

The Influence of Nanotechnology Applications in the Architecture of Medical Facilities

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ABSTRACT: Interior Design and material finishes are important factors in the design of healthcare facilities environment. Space components like floors, ceilings, and wall coverings are very important design elements that play a significant role in keeping the indoor environment of the medical facilities healthy and clean, so the selection process of the finishing materials during the design process and the properties of these materials should be considered as a priority. Hospitals and medical facilities need specific material finish characteristics to be used in all the utilities and spaces in the building, especially in critical areas such as surgery, intensive care and emergency units, as these materials supposed to be a protection level against moisture penetration, bacterial infections and growth of mildew. The research problem is crystalized as that the healthcare facilities in Egypt often suffers from contamination, infection and deterioration conditions, this is because of the bad behaviour and bad design solutions, which result in a negative impacts on the patients and staff health condition, the research will take a theoretical path discussing the different applications of nanotechnology in architecture and how they contribute into raising healthcare facilities efficiency, Nanotechnology plays an important role in The hygienic design of the interior environment in medical building with the help of nanomaterials. Hence, the research aims to explore new framework for using the nanomaterials in the healthcare buildings in Egypt.

KEYWORDS: Interior Design, Healthcare Architecture, Nanotechnology, Nanomaterials.

I. INTRODUCTION

Human's health is a very important need to keep a healthy community; however, it's common to get infected by different factors even in the therapeutic and medical facilities, that's called healthcare-associated infection (HIAs) infections, this type occurs in medical places where people are receiving treatment. Human's life is surrounded by germs in the air, water soil and their bodies, these germs can be helpful to the body and health and also can be harmful and cause infections and diseases. Otherwise, healthcare design is a new approach that investigates the needs of psychological and social of a human, as a new perspective on healthcare, in addition to concerning conventional biomedical and economic aspects. As part of this design approach, interior design of the healthcare facilities is considered a major vital element in the whole life span of the medical and therapeutic facilities. Interior finishes in the medical architecture is very important to be chosen well during the design process, these finishes include floors, ceiling, walls, furniture and medical equipment. Nanotechnology is the technology of the 21 century and the future, nanotechnology now is included in everything in our life in all the different fields. Nanotechnology in the architecture field witnessed huge developments in the materials industry.

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II. RELATED WORK

This work focuses and highlights the futuristic role of nanotechnology and its expected impact to the architectural field especially in the healthcare sector, it can be claimed that using such technology, applications and new materials into the built environment can end up increasing and raising the efficiency factor and functionality in the sector of healthcare architecture. This paper discusses the nanotechnology definition and carbon morphologies, which they are considered a main component of the Nano products, the paper also discusses the types of nanotubes and their properties. In this paper a discussion for a vast variety of nanotechnology applications in architecture for a sustainable design solutions for the interior environment, especially for the medical and healthcare interior design, in this paper a global survey were made for a different healthcare and medical facilities case studies and how they managed to apply the nanotechnology in different parts of the interior in order to raise the built environment efficiency, which is the main objective for the research.

III. NNANOTECHNOLOGY DEFINITION

Nano means small and its origin became from the Greek word Nanos (Latin nanus) means “dwarf” and this according to its very small sizes, as the nanometer is about one millionth of a millimeter (1/1000, 000) mm and a billionth of a meter (1 / 1,000,000,000) m. In December 29th 1959 at Caltech University Physicist Richard Feynman spoke for the first time about the manipulation of matter on a very small scale. He talked about the possibility of handling single atoms in a highly controlled manner, which inspired the beginnings of a new and fascinating and exciting field of study known as nanotechnology We can say that the simple known definition of the nanotechnology is the manipulation of matter in the level of molecules and atoms in the way of changing materials properties by enhancing them to gain desired properties. We can imagine that the scale of nanometer is about 80,000 times the diameter of a hair and the size of one Nano is about 5 to 10 atoms together, so we are dealing with tiny particles under the size of 100 nm. The German federal ministry of education and research put a definition that summarizes the nanotechnology as follows: Nanotechnology refers to the creation, investigation and application of structures, molecular materials, internal interfaces or surfaces with at least one critical dimension of with manufacturing tolerances of less than 100 nanometers. 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”. (Sylvia Leydecker 2008) Nanotechnology now is applied in different fields as it is an enabling technology a fundamental one that helps to make other technological developments possible. The use of nanotechnology in the construction field usually involves the optimization of existing products or common materials by improving and upgrading them with new functionalities and properties that can't be done without using the nanotechnology. This helps make materials and products more efficient, economical, conserves resources and protection from damage. Nanotechnology means the ability to create the materials and devices through changing the structure of molecules, atoms, and super-molecular which named by nano-scale to control the properties of matter. Nanotechnology has a lot of inclusive definitions mentioned in previous researches, however, the main concept is the changing of particles size as shown in Fig.1. In other words, the nano-meter (nm) scale dramatically impacts on the properties of materials that equal 10⁻⁹ meter(m).

IV. CARBON NEW MORPHOLOGIES

The carbon is the nanomaterial that has the greatest and most interesting innovation potential, it occurs in two vital primary morphologies, the first one is in a form of diamonds which is the hardest famous natural material in the world, the second morphology is a graphite a particularly soft material, but the carbon fullerenes is added to these vital primary morphologies for lying between them. A group of scientists at 1985 find out through an experiment designed for outer space that nature itself produces C60 and C70 carbon molecules. The name Buckminster fullerenes is derived from the formal similarity of C60 molecule to the geodetic dome that was designed by the American architect Buckminster fuller. Carbon molecules or Buckminster fullerenes are also called Bucky balls.

