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## The Role of Nanotechnology Applications in Raising The Efficiency of the Architectural Products in Egypt

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**Abstract:** Nanotechnology is one of the latest fields of technology that have appeared in recent times, and it brings us many surprises every day in different areas of life, especially the field of construction, which is the most critical modern application of nanotechnology, as this technology contributes to improving the properties of materials or adding properties Or producing new low-cost materials with unique thermal, electrical, physical, chemical, and mechanical advantages and properties, which lead to the production of buildings characterized by strength, lightness, durability, and long life, as well as contribute to raising the efficiency of the architectural product.

**Keywords:** nanotechnology, areas of applications of nanotechnology in architecture, factors for raising the efficiency of the architectural product.

### I. INTRODUCTION

The raw and manufactured materials and their characteristics are among the most critical elements affecting the design and construction process, which the architect is interested in raising the efficiency of the architectural product. Nanotechnology is one of the latest sciences that are concerned with materials, as it works on studying material particles at a level of 100 nanometres or less to control the interaction and properties of these particles and thus improving the properties of existing materials or producing new materials that give a highly efficient building.

**The research problem** lies in the fact that the building and construction sector in Egypt is one of the most negatively affecting sectors of the built environment that consumes energy and raw and manufactured materials, which reduces efficiency in general, and despite the presence of many modern technologies such as nanotechnology that contribute to raising the efficiency of the architectural product, Its areas of use are not clear to a large segment of Egyptian architects, due to the lack of scientific research dealing with such a topic. Therefore, **the research aims** to shed light on how to use nanotechnology applications and employ them to raise the efficiency of the architectural product, leading to an appropriate product that contributes to reducing efforts and costs resulting from maintenance. **The research assumes** the possibility of raising the efficiency of the architectural product in Egypt by using nanotechnology applications in architecture. To test this hypothesis, the research is divided into two main parts:

First: The theoretical study through which the basic concepts of nanotechnology and its various applications in the field of architecture are identified at the level of materials and devices, and how to employ these applications to raise the efficiency of the architectural product in the economic, functional, aesthetic, security and safety aspects.

Second: The analytical study, through which a group of architectural projects applied to nanotechnology, are analyzed to emphasize the role of these applications in raising the efficiency of the project, leading to the conclusion of the most frequently used applications.

### II. THEORETICAL STUDY

#### 2-1 Basic concepts of nanotechnology

**The concept of Nano:** Nano means a very small or precise thing in its size (infinitely small things). The word “Nano” appeared at the beginning of the Greek era, as it is derived from the word “Nanos” in the ancient Greek language and means in English “Midget,” meaning the dwarf and fro. From what is known, the concept of nanoscience is the science that means the study of the microscopic world, the world of atoms and molecules, with the study of phenomena associated with minimizing their sizes.

**Nanometre:** A nanometre means that it is a unit of length, as it specializes in measuring microscopic objects that can only be seen under an electron microscope and cannot be seen with the naked eye if the objects are smaller than (10 thousand nanometers), a billionth of a meter. (i.e., one-thousandth of a million) and in the language of numbers (10<sup>-9</sup>m),

i.e., one-millionth of a millimeter, i.e., a thousand times smaller than the micro that is used to measure the dimensions of germs, and the Nano is used as a unit for measuring the diameters of atoms, some molecules, and viruses.

**The concept of nanotechnology:** It is the scientific application of reformulating the arrangement of material atoms to manufacture molecules with specific physical and chemical characteristics that depend entirely on the arrangement that the atoms take to arrange that molecule, for example, precious stones (diamonds) and (coal), which are cheap fuels composed of only carbon atoms. The arrangement of atoms in the diamond molecule differs from that in the coal molecule. New nanomaterials are created due to restructuring the atomic structure on which the materials are located and minimizing their particles and granules.

## 2-2 Uses of Nanotechnology in Antiquity:

Humans intended to use nanotechnology thousands of years ago without knowing the truth of this use. It was used to manufacture steel, rubber, etc., and all uses were made based on random characteristics of atomic sizes. Specifying a specific era or era for using this technology is impossible. The following are some uses of nanotechnology in ancient times:

The use of nanotechnology is ancient and dates back to the Roman civilization and the Chinese civilization in the manufacture of glass; the most prominent example of this: is the famous Roman cup of the Roman king “Lycurgus” in the fourth century located in the British Museum, and it contains nanoparticles of gold and silver that cause a color change



Figure 1 Roman Cup

the angle of incidence of the light from glowing pink to glowing green, Figure (1).

In Christian civilization, church windows are a classic example of the early use of nanotechnology, as nanoparticles of gold are responsible for the bright red color of glass, such as the glass used in Cologne Cathedral dating back to 1280 AD, Figure (2).

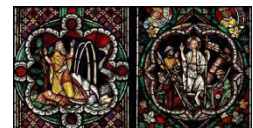


Figure 2 Classical church windows

Arab Muslims are among the first to use this technology, as they manufactured the Damascus sword in the seventeenth century, known for its durability, as it contains nanomaterials that give it mechanical hardness. Al-Saif), which designers employ modern technologies to make durable products that are light in weight, Figure (3).



Figure 3 The Damascus sword

## 2-3 PRINCIPLES OF NANOTECHNOLOGY TECHNOLOGY AND ITS ADVANTAGES

Nanotechnology contains many principles that carry multiple advantages that can be used in all areas of life. Perhaps the most important of these principles is the possibility of controlling the movement of individual atoms accurately and rearranging them, and distinguishing this principle with the possibility of building any material in the universe, as the atom is the building unit of all materials, In addition to the physical and chemical properties of matter at the nanometre scale differ from those at the natural scale, which results in benefiting from new properties. Nanotechnology also relies on the principles of physics, chemistry, biology, and electrical and electronic engineering, which connects the different sciences of these disciplines. One of the most prominent principles of this technology is the possibility of control. It used atoms to make materials and machines, purify them from impurities and defects, and rely on scientific research that can be applied to inventions and practical uses.

