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Applications Of Nanotechnology In Office Buildings

تطبيقات النانو تكنولوجي في المباني الادارية

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Abstract:

The study aims to discuss the applications of nanotechnology in architecture, especially in Office buildings. Nanotechnology is one of the most important modern applications that directly affect the characteristics and behavior of the smart materials used in the buildings, which have a direct impact on the use of materials in the internal and external environments. There are many different applications of nanotechnology in Office buildings to achieve the greatest efficiency such as (Carbon Nanotubes (C.N.T) - Temperature regulation: Phase change materials (PCMs) - Air purifying material - Vacuum insulation panels (VIPs) - Fire-proof) by selecting a set of examples of Office buildings that have applied nanotechnology. To the strategy of nanotechnology applications in the Office room.

Keywords:

Nanotechnology – Nano Architecture – Office buildings – Nano material

:الملخص

تهدف الدراسة الى مناقشة تطبيقات النانو تكنولوجى فى العمارة وخاصة فى المبانى الادارية . حيث ان تقنية النانو تكنواوجى من اهم التطبيقات الحديثة التى تؤثر بشكل مباشر فى خواص وسلوك المواد الذكية المستخدمة فى المبانى مما لها تاثير مباشر فى استخدام المواد فى البيئات الداخلية والخارجية . وهناك العديد من التطبيقات المختلفة للنانو تكنولوجى فى المبانى الادارية لتحقق اكبر كفاءة مثل (الانابيب النانونية الكربونية - مواد تنقية الهواء – الواح العزل بتفريغ الهواء – مضاد للهب) وذلك باختيار مجموعة من الامثلة المطبقة لتقنية النانو تكنولوجى . للوصول الى الاستراتيجية تطبيق النانو تكنولوجى فى الفراغ الادارى.

:الكلمات المفتاحية

نانو تكنولوجي – العمارة النانونية – المباني الادارية – المواد النانونية

Research objective:

The objective of this research is to investigate the importance of applying nanotechnology in office buildings in order to achieve a suitable indoor environment to increase the productivity of space user.

Research problem

Many studies were made on Nanotechnology but it didn’t show how it can be applied in an office building although it can be very effective tool in protecting the building from the surrounding environment.

Research methodology

The research starts with a theoretical approach stating the definitions of nanotechnology and its applications, moving to the analytical approach stating some architectural examples showing how the nanotechnology is applied in the office buildings then using the analytical comparative approach to compare examples, ending with applying nanotechnology in an office space.

1- Introduction

New technologies always provide new materials with qualifications and advanced behavior such as smart materials which are considered to be a leap in architecture world with several applications and possibilities.

Through the past years the term "Nanotechnology" was widely used in many fields (Architecture, Medicine, Construction, etc.), this study will try to explain the definition and the applications of Nanotechnology in Architecture and what are the new solutions it will give to the Architects and affect the design process by the coming years.

Before we talk about Nanoarchitecture there are some terms that we have to explain.

2- Nano scale

Most of the measurement prefixes used today originates from Greek and Latin words used in measurements. For example, 'kilo-' is from the Greek word "khilioi" meaning "one thousand" and 'milli' is from the Latin word mille meaning "one thousand" (Allhoff, Lin, & Moore, 2010, p. 3).

Nano is a scale unit, the word Nano is derived from Greek word Nano (in Latin "nannos"), and it means "dwarf". Nanometer (nm) is equal to a million of a millimeter (1/1,000,000 mm) (Leydecker, 2008, p. 12).

3- Definition of Nanotechnology

Nanotechnology has attracted the attention of many disciplines over the past few years.

Dr. George Elvin defined Nanotechnology as "the understanding and control of matter at dimensions of roughly one to one hundred billionths of a meter, is bringing dramatic changes to the materials and processes of science and industry worldwide. $13 billion worth of products incorporating nanotechnology were sold by the year 2006, with sales expected to top $1 trillion by 2017. In 2004, over $8 billion was spent in the U.S. alone on nanotech research and development".

German federal Ministry of Education and Research (BMBF) definition: "Nanotechnology refers to the creation, investigation and application of structures, molecular materials, and internal interfaces for surfaces with at least one critical dimension or with manufacturing tolerances of –typically- less than 100 Nano meters. The decisive factor is that the very Nano scale of the system components results in new functionalities and properties for improving products or developing new products and applications"

4- Nanoarchitecture

4-1- Introduction

As we have been saying before that Nanotechnology is dealing with the properties of the materials, Architects began to look for using this technology in their designs so the usual materials have new characteristics so as to have a positive effect on both indoor and outdoor environments.