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Buckyballs Carbon Molecule C60: This molecule is the most rounded and symmetrical. It consists of 60 carbon atoms and a diameter of 0.7 nm forming a shape like sphere consists of 12 pentagons and 20 hexagons as shown in figure (1) the difference between the structures of both types of buckyballs.

Buckyballs Carbon Molecule C70: The same thing with the C70 but with a larger number of atoms and with elliptical shape like an American football as shown in figure (1).

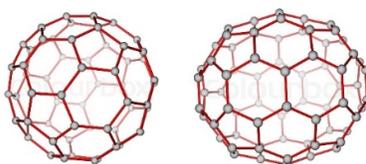


Figure 1: Buckyballs different structure which are Carbon molecule C60 on the left and C70 on the right

V. CARBON NANOTUBES

The current stars of the Nano world are another type of the fullerenes best known as carbon nanotubes (CNT) they were discovered in 1991 by prof.sumio iijima in japan. These Nanotubes consist of single walled (SWNTs) or multi walled (MWNTs) carbon tubes of rolled layers of graphite as shown in figure (2) which explains the difference between both types and their structure formation. They have the diameter of a one and a few nanometers and can be several nanometers long these nanotubes have some properties like they are flexible, lighter, have a tensile strength far in excess of steel, their thermal conductivity is higher than any other known material even more than diamond, So they can act as a semiconductor or as a conductor as their electric conductivity is excellent and they are always mixed with other materials or applied to surfaces all of these properties make it the best raw material for the future. Nanoparticles can be produced from different substances. The most common Nano raw materials include polymer emulsions, aerogel and zeolites, carbon black, dendrimers, Nano silica and metallic nanoparticles, titanium dioxide, ceroxide and aluminum oxide.

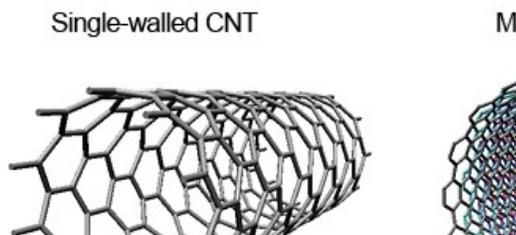


Figure 2: Single walled carbon nanotubes and multiwalled carbon nanotubes structure formation

VI. NANOTECHNOLOGY APPLICATIONS AND FUNCTIONS

Nowadays nanotechnology is being applied in most of our daily lives products in all fields that include architecture, construction, energy, environment, and food, industrial, medical and transportation, this chapter will discuss both the daily life applications and the architectural applications of nanotechnology. Nanotechnology plays a vital and major role in many branches and fields, the following examples represent some of these applications: cosmetic industry, transportation field, medical field, environmental technology, warfare and military weaponry, also applied in the field

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of food and textiles. Nanotechnology is being used widely in the construction and architecture field. The most compelling argument for using nanotechnology in architecture is the greater energy efficiency that provides. Nanotechnology offers a new technological tool to tackle climate change and greenhouse gas emissions in the future. The use of nanotechnology in construction field is linked to the sustainability, energy efficiency and reducing greenhouse gases. The construction industry is a major or the root causes for CO₂ emissions productions. On the other hand, Co₂ emissions across the world must be reduced to halve by 2050, Architects and planners should be concerned about finding innovative ideas and solutions for slowing climate change to combine ambitious architecture with energy efficiency. The use of materials and surface properties that have now become possible by applying the nanotechnology offer architecture, interior architecture and other fields a means of achieving greater sustainable construction and energy efficiency through innovation and creativity. Nanotechnology provides the maximum use of functions and using it is of lasting value and entirely irrespective of arbitrary fashions.

VII. APPLICATIONS OF NANOTECHNOLOGY IN ARCHITECTURE

Nanotechnology has a variety of applications shows the properties the nanomaterials and their applications on surfaces, such as self-cleaning, air purifying and so on rather than the chemical of physical principles they are based on. Such as photo catalysis, these applications show a variety of different creative and innovative ways to apply in design with real life examples that give a proof that through nanotechnology greater energy efficiency is now possible to achieve.

1) SELF-CLEANING: LOTUS EFFECT

This is one of the well-known means of designing surfaces with nanomaterials. The name lotus came from the microstructure of the lotus plant that have knobbls on it these knobbls tackle water droplets and making the surface in less contact with other materials or compounds making the surface remain clean due to the microscopic small structures, this effect can be used on the surfaces that are exposed to water and rain as explained in figure (3) which shows the work mechanism of the lotus leaf surface when a water droplet touches it.

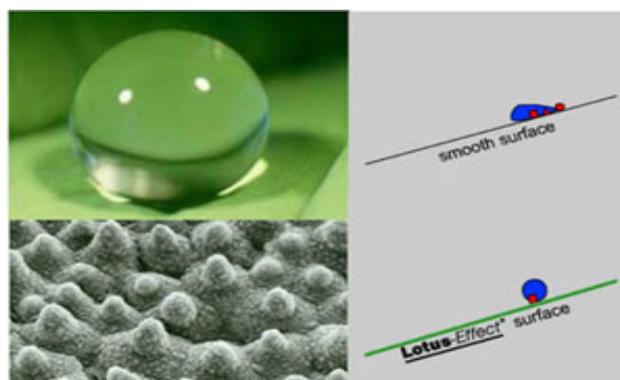


Figure 3: self-cleaning - lotus effect work mechanism and the different way of how the water droplet acts when touches a smooth surface and surface with lotus effect

2) SELF-CLEANING: PHOTOCATALYSIS

photo catalytic self-cleaning or the hydrophilic surfaces is probably the most widely used Nano-function in building construction, this technology is mainly active by ultraviolet (UV) light and water that start specific reactions making dirt lie loose and broke down on the surface, it also reduces maintenance required.