We conclude from the previous the possibility of constructing any material in the universe because the atom is the building unit of all materials, as well as discovering distinctive properties of materials that can be used in many inventions and applied fields, in addition to linking different sciences and encouraging scientists with their various specializations to research and study in other disciplines, the most important of which is obtaining materials And machines with better characteristics, savings, and less energy consumption, and turning science fiction into reality.



**2-4 Applications of Nanotechnology in Architecture**

Nanotechnology applications are a multidisciplinary field that provides a wide variety of applications and provides new opportunities for development and progress in various fields, including biology, chemistry, physics, engineering, various industries (spinning, weaving, aerospace, cars, and cosmetics), environmental technology, medicine, pharmacy, military, sports, and entertainment. In addition to the informational, electronic, computer, agricultural, and required fields in general and in the field of architecture in particular, where nanotechnology was able to work within the particles of matter to improve their properties and give them enormous capabilities regarding them contain advantages that they did not have, and also contribute to the manufacture of new construction materials with unique properties and work Lighter and stronger composites, fire insulation, sound absorption, maintenance reduction, water repellency, Nano-impregnated polymers, self-cleaning surfaces, UV protection, water and air purifiers, nanosized sensors, highly conductive microchips, solar cells, and countless other products. It helps the architect to overcome the design and implementation restrictions. Nanotechnology applications in architecture can be classified in terms of materials and devices as follows.

Applications of Nanotechnology in Architecture			
First: Nanotechnology applications in materials			
structural materials	traditional construction materials	Nano additive	Advantages
	concrete	Nano silica (NS)	<ul style="list-style-type: none"> <li>The possibility of using it as a substitute for cement in the concrete mix.</li> <li>Increase the concrete mixture's compressive, flexural, and tensile strength.</li> <li>Reduce the emission of carbon dioxide Co2.</li> </ul>
		Carbon nanotubes (CNT)	<ul style="list-style-type: none"> <li>Increase the compressive and tensile strength of concrete.</li> <li>Accelerate the saturation of concrete with water.</li> <li>Increase the resistance of concrete to frost.</li> </ul>
		titanium dioxide (TiO2)	<ul style="list-style-type: none"> <li>Increase the compressive strength of concrete.</li> <li>Self-cleaning.</li> <li>Purifying the air of pollutants, organic compounds, fumes, and unpleasant odors.</li> </ul>
	Iron	Nanomaterial fillers	<ul style="list-style-type: none"> <li>Increase the physical and chemical properties of iron.</li> <li>Increased bending strength of iron.</li> </ul>
		magnesium and calcium Nano	<ul style="list-style-type: none"> <li>Corrosion and heat resistance.</li> <li>Increased hardness of iron.</li> <li>Producing free designs characterized by high flexibility in forming spaces with vast seas without using structural elements (columns, beams) and enjoying static dynamism.</li> <li>Reducing carbon dioxide emissions.</li> </ul>
	the wood	nanoparticles of aluminum oxide ,	<ul style="list-style-type: none"> <li>Resistant to abrasion, scratching, and heat.</li> <li>Increased hardness of wood.</li> </ul>
		Iron oxide and silver	<ul style="list-style-type: none"> <li>Protect wood from ultraviolet radiation.</li> <li>Resistance to bacteria.</li> </ul>
		Nanoscale titanium dioxide	<ul style="list-style-type: none"> <li>Protect wood from ultraviolet radiation</li> <li>Resistance to fungus, mold, and algae, thus increasing the life span of the building.</li> </ul>
		Nano Silica(NS)	<ul style="list-style-type: none"> <li>Increased wood hardness, waterproofing, and vapor permeability.</li> <li>Abrasion and scratch resistance.</li> </ul>
new construction materials		Advantages	
Translucent concrete		<ul style="list-style-type: none"> <li>Lightweight.</li> <li>Sound and heat insulation.</li> <li>Low absorption of moisture.</li> <li>Achieve transparency and give an aesthetic appearance at night due to the appearance of lighting from the inside to the outside and during the day because it reflects the surrounding environment.</li> </ul>	
Carbon Nanotubes (CNTs)		<ul style="list-style-type: none"> <li>100 times stronger than iron and six times lighter.</li> <li>Dispersion of electromagnetic radiation.</li> </ul>	
Non-structural materials	Complementary materials	Nano additive	Advantages
	the glass	Titanium Dioxide (TiO2)	<ul style="list-style-type: none"> <li>Providing glass with sterilization properties.</li> <li>Resistance to bacteria and dirt.</li> </ul>
		Silica particles (SiO2)	<ul style="list-style-type: none"> <li>Provide anti-fire glass.</li> </ul>
reflective glass		<ul style="list-style-type: none"> <li>Wearereducing the percentage of reflected light from 8% to less than 1%.</li> <li>Improve energy gain and efficiency of photovoltaic systems.</li> <li>The glass is characterized by high transparency, which gives a clear vision and a more attractive aesthetic appearance.</li> </ul>	



