ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF ARTS AND SOCIAL SCIENCES

EMERGENCE OF NANOMATERIALS IN ARCHITECTURE AND INTERIOR ARCHITECTURE AND THEIR USE IN PATIENT ROOMS IN HEALTHCARE DOMAIN

M.Sc. THESIS

Ahou AKBARI HAGHIGHAT

Department of Interior Architecture
International Master of Interior Architecture Design Programme

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ SOSYAL BİLİMLER ENSTİTÜSÜ

NANOMALZEMELERİN MİMARLIK VE İÇ MİMARLIKTAKİ UYGULAMALARININ SAĞLIK YAPILARI ÇERÇEVESİNDE HASTA ODALARINDA KULLANIMI

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ARALIK 2015

Ahou Akbari Haghighat, a **M.Sc.** student of ITU **Graduate School of Social Sciences** student ID 418131001**,** successfully defended the **thesis** entitled "**EMERGENCE OF NANOMATERIALS IN ARCHITECTURE AND INTERIOR ARCHITECTURE AND THEIR USE IN PATIENT ROOMS IN HEALTHCARE DOMAIN**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my family,

FOREWORD

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December 2015

Ahou AKBARI HAGHIGHAT
(Architect)

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ABBREVIATIONS

AFP	**:** Anti-Fingerprint
Ca(NO3)2	**:** Calcium nitrate
CeO	**:** Cero Oxide
CO^2	**:** Carbon dioxide
CSIRO	**:** Commonwealth Scientific and Industrial Research Organization
ETC	**:** Easy to Clean
ICE	**:** Inventory of Carbon and Energy
LEED-NC	**:** Leadership in Energy and Environmental Design for New Construction
LIV	**:** Leading International Vision
MIT	**:** Massachusette Institute of Technology
MNM	**:** Manufactured Nano Materials
MWh	**:** megawatt hour
NO	**:** Nitrogen oxide
NT	**:** Nano Technology
PCM	**:** Phase Change Material
PVC	**:** polyvinyl chloride
SBS	**:** Sick Building Syndrome
SERT	**:** Sustainable Energy Research Team
SiO2	**:** Silicon dioxide
TiO2	**:** Titanium dioxide
UV	**:** Ultraviolet
UV-A	**:** Ultraviolet long rays
UV-B	**:** Ultraviolet short rays
ZnO	**:** Zinc Oxide
VOC	**:** Volatile Organic Compounds

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EMERGENCE OF NANOMATERIALS IN ARCHITECTURE AND INTERIOR ARCHITECTURE AND THEIR USE IN PATIENT ROOMS IN HEALTHCARE DOMAIN

SUMMARY

By playing a significant role in the field of architecture and interior design, materials not only affect buildings form and functional performance, but also perform immense impacts on environment as well as human's health. Earlier times, materials appear as simple followers of the functional and formal configuration of space, however reciprocally affecting the form language of the design output due to their characteristics. But with the technological advancements and rapid developments in the realm of material sciences, which further paved the way to the emergence of new design practices i.e. from modern architecture to nano-architecture. This shift has also triggered the development of novel synthetic materials, such as composites and nanomaterials, whereas these novel materials has begun to play an active role in both early phases of design process, as well as the thought of architecture and the way how architects think.

Materials that are made out of *nano-matter*, which are the substances that possess extraordinary physical and chemical characteristics in the nano-meter scale, in terms of *intrinsic* and *extrinsic* capacities. These differences of characteristics cause the differentiation of the nanomaterials in type. This study, describes and analyzes particularly these different types of nanomaterials, and discusses their impact within the architecture and interior architecture realm first generally, then specifically through the contemporary cases from health-care facilities and limiting its focus on the use of nanomaterials in the patient rooms.

Doubtlessly, the manufactured nanomaterials (MNMs) or nano-composites, which are produced by manipulating their physical and chemical properties have been deployed in diverse fields recently. These materials in construction and design industries are mostly utilized as coatings, like insulators and air-purifying surfaces; or in furniture and related products' manufacture, which enhances flexibility, physical durability and strength of the materials; or in the implementations related with the maintenance like energy conservation, self-cleaning and anti-bacterial properties. Therefore, nanomaterials opens up a brand new page in design, both by being a reliable and sustainable alternative for natural materials, as well as for the environmental sustainability in global terms in the presence of counter and indirect relations of consumption and maintenance facilities.

Due to this grate amount of interest in nanotechnology and nanomaterials, the objective of this thesis is to focus on the potentials of nanotechnology and nanomaterials in the field of architecture and interior design discipline, by mapping out the contemporary use of nanomaterials in the realized designs, on behalf of outlining the material capacities of the nanomaterials.

This study aims to reveal the frequency of the nanomaterial use in interior architecture, particularly in the milieu of healthcare centers, in terms of comparing

the design, implementation, maintenance and heat insulation, water and humidity prevention and total energy efficiency through hygiene, heating, indoor air quality, while also trying to shed light up on the transfiguring language of design form. This study deploys case-based research methodology by selecting the contemporary hospital examples from Istanbul, where both nanomaterials and conventional materials are utilized, in order to set the material performance comparisons.

In this regard, LİV Hospital-Istanbul, Kolan Hospital-Istanbul and Medicana Hospital-Istanbul have been selected as the case-studies, to dismantle the use of nanomaterials in the patient rooms; the material characteristics, the frequency of the material use, and the financial dimension of the material use, in order to give a perspective to the interior architects that may deploy nanomaterial in their designs as well as following researchers that may use this study as a primary text to start their studies.

NANOMALZEMELERİN MİMARLIK VE İÇ MİMARLIKTAKİ UYGULAMALARININ SAĞLIK YAPILARI ÇERÇEVESINDE HASTA ODALARINDA KULLANIMI

ÖZET

Kuşkusuz, gerek mimarlık, gerekse iç mimarlık alanında önemli bir rol oynayan malzeme unsuru, binaların formu ve işlevsel performansından, çevre ve insan sağlığına kadar sayısız etkiye sebep olmaktadır. Önceki dönemlerde, malzeme basit süreçlerle, kimi zaman binanın fonksiyonun izini sürmüş, formun takipçisi olmuş; kimi zamanda karakteristik özelliklerinin neticesinde, formel dili belirleyen bir unsur olmuştur. Fakat, endüstrileşmeylebirlikte, teknolojik ilerlemeler ve malzeme bilimindeki hızlı gelişmelerin ışığında, mimarlığın ve iç mimarlığın da kabuk değşitirdiği gözlenir. Yoğun değişim ve dönüşüm, bir taraftan kendi terminolojisini (Modern Mimari, Nano-Mimari vb.) yeniden oluştururken; diğer taraftan da vücuda gelmenin kaçınılmaz karşılığı olan sentetik malzemelerin (kompozitler, nanomalzemeler vb.) geliştirilmesine de neden olmuştur. Bu değişim sürecinde, malzeme seçiminin, tasarım sürecinin ilk aşamasından sonuna kadar, gerek tasarımın yaratıcı düşüncesinin geliştirilmesinde, gerek istenen biçim dilinin oluşturulmasında, gerekse ürünün inşasına kadar, hemen hemen her aşamada belirleyici olduğu gözlenir.