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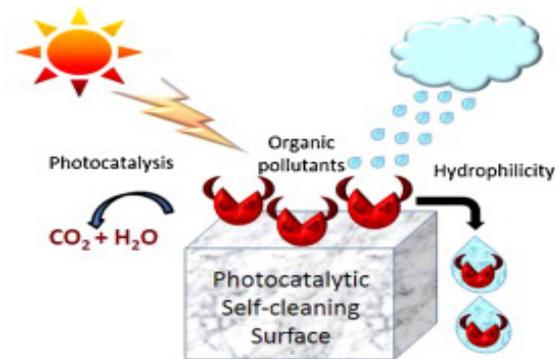


Figure 4: Self-cleaning activation process by UV light

3) EASY TO CLEAN (ETC)

Easy to clean surfaces are smooth surfaces with reduced surface attraction, it's also water and dirt repellant without the lotus effect. This type of technology can be applied to smooth surfaces such as poolside, armchair and the interior of a yacht in the form of a coating. This coating is also a water repellent but it is not the same as the lotus effect, as the surface in this case is smooth rather than rough. Surfaces with ETC have a lower force of surface attraction due to the decrease in their surface energy that makes the adhesion to the surface too hard, so the water of any liquid can be repelled, surfaces with ETC can be called hydrophobic and also oleophobic which means it also repels oily substances. ETC doesn't require UV light to be activated and this is the difference between the ETC and the other self-cleaning coatings as shown in figure (5) that shows the adhesiveness wettability between hydrophilic and hydrophobic surfaces, but it can be activated due to its surface properties. ETC surfaces form droplets, washing away surface grime in the process. This function is used for coating ceramic sanitary installations and shower cubicle glazing. Wood, metal, masonry, concrete, leather as well as textiles.

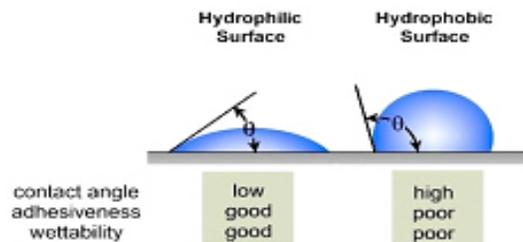


Figure 5: Easy to Clean on hydrophilic and hydrophobic surfaces and the difference of the adhesiveness between both surfaces

4) AIR-PURIFYING

In this technology pollutants and odours are broken down into their constituent parts by some reactions due to the structure of the nanomaterial applied on the surface. This method does not replace ventilation, but improves the air quality. It can be used indoors: in curtains and wall paintings and outdoors: in photocatalytic pavement surfacing and different pavement tiles and in the car parking lots as shown in figure (6) which explains how the outdoor pavement surface and tiles work in order to activate the air purification technique with the help of the UV light and rain that cause some reactions which result in a dissolution of dirt and germs.

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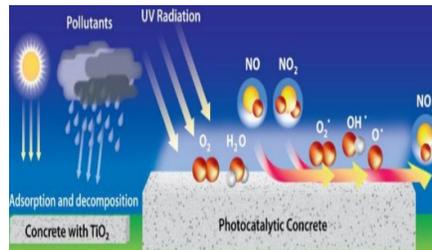


Figure 6: Air-purification coating on outdoor surfaces and activation process.

5) ANTI-FOGGING

Clarity for steamed up surfaces or very cold surfaces that improve the properties of material like glass or mirror remain clear despite of reasons that cause fog. Nanotechnology allows to create anti-fog sprays for different surfaces like glasses, mirrors in the bathroom or car wind screens. These products combine cleaner, anti-fog effect and anti-static effect. Anti-fog layer is invisible and does not change the appearance in any way.

6) FRAGRANCE CAPSULES

These technology is applied for achieving sophisticated fragrances from microcapsules these tech can be applied on furniture in interior architecture for example padded benches or walking on carpets these make this micro capsules to explode launching fresh smile and to refresh the space.

7) THERMAL VACUUM INSULATION (VIPs)

These panels are ideally suited for providing a good thermal insulation with much thinner insulation thickness than usual. In comparison to usual insulation materials this method is up to 10 times lower in thermal conductivity. These panels come in special dimensions and had to be measured before installations as shown in figure (7). VIPs panels should be carefully installed as it is imperative that the skin encloses the vacuum not to be pierced and this means that when it comes to the installation process of the VIPs panels it's important not to cut through the insulation layer, but one should use a combination of panel sizes or panels that are made in factories with its specific size and place to apply. These panels must be handled with care in order not to damage the skin layer as a damaged skin layer means that the whole VIPs panel is damaged and can't be used, so it's advisable to instruct the site supervisor to pay special attention while transporting and handling the VIPs. VIPs are a little more expensive than conventional insulation systems, but it became an advantage for usage in areas where a thin insulation layers are desirable and especially in small and narrow spaces with limited areas and this what makes the VIPs the suitable choice for a very good insulation system with almost ultrafine thickness, also their thickness and high resistance and insulation properties make them very useful in renovation process for the existing buildings as shown in figure (8) it shows the high thermal resistance of the VIPs comparing to other products and insulation systems, in all cases vacuum insulation panelling system offers great potential in the architectural context of improving the energy efficiency and reducing the CO2 emissions.