			<ul style="list-style-type: none"> <li>• Anti-UV and resistant to high temperatures.</li> <li>• Protection from scratching and external factors.</li> </ul>
		Tin oxide (SnO <sub>2</sub> )	<ul style="list-style-type: none"> <li>• The ability to control the sun.</li> <li>• Providing natural lighting and a suitable climate for the interior spaces of buildings away from the cost of industrial lighting and industrial air conditioning.</li> <li>• Sound insulation and no need for curtains.</li> <li>• Saving energy and thus achieving environmental sustainability.</li> </ul>
		Smart glass (electrochromic glass)	<ul style="list-style-type: none"> <li>• Saving energy in buildings, cars, and planes.</li> <li>• Controlling the temperature and the amount of light entering the space, thus reducing energy.</li> <li>• The ability to resist fire and save maintenance costs.</li> <li>• Improved coloring efficiency.</li> </ul>
	aluminum	<ul style="list-style-type: none"> <li>• Lightweight.</li> <li>• Mildew and water resistance.</li> <li>• Saving energy during manufacturing.</li> </ul>	
	Ceramic tile	<ul style="list-style-type: none"> <li>• Increased strength and durability.</li> <li>• Scratch resistance.</li> <li>• Flexibility and high operability.</li> <li>• Easy to clean and self-cleaning as it is water and repellent-dirt.</li> <li>• Anti-bacterial.</li> </ul>	
	Gypsum walls	<ul style="list-style-type: none"> <li>• Lightweight.</li> <li>• Achieving high strength and hardness.</li> <li>• Rust resistance.</li> <li>• The smoothness of the surface and keeping it clean for a more extended period.</li> <li>• Sound and heat insulation.</li> <li>• Ease of cleaning and resistance to pollution and oiling.</li> <li>• Good resistance to abrasion, acids, alkalis, and weather.</li> </ul>	
	Thermal insulation materials	Advantages	
	Thermal Insulating Material (Aerogel)	<ul style="list-style-type: none"> <li>• High transparency, which results in 91% light transmission per cm<sup>2</sup>.</li> <li>• Low thermal conductivity.</li> <li>• Sound and noise insulation.</li> <li>• Reducing solar heat gain.</li> <li>• Reducing energy consumption and reducing carbon spread.</li> <li>• Resistant to discoloration, mildew, and moisture.</li> <li>• Achieving environmental sustainability.</li> <li>• Eliminate glare and light scattering.</li> </ul>	
	Vicious thermal insulation panels (VIPs)	<ul style="list-style-type: none"> <li>• High heat insulation.</li> <li>• Low thickness.</li> </ul>	
	Phase change material (PCMs) for temperature regulation	<ul style="list-style-type: none"> <li>• The ability to store and release thermal energy during the thawing and freezing process and maintain it.</li> </ul>	
	coating materials	Advantages	
	Self-cleaning coatings (lotus effect).	<ul style="list-style-type: none"> <li>• Self-cleaning.</li> <li>• Sun protection and color fastness.</li> <li>• Significantly reduce maintenance requirements.</li> </ul>	
	Self-cleaning (photocatalytic) coatings.	<ul style="list-style-type: none"> <li>• Water repellent.</li> <li>• Self-cleaning and clean-to-easy surfaces.</li> <li>• Air pollution control.</li> <li>• Blocking UV rays.</li> <li>• Reduced maintenance costs.</li> </ul>	
	Easy to clean coatings.	<ul style="list-style-type: none"> <li>• Easy to clean surfaces.</li> <li>• Repellent to water and oils.</li> <li>• The smoothness of the surface, like the texture of marble.</li> <li>• Save time, effort, and maintenance costs.</li> <li>• Do not rely on solar radiation for cleaning.</li> </ul>	
	Anti-fingerprint coatings.	<ul style="list-style-type: none"> <li>• Anti-appearance of hand fingerprints on the outer surface of the paint through the refraction of light.</li> <li>• Maintaining clean surfaces, thus reducing cleaning and maintenance costs.</li> </ul>	
	Anti-graffiti paints.	<ul style="list-style-type: none"> <li>• Strong water and dirt repellent.</li> <li>• Resistance to writing adhesion on surfaces.</li> <li>• Easy to clean using only water.</li> <li>• Longevity.</li> <li>• Resistance against weather conditions and UV rays.</li> </ul>	
	Anti-bacterial coatings.	<ul style="list-style-type: none"> <li>• Easy to clean surfaces</li> <li>• Resistance to bacteria and germs.</li> <li>• Reducing the use of traditional disinfectants and thus reducing the cost.</li> </ul>	
	Anti-reflective coatings.	<ul style="list-style-type: none"> <li>• High light transmittance of up to 98% in glass and 99% in plastic.</li> </ul>	



		<ul style="list-style-type: none"> <li>Reducing reflected light from 8% to 1%.</li> <li>Improving the building's lighting efficiency by 15%.</li> <li>Improve the transmission of solar energy.</li> </ul>
	UV protection coatings.	<ul style="list-style-type: none"> <li>Transparency of the paint material.</li> <li>Protection from harmful ultraviolet rays and leaving the beneficial rays without blocking the light.</li> </ul>
	Anti-fog coatings	<ul style="list-style-type: none"> <li>Evaporation of the accumulated drops on the roofs of the glass surfaces of the buildings.</li> <li>Reducing ice build-up, thus reducing efforts and maintenance.</li> </ul>
	Fire resistant coatings	<ul style="list-style-type: none"> <li>High resistance against fire and a relatively large surface area make it more effective.</li> <li>Transparency and beautiful visual form in the construction of buildings.</li> <li>Fire resistance and preventing its spread for a long time.</li> <li>Lightweight.</li> </ul>
	Scratch and resistant-abrasion coatings	<ul style="list-style-type: none"> <li>Protection from scratching and corrosion and maintaining the original and aesthetic features of the surfaces.</li> <li>Easy to clean.</li> <li>Transparency of the paint.</li> <li>Protection from heat and UV rays.</li> </ul>

