass with anti-fogging coating do not steam up using nanotechnology. [7]

3.5.2 Nano thermal insulation:

3.5.2.1 Thermal insulation: Vacuum insulation panels [VIPs]:

-Maximum thermal insulation. [Figure 9]

-Minimum insulation thickness.

Vacuum insulation panels [VIPs] are ideally suited for providing very good thermal insulation with a much thinner insulation thickness than usual. In comparison to conventional insulation materials such as polystyrene, the thermal conductivity is up to ten times lower. This results either in much higher levels of thermal resistance at the same insulation thickness or means that thinner insulation layers are required to achieve the same level of insulation. In other words, maximum thermal resistance can be achieved with minimum insulation thinness. At 0.005 W/mK, the thermal conductivity of VIPs is extremely low. The thickness of these VIPs ranges from 2mm to 40mm. Vacuum insulation panels can be used both for new buildings constructions as well as in conversion and renovation work and can be applied to walls as well as floors. The lifetime of modern panels is generally estimated at between 30 and 50 years. It can be applied not just for buildings but also to insulate pipelines, in electronics and for insulating packages, for example for the cool chain transport of medications.

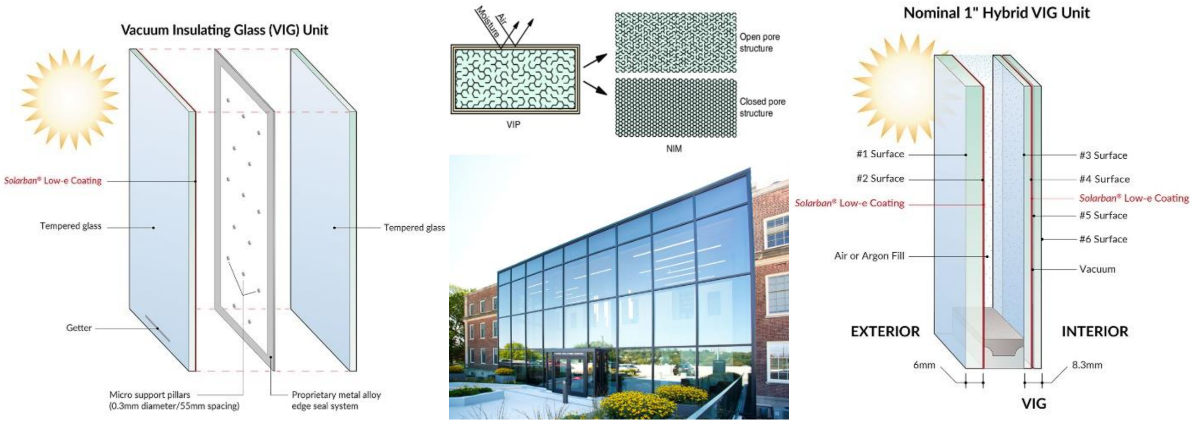


Figure 9. Thermal insulation: Vacuum insulation panels [VIPs]

3.5.2.2 Thermal insulation: Aerogel "Frozen Smoke":

-High-performance thermal insulation. [Figure 10]

-Light and airy nanofoam.

Aerogel currently holds the record as the lightest known solid material and was developed back in 1931. It is relatively banal: it is simply an ultra-light aerated foam that consists almost 100% of air. The remaining foam material is a glass-like material, and silica. The nanodimension is of vital importance for the pore interstices of the foam: the air molecules trapped within the minute nanpores –each with a mean size of just 20nm – are unable to move, lending the aerogel its excellent thermal insulation properties. [8]

Figure 10. High-performance thermal insulation using nano Aerogel "Frozen Smoke"

It is used as an insulating fill material in various kinds of cavities – between glass panes, U-profile glass or acrylic glass multi-wall panels – and is therefore well suited for use in external envelopes of buildings. That way aerogels can help reduce heating and cooling costs significantly. Because it is translucent, aerogel exhibits good light transmission, spreading light evenly and pleasantly [Figure 11]. In addition to its thermal insulating properties, aerogel also acts as a sound insulator according to the same basic principle. [8]

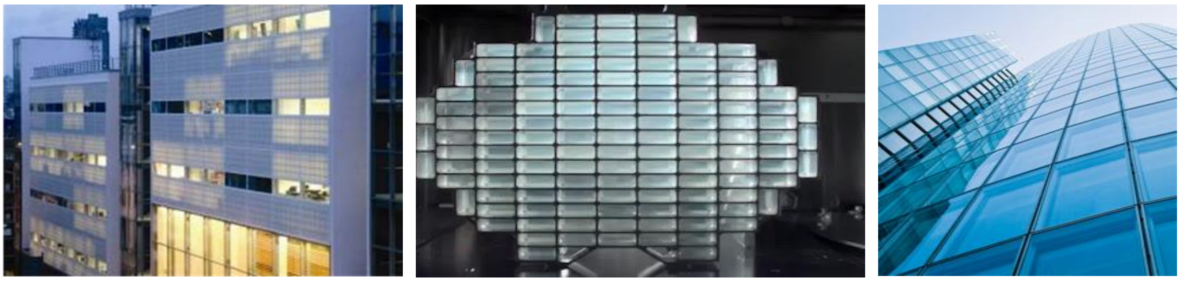


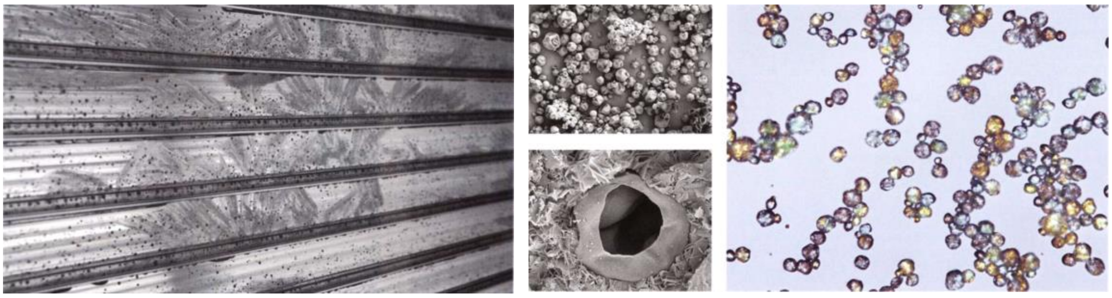
Figure 11. Light and airy nanofoam using nano Aerogel “Frozen Smoke” [10]