Figure 7: VIP Insulation panel showing its tiny thickness and its size

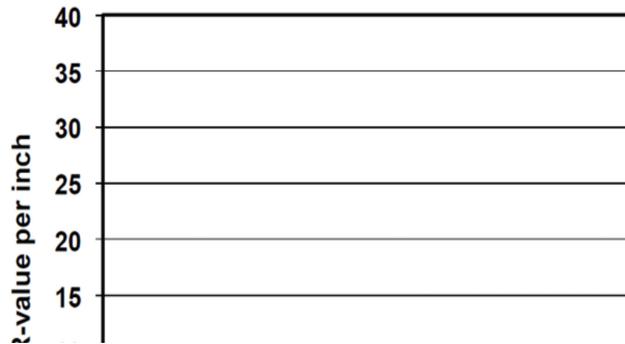


Figure 8: Thermal Resistance of the VIP Insulation system compared to other insulation products and it shows the high rate of the thermal resistance of the panels

8) AEROGEL INSULATION

High performance thermal insulation and Light and airy Nano foam this material holds the record as the lightest solid material. Aerogel has a lot of good properties making it a good material for indoor and outdoor uses and beside its thermal properties it's also a sound insulator. Aerogel is an ultra-low density solid, a gel in which the liquid component has been replaced with gas. It can be called “frozen smoke”, aerogel is just 5 percent solid and 95 percent air as shown in Figure (9), and is said to be the lightest weight solid in the world. Despite its lightness, aerogel can support over 2,000 times its own weight. Nano porous aerogels are sensitive to moisture, so they are often designed to be sandwiched between wall panels that repel moisture. Aerogel panels are available with up to 75 percent translucency, and their high air content means that a 9cm (3.5”) thick aerogel panel can offer an R-value of R-28, a value previously unheard of in a translucent panel. Architectural applications of aerogel include windows, skylights, and translucent wall panels.



Figure 9: Aerogel insulation the lightest solid material on earth

9) PHASE CHANGE MATERIAL (PCMs)

This technology is used for achieving Passive temperature regulation, reduced heating and cooling demand. This PCM plaster can be applied to walls to provide thermal insulation. Phase Change Materials (PCMs) are ideal products for thermal regulation solutions. This is because they have the ability to store and release thermal energy during the process of melting and freezing. When such a material freezes, it releases large amounts of energy in the form of latent heat of fusion, or energy of crystallization. Conversely, when the material is melted, an equal amount of energy is

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absorbed from the immediate environment as it changes from solid to liquid. PCMs can be used in a number of ways, such as thermal energy storage, as heat or coolness can be stored from one process or period in time, then they can be used at a later date or different location. PCMs are also very useful in providing thermal barriers or insulation, for example in temperature controlled transport. One of the most know materials and the simplest, cheapest, and most effective phase change material is water and ice, but the freezing temperature of water is fixed at 0°C (32°F), which makes it unsuitable for the majority of energy storage applications. Therefore a number of different materials have been identified and developed to offer a variety of products that freeze and melt like water and ice, but at temperatures from the cryogenic range to hundreds degrees centigrade.

The switching process occurs in the PCMs according to the temperature in which the material changes from solid to liquid or from liquid to solid or gaseous can be set to a defined number that is considered comfortable for the space users as shown in figure (10), (11), like a 25°C is the standard degree in which the PCM changes according to any change in this temperature. Depending upon the PCM used, for example to regulate a 5°C increase in temperature only a 1nm of PCM is required in comparison to 10 to 40 nm of concrete.

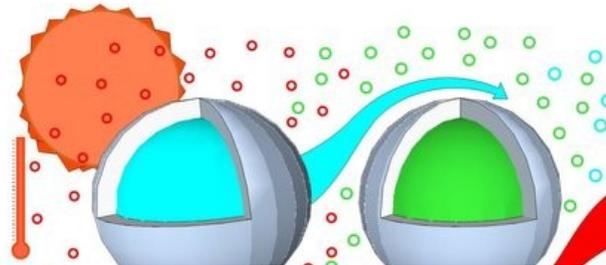


Figure 10: PCMs work mechanism during the day and different weather and how the systems changes its state from solid to liquid

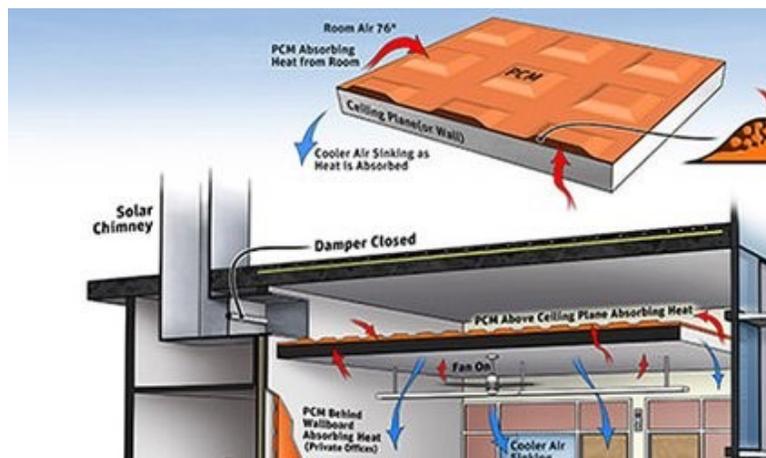


Figure 11: PCMs application in interior spaces in different parts walls and ceiling and how it changes material state (phase) according to the temperature and the day

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10) FIRE-PROOF

Highly efficient fire protection by using a 3 mm thick material between glass panels that provide more than 120 minutes of fire resistance Light and transparent using it in what called fire safety glass as shown in figure (12). In the construction and architecture field protection from fires is a prime concern, in the Nano scene a company from Switzerland called Interver Special Glass Ltd. Announced about the product they designed a fire safety glass with a thickness of only 3 mm of a functional fill material between glass panels, it's sufficient to provide time more than 120 minutes of fire resistance against constant exposure to flames of a temperature over 1000°C. The fill material is sandwiched between the glass panes, the size of the fill particles can be modified according to the need to increase the protection and resistance time and it also differ according to the surface area in square meters per gram. Standard products are generally between 90 and 380 m² per gram.