**Second: Nanotechnology applications in devices**

Nanodevices		Advantages	
Purification filters	Air purification	Indoor air purification	<ul style="list-style-type: none"> <li>Eliminate all harmful VOC vapors from the paint.</li> <li>Eliminating 99.7% of influenza viruses and 98% of unpleasant odors.</li> <li>Remove pollutants such as viruses and bacteria without releasing any oxidation into the air.</li> <li>Decomposition of harmful substances into substances such as water and carbon dioxide.</li> </ul>
		Outdoor air purification	<ul style="list-style-type: none"> <li>Eliminate volatile oxides and pollutants, thus achieving outside air quality.</li> </ul>
	Water Purification	<ul style="list-style-type: none"> <li>Detoxification of carcinogenic hydrocarbons in groundwater by adding nano iron.</li> <li>Removal of trichloroethylene from groundwater is 2200 times better by adding gold particles coated with palladium.</li> <li>Altair Nano water treatment</li> <li>Eliminate pesticides, industrial solvents, and germs by adding titanium dioxide (TiO<sub>2</sub>) with the photocatalytic process.</li> </ul>	
lighting	emitting-light diodes (LEDs)		<ul style="list-style-type: none"> <li>Energy conservation by light-emitting diodes is estimated at (82 to 92%).</li> <li>Save energy more than traditional lamps by 82-93%.</li> <li>Economical costs in the long run.</li> <li>Long life span of 35,000-50,000 hours.</li> <li>Lighting speed, lighting color changing property.</li> <li>Efficiency is not affected by color or size.</li> </ul>
	organic emitting-light diodes (OLEDs)		<ul style="list-style-type: none"> <li>Providing many colors in addition to the high quality of the emitted light.</li> <li>More durable and lighter.</li> <li>Flexibility enough to form on any straight or curved surface.</li> <li>Low electrical consumption ranging from 2-10 volts.</li> <li>Brighter.</li> <li>With a thickness not exceeding millimeters.</li> </ul>
	Quantum dot lamps (experimental)		<ul style="list-style-type: none"> <li>Luminance efficiency is 30-40% higher than OLED screens.</li> <li>Pure color lighting.</li> <li>Low power consumption.</li> <li>cost-Low manufacturing.</li> <li>High efficiency, twice the efficiency of OLED screens.</li> </ul>
solar energy	solar energy	silicon solar cells	<ul style="list-style-type: none"> <li>Fivetimes more energy production than conventional cells.</li> <li>Lower cost.</li> <li>Possibility of recycling.</li> <li>Possibility of placing them on windows and curtain walls.</li> <li>Transparent and semi-transparent.</li> <li>Cell thickness is less than conventional cells.</li> </ul>
		Thin film solar cells	<ul style="list-style-type: none"> <li>Less expensive than silicon solar cells.</li> <li>Flexibility of formation on all forms of curved surfaces.</li> <li>Higher efficiency than silicon solar cells.</li> <li>Increasing the storage capacity of batteries reduces the space required for these devices.</li> </ul>
	Energy storage		<ul style="list-style-type: none"> <li>Reduce shipping time.</li> <li>Improved battery efficiency.</li> <li>Reduce carbon emissions.</li> <li>Improve the efficiency of electricity storage.</li> <li>Developing methods of hydrogen fuel production and storage.</li> </ul>



**2-5 Employing nanotechnology applications to raise the efficiency of the architectural product**

The efficiency of the architectural product can be raised through several aspects represented in the economic, functional, aesthetic, and aspects of security and safety. Nanotechnology contributes to achieving these aspects through a set of applications according to its advantages in line with the built environment and its needs. These are identified as follows:

**2-5-1 Employing nanotechnology applications to raise the efficiency of economic aspects**

The aim of studying the economic aspects of the architectural product is to reach distinctive and unique buildings. This efficiency is achieved by achieving a set of elements represented in reducing the operational cost and saving energy in addition to reducing the use of raw materials, reducing work time and effort, as well as reducing the continuous need for periodic maintenance and increasing the life span Nanotechnology contributes to achieving these elements through a set of applications that can be summarized as follows:

Economic aspects										Applications of nanotechnology	
Nano devices			nanomaterials								
energy	lighting	Purification materials	Non-structural materials				Structural materials				
energy storage units Thin film solar cells Silicon solar cells	Quantum dot lights organic light emitting diodes light emitting diodes	Water Purification Outdoor air purification Indoor air purification	coating materials				Thermal insulation materials	Complementary materials	new building material	traditional building materials	Applications of nanotechnology Positive
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

**2-5-2 Employing nanotechnology applications to raise the efficiency of functional aspects**

The functional aspects are represented in achieving the primary goal of the architectural space, which is the space that includes most of the activities practiced by a man with the availability of the required level of thermal, acoustic, and light comfort and good ventilation inside it, in addition to protecting the human being and reducing the harmful adverse effects of the environmental and climatic factors that he may be exposed to. Nanotechnology achieves these elements through a set of applications that can be summarized as follows:

functional aspects										Applications of nanotechnology	
Nano devices			nanomaterials								
energy	lighting	Purification materials	Non-structural materials				Structural materials				
energy storage units Thin film solar cells Silicon solar cells	Quantum dot lights organic light emitting diodes light emitting diodes	Water Purification Outdoor air purification Indoor air purification	coating materials				Thermal insulation materials	Complementary materials	new building material	traditional building materials	Applications of nanotechnology Positive
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