3.5.2.3 Temperature regulation: Phase change materials [PCMs]:

-Passive temperature regulation.

-Reduced heating and cooling demand.

The good thermal retention of PCMs can be used both in new and existing buildings as a passive means of evening out temperature fluctuations and reducing peak temperatures. It can be used both for heating as well as cooling. As PCM is able to take up energy [heat] without the medium itself getting warm, it can absorb extremes in temperature, allowing indoor areas to remain cooler for longer, with the heat being retained in the PCM and used to liquefy the paraffin **[**Figure 12]. Energy is stored latently when the material changes from one physical state to another, whether from solid to liquid or from liquid to gaseous. The latent warmth or cold, which effectively fulfils a buffer function, can be used for temperature regulation. [9]



[1] [2] [3]

1-Close-up of a phase-changing material embedded in glazing

2-An image of minute paraffin-filled capsules in their solid state, taken using light microscopy.

3-An image of an opened microcapsule embedded in a concrete carrier matrix, taken using SEM.

Figure 12. They exhibit an exceptionally high thermal capacity and during a phase change turn to liquid using nano technology. [9]

Also, Dynamically tunable PCM-based TES device enhances the thermal storage efficiency figure 13

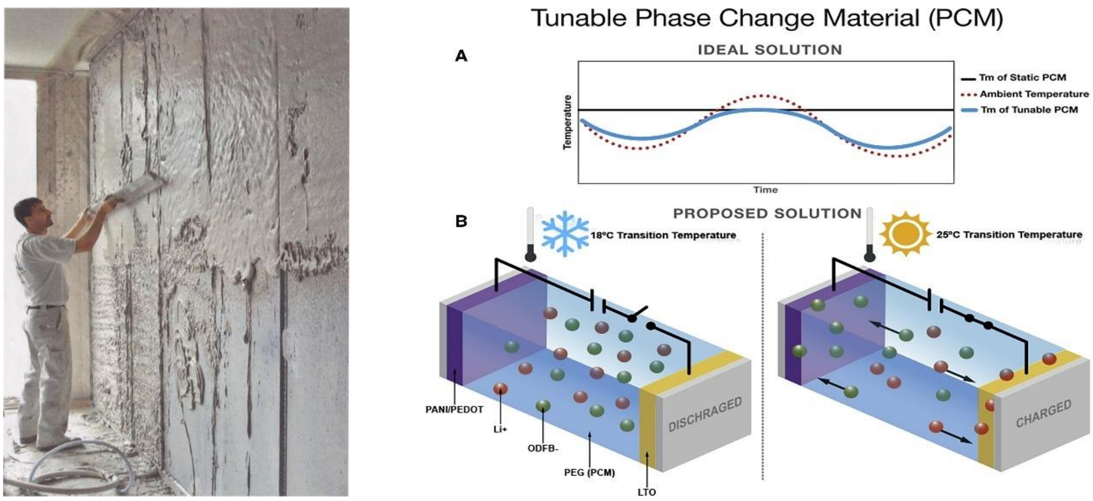


Figure 13. PCM plaster applied on Interior walls provides thermal insulation**.** [9]

3.5.3 UV protection

-Lasting and highly transparent protection. There are two kinds of UV protection, both of which are organic and employ additives. Both are typically used in combination: one variant involves the use of UV absorbers that filter out the harmful rays in sunlight before they come into contact with the material itself. As such they need to be on an upper layer and are typically applied in the form of a protective lacquer.

The second approach uses so-called free-radical scavengers, which in contrast to the first approach take effect at a later stage. [Figure 14]

A prerequisite of protective coatings is that they are transparent so that the coloring and structure of the material beneath is preserved. To achieve this, the individual inorganic UV-absorbing particles in the formulation must be smaller than 15nm in size. Below this size they no longer scatter visible light and become effectively visible.

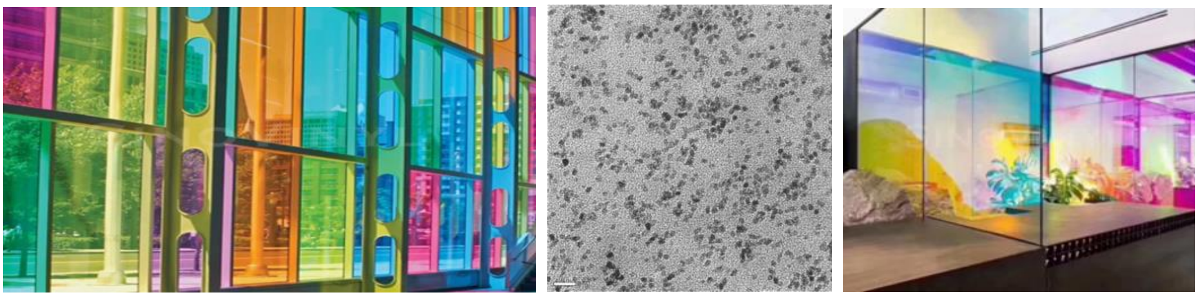


Figure 14. UV-absorbent zinc oxide particles contained within a clear varnish.