4-2- What is Nanoarchitecture?

Nanoarchitecture is the integration between Nanotechnology and Architecture which leads to a new generation of Architectural designs which will affect the built environment.

5- Applications of Nanotechnology in Office buildings

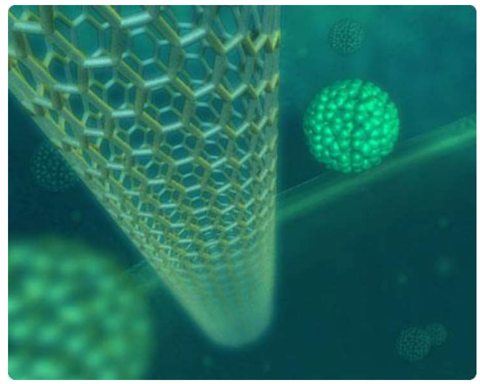


Figure 1: Carbon nanotubes (Leone, 2012)

5-1- Carbon Nanotubes (C.N.T)

Carbon nanotubes (CNTs) are among the most promising types of Nanomaterials for their excellent electrical and mechanical properties and the many potential applications in the building sector (Leone, 2012, p. 7). It makes its way into many architectural components. It was discovered in 1991 by Professor Sumio lijima at the electronics concern NEC in Tsukuba, Japan.

-Carbon nanotubes also have extraordinary mechanical properties. They are 100 times stronger than steel, while only one sixth of its weight. These mechanical properties offer huge possibilities, for example; it is used in the production of new stronger and lighter materials for military, aerospace and medical applications.

-It has been calculated that nanotube-based material has the potential to become 50–100 times stronger than steel at one sixth of its weight (Arnall, 2003, p. 8).

- They have 5 times the Young's modulus and theoretically 100 times the strength of steel whilst it being 1/6th of steel density (Mann, 2006, p. 10).

CNTs have a tensile strength far in excess of steel, yet are flexible and lighter. Their thermal conductivity is also higher than any other known material, exceeding that of diamond. Their key properties of great strength coupled with low weight are predestined for use in future composite materials (Leydecker, 2008, p. 35).

Carbon nanotubes can be mixed with other materials, or applied to surfaces in order to enhance and improve its qualifications, so it is not related to structural materials only but it goes far to other non-structural and coating materials. Therefore expectation put this material as one of the most important factors that will impact architecture. This material and its derivatives will affect external and internal construction materials.

5-2- Temperature regulation: Phase change materials (PCMs)

Figure 2: PCM is applied in an indoor to regulate temperature, (Leydecker, 2008)

Regulating the temperature of buildings consumes vast quantities of energy for both heating and cooling, in the process producing CO2 emissions. With the help of nanotechnology, the energy consumption can be significantly reduced. Latent heat storage, also known as phase change material (PCM), can be used as an effective means of regulating indoor room temperatures. The good thermal retention of PCM 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 (e.g. to protect against overheating).

A good example that illustrates the high thermal capacity of latent heat stores is an ice cube that begins to change to its liquid state at 0°C. The liquid state also begins at 0°C but the energy required for this change of state is equivalent to that required to heat liquid water from 0°C to 80°C. This "hidden" thermal buffer, or the latent thermal storage, is correspondingly large, and this principle can be used for the insulation of buildings using PCM (Leydecker, 2008, pp. 122-123).

5-3-Air purifying material

Though not able to completely purify air, the use of nanomaterial makes it possible to improve the quality of air. It enables unpleasant odors and pollutants to be eradicated. Healthy air is a fundamental and ever more important resource that at the same time is becoming ever more precious. Legislation was initially introduced to reduce the level of outdoor air pollution; the need to improve indoor air quality followed later. The air-purifying properties of nanomaterial are beneficial in both cases and play an important role both for indoor as well as increasingly for outdoor environments (Leydecker, 2008, p. 108).

By the way, air purifying material does not replace ventilation, but improves air quality.

5-3-1- Indoor Air purifying

Figure 3: Air Purifying material in an office building, (Leydecker, 2008)

The indoor air quality is particularly important in industrialized nations where people spend a large amount of time indoors and unpleasant smells or even pollutants are commonly associated problems. Although our sense of smell greatly influences our general feeling of well-being, it is all too often neglected. Together with hazardous substances, unpleasant smells have a significant effect on how we feel. Even the most beautiful space will not feel comfortable if the indoor air quality is disagreeable (Leydecker, 2008, p. 110).