**2-5-3 Employing nanotechnology applications to raise the efficiency of aesthetic aspects**

Aesthetic aspects are directly related to the extent of visual comfort for users, which is often represented in the external and internal shape of the building through diversity and consistency in colors and materials, achieving cleanliness and unpleasant odor, and producing anti-bacterial buildings, mold, fungi, anti-fingerprints, as well as resistant to fog, corrosion, scratching, color change and graffiti In addition to providing lighting that affects the aesthetic appearance of the building without affecting the natural environment or conflicting with the required level of comfort for users, nanotechnology contributes to achieving these elements through a set of applications that can be summarized as follows:

aesthetic aspects										Applications of nanotechnology	
Nano devices			nanomaterials								
energy	lighting	Purification materials	Non-structural materials				Structural materials				
energy storage units Thin film solar cells Silicon solar cells	Quantum dot lights organic light emitting diodes light emitting diodes	Water Purification Outdoor air purification Indoor air purification	coating materials				Thermal insulation materials	Complementary materials	new building material	traditional building materials	Applications of nanotechnology Positive
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

**2-5-4 Employing nanotechnology applications to achieve safety and security aspects.**

Building security and safety standards are represented in factors, determinants, and standards that aim to reduce human or material losses. Dirt and germs, and nanotechnology contribute to achieving these elements through a set of applications that can be summarized as follows:

Security and Safety Aspects										Applications of nanotechnology	
Nano devices			nanomaterials								
energy	lighting	Purification materials	Non-structural materials				Structural materials				
energy storage units Thin film solar cells Silicon solar cells	Quantum dot lights organic light emitting diodes light emitting diodes	Water Purification Outdoor air purification Indoor air purification	coating materials				Thermal insulation materials	Complementary materials	new building material	traditional building materials	Applications of nanotechnology Positive
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		



### 2-6 Matrix for evaluating the efficiency of the architectural product using nanotechnology applications

Through the previous paragraph (employing nanotechnology applications to raise the efficiency of the architectural product), it is possible to reach a matrix conclusion to assess the extent to which aspects of raising the efficiency of the architectural product are achieved by using nanotechnology applications collectively, and it can be reviewed as follows:

Applications of nanotechnology in architecture																																				
Aspects of raising the efficiency of the architectural product		Nano devices							nanomaterials																											
		energy			lighting		Purification materials		Non-structural materials												Structural materials															
		Solar cells					Air purification		coating materials										Thermal insulation materials		Complementary materials			New building material	traditional building materials											
		energy storage units		Thin film solar cells	Silicon solar cells		Quantum dot lights	organic light emitting diodes		light emitting diodes	Water Purification	Outdoor air purification	Indoor air purification	Fire protection coatings.	Anti-corrosive and anti-scratch coating	UV protection coatings	Anti-fog coatings.	Anti-reflective coatings	.Anti-bacterial coatings	Anti-graffiti paints	Anti-fingerprint coatings	Easy to clean coatings	Self-cleaning (photocatalytic) coatings	Self-cleaning coatings (lotus effect)	temperature regulating material	Vicious Thermal Insulation Sheets	Airgel	Gypsum walls	Ceramic tile	aluminum	the glass	Carbon nanotubes	Translucent concrete	the wood	Iron	concrete
Economic aspects	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
functional aspects				√	√	√		√	√	√	√	√		√		√		√		√	√	√	√	√	√			√	√	√	√	√	√	√	√	√
Economic aspects			√	√	√	√							√		√	√	√	√	√	√	√	√			√	√	√	√	√		√	√	√	√	√	
security and safety aspects							√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√	√	√	√	√		√	√	√	√

### III. ANALYTICAL STUDY

#### 3-1 Analytical study methodology

The research is directed towards studying the effect of using nanotechnology applications on aspects of raising the efficiency of the architectural product through an analytical study of a group of selected architectural projects that achieve aspects of raising efficiency due to the use of nanotechnology applications at the level of materials or devices or both.

#### 3-2 Criteria for Selecting a Sample for the analytical study

Three architectural projects were selected according to criteria represented by the diversity of design ideas and the different uses of architectural projects to illustrate the possibility of using nanotechnology applications with any buildings. Indeed, it has been restored and maintained using nanotechnology applications to cover the possible possibilities of application fields; the field of employing nanotechnology applications in the selected sample has expanded, whether at the level of materials only or devices only, or both together, in addition to expanding the achievement of aspects of raising efficiency between (economical - functional - Aesthetic-security and safety) or all of them.



3-3 study samples

3-3-1 The Dalian Museum project

The Dalian Museum is located in the heart of the government district of Dalian, and it is one of the seven projects undertaken by municipalities to support culture and innovation within Chinese cities.



Figure (4) shows the sculptural shape of the museum.

Dalian Museum	
the site	Dalian, China
Date created	2011
designer	Design Office: 10 designs Design team: Ted Givens, Adrian Yau, PebyPratama, Audrey Ma, EwaKoter
building activity	Service - entertaining
Nanotechnology applications used	(nano photovoltaic cells - nano solar cells) Nanodevices (nano-treated aluminum- self-cleaning nano Nanomaterials - heat-coating-nanocoating - anti-bacterial and anti-fungal )airtel (nanomaterialsinsulating
Achieved efficiency factors	Economic-functional-aesthetic-security and safety factors

Project Description

The building consists of two levels below the ground surface and five levels above the ground surface, Figure(5)

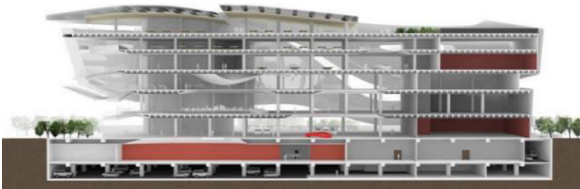


Figure (5) A vertical sector showing the different levels of the building

The internal and external facades (western and eastern) are clad with aluminum treated with nanotechnology to resist rust, pollution, oiling, ease of cleaning, and high sound and heat insulation, in the form of pyramidal cells to disperse winds in winter and improve solar energy strategies, Figure (6).