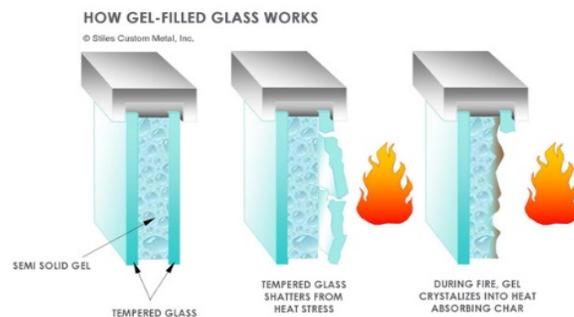


Figure 12: Fireproof Glass Panels Internal activation mechanism

11) ANTI-GRAFFITI

Permeable surfaces with permanent anti-graffiti coatings with highly hydrophobic and dirt resistant, this technology's disadvantage is that the protective coating can't be removed and the material it is applied to is sealed, but it has so many advantages for being applied to surfaces. This type of coating is applied to many historical monuments and buildings such as the Brandenburg gate in Germany, in order to protect the gate from any external damage. Anti-graffiti coating is translucent and with its nanostructure it can keep the surface safe for years.



Figure 13: Brandenburg gate is coated with the anti-graffiti coating

12) ANTI-BACTERIAL

In this technology Bacteria are targeted and destroyed, also the use of disinfectants can be reduced, moreover it supports hygiene methods especially in health care environment this system is mostly used in interiors more than exteriors for examples flooring, walls, furniture and facilities in the space, also in some space parts that are exposed to frequently

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usage by individuals. Antimicrobial Nano coatings reportedly offer the benefits of conventional antimicrobial products without any environmental and health concerns as they aren't a harmful technology. Bioni, for example, offers a combination of antimicrobial and heat deflective properties, with low thermal conductivity and the ability to reflect up to 90 percent of the sun's rays and it can reduce heat absorption in coated walls, thereby reducing air conditioning and energy consumption. Antibacterial (anti-microbial) coating is widely used in interiors, but it can also be used in public places and transportation. Many surfaces that people touch every day in a subway carry thousands of bacteria and germs. With news of powerful flu strains like avian flu and hand-transmissible diseases like colds, public transportation operators are considering using new Nano-enhanced disinfectants subways. Hong Kong is among the first cities to apply silver-titanium dioxide Nano coating to subway car interiors. Tests showed that the usage of these Nano based disinfectant reduced the presence of bacteria by 60%, as shown in figure (14) it explains the Fungicidal coatings on stainless steel plates reduce the formation of the mould aspergillus niger that applies the anti-bacterial coating effect.

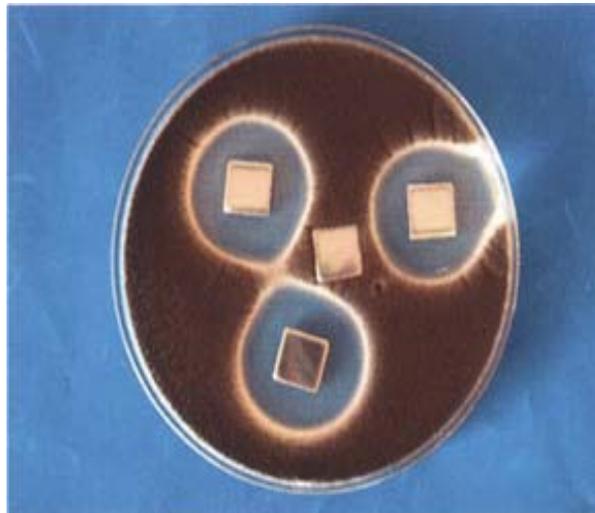


Figure 14: Fungicidal coatings on stainless steel plates reduce the formation of the mould aspergillus niger

VIII. ARCHITECTURE OF HOSPITALS

Modern Movement of Architecture had its effect on the hospital design, design has evolved and adjusted to the changing needs. "Hospital architecture demonstrates how modern culture reconciles highly specialized medical functions, and respect for people's personal, individual integrity" (Jaspers, 2006, p. 7). The design is considered to be a function of multiple variables, as an architect's duty to design an environment - which includes interior and exterior - that will provide security and affects the patient positively. "The hospitalization process causes stress for an individual. This is caused due to the absence of a familiar setting, the insecurity of the future, the fear of unknown medical tests or surgery, the pain, the restriction of social and everyday life that automatically affect the patient" (Vavili, 2009). The patient stay in the hospital is always associated with negative and depressing thoughts. Patient's Health is a condition that depends on the environmental, psychological, social and emotional factors, as the environment of the space can have positive effects on visitors and most important on recovering patients. There are different types of patients depending on what the problem they have, but there is a crucial group of patients that need special designs in order to make them comfortable, this group is the children, children's hospitalization in this case the feeling of insecurity and fear are even stronger, crucial and more complicated for their well-being. The quality of healthcare facilities

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environment is crucial and more significant when the patients are children. “Kids are vulnerable due to their developmental age. Hospitalization is a defining experience for a child”. In this case a major difference between adults and children is the way that they perceive the surrounding environment, due to the fact that they are still in a developmental stage (physically and spiritually).

IX. EVOLUTION AND ADVANCES IN HEALTHCARE FACILITIES

The research of the interior designs in the sector of healthcare developed in the period from 1978 to 1991, then in 1993 was a promotion to a more open to nature designs, during 1995 to 1997 there were some innovators and risk takers, following with the phase of major projects which included connection with nature through the incorporation of oxygen rich varieties, after that some design principles were evolved in the next years and these principles were:

- Providing access to gardens when possible
- Creation of comfortable size rooms
- Increase quantity and size of windows
- Creation of family zones in patient rooms
- Providing decentralized, barrier free nursing stations.