Öte yandan, günümüzde hızlıca azalmakta olan doğal kaynaklara alternatif olarak gelişen sentetik malzemler içerisinde, kuşkusuz, geçtiğimiz yüzyıla damgasını vuran, ve aslında daha kapsamlı etkisini 21.Yüzyıl'da yogun olarak hissettirmesi beklenen nanomalzemelerin, mimarlık ve iç mimarlık disiplininde, malzeme ve mekân etkileşiminde yeni bir boyutu tariflediği izlenir.

Geleneksel malzemelere oranla, yüzey temizliği ve hijyen, termal kontrol, su yalıtımı ve rutubet giderici özellikleri ile, yangın vb olumsuzluklara karşı gösterdikleri dirençle, tasarım-yapım-kullanım maliyetleri açısından daha yüksek bir performans ortaya koyan nanomalzemelerin, özellikle sağlık sektöründe etkin olarak kullanılmaya başladığı bilinmektedir.Bir diğer taraftan tasarım disiplinin içine girmesiyle, tasarımın biçim dilinin de değişimine sebep olduğu izlenen nanomalzemlerin, önerilen bu çalışma kapsamında, geleneksel malzeme kullanımına koşut, kullanım sıklıklarının ortaya konması hedeflenmektedir.

Bu çalışma kapsamında, sağlık mekânlarına odaklanılarak, nanomalzemelerin, hastane mekânlarındaki farklı gerekçe ve işlevler çerçevesinde kullanımlarına odaklanılarak, söz konusu malzemelerin kullanım yeri ve sıklığının, özellikle, hasta odalarına odaklanılarak incelenmesi hedeflenmiştir. Dolayısıyla, hasta odalarında kullanılan nanomalzemlerin, hastane iç mekân konfor koşullarına ilişkin temizlik ve hijyen (hasta odaları, ameliyathaneler, laboratuvarlar), ısıl konfor (yalıtım), ışıl konfor (hasta odalarına gelebilecek fazla miktardaki doğal ışığın filtrelenmesi), iç mekân hava kalitesi (kirlilik yaratmama, kanserojen gaz salınımının daha az olması vb.), su ve yangın yalıtımı gibi sergiledikleri farklı davranış özelliklerine gore kullanımlarının irdelenmesi, analizler ve karşılaştırmlaı değerlendirmelerle tartışılması amaçlanmıştır. Çalışma kapsamında, İstanbul'dan üç örnek hastane inceleme için belirlenmiş, ve LİV, Kolan ve Medicana hastanelerinin hasta odalarına odakalnılarak çalışlma yürütülmüştür. Daha once de değinildiği gibi, vaka incelemesi sırasında, hasta odalarındaki nanomalzeme kullanım sıklığı, farklı nanomalzeme karakteristikleri, malzeme kullanımının finansal boyutu gibi tasarım sürecine etki

veren önemli baslıklar irdelenmiştir. Bu araştırmanın çıktısı olarak bu tez çalışmasının nihayi süreçte; tasarımlarında nanomalzeme kullanacak iç mimarlara rehber olması, ilerki aşamalarda nanomalzemeler üzerien çalışacak diğer araştırmacılara birincil kuşak bir veri-seti, yahut bir referans düzlemini oluşturması öngürülmüştür.

1. INTRODUCTION

Due to the vital consequences of Industrial Revolution and the vast population growth in the cities, during 19^{th} and 20^{th} Centuries, building construction and destruction techniques have been immensely evolved in terms of maintaining the user needs and the volatile demand. Unfortunately, this implementation has given rise to some unfavorable ecological results, where asexcessive consumption of non-renewable resources and non-repairable damage to environment emerge as the major after effects. In terms of taking environmental concerns into account, novel interventions are sought to solve the rising problems on environmentally friendly resources. In this respect, nanotechnology has come into design scene as one of the most promising responses to the increasing environmental problems in the 21^{st} Century.

As it is known, the impact of nanotechnology extends from its medical, ethical, mental, and environmental applications, to fields such as engineering, biology, chemistry, computing, communications and materials science and even architecture. In 1990's nanotechnology has showed its particular presence in the field of architecture and gave birth to many possibilities, which were all a dream before.

As mentioned above, increasing numbers of human population on earth and the growing capacity of the industrialization in synchronized with the evolutional lane, have further brought in the need to consume more and more resources, which was already inadequate of the planet earth could offer. This was the initial spark that steered the sustainability and sustainable design in terms of man-made materials in design; leading people, industries, engineers towards renewable materials and resources. Sustainable design can be defined as healthy facilities designed and built in resource efficient manner (Zabihi et al, 2012). In this regards, by using ecology-based principles, in other words ecological design, the notion of sustainability gained a significant role in the field of architecture and design. Thus, adapting sustainability in architectural design has become the most premising issue for the future of design and the designed environment.

In the field of architecture, materials could be another decision criteria for architects and designers in order to maintain a balance between their designs through raising concerns about sustainability. Undoubtedly, no one can access to this goal just by design itself. Since the most important objects that both affect and being affected by nature are materials, which are either used outside or inside of the buildings; so that the notion of design has to be rendered as a big whole together with its material qualities and capacities in relation to function and aesthetical demands as retaining existence. Thus, in terms of reaching the goal of sustainable solutions in the architectural domain, it is imperative to avoid consuming and depleting of resources in favor of new designs that are constituted of ecofriendly materials, which can get along with the natural ones and non-hazardous to the ecosystem. For this purpose, nanotechnology offers advanced functional nanomaterials, by manipulating the properties of the materials in nano-scale, which respect environmental factors, via advanced design optimization even in material scale, and achieving a sustainable construction through innovation.

Nanomaterials have been poised for widespread use in the architecture and interior architecture; from commercial spaces, to domestic facilities, from schools to healthcare facilities and hospitals etc. But, recently as it is mostly observe the excessive amount of use in healthcare facilities, particularly for optimizing the numerous needs of hygiene, insulation, technical proofing etc. Like many public-accessed service spaces of the city, hospitals hold the major importance in terms of maintaining the physical existence of the city, together with its citizens in the frame of physical and mental healing facilities.

From this vital presence of the typology, as well as its adaptability and akinnest to the developing use of nanomaterials, health care spaces have been selected as the case study, to reveal the use of nanomaterials in comparison to conventional materials, in terms of drawing out a statement about the frequency of the material use, and generating a basic outline or a guideline for designers, so that the outline introduces the variety and the characteristics of the materials to be used in design. Therefore, with a briefer description, the aim of this graduate study is to investigate the emergence of nanomaterials in architecture and interior design particularly by focusing on hospitals and healthcare centers.