The building is also provided with nano-materials (airtel) for thermal and acoustic insulation, 10-20% more insulation than traditional materials, and a self-cleaning nano-coating resistant to bacteria and fungi.

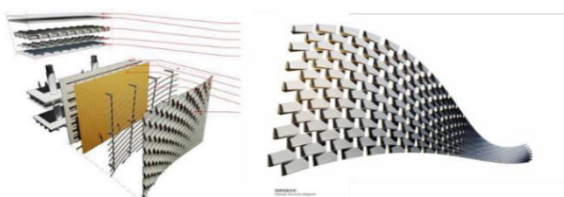


Figure (6) Aluminum cladding treated with nanotechnology used in the eastern and western facades.

The building uses nanocoatings for self-cleaning, purifying the surrounding air, and resisting bacteria and fungus on the external walls. The building relies on natural lighting during the day and nano-photovoltaic cells at night, as energy is collected in the morning to feed the building with lighting at night. The main facade facing government buildings is illuminated in golden color to give a distinct visual image of the building—figure (7).

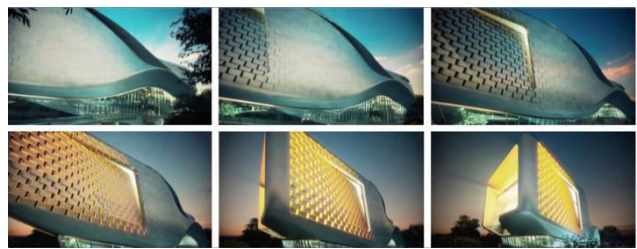


Figure (7) The shape of the facades, day and night, increases the strength of the visual and mental image of the museum.

Aspects of raising the efficiency achieved in the project

**Economic aspects:** These aspects are achieved by providing the energies consumed in the building’s needs, such as natural lighting and air purification, as a result of the building’s reliance on nanotechnology using solar and photovoltaic nano cells and nano energy storage units to feed the building with natural lighting at night and the use of nanomaterials for thermal insulation, as well as providing maintenance work and reducing The cost as a result of the use of nanocoatings that resist bacteria, fungi, self-cleaning, and the use of nano-treated aluminum cladding to resist rust, pollution, and oil, thus increasing the life span of the building.

**Functional aspects:** These aspects are achieved by providing natural lighting as a result of the use of nano-photovoltaic cells, as well as providing good ventilation as a result of the use of self-cleaning and air-purifying coatings, in addition to achieving thermal and acoustic insulation for users as a result of the use of nano-treated aluminum panels and nano-materials (airtel) for sound and heat insulation.

**Aesthetic aspects:** These aspects are achieved by maintaining the cleanliness of the building as a result of using nanocoatings for self-cleaning and resistance to bacteria and fungi, thus maintaining a clean environment, which gives an aesthetic appearance to the place.

**Aspects of security and safety:** These aspects are achieved by purifying the air surrounding the building as a result of the use of nanocoatings for self-cleaning, resistance to bacteria and fungi, air purification, as well as the use of nano-treated aluminum first to resist Pollution and oil, thus achieving a clean and healthy environment for users.

**Nanotechnology applications used in the project according to the evaluation matrix**

Applications of nanotechnology in architecture										
Aspects of raising the efficiency of the architectural product	Nano devices			nanomaterials						
	energy	lighting	functional materials	Non-structural materials				Structural materials		
	Solar cells		Air purification	coating materials			Thermal insulation materials	Complementary materials	New building material	traditional building materials
	energy storage units Thin film solar cells Silicon solar cells Quantum dot lights Organic light emitting diodes Light emitting diodes	Water Purification Outdoor air purification Indoor air purification Fire protection coatings Anti-corrosive and anti-scratch coating UV protection coatings Anti-fog coatings Anti-reflective coatings Anti-bacterial coatings Anti-graffiti paints Anti-fingerprint coatings Easy to clean coatings Self-cleaning (photocatalytic) coatings Self-cleaning coatings (lotus effect) Temperature regulating material Viscous Thermal Insulation Sheets	Gypsum walls Airtel Ceramic tile aluminum the glass Carbon nanotubes Translucent concrete the wood Iron concrete							
Economic aspects	✓				✓		✓	✓		
functional aspects	✓				✓		✓	✓		
Economic aspects	✓				✓		✓	✓		
security and safety aspects					✓		✓	✓		

**3-3-2 Strucksburg housing Hamburg**

It is a residential complex (figure 8), the architects chose to renovate its facades with self-cleaning nanocoatings in 1970, and the self-cleaning function was emphasized because it rains heavily in Hamburg.