X. INNOVATIVE MATERIALS IN HEALTHCARE AND MEDICAL FACILITIES DESIGN

The field of health architecture is at a turning point, as hospital architecture was immediately affected by global economy recession that begun in 2008 until the past three years hospitals were among the institutions suffering from global economic malaise and many are reacting by laying off staff, limiting services or even cancelling the construction projects, also the high cost of construction of renovation prevent private investors from financing. The climatic changes have a direct effect on hospitals building architecture, as the goal of design is carbon neutrality, regenerative strategies on new constructions and preservation and increasing social capital through environmental design. The changing of priorities of our current situation is seeking the trends for the future, so the hospital needs consideration as an idea and as a building type, last but not least the technology is an important and crucial matter in the design process, Nanotechnology, telemedicine, robotics, virtual reality and the role of nature in healing all of these matters will influence the layout and the space, so in a brief hospitals now aren't a place for sickness and sick people, but rather a place for health and recreation. One of the most recent trends in hospitals and healthcare facilities especially in children's hospital design that is linked with technology is including interactive elements in the design. In this way the child would get the feeling of altering the hospital environment and maybe feel more secure by controlling the surroundings. Interactive elements are also positive distractions during the hospital visit or stay. The main aim is to encourage curiosity, wonder, and learning so that the negative feelings are not the dominant ones.

XI. A SURVEY ON NANOTECHNOLOGY APPLICATIONS IN HOSPITALS AND HEALTHCARE FACILITIES

This analytical part will discuss a number of advanced healthcare facilities and hospitals case studies that were and being designed with the help of new technologies like nanotechnology and other innovative technologies and materials. In the last decades, evidence-based design features that for improving the patient healing, mood, and well-being, staff efficiency and safety can be achieved using new technologies in design and through thoughtful and research based design initiatives that will totally change our thoughts on how to design hospitals interiors. Achieving a healthy indoor environment especially in hospitals is a process that includes every small detail in the space from recycled paints and coatings, less toxic adhesives with low gas emissions, carpets and ceiling tiles to furniture and every space and tool exposed to consumers.

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1) BELLA VISTA EYE CLINIC (SWITZERLAND)

LOCATION: Speicher, Switzerland
OWNER: Dr. Stiegler, Bellavista Eye Clinic
ARCHITECT: Carlos Martinez Architects
FLOOR AREA: 7400m²
FAÇADE CONTRACTOR: Krapf AG
GENERAL CONTRACTORS: HRS St Gallen
PRODUCT: Sageglass Vario Climatop Blue
PHOTOS: Adrien Barakat

DESIGN CHALLENGES

During the design process of the new Bellavista Eye Clinic in Switzerland, located next to the well-known Bent Clinic in Speicher, Carlos Martinez Architects envisioned a strong, rock-like building following the slope's topography as shown in Figure (14). Yet to keep the building light and well-ventilated inside, a window belt runs horizontally across the building's façade, maintaining the magnificent unobstructed picturesque views of Lake Constance. Research has demonstrated that the natural light and views of the outdoors have a positive effect on people's mood, health and wellbeing and has been proven to boost patient's vitality and quality of life. Any glass façade has two key challenges excessive heat and glare and the design needed to ensure patients with sensitive eyes would not suffer from too much light exposure.

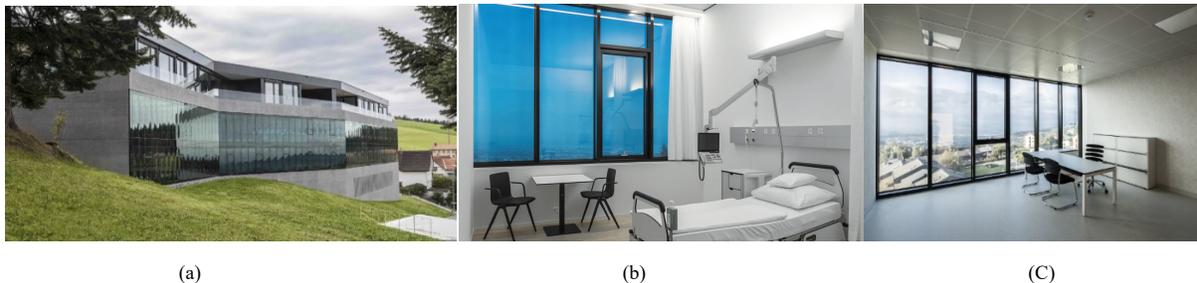


Figure 15: (a) the Bellavista Eye Clinic Exterior Designed by Carlos Martinez Architects, (b) Sage Glass while in Darkened and tinted condition, (c) Interior Environment of Bellavista Clinic Spaces.

DESIGN SOLUTIONS

The clinic architect chose the SageGlass dynamic glass for its ability to meet the design intent, while maintaining unobstructed views of the outdoors, unlike blinds or shades. By darkening and lightening in response to the sun applying the application of UV resistance and anti-reflection properties, SageGlass helped to ensure the interior of the clinic, which consists of 28 beds and two operating rooms, would receive the optimal amount of light throughout the day as shown in Figure (15). Additionally, the tint of the glass can be manually controlled via a wall panel to meet individual patient preferences, making it possible to progressively darken the interior, which is an important consideration for patients with sensitive eye conditions as shown in Figure (15)

BENEFITS OF APPLYING NANO PRODUCT SAGE GLASS

By providing access to optimal levels of daylight while maintaining unobstructed views of the outdoors, SageGlass helps to provide patients with a more comfortable recovery space that contributes to their overall health and wellbeing. In the case of the eye, the retina has not only a surface on which surrounding views are projected, but also cells that dictate a human's biological clock. By providing patients with access to natural daylight, SageGlass helps strengthen patients' biorhythm, boosting patient vitality and quality of life. Additionally, unlike interior blinds or shades,

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SageGlass does not accumulate dust, which helps decrease maintenance costs and contributes to the overall sanitation of the clinic. Furthermore, as SageGlass continues to adapt to the climatic conditions, the clinic will save on heating and air conditioning costs.