3.5.4 Solar protection:

- No blinds necessary.
- Glass darkens automatically or is switchable without the need for a constant electric current [memory effect].

The advent of nanotechnology has provided a new means of integrating electochromatic glass in buildings. The primary difference to the earlier product is that a constant electric current is no longer necessary. [3]

A single switch is all that is required to change the degree of light transmission from one state to another, i.e. on switch to change from transparent to darken and a second to change back. The electrical energy required to color the ultra-thin nanocoating is minimal and the switching process itself takes a few minutes. Photochromatic glass is another solution for darkening glass panels. Here the sunlight itself causes the glass to darken automatically without the switching. Nanotechnology has made it possible to provide an energy-efficient means of solar protection that can also be combined with other glass functions. [Figure 15].

Photo chromic glass　　Thermochromic glass　　Electro chromic glass

Figure 15. Electrochromic glass with an ultra-thin nanocoating needs only be switched once to change state Solar protection [photo chromatic glasses]

3.5.5 Fire-proof: [2]

-Highly efficient fire protection. -Light and transparent.

The German Degussa has produced the Aerosil material, a pyrogenic silicic acid used for a number of purposes including the paint industry. The pyrogenic nanoparticles, or nano-silica, are only 7nm large and due to their relatively large surface area are highly reactive. Depending on the desired duration of fire resistance, the highly effective fill material is sandwiched between one or more panes of glass. Standard products are generally between 90 and 380m2 per gram! The main advantages are the comparatively lightweight of the glass, the slender construction and accompanying optical appearance as well as the long duration of fire resistance. In the event of fire, the fire-resistant layer expands in the form of foam preventing the fire from spreading and keeping escape routes accessible for users and firefighters alike. The additional layer doesn't exhibit any clouding, streaking or fractures and is practically invisible. An additional side effect I improved noise insulation.

3.5.6 Anti-reflective [Anti-Glare film] :

-Improving solar transmission. [3]

The use of anti-reflective glass to solve the problem of reflection is in itself nothing new. In interior architecture, such glass is used in exhibition design for glass cabinets for example. Its complicated manufacture, which involves applying several layers, means that it is expensive and other disadvantages. Transparent nano scalar surface structures, where the particles are smaller than the wavelength of visible light, offer not only an innovative but also a cost-effective and efficient anti-reflective solution. Their structure consists of minute 30-50nm large silicon dioxide [SiO2] balls. A coating thickness of 150nm is regarded as ideal. The ratio of reflected light reduces from 8% to less than 1%. Another cost-effective means of producing anti-reflective surfaces is the moth-eye effect, the cornea of moths, which are active mostly at night, exhibits a structure that reduces reflections. [Figure 16]

Figure 16. Anti-reflective glass [Anti-Glare film]

3.5.7 Antibacterial:

-Bactria are targeted and destroyed.

-The use of disinfectants can be reduced.

-Supports hygiene methods – especially in health care environments

Photocatalytic surfaces have an antibacterial side effect due to their ability to break down organic substances in dirt. With the help of silver nanoparticles –for its antimicrobial properties, it is possible to manufacture surfaces specifically designed to be antibacterial or germicidal. [2]

Various products are already commercially available and the product palette ranges from floor coverings to panel products and paints to textiles with an innovative finish that renders them germ-free.

The antibacterial effect of silver results from the ongoing slow diffusion of silver ions. The very high surface area to volume ratio of the nanoparticles means that the ions can be emitted more easily and therefore kill bacteria more effectively. The antibacterial effect itself is also permanent – it doesn't wear off after a period of time. [13]

As the use of disinfectants in health care cannot yet be avoided, it is important that coatings and materials are proven to withstand standard disinfections. In addition, it is also advisable to equip surfaces with an anti-stick function to prevent the buildup of a bio-film of dead bacteria from which new bacteria could eventually grow.

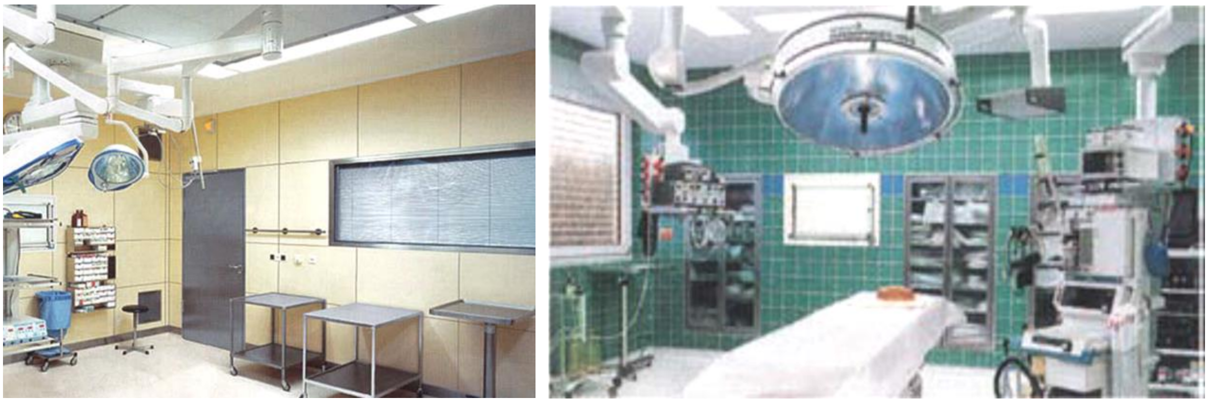


Figure 17. "Hydrotect" tiles, photocatalytic surface with antibacterial effect , Agrob Buchtal Architectural Ceramics, Deutsche Steinzeug AG, Operation theatre interior shows the green antibacterial tiles, Germany, 2019