In the light of these cause and sequences, this graduate study intends to focus on nanotechnology and nanomaterials, by highlighting its importance in terms of the perspective of architecture and interior architectural implementations. The initial objectives of this study are identification and categorization of nanomaterials, and their properties that are used in contemporary implementations. Besides, departing from these objectives, the main aim of this study is to dismantle the particular use of nanomaterials in health care centers,especially in hospitals and healthcare facilities to generate a referential study, which would focus on the material performance of the mentioned category and creation of a material table of nanomaterials, which are suitable for health care centers to be deployed for the prospect use of designers, who want to choose the nanomaterials in their design is the remote goal of this study.

2. TRANSFIGURING USE OF MATERIALS IN ARCHITECTURE AND DESIGN

2.1 The Role of Materials in the History of Modern Architecture and Design

As it is known, in the realm of architecture and construction, since the very beginning until the Industrial Revolution in 18th Century, there had been a simple and a straightforward relationship between materials and the architecture. Yet, the main selection criteria of the materials that were deployed in the structures was particularly due to its properties. In other words, during those times, architects and designers mostly utilized the materials that had been existing in their close milieu, in their designs (Abdellatif, 2011).They further developed the material capacities on behalf of aesthetical values, appearances and ornamental qualities. For instance stone, brick and timber were the principle structural materials, whereas organic materials like reeds were used for finishings, likewise marbles being as the best selection of the architects to cover their design and realize their ideas (Abdellatif, 2011). For this pragmatic reason, it is not that much surprising to observe the use of similar materials on different types of buildings of the same neighborhood. On the other hand, until Industrial Revolution there had not been an adequate technological enhancement to examine the properties and characteristic of materials. Thus, architects and designers could only experiment the performance of materials basically through observations, while gaining experience as the time passed. So, the guilt tradition and the master-pupil method had been significant ways to convey the limited knowledge of materiality and its capacities from one generations to another, through which only limited experiments were done to create new materials, or novel use of existing materials.

Doubtlessly, the important role of materials in architecture and interior architectural design has been drastically changed with the advent of the Industrial Revolution. Industrial Revolution brought architects fully engineered new materials, which further influenced the material selection and increased its importance in terms of representational and performative capacities in every architectural design. This revolution and technological shift in architecture gave the gift of time to designers by examining the properties and the performance of each material before using it, and there were no need to wait and observe what the outcomes of the chosen material would be, which further decreased failures in constructions into a certain ratio.

As all these technological transformations had given rise to a revolution also within the architectural discourse namely Modern Movement in late 19^{th} Century, the use of novel materials constituted the major impact and the representational language of the new epoch. Modern Movement could be also visualized chronologically through the lenses of the history of architectural materials.

Without a doubt, numerous important factors, such as transformation in the philosophical discourse, scientific developments and technological advancements, as well as emergence of the rational architectural discourse had all given the way to the birth of this movement in architecture. The term “modernism” emerged as a response by architects for the rapid technological advancements and urbanization, yet inter-connected with the transformation of the society at the turn of the 20^{th} Century. Modern Architecture has appealed with its use of new materials and new construction technologies, which consisted of simple forms enclosed with flat opaque or transparent facades that were all considered progressively rather than regressively, expressing the importance of volumes rather than masses, and making an elegant balance in design instead of stuck into symmetry, through eliminating the ornament and decoration at the far end. It is also worthwhile to notice that, the utilization of new materials such as steel and glass, not only changed the process of design and construction, but also shifted the language of the design (Url 1).

As it has been observed, Modernism has further accommodated varying tendencies within itself such as Rationalist approach (the technical rationalism), Formalism (the architectural formalism), and Functionalism. It is also important to mention that Functionalist tendency is one of the most important approaches in Modernism, which has paved the way, not only to the novel configuration of spatiality based on the functional needs, but also has lead the way to the development of Modernism’s novel form language. Like summarized in the sentence of Ianca and Georgescu (2015) “the form is the logical result of the function”, the direct relationship between architectural expression with function of the building and functional appreciation of spatial configuration emerged as the essence of Functionalist tendency (Ianca and Georgescu, 2015, p. 222). By taking this sentence into account, it is clear and comprehensible that there is a straight relationship between architectural expressions with function of the building. Also by focusing on the very well-known statement of Louis Sullivan, in the late 19th Century, where he says “the form follows the function”, it could be clearly understood that the principles of Functionalism affirms thatevery building has a defined function or a performance such as an office, industrial building, commerce or housing, for this reason there should be a harmonyand balance, as well as a reasonable relationship between the function of building with its aesthetical and conceptual materialization (Ianca and Georgescu, 2015 p. 223). Consequently, the constructions have been also performed with the recent technological advancements and materials such as concrete, steel, glass and plastic. In other words, the Functionalism in Modern Architecture is characterized by new construction materials and new technologies, which let architects and designers toenvision and practice space and design in different manners. It may further stated that, the progress in the use of novel materials and the practice of novel technologies, yet a priori knowledge derived out from the processes of practicing, have all given the way to the emergence of novel interventions, which are even today, developing still from this initial spirit.

Doubtlessly the principles of the Functionalist approach had been enhanced by two consequent remarkable institutions; the Chicago School and the Bauhaus School in the early years.Bauhaus has been one of the most innovative and influential architectural schools, initiated in Weimar Germany, in 1919, and had been the leader of Modern Movement until 1933, when it was suppressed by Nazi regime of WWII (Url 2). Apart from very unique pedagogies and interventions of the school, optimized usage of industrial materials and their properties; avoiding extra ornamentation and decorations on facades of buildings; attaining balance and harmony between function and aesthetic of buildings may all count as the pioneering design principles of the professional education (Ianca and Georgescu, 2015, p. 223).

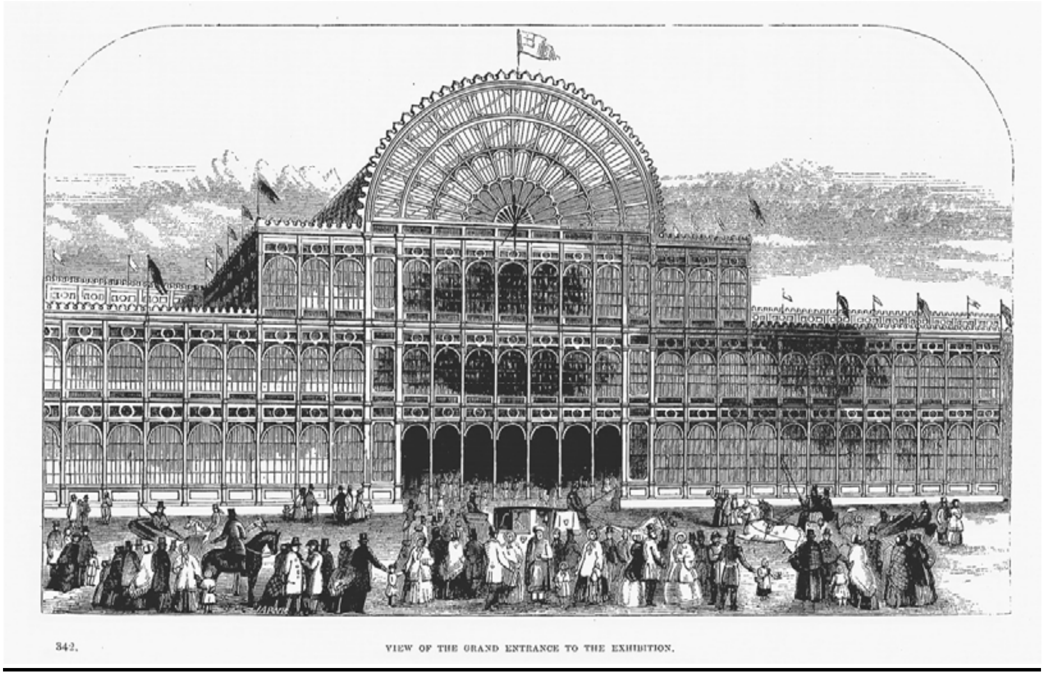


Figure 2.1: Steel frame structure of Crystal Palace, London, Joseph Paxton, 1851.