2) MEDICAL AND THERAPUTIC CENTER LA LIGNIERE (SWITZERLAND)

LOCATION: Gland, Switzerland

OWNER: Clinique La Lignière SA

ARCHITECT: A.S.S architectes associés SA

FAÇADE CONSULTANT: Buri, Müller + Partner GmbH

GENERAL SPECIALIST: Progin SA

PRODUCT: 450m² of Sageglass Climatop Classic with Lightzone

DESIGN CHALLENGES

The Clinique La Lignière, was built in 1904, wished to expand its offerings through a new outpatient healthcare facility on its campus in Gland, Switzerland. The Medical & Therapeutic Centre would provide well-rounded outpatient care, The Center will focus on patients' biological, psychosocial and spiritual needs to help them develop their own healing skills. The facility would include medical consultation and therapeutic treatment spaces, as well as meeting rooms for advising patients on health and wellbeing, in line with La Lignière's tradition of care and its vision of health. The Clinique La Lignière wanted a modern new building that would harmonize with its original facility and offer bright, open spaces with plenty of daylight to benefit patients and improve wellbeing. After considering a number of solar control solutions, including a double-glazed façade and exterior Venetian blinds Figure (17), (18) The Clinique La Lignière installed SageGlass LightZone™ dynamic glass on the façade and central skylight of the new Medical & Therapeutic Centre to balance daylight, maintain access to outdoor views, and prevent heat gain and glare inside the facility. The LightZone technology allows for three individual tint zones within a single pane of glass to ensure optimal daylight control. The tint level also can be controlled through a wall panel integrated with the building's operating system or with a Smartphone app. Even when fully tinted, SageGlass remains transparent to preserve outdoor views.

BENEFITS OF APPLYING NANO PRODCUT

Several scientific studies highlight the positive influence of natural light and outdoor views on the healing process. SageGlass contributes to the Clinique La Lignière's mission to put patients first and ensure they receive optimal treatment in an open, bright space. Through reduced reliance on overhead electrical systems and HVAC to monitor solar heat gain, SageGlass will also help the clinic save on energy and maintenance costs due to the help of nanotechnology and its properties in sageglass products, also both public spaces and health club in the center are finished with Nano based materials like the lotus effect wooden floor with antibacterial coating for furniture and walls.



Figure 16: (a) medical and Therapeutic Center La Ligniere, (b) Skylights in the Interior Environment of La Ligniere Clinique, (c) Bright Interior Design of the Center with Antibacterial Coating for furniture and regularly used and touched spaces

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3) HENNEPIN HEALTHCARE CLINIC AND SPECIALTY CENTER (USA)

LOCATION: Minneapolis, USA
ARCHITECT: BWBR architects
AREA: 384000 Square Feet
COMPELTION: 2018

This hospital is one of the unique projects made by BWBR architects as it was given the Gold LEED v3 BD + C new construction and was awarded in 2018 the award of merit. In the first phase of Health Campus 2030, a master campus plan that reorganizes nearly two million square feet to offer centralized and accessible care, Hennepin Healthcare opened the new Clinic & Specialty Center (CSC). The 384,000-square-foot building consolidates 26 primary and specialty clinics previously spread across nine buildings, and marks the biggest expansion in the history of Minneapolis/Saint Paul's largest teaching hospital. The design from St. Paul-based BWBR Architects is meant to be a major improvement over older buildings with more user-friendly features like digital directories, large windows to bring in natural light and color-coded floors. New technologies was applied in this center in different areas for example in the exterior this unique orange elevation is made of self-cleaning tiles with the hydrophilic properties to make it clean and prevent any germs and dirt accumulation, curved walls are embedded with anti-reflective system and easy to clean in order to reduce maintenance cost and raise the buildings' efficiency.



Figure 17: (a) The hennepin hospital building with its attractive design at night, (b) Application of sageglass in Service rooms

The interior environment of the Hennepin clinic is certified by the LEED Gold, due to the sustainable design and materials used with the latest applications of nanotechnology in the interior design process with the help of nanotechnology and its applications in the interior architecture, as shown in Figure (23, 24) the use of antibacterial coatings for the furniture and most touched parts like electric switches and door knobs, also the use of the anti-scratch wooding floors to resist the regular moving on it, moreover furniture has to be resistant to water and other liquids and this is being applied by the textile and fabric Nano coatings that can repel the liquids out of the surface of any piece of furniture. The Hennepin clinic has a large glass facades in different parts of the building to gain the most of natural lights without harming the patients with the UV and also to connect the patients with the outer view to help them in their emendation and therapy process. This is one of the unique elevations that is being covered with Ceramic tiles covered with Tio2 coating that is transparent but resistant to any pollutants that may affect the occupants of the building and it has the ability to destroy these pollutants and any harmful composites.