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3.5.8 Concrete & Steel :

First of all, concrete is one of the most widely produced materials in the world. Each year about one tonne of concrete is produced per human being [about six thousand million tonnes per year], releasing into the atmosphere 1.3 tonnes of $CO2$ for every tonne of concrete produced. On the global scale, concrete production generates over 1.6 thousand million tonnes of carbon, which represents over 8% of total carbon dioxide emissions. There is also considerable waste, seeing as concrete accounts for two thirds of all waste from demolition, only 5% of which at present is recycled. The introduction of nanotechnology will help improve the performance of concrete and reduce energy consumption. The addition of nano-particles, for example, can contribute to improving the durability of concrete through the filling-in of pores, in the same way as the introduction of carbon nano-tubes, which have the potential to effectively prevent the spreading of cracks in concrete, can significantly improve its strength. The addition of a few carbon nano-tubes and Photo catalytic $TiO2$ so, it can improve resistance to compression and flexion [when compared to non-reinforced concrete] and when using nano technology with reinforced concrete for the MMFX steel using Sandvik Nanoflex technology.figure 18,19 then it is called Nano silica and clinker although the cost represents a considerable obstacle in its utilisation. Only with the injection of considerable resources on the part of industry, governments and the academic world, might costs be reduced, eventually making it an economically viable prospect. Chinese researchers have created sensors for monitoring reinforced concrete and these can be incorporated into concrete to enable the structure to be monitored throughout its life-span. [13]
These nano-sensors can collect data regarding the performance of the material, from temperature to humidity; they can also monitor external conditions, such as seismic activity and the building's load, as well as the volume of traffic on the roads and the state of the roads. These are examples of smart materials, in which the micro-electro-mechanical devices are embedded directly in the concrete. There is on-going experimentation with self-repairing concrete; when the latter starts to crack, a micro-capsule embedded in the material breaks and the material then releases into the damaged area a substance [agent], which then contacts a catalyzer, setting in motion polymerisation capable of sealing the crack. In tests carried out, the self-repairing compound retains over 75% of its original strength; it could increase the life-span of structural components two or three times over, when compared to present expectations. [12]

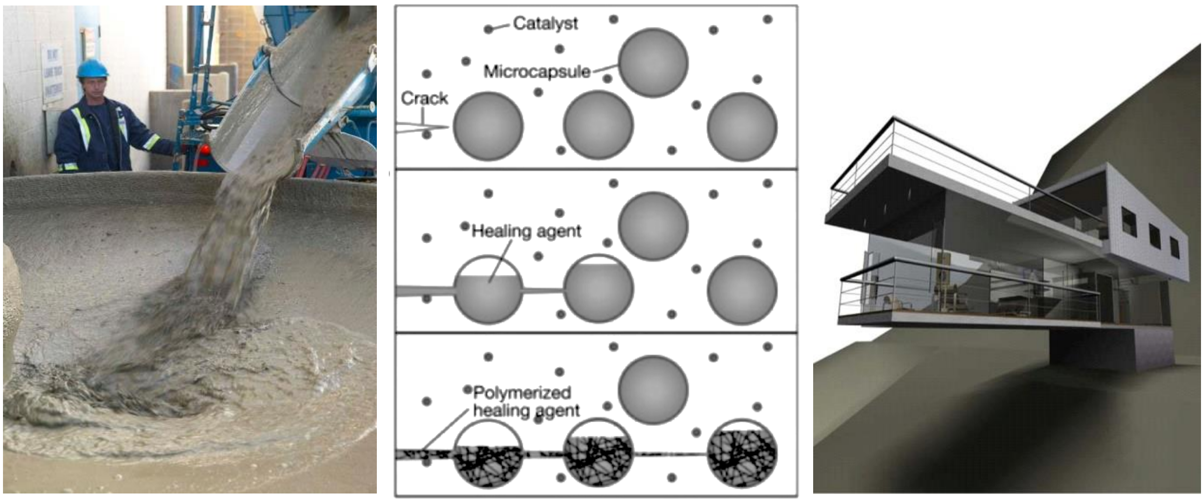

Figure 18. Nano Concrete using Nano silica & clink and Photo catalytic $TiO2$.

Figure 19. MMFX steel using Sandvik Nanoflex technology.

3.6 Nano Devices:

3.6.1 Nano photovoltaic & solar panels: Figure 20

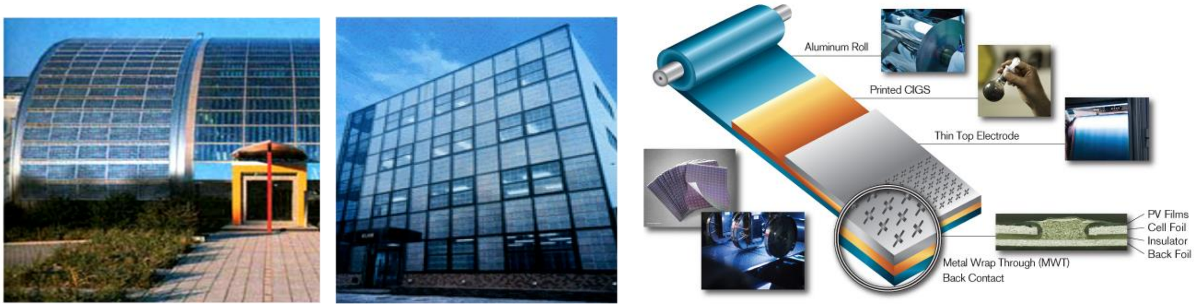

Figure 20. Nano High-throughput roll-to-roll printable semiconductor technology to enable the world's lowest-cost thin-film solar panels.