5-4- Vacuum insulation panels (VIPs)

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. These 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 thickness. At only 0.005 W/mK, the thermal conductivity of VIPs is extremely low.

The historical precursor to vacuum insulators is the thermos flask, which functions according to the same basic principle: low thermal conductivity is achieved not, as usual, by enclosing pockets of air but by evacuating the air entirely, i.e. the creation of a vacuum. In thermos flasks the air between a twin-walled glass vessel is evacuated, whilst the cylindrical form withstands the high pressure created by the vacuum. This approach is more difficult for flat insulation layers as they are unable to withstand the pressure. The solution to the problem is the use of an extremely fine fill material with a nanoscalar porosity of around 100 nm. A comparatively low pressure is then sufficient to evacuate the air making it possible to construct panels that can be used in building construction. The thickness of these VIPs ranges from 2 mm to 40 mm.

Vacuum insulation panels can be used both for new building constructions as well as in conversion and renovation work and can be applied to walls as well as floors.

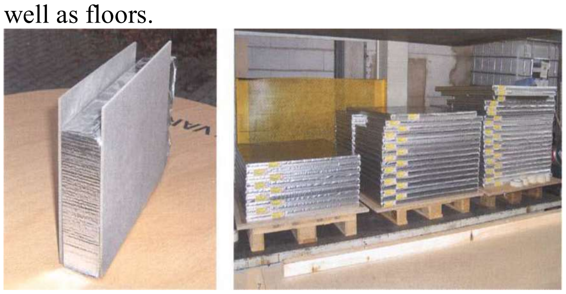


Figure 4: Vacuum insulation panels, (Elvin, 2007)

5-5-Fire-proof

-Highly efficient fire protection.

-Light and transparent.

Figure 5: The gel filling material in the glazing cavity, (Leydecker, 2008)

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 is improved noise insulation.

Flame-resistant lightweight building boards, sandwich constructions made of straw and hemp, are a further interesting application by coating the product in a transparent covering of glasslike particles, it's to render its weatherproof and flame-resistant. The glass-like coating also serves as the adhesive and further flam-retardant additives are not required. It is of particular interest for corridors, foyers and meeting rooms, i.e. wherever fire safety is very important.

6- Case studies

6-1- Shimizu Mega City Pyramid

Project: Shimizu Mega City Pyramid
Architect: Dante Bini
Location: Tokyo, Japan
Description: The Shimizu Mega City Pyramid is a proposed project for construction of a massive pyramid over Tokyo in Japan. The proposed hyper-structure has a footprint of approximately 8 square kilometers. It contains office buildings, residential complexes, and other facilities and It would house 1,000,000 people. The structure would be about 14 times higher than the Great pyramid at Giza which is 146 m, and it would be 2000 meters height. This pyramid would help answer Tokyo's problem of limited areas, although the project would only handle 1/47th of the Greater Tokyo Area's population. Housing and office spaces would be provided by twenty-four or more 30-story high skyscrapers suspended from above and below, and attached to the pyramid's supporting structure with nanotube cables.
Product: carbon nanotubes

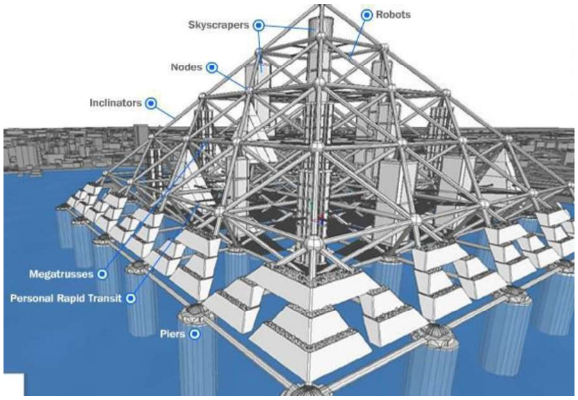


Figure 6: Shimizu Mega City Pyramid detail

https://anarchytects.wordpress.com/2012/12/22/tokyo-mega-pyramid-project-the-future-of-cities/

6-2- "Sur Falveng" housing for elderly people

ARCHITECTURE: Dietrich Schwarz, GlassX AG, Zurich, Switzerland
CLIENT: Jürgen Schwarz
Location: Domat/Ems, Switzerland
PRODUCT: Latent heat storing glass, phase change material (PCM), GLASSXcrystal
MANUFACTURER: GlassX
AREA: 148m2 GlassXcrystal glazing