But in fact, as it is known, prior to the Bauhaus School and its fostering impact on Modern Movement, it was the ideas of Chicago School that initiated the shift of Modernism in architecture. In 1871 the Chicago School had initiated the fundamental principles of the modernist approach in architectural discourse, by highlighting the importance of Functionalism in Modern Architecture (Ianca and Georgescu, 2015, p. 224). The other groundbreaking innovation that the Chicago School has introduced was also the deployment of steel structure in building construction, as well as utilizing wide windows that could span the entire column cover. It could be observed, that after 19^{th} Century new materials such as concrete, steel and specially glass, had become the important components of architectural language, which further transform the praxis. For instance, the use of steel in architecture at the beginning of 19^{th} Century haseffected the emergence of long-span and high-rise buildings, because of its tremendous strength to carry the loads, which at the end enabled the buildings became taller and lighter, while providing larger openings on the façade. The first major applications of steel had occurred in public and transportation buildings particularly in railroads and bridges, which quickly made the best use of steel.It is also worth to remember that before the 1871 manifestation of the Chicago School in states, it was the Crystal Palace in 1851, which was emerged as the foremost example urban interiors, designed and crafted with the latest material and technological capabilities of its time.The Crystal

Palace had been one of the first buildings built up with vast amounts of glass supported by a steel construction strongly giving the hints of emerging novel undecorated, simple language of Modern Architecture (Url 3) (Figure 2.1). When the later use of glass and steel constructions in Modern Architecture has been retrospectively examined, although time has passed and newly developed materials have emerged; like in the pioneering example of Flat Iron Building in Time Square New York City from 1902, glass and steel remained actively deployed materials, in the realm of architecture (Figure 2.2 and 2.3).

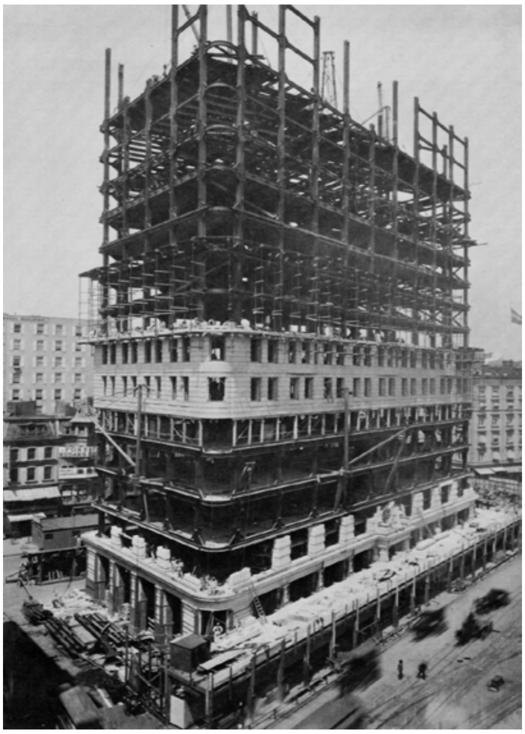



Figure 2.2 and 2.3: Steel frame structure of Flat Iron Building, New York, Daniel Burnham, Frederick P. Dinkelberg, 1902.

Another vital material in the revolution of architecture during the late 19th Century has been glass, which further triggered the shift of conventional window notion into a glazed screen surface that becomes an interface of inside and outside relations. So, rather than discussing the poetic transformation of window element, when it is functionally examined; it is known, in earlier time, window had a single purpose of indoor air conditioning and using the heat of the sun while blocking out the disturbing winds in the cold season. After the Industrial Revolution and the invention of cooling and heating systems, which made indoors a favorable habitat for people, then afterwards architects have been able to use fully glazed facades in every climate.Besides, saving its primary purpose in architecture, glass brought a lot of advantages by itself to architecture and design. For instance in a climate such as Dubai we observe the world's tallest buildings emerging in glazed envelopes (Figure 2.4). If we take a closer look to the features that this material brought to such an enormous building, we could also observe that although it is all covered by nano-based Sun-Gard-glass, the light and heat caused by sun is controllable inside, in relation to the technological preventions. In earlier times, glass had been used as ornamentation and a decorative material not simply functional on the facades. Due to its lightweight quality it made possible to design a 900-meter tower and also brought an open relation between inside and outside (Url 4).

Figure 2.4: Glazed facade of Burj Khalifa Building, Dubai, Adrian Smith, 2009.

To summarize, beside the variety of materials and possibilities in design, the evolution of architectural materials constitutes the vast affect not only on the design itself, but also in broader terms in architectural discourse and praxis. What it means is that the limits in design become vague in terms of material and construction technologies. By improving technologies and getting familiar with new and modernmaterials and techniques, the architects and designers were able to choose and think about the materials from the beginning of the design process by considering all aspects of materials such as their performance, function, ornamental qualities, production time, implementation procedures and costs. Accordingly, materials become the most important part of design, which can affect both the processes and the outputs. Furthermore, by considering all the advantages that these technologies brought to architecture and design, they also came with some difficulties in the processes of design. For instance, while choosing the materials designers must possess the basic information about the nature of materials, their physical and chemical properties, their characteristics and behaviors in diverse situations; their interactions with other materials; their structural properties; their potentials for recycling procedures and other related environmental codes; their impact on health and safety and finally of course their costs.

2.2 Shift from Conventional Materials into Nanomaterials

As it has been discussed earlier, the developments in materials, either their use in contemporary/present realm, or their manufacturing and refinement processes have been playing an important role in the evolution of contemporary architecture and design. Today architecture is facing greater challenges than ever, particularly with the immense stress of environmental constraints and increasing urbanization. Thus, in terms of these challenges new materials with new technologies have been introduced to the realm of architecture, which are providing hopeful solution against contemporary problems.

So, when dealing with materials and surfaces in architecture, we observe that two fundamentally different design approaches prevail. On one hand, there exist the natural materials, in other words, “what you see is what you get” (Fahmy, 2010, p. 13). This approach is appreciated by the architects, who show priority to high-quality and original materials such as natural stone or solid woods (Fahmy, 2010). There are two reasons behind this approach that is not accepted by most of the people. First of all consuming natural materials cost more money and is not economically logical. Secondly this kind of material usage destroys our natural environment, which is in fact emerging as the most important point in terms of not appreciating the deployment.