3.6.2 Optical Fibers and Plasmonics : Figure 21

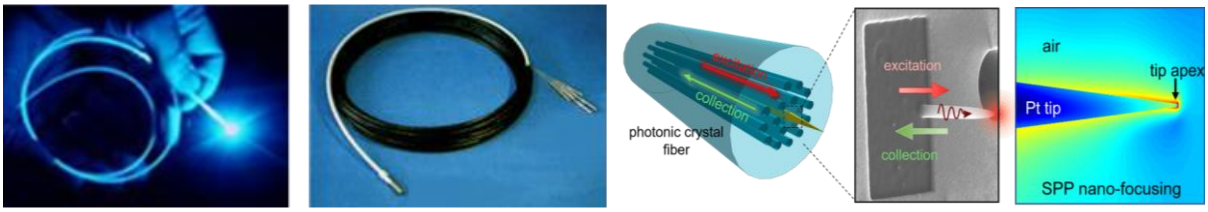

Figure 21. Nanofocusing of Light for Chemical Imaging. [14]

3.6.3 Active Matrix Liquid Crystal Displays [AMLCDs]: Figure 22

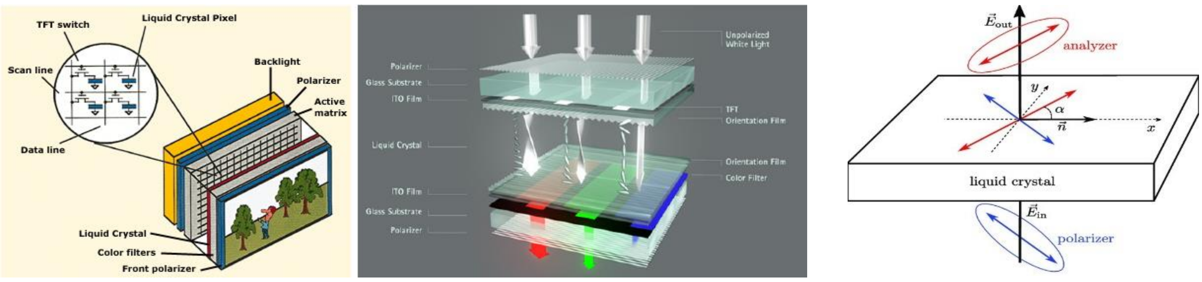

Figure 22. Active-matrix liquid crystal display. [15]

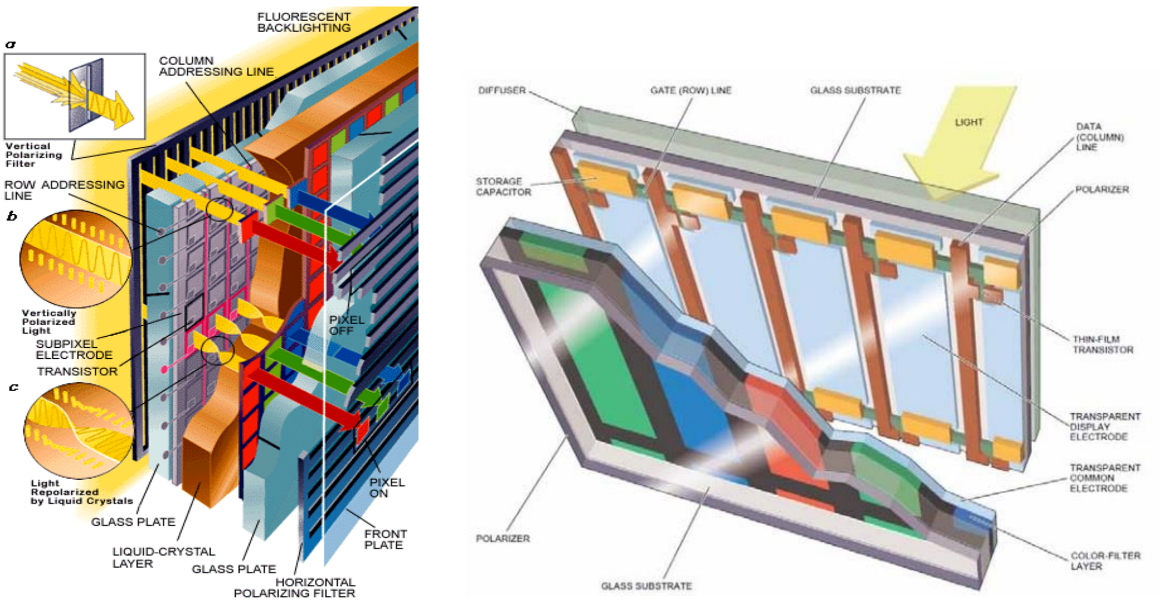

Figure 23. Electrical and Electronics Engineering - EEE - Active matrix liquid crystal displays .