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(a)

(b)

Figure 18: (a) Waiting Zone in the Hennepin healthcare clinic, (b) kids Creation Area in the Hennepin healthcare clinic

4) HARTFORD HOSPITAL BONE AND JOINT INSTITUTE (USA)

LOCATION: Hartford, Connecticut, USA

ARCHITECT: Perkins + Will

AREA: 13,657 Square Meters

COMPELTION DATE: 2016

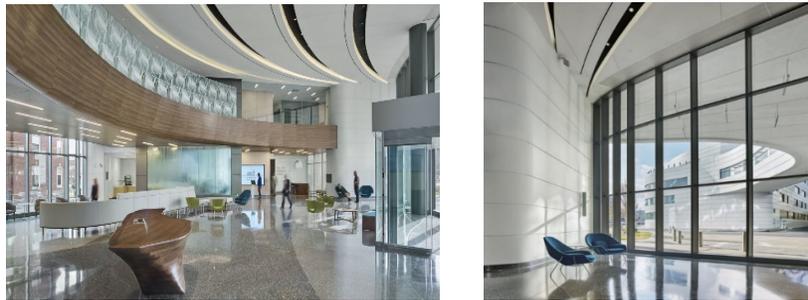
The Bone & Joint Institute integrates all elements of orthopedic and treatment, becoming the destination of superior patient-centered and innovative musculoskeletal care in the region. Having worked together for many years, the team of HDR and Perkins and Will joined forces with Hartford Hospital leadership, doctors, and staff to design the hospital with the “Patients First” principle guiding their way. With this commitment to the healing environment, Architects worked on creating a facility that reflects a dynamic expression of the institute’s clinical vision of “life in motion,” employing a language of sculptural, fluid forms that link program elements and subtly adjust for internal demands, site configuration, and views. The journey of the patient from their initial entry to the concierge to outdoor spaces creates a welcoming first impression with generous day lighting and outdoor views that offer staff and patients moments of respite. And a sinuous, wood clad balcony inspired by (and serving as) connective tissue links both sides of the building. The Hartford hospital has a unique visual image starts from the patient’s journey at the main entry, first the patient will experience the wrapping shape of the building into a two-story covered drop-off area and the main lobby as shown in Figure (19). In the interior environment the design language of the exterior continues inside with clean, modern details and elegant finishing materials such as the terrazzo and dark wood, while most of the admissions processes will be done online prior to arrive for treatment. On the patient’s arrival, he/she will be greeted by a concierge that will assist them and learn about their condition and treatment with the help of interactive media inspired by first class hospitality design. This lobby and main reception area feature warm cherry wood cladding and generous amenities including a café, private lounge areas, access to outdoor seating, and social gathering spaces As shown in Figure (19). In the hospital all the public spaces are placed along the building perimeter, theses spaces provide a view to the outside and outdoor environment, also reinforce an intuitive way finding approach for the place. The hospital has a large number of glass facades that is automatically optimize day lighting and enhance staff experience.

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(a)

(b)

Figure 19: (a) The Main lobby of the Hartford hospital bone and joint institute, (b) private lounge in the hospital beside a floor to ceiling glass wall to connect the interior with the outdoor environment

With the help of nanotechnology applications in the materials and architecture field the design team's conscientious approach to the selection of finishes and furniture endorsed by the owner, contractor, and users resulted in choosing products to decrease the use of chlorinated plastics, and reduce persistent, bio accumulative toxins. Millwork and ceiling panels contain no added urea formaldehyde, green label plus carpeting, ceiling products, wall covering, and PVC-free resilient flooring made with bio-based content, and furniture specified without flame retardants and with the latest technologies of resistant coating against any germs and pollutants.

In Figure (20) an example for a patient room in the Hartford hospital bone and joint institute equipped with the latest materials and technologies using the cherry wood in the room decoration with LED panels, the room has a massive window with the ability of auto-tinting feature and optimization of daylight in order not to cause glare and heat, also to connect the patient to the outdoor view as a part of treatment and relaxation. The room equipment ranging from devices and furniture are all treated with the latest technologies of Nano coating to protect the patient against any germs, toxins and pollutants that may have a negative effect on the patient's health. In Figure (20) it shows the design of one of the operation theatres in the institute with the bright colours in walls and ceiling, LED light panels in the ceiling to reduce the energy consumption of the building due the large amount of lights in the operation rooms, all of the room furniture and equipment are covered with protective layers of anti-bacterial coatings and easy to clean surfaces in case of any blood or pollutants that may occur in these rooms.



(a)

(b)

Figure 20: (a) Patient Room in Hartford hospital bone and joint institute, (b) Operation theatre in Hartford Hospital

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XII. CONCLUSION

- The nanotechnology is producing hygienic products without harming human health or the environment. In addition, it is considered the solution for environmental problems especially that related to building problems. The study focused on discussing the impacts of nanotechnology applications in the interior and exterior environment of the building. With applying nanotechnology it can increase the lifespan of healthcare buildings and keeping them in the best quality and efficiency through application of nanomaterials that make the building more sustainable, environmental friendly and protected from damage for long time periods.
- Nanotechnology applications is considered a revival and upgrade process for the building to protect it from different tearing, bacterial, and damage factors that affect the building's performance whether in interior or exterior and the cost of maintenance is reduced due to the properties of these materials.
- Applying nanotechnology techniques in Egypt in the construction industry and healthcare and medical facilities designs is a must because it contributes in improving healthcare buildings efficiency as in all the developed countries. The research argues the architects and designers to apply the latest techniques of the nanotechnology materials and its applications in the finishing materials selection phase especially in healthcare and medical facilities and buildings to keep it protected over time as possible without any defects appearance and damage.
- We are living in the age of technology, so all architects, designers and Authors in the construction and architecture field should find and explore more new ideas and new nanotechnology materials to apply in order to raise the efficiency of the medical buildings. It is recommended for the architects, and interior designers to be aware of the benefits of using these materials and its impact on the human health and surrounding environment for applying them.

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