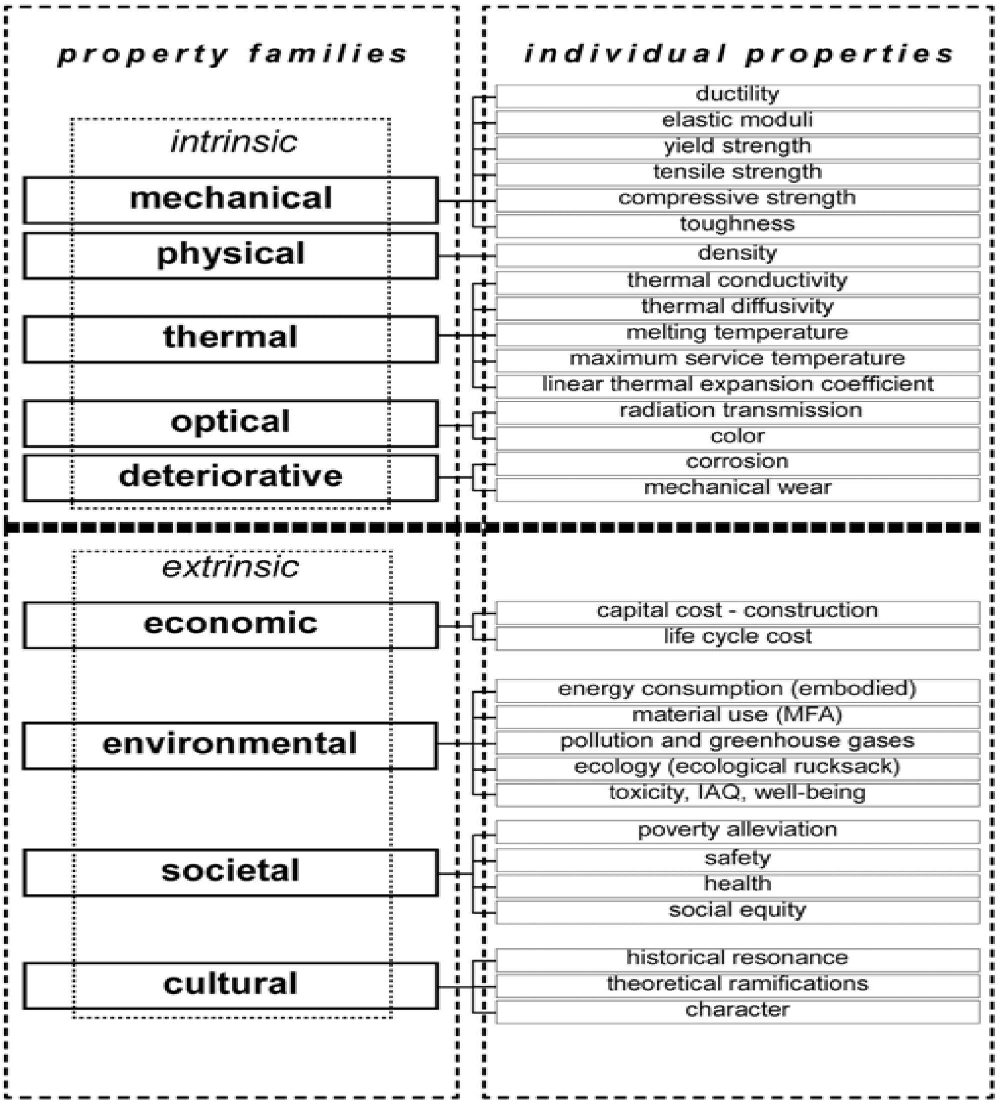
On the other hand, we confront with the man-made materials. The main reason for using artificial materials is because they are economically convenient, and efficiently available. For example, wood, whether in the form of veneer or synthetic wood-effect plastics, is considerably cheaper than solid wood (Fahmy, 2010). Artificial surfaces are unlimited, the grain can be tailored to appear exactly as desired, even the color matches the sample precisely and does not change over the course of time and would not have any differences with the natural ones (Fahmy, 2010, p. 13). With the advent of new technologies, artificial surfaces manufactured more durable and even lighter than the natural ones, so that the natural sources are reserved in this way (Fahmy, 2010).

One of the important outcomes of 19^{th} Century's technological developments was the evolvability of novel and various materials. The variety of new materials not only opened the door to Modernism in architecture, but also gave limitless choices on design process and made it possible to; i.e. like in the use of steel as a structural material on buildings or create transparent facades. Besides, 19^{th} Century's technological developments also made the design process complicated for architects to decide on choosing the proper material for their design. Therefore, it became more crucial for the architects and designers to develop the appropriate knowledge about the properties of the new materials to decide and to select the proper material for the every relevant condition. Materials are usually recognized by their properties, it is clear that the fundamental properties of materials have essential importance to the engineering and designing perspective of architects and designers to select and utilize the materials in product and building design process. Therefore, it is important to have awareness of material properties to understand the benefits and limitations, which affect the whole design development.

For this reason, this sub-section focuses on classification, structure and general properties of materials. Generally material properties are classified in two main categories, which are known as *intrinsic* and *extrinsic* properties (Addington and Schodek, 2005, p. 14) (Table 2.1). In one hand, *intrinsic* characteristic of materials, which are manufactured by fundamental atomic and molecular-structure or microstructure of the materials (Addington and Schodek, 2005). For instance, typical technical properties such as strength, resistance, elastic moduli values, electrical conductivities, thermal conductivities etc. are the most important features of materials that are emerged by atomic and molecular forces (Addington and Schodek, 2005, p. 14). As an example, there is a direct relationship between atomic forces of materials and the strength property. Accordingly, if atomic or molecular forces were getting stronger and intense, then the qualities of strength and hardness of the materials would be also enhanced. This feature depends on the nature of matter. (Addington and Schodek, 2005, p. 14).

On the other hand, *extrinsic* properties are recognized through macro-structure of the materials and these properties could be observed clearly (Addington and Schodek, 2005, p. 14). In addition to these, economic, environmental effects, social and cultural points could also be counted as some of the extrinsic properties of materials. Ultimately, material behaviors stem from their technical attributes, which are related both to their *intrinsic* and *extrinsic* properties.

Table 2.1: Proper subset of intrinsic and extrinsic properties of materials, John E. Fernandez, 2004



In fact, these properties are what mediate those differences between the materials. It can be understood that, properties generally have units that reflect the nature of these differences. In other words, enhancing or reducing, or modifying intrinsic and extrinsic qualities of materials are entirely possible by means of nanotechnology.