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3.6.4 Nano Sensors: Figure 24,25

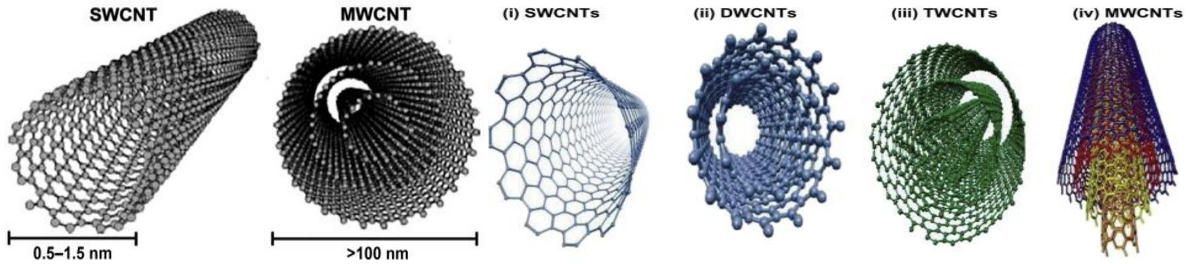

Figure 24. Nanosensors in biomedical and environmental applications: Perspectives and prospects[16]

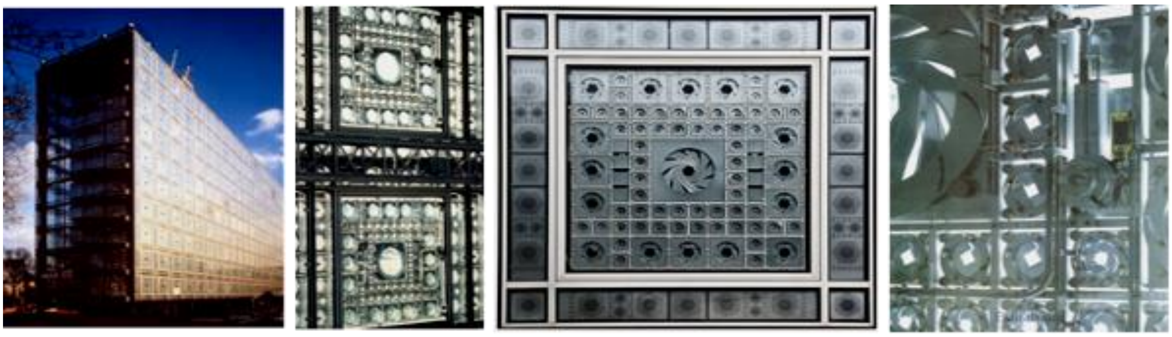

Figure 25. Nanosensors in architecture.

3.6.5 Piezoelectric Sensors: Figure 26

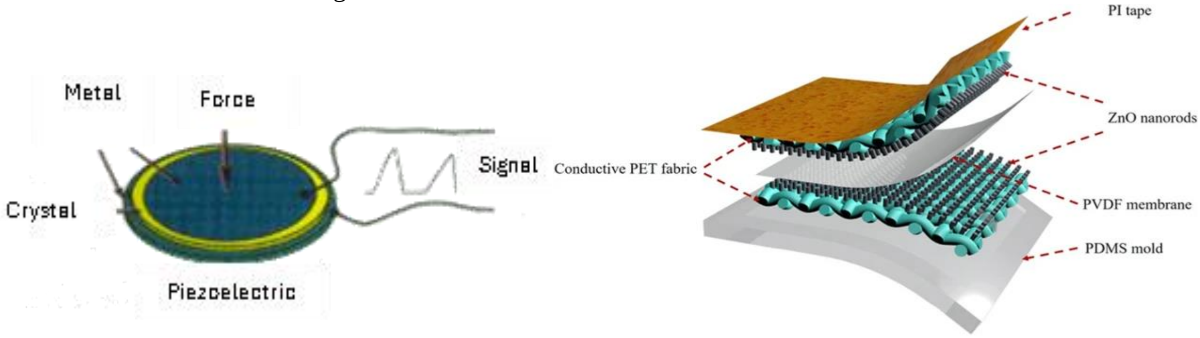

Figure 26. High-performance textile piezoelectric pressure sensor with novel structural hierarchy. [17]

3.6.6 Shape Memory Alloys [SMA]:

Most of the world's refrigeration and heating, ventilation, air-conditioning and refrigeration [HVACR] systems have used vapor compression cooling, **[**Figure.27] which releases harmful chemical refrigerants such as HCF-134c into the environment. This type of cooling exerts stress on metal to change its properties. Smart memory alloys are alloys or mixtures of metals The SMAs deform or change their shape depending on temperature and return to their non-deformed or remembered shape when subjected to the opposite end of the temperature scale. SMAs can generate a significant electrocaloric cooling effect, making them ideal for the cooling and refrigeration industry, allowing it to produce a cooling or heating effect, this is where smart memory alloys can be useful. [18]

Figure 27. Shape Memory Alloys and the Opportunity for Cleaner Energy. [18]

4. The questionnaire:

A questionnaire with the questions was conducted using scale to understand participants perceptions if they aware the nano Materials & nano devices. [Figure 28,29]

There were 10 participants of every target , representing different positions category of the 10 architectural student, 10 postgraduate students, 10 architects, 10 Consultants, and 10 professors as total 50 participants, . Purposive sampling method was used, to ensure that respondents spread evenly in every category. [Authors]

Nano Devices / Participants	Cou.	Solar Panels	Optical Fiber	AMLCDs	Piezoelectric Sensors	sensors	SMA
Arch. Students	10	9	1	3	3	9	4
post Graduated	10	8	1	5	5	8	5
Archetects	10	8	1	8	4	8	9
Consultants	10	10	4	6	3	10	6
Professors	10	10	8	8	8	10	8
Average		90%	30%	60%	46%	90%	64%