Figure (8) shows the Strucksburg group of residential blocks

Strucksburg housing	
the site	Hamburg, Germany
Date created	2007
designer	Renner Hainke Wirth Architekten
building activity	residential
Nanotechnology applications used	Nanomaterials (aerogel) - nano-treated glass - lotus effect self-cleaning coating
Achieved efficiency factors	Economic-functional-aesthetic factors

**Architectural description**

This residential complex comprises a high-rise building and several tiered multi-story residential blocks. The heights of this building have been renovated and covered with nanomaterials for thermal insulation (airtel). This highly transparent material allows light transmission up to 91% and removes glare and light scattering. It has low thermal conductivity, and sound and heat insulation resists discoloration, mildew, and moisture. The material is composited with a



Figure (9) Renovating the building's elevations and covering them with a thermal insulation system with light beige and red paint

Self-cleaning lotus effect nano-coating is dyed in light beige and red as part of the redesign.

Also, the window cavities were given prominent colors (Figure 9). The entrances to the house became more prominent. The wired glass was replaced with transparent glass treated with nanotechnology for self-cleaning and air purification. The building is energy-saving by 50-65% due to nanotechnology applications in renovation work.

**Aspects of raising the efficiency achieved in the project**

**Economic aspects:** These aspects are achieved by providing the energies consumed in the building's needs, such as (achieving natural lighting, cooling, and heating processes) as a result of the building's reliance on nanotechnology in the outer shell, where it consists of nanomaterials for thermal insulation (airtel), which work on light transmittance by 80% and reduce Gaining heat in the summer and retaining it in the winter and the vehicle with a self-cleaning nano-coating, which works to reduce the cost and maintenance operations in addition to the use of self-cleaning treated glass.

**Functional aspects:** These aspects are achieved by providing natural lighting and good ventilation due to the use of heat-insulating aerogels, which reduce heat gain, act as sound insulation, and contribute to light permeability, thus achieving thermal, acoustic, and light comfort.

**Aesthetic aspects:** These aspects are achieved by providing a clean environment and aesthetic appearance due to using aerogels combined with nano-coating for self-cleaning and nano-treated glass for self-cleaning.

**Aspects of security and safety:** These aspects are achieved by providing a clean and healthy environment as a result of the use of airtel to resist mold and moisture, reduce solar heat gain, reduce carbon diffusion, and remove glare and light scattering, in addition to the use of nano-treated glass for self-cleaning.

**Nanotechnology applications used in the project according to the evaluation matrix**

Applications of nanotechnology in architecture										
Aspects of raising the efficiency of the architectural product	Nano devices			nanomaterials						
	energy	lighting	functional materials	Non-structural materials				Structural materials		
	Solar cells		Air purification	coating materials			Thermal insulation materials	Complementary materials	New building material	traditional building materials
	energy storage units Thin film solar cells Silicon solar cells Quantum dot lights Organic light emitting diodes Light emitting diodes	Water Purification Outdoor air purification Indoor air purification Fire protection coatings Anti-corrosive and anti-scratch coating UV protection coatings Anti-fog coatings Anti-reflective coatings Anti-bacterial coatings Anti-graffiti paints Anti-fingerprint coatings Easy to clean coatings Self-cleaning (photocatalytic) coatings Self-cleaning coatings (lotus effect) Temperature regulating material Viscous Thermal Insulation Sheets	Gypsum walls Airtel Ceramic tile aluminum the glass Carbon nanotubes Translucent concrete the wood Iron concrete							
Economic aspects							✓	✓		✓
functional aspects							✓	✓		✓
Economic aspects							✓	✓		✓
security and safety aspects							✓	✓		✓

**3-3-3 Indigo Tower**

As a result of the problems of environmental and urban pollution that significant cities are exposed to, the Hong Kong-based IO company has worked to develop a series of projects to improve the urban environment. The Indigo Tower project (Fig. Air by a combination of solar and nanotechnology technologies.



Figure (10) Indigo Tower, using ultraviolet rays at night

Indigo Tower	
the site	Qingdao, China
Date created	future proposal
designer	Ted Givens, Benny Chow, Mohamed Ghamlouch
building activity	Mixed uses (residential-administrative-commercial)
Nanotechnology applications used	Nanomaterials (nano-treated glass - self-cleaning coating) NNanodevices (lighting - nano solar cells - energy storage units)
Achieved efficiency factors	Economic-functional-aesthetic-security and safety factors

**Project Description**

The Indigo Tower consists of three separate towers. They are linked by bridges (11) to increase the surface area of the facades, expose larger areas to southern lighting, and create a pressure difference to increase the wind speed between the towers to achieve natural ventilation and increase the effective area to maximize the role of titanium dioxide.

All units in the building are on two floors (duplexes) to reduce the movement of electric elevators and create a natural separation between living and sleeping.

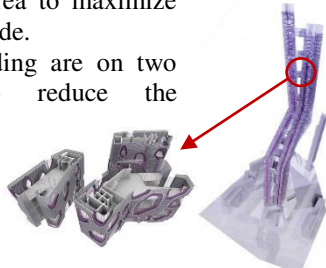


Figure (11) The mass division of the Indigo Tower

Each unit also contains a small garden to create recreational green areas and adjust the humidity levels in the units. The tower also provides each unit with a panoramic view on four facades. The outer cover consists of glass treated with nanotechnology by adding (TiO<sub>2</sub>) and titanium panels treated with Nano-coating for self-cleaning using dioxide Titanium also performs the photocatalytic process as a result of the interaction of (TiO<sub>2</sub>) with ultraviolet (UV) rays, which results in the property of self-cleaning and combating air pollutants, in addition to the presence of Nano-photovoltaic cells that give night lighting to the tower thanks to solar Nano-cells through ultraviolet rays that Collected during the day, stored, and then powered by Nano photovoltaic cells, the tower will glow at night, varying in intensity according to the amount of solar energy collected during the day.