In his book entitled “Nanomaterials, Nanotechnology and Design”, Daniel L. Schodek (2009) states that; “If you stop for a moment and look around you, you will notice a wide variety of materials, either artificially produced by humans or naturally existing in nature. Both types can be categorized in particular classes to provide a better understanding of their similarities and differences” (Schodek, 2009, p. 87). He highlights the importance of classification of materials, and groups them in seven major categories, which are: metallic, ceramic, polymeric, composite, electronic, biomaterials and nanomaterials (Table 2.2). Among these materials metallic, ceramic, polymeric, composite and nanomaterials are used in architecture and interior design field.

Being an architect or designer is not only about selecting materials from catalogue while designing process. It is important to initiate the design process, being aware of attributes of the materials, which stem from their chemical and biological properties, so that designers can select suitable materials into the designs. Due to technological developments, scientists could further generate purposeful materials, which consist of valuable properties such as composites and nanomaterials, that all could for instance last longer, be transportable, reduce waste, be transformable and adjust to environment conditions in different context etc. So, for this reason architects and designers should have the basic awareness, ethics and creativity to transfer these technological innovations developed by other industries into the built environment. According to researches it is also observable that, new materials and construction methods as well as new uses for existing materials, also cause a transformation in design attitudes. In other words, like Antonelli (1995) states; “Contemporary designers are facing the challenge of defining its [materials’] new multifaceted manifestations. The mutant character of materials, as expressive as it is functional and structural, generates new forms and a more experimental approach toward design”(Antonelli,1995,p.17).

2.3 Importance of Nanotechnology in the Scope of Sustainable Design

"The modern buildings we live and work in rival such well-known polluters as cars and manufacturing as sources of harm to the environment, adding greatly to deforestation, the risk of global warming, over use of water, and acid rain" (Roodman and Lenssen, 1995). Like Roodman and Lenssen critically highlight in their statement above, according to statics, approximately fourty percent of produced energyand materials in the globe are consumed by means of buildings (Cross Cain, 2007). The mentioned figure, does not only represent the amount of energy require to harvest, manufacture, transport all materials, which are used for the construction and maintenance of the buildings, but also this statics further implies that, people are relinquish the natural resources at a rate 1.2 times the capability for the planet to replenish what our society uses every year (Cross Cain, 2007). In other words, we are consuming more than the earth could recover. For this reason, it is imperative to behave sensitive to environmental issues, by reducing the rate of consumption to save our environment and natural resources for future generations.

In addition, in this age, the existing buildings and/or factories all around the world are still emerge as kinds of machines, which cause pollution, contamination, and depleting the surrounding environment, and relying on scare amounts of natural lights and fresh air. People are essentially working in the dark, and they are often breathing unhealthy air (McDnough, 2001). Health complains such as nasal congestion, headache, irritated eyes, lethargy and tiredness, which are difficult to medically diagnose are the symptoms that are accrued through the people remained indoors, and are reduced or vanish particularly when they get out from the building. These feelings of discomfort diagnosed as Sick Building Syndrome (SBS), and the main reason of this disease is being located in hazardous conditions, such as poor air quality, unhealthy materials, low natural light and etc. within the buildings (Roodman and Lenssen, 1995). A study in 1995 represents that; SBS affects thirty percent of new orrebuilt buildings (Roodman and Lenssen, 1995).

By taking these problems into consideration, such as people being surrendered by environmental problems that are causing irreversible damages to the nature and every means of life; novel tendencies and trends have emerged to reach the notion of sustainability in the field of architecture. With a glance, in the past fifty years, various factors have affected the environmental building movements, such as: during 1970’s with the increase of oil-prices, energy-conserving building materials had been considered as favorable materials to reach sustainability; in 1980’s, building materials which had been reduced or omitted pollutants and became the significant materials causing the *Sick Building Syndrome* or indoor air quality, and in 1990’s architects were involved with the comprehensive definition of environmental materials and technology, which consisted of both the topics of energy conserving products (nontoxic or healthy products) and resource management (Bierman-Lytle, 1995). It is important to notice that, construction industryplays a significant role and great responsibility on resource management and this role is still in progress at the level of selecting materials and used appropriate technology, which leads to sustainability in the field of architecture and interior design. For this reason, architects and designers, who pay attention to the environmental issues in their design have been observed to be more carious in the material-selection process, in terms of maintaining better life conditions to the users. Thus, in terms of sustainable design scope, renewable, recyclable, economic, and easily-provided local materials are suitable with their design. In addition to architects and designers, users should also consider about the environmental problems in order to collaborate with them for the sustainability, as the future will shape by our decisions. “Imagine, a building as a kind of tree, it would purify air, accrue solar income, produce more energy than it consumes, create shade and habitat, enrich soil, and change with seasons”. (McDonough, 2001), for reaching these types of transformations in the field of architecture and design it should be reconsideration about architectural theories and use new tools and ecofriendly materials to reach sustainability.

There has been a misinterpretation of the interior architecture and its significant effect on sustainability of a building, through negative perspective. However, like in Pilatowicz’s building life-cycle definition, which addresses to human health, safety, well-being and productivity, the interior architect emerges as one of the actors that may affect the cycle through the choices s/he make (Pilatowicz, 1995). Therefore, by taking environmental, social and economic aspects of the materials into consideration s/he is responsible of addressing client needs to provide better life quality with healthy designs.

In terms of attaining the sustainability in design, architects and interior architects should select materials and products, by considering their entire life-span, from extraction to disposal, or from reuse to recycling phases to minimize environmental impact during all stage of buildings life (Pilatowicz, 1995). Because, indoor materials have the ability to support healthy environments, by reducing the transmission of inappropriate energies that cause secondary health concerns with their direct impact on thermal performance, air quality and out-gassing, toxicity, and mold (Bacon, 2011). With this respect, interior architects could have positive influence on sustainable movement by means of taking right decisions and actions in selecting indoor materials according to the situation (Bacon, 2011). According to LEED-NC (Leadership in Energy and Environmental Design for New Construction), in the category called Materials and resources, designers may have direct control of 7 of the 14 points (LEED, 1998). For the Category Indoor Environmental Quality, interior designers may have control 6 points out of 17 points, which equates to a total of 13 out of 57 points or 23% in the entire LEED scorecard (LEED, 1998). This does not take into account the four points available for innovation in design or the one point awarded for having a LEED accredited professional on the design team. Considering that, it requires 21 points to receive certification, it appear evident that interior designers can indeed play a significant role in the sustainability of a building (LEED, 1998).

As an example, indoor air pollution could be increased through materials, finishing, furniture, textiles, cleaning equipment and chemicals that are used inside building, as well as human activities and biological processes (Spiegel and Meadows, 2006). For this reason, indoor air pollution is the fifth greatest health threat to public health (Johnson, 2000), and obviously it could be controlled with the help of interior designers, by taking precautions with construction or renovation procedures, and selecting proper materials in their design processes. Therefore, it is worth to mention that all materials, which are used inside and outside, play an important role in construction sector to attain sustainable design solutions.