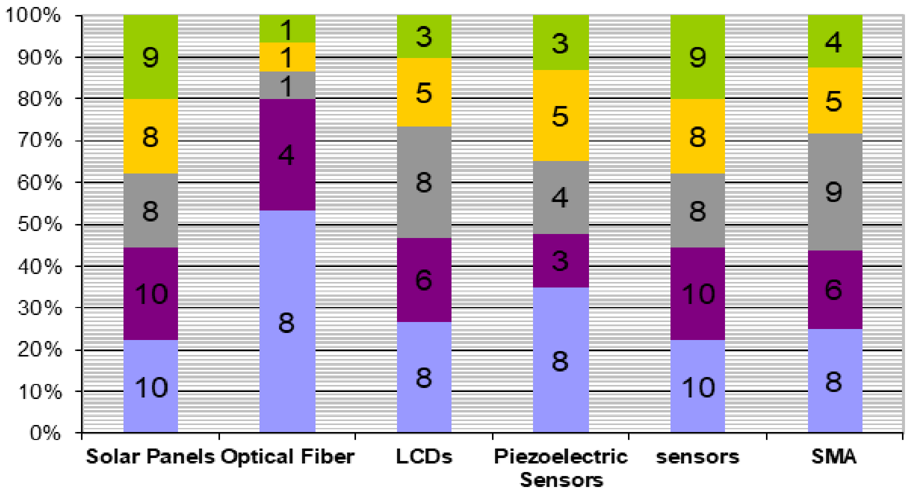

Figure 28. Awareness of nano Devices. [Authors]

Nano Mat / Participants	Cou.	Nano Concrete	Nano Steel	Fiber Glass	Nano coating	photo chromatic glasses	Film insulation	Aerogel
Arch. Students	10	2	9	9	0	0	0	0
post Graduated	10	7	10	8	0	0	0	0
Archetects	10	6	10	8	1	1	1	1
Consultants	10	8	10	10	0	1	1	2
Professors	10	10	10	10	1	1	2	4
Average		66%	98%	90%	4%	6%	8%	14%

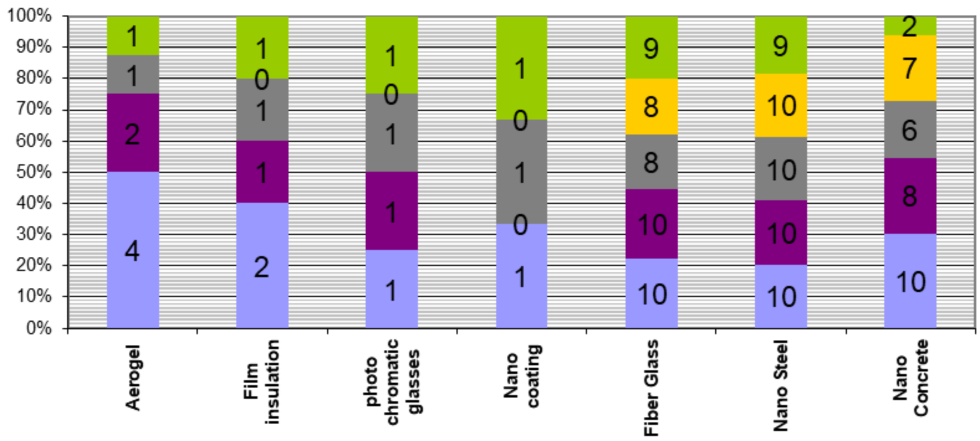

Figure 29. Awareness of nano Materials. [Authors]

5. Results:

- Nanotechnology is one of the new emerging technologies of our contemporary times, because of the international focus on nanoscience. Such technology has made it possible for us to manipulate the matter on an atom-by-atom basis; this is expected to transform and revolutionizes the way we live. Its applications can be submitted in the industrial field, science and our day life; from medicine, and cosmetics to building façades and space elevators. In architecture, it offers a variety of applications, either in designing new materials with the new properties, Nano sensors that can help us inspect the surrounding environment, nanobots that might replace the human labor reducing building time and cost, or even in changing the way the architect think of the forms to design the building. [Authors]
- We can divide nanotechnology by using it in architecture as nano Materials and Nano Devices [table 1]

Table 1. Nano Materials and Nano Devices. [Authors]

Nano Materials	Nano Devices
Aerogel	Nano Photovoltaic
Film insulation	Nano Solar Panels
photo chromatic glasses	Optical Fiber
Nano coating	Active Matrix **L**iquid **C**rystal **D**isplays [AMLCDs]
Nano Fiber Glass	Sensors
Film insulation	Piezoelectric Sensors
Nano Concrete & MMFX steel	Shape Memory Alloys [SMA]

- After gathering the results, they were analysed using ANOVA to test for significant differences between the mean responses to the awareness of nanotechnology based on the participants positions in there work. The following table presents the mean responses from participants for nano materials & nano devices, and the results. [Authors]

- When the questionnaire [about nano devices] is completed, there were 90% of participants awarded photovoltaic and solar panel, 30% of participants awarded Optical Fiber, 60% of participants awarded the Active Matrix **L**iquid **C**rystal **D**isplays [AMLCDs] , 46 % of participants awarded Piezoelectric Sensors, 90% of participants awarded Sensors and 64% awarded Shape Memory Alloys [SMA]. [Figure 30]