Figure 7:"Sur Falveng" housing for elderly people interior shot, Zurich, Switzerland, (Elvin, 2007)

An experienced architect, who is also a scientist, developed a latent heat storing glass, which was followed soon after by the founding of a start-up company under the name GlassX AG. Among the projects realized using this glass is a building with 20 disabled-access sheltered flats in the Swiss Alps. All flats have large expanses of south-facing glazing and, depending on the season, the flats are heated actively or from passive solar gain. The central of three cavities of an 8 cm thick composite glass element contains a salt hydrate fill material that functions as a latent heat store for solar heat and protects the rooms from overheating. The latent heat store has a thermal absorption capacity equivalent to a 15 cm thick concrete wall. The glass panel is transparent when the fill material has melted and milky-white when frozen. The material's change of state is therefore immediately reflected in the building's appearance - function and aesthetics are inseparably connected. The buffer function of the latent heat store enables the indoor temperature to be regulated mostly passively, resulting in significant energy savings for heating (and cooling).

Figure 8: "Sur Falveng" housing for elderly people exterior shot, Zurich, Switzerland, (Elvin, 2007)

6-3 - Indigo Tower

Project: Indigo Tower
Architect: 10 Design Architects Team: Ted Givens, Benny Chow, Mohamed Ghamlouch
Location: Qingdao, China
Description: It is a three high-rise building which takes an active stance and attacks the problem of polluted air, by aiming to help purifying the air of our cities. The tower keeps out dirt, grease, and bacteria out of the air. The tower is split into three bars in order to: 1) Increase the amount of surface area. 2) Provide more light to the south face of each bar. 3) Focus and increase wind speed. The tower will be a glowing indigo object at night varying in intensity according to the amount of solar energy collected during the day. This glow will become symbolic of the cleansing, counteracting the yellow haze that appears during daytime hours.
Product: Air purification Nano coating

Nano material used to decrease the amount of pollution. The reaction is triggered by the use of air purification Nano coating on the outer skin of the project.

Figure 9: Indigo tower, china

The used coating-based photo-catalysts can trigger a series of chemical reactions to generate hydroxyl radicals when exposed to sunlight or ultraviolet light.

The reaction is naturally powered by sunlight acting on the titanium dioxide during the day and supplemented by ultraviolet light at night. These ultraviolet lights are powered by energy collected through PV (Photo voltaic) panels during the day.

6-4- Sonnenschiff center

ARCHITECTURE: Rolf Disch, Freiburg, Germany
CLIENT: Solarsiedlung GmbH
Location: Freiburg, Germany
PRODUCT: Vacuum insulation panel (VIP) and phase change material (PCM)
AREA: 6,500m' residential and commercial floor area.

Figure 10: Sonnenschiff centre exterior shot, Freiburg, (Elvin, 2007)

Vacuum insulation panels (VIPs) have been used for insulation and phase change material (PCM) latent heat storage systems for regulating indoor temperatures – both highly energy efficient systems. The V1Ps constitute the insulation of the external walls and window parapets as well as the ventilation flaps on the main facade.

Compared with other insulation materials of the same thickness, they offer ten times better insulation. PCMs in the walls and roof construction store ambient heat as they change material state. As such they help keep rooms cool and passively regulate the indoor air temperature. The concept is rounded off by an ingenious light, ventilation and heating concept. The implementation of a colorful artistic concept gives the building an eye-catching appearance.

Figure 11: Sonnenschiff center interior and exterior shots, Freiburg, Germany, (Elvin, 2007)

6-5- Deutsche Post headquarters

Architecture	Murphy/Jahn, Chicago, IL, USA
Location:	Bonn, Germany
Product	SGG Contraflam fire safety glass
Manufacturer	Vetrotech SaintGobain
Completion	2005
Area	90.000 m2 gross floor area