So, the most compelling rationalization and legitimacy of deploying nanotechnology in architecture and interior design field is the goal of sustainability. Because, utilization of nanotechnology in construction industry is bringing huge improvements in building performance and environmental factors such as; energy efficiency, environmental sensing and coping with climate changes, which all reduce the greenhouse effect on the globe (Fouad, 2012). Nano-products and nanomaterials, which are emerged by applying nanotechnology on materials, are offering ecological advantages in terms of conservation of resources, as well as economic advantages in terms of energy efficiency (Leydecker, 2008).

The costs of nanomaterials have been relatively more expensive than the conventional others due to the required production technology. But, it should be noticed that, in the long-term use, these kind of materials are more economic and ecological than other products (Url 7). I.e. in terms of economical approach self-cleaning surfaces, reduce the cost of cleaning; or again when considered in terms of ecological approach, it is also advantageous with the life span of materials can be extended, so that materials would less wear out and tear down from regular cleaning or aggressive detergents, likewise, far fewer detergents pollute the environment and both contribute towards conserving resources (Leydecker, 2008). Figure 2.5 displays three subcategories of sustainability. By taking this sample into account, nanotechnology also emerges as an essential chance for environmental recovery and resource management. And as it's mentioned before, due to construction industry's huge role in the use of produced energy, the materials do also process an immense impact on CO^2 gas emission (Leydecker, 2008). For this reason, nanotechnology offers architecture,interior architecture and related disciplines a novel milieu for achieving greater energy efficiency and sustainable construction through innovation.

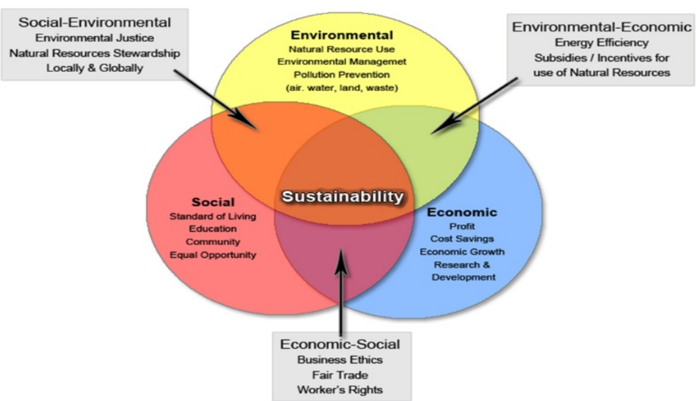


Figure 2.5: Three spheres of sustainability (Adapted from 2002 University of Michigan Sustainability Assessment Report

2.4 Emergence of Nanotechnology and Nanomaterials in Architecture and Interior Architecture

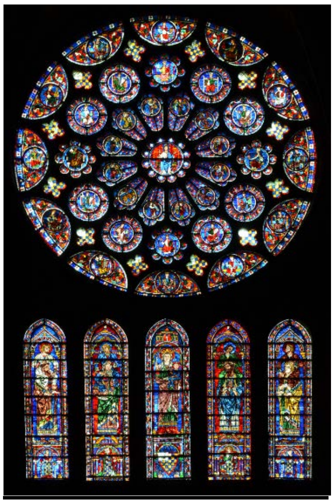
2.4.1 Nanotechnology and Nanomaterials

Nanoscience is a type of science and technology, which investigates and controls the structure and behavior of matter in order to understand and exploit their properties (Mendez, 2006, p. 20). According to Mendez (2006), the prefix *nano* derives from the Greek root "νᾶνος," which resembles the meaning"dwarf" (Url 8).

On the other hand, when we look at the history of the nanomaterials, recent discussions on nanomaterials derive back the initial use of them back to ancient times. It is acknowledged that ancient artists were the first nanotechnologists, in terms of using the principles of nanotechnology in their crafts (Url 9). For instance the glass blowers have been referred as the pioneers, due to their deployment of materials with transformative capacities, without possessing any knowledge or awareness about it. One of the most importantartifact, which is created by Roman glass blowers 2400 years ago (4th Century A.D.) is the priceless "Lycurgus Cup", which is kept in British Museum's collections (Freestone et al., 2007, p. 270), (Figure 2.6). This masterpiece resembles like jade with an opaque greenish-yellow tone, when exposed directly to the light turns into a translucent ruby color with the shining light through it (Freestone et al., 2007, p. 270). The reason behind this story is the presence of silver gold alloys in the mixture of the material, which is later proved by nanotechnology scientists nowadays (Freestone et al., 2007, p. 270). Without having any knowledge about nanotechnology the Romans have changed the fundamental structure of the material by adding the silver gold alloys and granting a new character to the existing material which is the basis of the nanomaterial science.

Figure 2.6: Lycurgus Cup, 4th Century A.D. British Museum’s collections

Medieval Ages were the very first years, which mankind had used this technology without having knowledge about the revolutionary effect of the experiments they did (Url 9).In 9-10th centuries by using the technique of adding metals such as copper, silver or gold to the combination of glass, glassblowers of the time created colorful windows offering variety of colors from yellow or green with silver to amber or brown red with copper (Url 9).Finally, the outstanding work of glass blowers during Gothic making stained glass windows in the churches as again the result of simple nanotechnology processes (Figure 2.7 and 2.8) (Url 9).



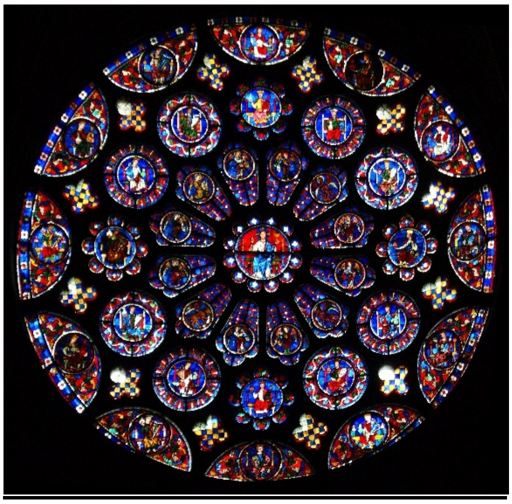


Figure 2.7 and Figure 2.8: The South Transept rose window in Chartres Cathedral, Paris, 1220

When we return to the contemporary world, we observe that the major kickoff with the deployment of sophisticated technologies has started with the Nobel Prize winner Richard Feynmann’s lecture entitled "There's Plenty of Room at the Bottom" in December 1959, in APS-American Physical Society (Mendez, 2006, p. 7). In his lecture, Feynmann briefly shares the basic principles of nanotechnology, by explaining his experiments about catching atoms and molecules while putting them down in a given position, and manufacturing the artifacts with a precision of a few atoms, yet further more acknowledging the society about the possible benefits of nanotechnology (Mendez, 2006, p. 24). (Figure 2.9).

Figure 2.9: Richard Feynman talking with a teaching assistant after the lecture on The Dependence of Amplitudes on Time, April 29, 1963.