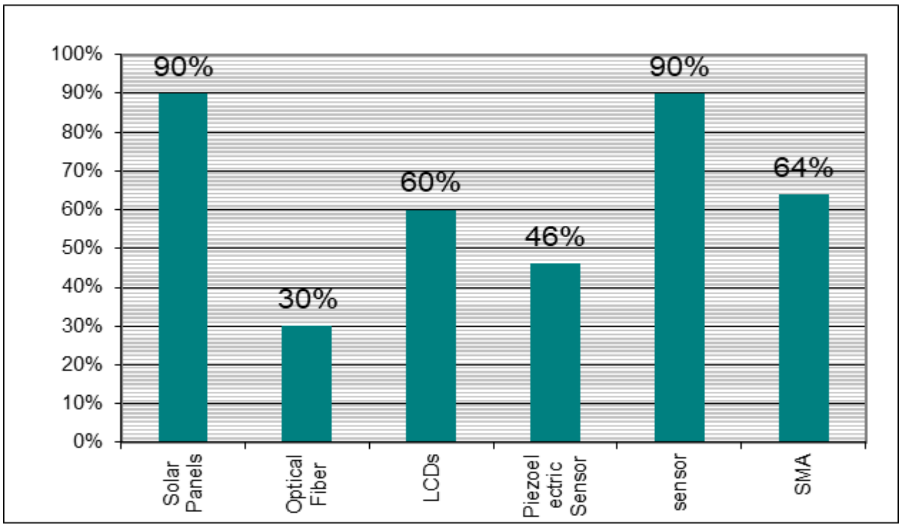

Figure 30. Percentage average of nano Devices participants awareness. [Authors]

- When the questionnaire [about nano matrials] is completed, there were 16% of participants awarded aerogel , 10% of participants awarded film insulation, 8% of participants awarded photo chromatic glasses, 6% of participants awarded nano coating, 90% of participants awarded nano fiber glass, 98% of participants awarded MMFX nano steel and 66% of participants awarded nano concrete. [Figure 31]

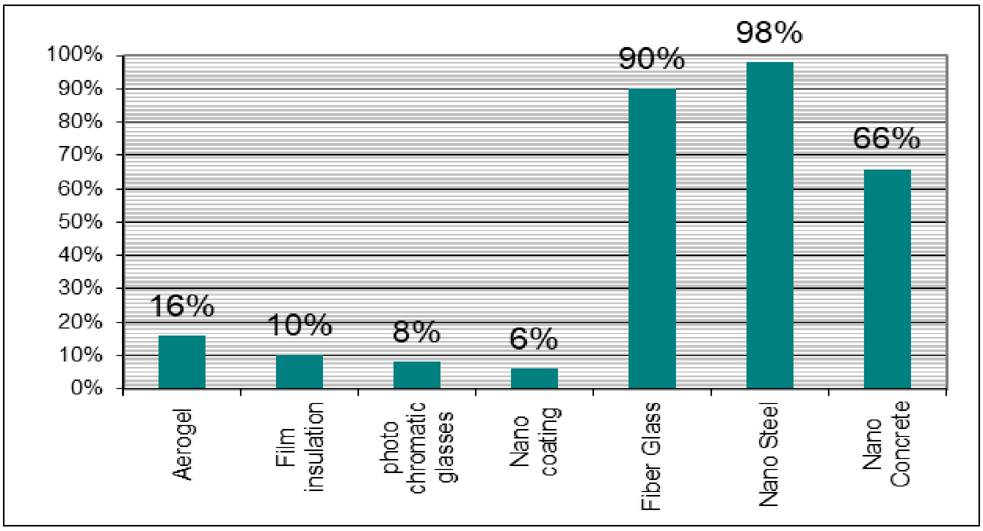

Figure 31. Percentage average of nano Materials participants awareness. [Authors]

In spite of its enormous potential, there are several factors that might impede the adoption of nanotechnology on a large scale: above all the high cost of nano-products compared to conventional ones. Nanotechnology does represent a relatively recent accomplishment and prices are destined to fall, as is usually the case, over the course of time, with all new technology. Secondly, the building market is extremely conservative and therefore tends to proceed cautiously in adopting new technologies; those in the trade seem to know very little about nanotechnology and its potential implications for the building sector. Knowledge and skills are still too fragmentary to enable it to spread extensively in the building sector. Moreover, from the point of view of demand, there will be a certain reluctance regarding the introduction of nanotechnological materials until convincing documentation is produced regarding its functionality and the long-term effects. Finally, there is considerable anxiety about the general public's seeming reluctance to accept nanotechnology. [Authors]

6. Discussion

- Nanotechnology is a fusion technology and therefore incorporates, for instance, bio and information technologies. The synergy effects, resulting from the interface of two or more systems, will amplify the complexity and inevitably exceed the hypothetical consequences of one single technology. [5]
- The world is entering the sphere of nano, even where information and communication technologies have not yet pervaded society at large. In the developing countries, where preindustrialized and post-modern technologies coexist with the newly emerging technologies, nano-engineered commodities and services can be designed for the needs of people belonging to pre-industrialized, post-modern or knowledge societies since no preclusions apply. [10]
- As far as the predictions of nano‘s future are concerned, global trends suggest that nano is gathering momentum. Expansion in scientific research and development, public and corporate investments, public-private partnerships, media coverage, patents, services and devices clearly indicate that nanotechnology is growing rapidly. [7]
- Nano has the potential to become the flagship of the new millennium‘s building methods and architectural style in the developed as well as in the developing worlds. Nanotech will certainly not replace all other technologies used in architecture, but will coexist with and borrow from the technological inventions of the past. It is thus unlikely that the nano era wil replace the digital. Instead, the digital age will converge with the nano, and their synergy effects will lead to fundamental and irreversible alterations in the existing, cultures and institutions of society, societal organization, and various mechanisms and patterns, including the demographic structure of society. [Authors]
- Nanoarchitecture would be the upcoming new architectural trend of the contemporary time. The impact of such new technology will exceed those of the precedent technologies because the intensity of the impact of any phenomenon is positively correlated with its pervasiveness. The circumstances indicate that the possible impacts of nanotech will exceed even those of the past century revolt against classicism. [Authors]

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