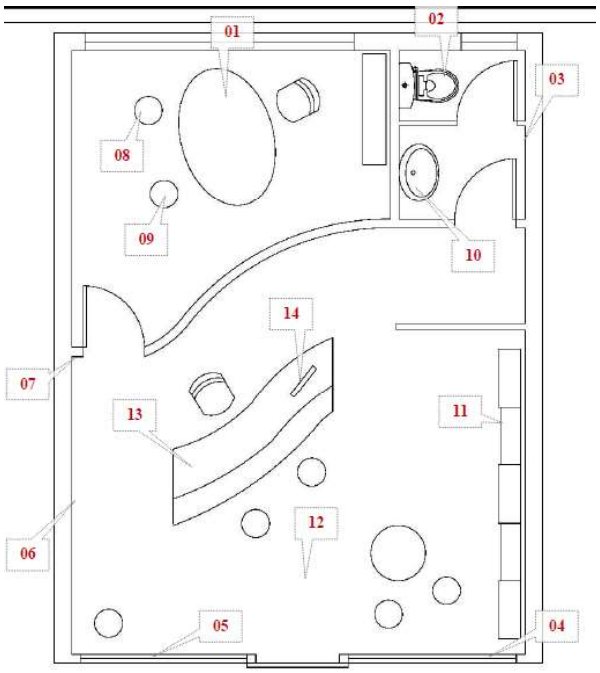
Figure 12: Deutsche Post headquarters, Germany
https://facadeworld.com/2014/07/15/deutsche-post-headquarters-bonn/

The landmark 160m high office tower in Bonn accommodates more than 2000 members of staff. The oval towers façade is clad in high-tech transparent glazing and transparent materials are also used throughout its interiors: glazed partition, glazed staircases and glazed connecting bridges are central elements of the interior design concept. A fire safety glass with a particularly slender profile was selected for the project. Space, form, construction and materials are carefully coordinated, resulting in a harmonious overall concept.

Project / P. O. C.	Shimizu Mega City Pyramid	"Sur Falveng" housing for elderly people	Indigo Tower	Sonnenschiff center	Deutsche Post headquarters
Architect	Dante Bini	Dietrich Schwarz, GlassX AG, Zurich, Switzerland	10 Design Architects Team: Ted Givens, Benny Chow, Mohamed Ghamlouch	Rolf Disch, Freiburg, Germany	Murphy/Jahn, Chicago, IL, USA
Location	Tokyo, Japan	Domat/Ems, Switzerland	Qingdao, China	Freiburg, Germany	Bonn, Germany
Description	Housing and office spaces would be provided by twenty-four or more 30-story high skyscrapers suspended from above and below, and attached to the pyramid's supporting structure with nanotube cables.	A building with 20 disabled-access sheltered flats in the Swiss Alps. All flats have large expanses of south-facing glazing and depending on the season, the flats are heated actively or from passive solar gain.	It is a three high-rise building aiming to help purifying the air of our cities. The tower keeps out dirt, grease, and bacteria out of the air.	Vacuum insulation panels (VIPs) have been used for insulation and phase change material (PCM) latent heat storage systems for regulating indoor temperatures – both highly energy efficient systems.	The landmark 160m high office tower. The oval towers façade is clad in high-tech transparent glazing and transparent materials are also used throughout its interiors.
Product	Carbon nanotubes.	Latent heat storing glass, phase change material (PCM), GLASSXcrystal	Air purification Nano coating.	Vacuum insulation panel (VIP) and phase change material (PCM)	SGG Contraflam fire safety glass.

As we can see from the above table, all the examples are using different types of Nano materials which are structural and non-structural materials, carbon nanotubes help in constructing the building reaching higher levels with light weight construction materials. Other examples show non-structural materials like PCM, VIP, air purifying and fire safety glass, the usage of those materials together help the building to achieve a suitable indoor environment which helps in increasing productivity and work efficiency and reducing building's running cost.

7- Schematic plan for an office room in a bank branch with a general strategic approach for the use of Nanomaterials



01 – **Glass Table**: Anti-fingerprints	08 – **Chairs:** Dirt-repellent
02 – **W.C.:** Easy to clean	09 – **Upholstery:** Air-purifying
03 – **Walls:** Nanoparticles ceramic covering	10 – **Sanitaryware:** Anti-fingerprints
04 – **Window:** Self-cleaning photochromatic or electrochromic	11 – **Screen:** Anti-reflective
05 – **Windows**: Self-cleaning photocatalytic	12 – **Carpet:** Air-purifying
06 – **Walls:** Nanoparticles ceramic covering	13 – **Counter:** Anti-fingerprints
07 – **Switches & Handles:** Antibacterial, non-stick	**14- Screen:** Anti-reflective

8- Conclusion

1. Nanotechnology is a very effective way to help in reducing many harmful effects from the surrounding environment.
2. Nanotechnology reduces the running cost of the building for example using glass coating reduces heat transfer into the building which leads to the reduction of electricity usage in air conditioning.
3. Nanotechnology's applications give the Architects many effective tools and varieties in developing their design ideas.
4. Applying Nanotechnology indoors helps the space user to feel more comfortable and protected from the surrounding harmful effects.
5. Nanotechnology applications increase the user productivity and performance.

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