**Aspects of raising the efficiency achieved in the project**

**Economic aspects:** These aspects are achieved by saving the energies consumed in lighting as a result of the use of solar and photovoltaic Nano cells and nano cell units that store ultraviolet rays and discharge them at night, as well as saving the energies consumed in air purification and maintenance work as a result of the use of nanocoatings for self-cleaning and air purification.

**Functional aspects:** These aspects are achieved by purifying the air and resisting bacteria and fungi due tousingNanocoatings for self-cleaning and air purification. **Aesthetic aspects** are achieved by providing an aesthetic and clean environment usingNanocoatings for self-cleaning and air purification.

**Aspects of security and safety:** These aspects are achieved by providing a clean and healthy environment that purifies the surrounding air and resists bacteria and fungi due tousingNanocoatings for self-cleaning and air purification.

**Nanotechnology applications used in the project according to the evaluation matrix**

Aspects of raising the efficiency of the architectural product	Applications of nanotechnology in architecture																								
	Nano devices				nanomaterials																				
	energy	lighting	Purification materials		Non-structural materials				Structural materials																
	Solar cells		Air purification		coating materials				Thermal insulation materials	Complementary materials	new building material	Traditional building materials													
	Thin film solar cells	Quantum dot lights	Water Purification		UV protection coatings	Anti-fog coatings	Anti-reflection coatings	Anti-bacterial coatings	Anti-graffiti paints	Anti-fingerprint coatings	Easy to clean coatings	Self-cleaning (photocatalytic) coatings	Self-healing coatings (heal effect)	temperature regulating materials	Various Thermal Insulation Sheets	Arggel	Gypsum walls	Ceramic tile	aluminum	the glass	Carbon nanotubes	Thermoset concrete	the wood	iron	concrete
Economic aspects	✓	✓										✓								✓					
functional aspects	✓																				✓				
Economic aspects	✓																					✓			
security and safety aspects													✓									✓			



3-3 Results of the analytical study

Through the analytical study of a group of different architectural projects used for nanotechnology applications, whether at the level of nanomaterials or Nanodevices, or both together, and through the deduced evaluation matrix, we find that the projects that have been implemented are of high-efficiency thanks to the use of nanotechnology applications according to the building’s need, function, and environment of origin In it, the following is a comparison between the architectural projects that were analyzed to conclude and limit the range of nanotechnology applications

Applications of nanotechnology in architecture																															
Aspects of raising the efficiency of the architectural product	Nano devices						nanomaterials																								
	energy		lighting		Purification materials		Non-structural materials								Structural materials																
	Solar cells		Quantum dot lights	organic light emitting diodes	light emitting diodes	Water Purification	Air purification		coating materials						Thermal insulation materials		Complementary materials		New building material	traditional building materials											
	energy storage units	Thin film solar cells					Silicon solar cells	Outdoor air purification	Indoor air purification	Fire protection coatings.	Anti-corrosive and anti-scratch coating	UV protection coatings	Anti-fog coatings.	Anti-reflective coatings	Anti-bacterial coatings	Anti-graffiti paints	Anti-fingerprint coatings	Easy to clean coatings	Self-cleaning (photocatalytic) coatings	Self-cleaning coatings (lotus effect)	temperature regulating material	Vicious Thermal Insulation Sheets	Airgel	Gypsum walls	Ceramic tile	aluminum	the glass	Carbon nanotubes	Translucent concrete	the wood	Iron
	Dalian Museum	√																		√		√									
Strucksbar g housing																√			√					√							
Indigo Tower	√	√													√									√							
The number of repetitions	1	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	1	-	-	2	-	-	1	2	-	-	-	-

that are most widely used.

Through this comparison of the results of the analytical study, it becomes clear to us that several points can be summarized as follows:

The rate of use of **nanomaterials** in the examples under the study of glass, self-cleaning Nanocoatings with the photocatalytic feature, and thermal insulation materials, aerogel, comes first in terms of use, followed by the use of aluminum materials, self-cleaning Nanocoatings (with the lotus effect, and antibacterial Nano-coatings). At the same time, other materials have yet to be used. And the use rate of Nano-devices in the examples under study shows that the use of solar energy devices comes in the first place as it was used on a large scale, followed in the second place by energy-storage devices. Nano-devices were not used for lighting and air and water purification.

IV. EXPERIMENTAL RESULTS

After shedding light on nanotechnology and its applications in architecture to raise the efficiency of the architectural product, we find that nanotechnology has opened broad horizons for designers because of the unique capabilities and applications it provides that were, in the past, a path of imagination. The most important findings of the research can be reviewed through the following points:

- The possibility of controlling the movement of atoms and thus the possibility of building any material in the universe, as the atom is the building unit of all materials.
- Nanotechnology plays a significant role in architecture and the development of the built environment through various nanotechnology applications.



- The use of nanotechnology applications in architecture improves the performance of many building and cladding materials. It removes environmental pollution, thus raising the efficiency of the architectural product in terms of economic, functional, aesthetic, and security aspects.
- The possibility of applying nanotechnology to new and existing buildings to improve efficiency.
- The application of nanotechnology in architecture raises the efficiency of the architectural product without hindering the design process in terms of the use of any architectural character, a specific color, or any process involved in the design and implementation.

#### V. CONCLUSION

Through this research, the fields of nanotechnology applications in architecture were identified by reviewing their various characteristics and advantages and how to employ them to raise the efficiency of the architectural product at the level of economic, functional, aesthetic, security, and safety aspects, as well as emphasizing the role of this technology by analyzing a group of architectural projects with high-efficiency thanks to the application This technology.

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