Doubtlessly, this let the way to an immense challenge and progress in the development of the nanotechnology and the nanomaterials. In terms of realization process, calculations and the measurements, nano-meter emerges as the measure of this novel convention, and resembles a billions of a meter, i.e. “tens of thousands of times smaller than the diameter of a human hair” (Url 10). For a better understanding, there are some examples, which may help us to explain the terms of nano-scale in simple ways. For instance there are 25,400,000 nano-meters in an inch or a sheet of newspaper is about 100,000 nano-meters thick and on a comparative scale, if a marble were a nano-meter, than one meter would be the size of Earth (Url 11) (Figure 2.10).

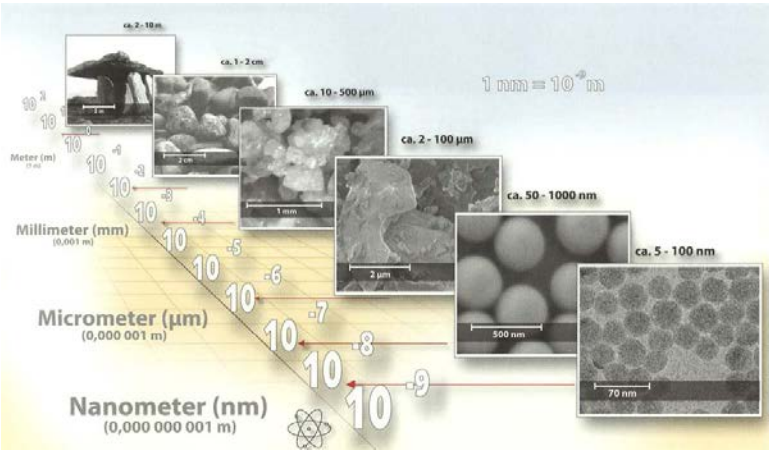


Figure 2.10: Nano-scale to a meter, Leydecker, 2008.

The important point of nano-science is not only to figure out the properties of matter, but also to reach the preferred position of properties in ranging level of atoms or molecules, by changing thenature and fundamental structure of the matter (Mendez, 2006). In other words, the term nanotechnology refers to all technologies, which cause to produce as a consequence of manipulating and application in the fundamental structure of matter in the nano-scale.

Referring to Mendez (2006), the field of nanotechnology is based on three different aspects: first, dimension oriented nanotechnological interventions, where scientists are seeking to build smaller and smaller structures and devices, down to nanometric-scales; second, operation oriented nanotechnological interventions, where scientists are also investigating new characteristics of materials by manipulating them at atomic or molecular scale; and third, fabrication oriented nanotechnological interventions, where bottom-up assembly or molecular self-assembly, in other words the union or conjugation of atoms and molecules to create a new more complex structure (Mendez 2006, p.22). Nanotechnology reveals revolutionary developments in many areas such as medicine, textile, energy, computing and etc. The most concrete reflection of nanotechnology that is observed in the architecture and interior design and construction industry is nanomaterials. Self-cleaning surfaces, easy to clean surfaces, self-healing concrete, anti-reflective glass surfaces, antibacterial, anti-fingerprints, fire-proof, solar protection, thermal insulating, air-purifying, anti-fogging nanomaterials and etc. are the essential building nanomaterials, which all have important roles in contemporary architecture and interior design field.

On the other hand, as it has been mentioned earlier, all types of nanomaterials consist of extraordinary chemical and physical properties in their essence, which possesses the potential transformability capacity in nano-meter scale by means of nanotechnology. There are specifically manufactured nanomaterials with their purposeful properties, to be used in numerous fields in prospect steps. In recent years, nanotechnology is progressively under in development for its further implementations both in the field of construction industry and in the field of architecture, as well as interior design. As a simple example, concrete has been one of the most important building materials in the architectural realm and construction industry for ages. But, in contemporary architecture, architects and designers need additional features and accompanying properties, which materials don’t have in their natural position. However, with the effect of nanotechnology by using nano-structure characterization tools on concrete combination causes to form nano-concrete, which have no estimated properties such as improving mechanical properties like concrete tensile, compression, bending, cutting, strength, providing worthy workability of the concrete (Figure 2.11) (Kart, 2011).This also maintains a uniform structure and reduces constructional segregation; reduces the use of additives in concrete and environmental pollution, moreover the risk of *silicosis* which is a long disease that occurs due to fading micro silica and as a final point, it is low cost (Kart, 2011).

Figure 2.11: An example for fast-drying concrete implementation (Sullivan, 2012).

In addition to nano-concrete, there are various types of nanomaterials such as self-cleaning, anti-fogging, solar protection, fire proof etc. that are also indicated briefly in Table 2.3 on page 28.

Widespread application of nanomaterials in diverse types of industries especially in architectural design and construction industry because of the benefits and advantages of their purposeful properties, in some rare cases, give rise to emerge in deliberately health and environmental risks. It is important to notice that; people always are in direct contamination with these kind of materials in their habitat, work places, entertainment environments etc. (Rajive Dhingra et al, 2010). In order to prevent possible hazards that could occur during the manufacturing process, green nano-manufacturing procedure is used in the production. (Rajive Dhingra et al, 2010). Like, Dhingra et al. (2010) mention; "[l]ife cycle of building nanomaterials are important in determining the impacts on the health of building inhabitants and construction workers, as well as the environmental effects as all stages of manufacturing, construction, operation, demolition and disposal. Therefore, application of sustainable manufacturing practices and use [of] green chemistry alternatives would be an efficient solution thorough the environmentally risks and problems which are arising from nanomaterials." (Dhingra et al., 2010).

2.4.2 Nanotechnology and Nano-Architecture

Nanotechnology, which is obviously recognized as the most transformative technology, has the potential to alter not only our built environment, but also as a result our everyday life. It is explicitly observed that the penetration of nanotechnology into the realm of architecture and construction industry has given the birth to Nano-Architecture: Nanotechnology + Architecture (Elvin, 2007).

In the domain of architecture, nanotechnology has appeared by means of materiality. It should be pointed out that, the aim of nano-architecture is not to create new and extraordinary spaces with particular design aspects, but to main the goal of integrating this technology with architecture in terms of attaining a substantial level of sustainability Fouad, 2012).This means that, through nano-architecture every building should be designed in a way, which consumes less raw materials and non-renewable resourcesand at the end of their life cycle, so that the used materials would be a source to build newconstructions. At the present times, through applying nano-building materials in construction industry, buildings may become adaptable with environmental conditions, which provide the sustainability for future (Fouad, 2012).

With the adventof nano-building materials in architecture and interior architecture we observe the positive results both in the construction process, and in long-term use of materials (Url 12). As an example, in the process of construction, with the use of nanomaterials such as nano-concrete and etc. natural phenomena like acid rains, temperature and chemical reactions in construction stage, will neither be considered as a barrier, nor a destructive factor any more (Url 12). So, it is examined that buildings could perform perfectly to deal with environmental issues, for instance, respond automatically to variation in temperature, airflow, energy consumption, wind loads and other conditions via technological enhancement and using of nanomaterials, which are designed for attainment to suitable conditions in aspect of architecture and interior design field in every scales such as site, structure, furnishing, finishing and fixtures (Url 12).

2.5 Embodied Energy and Embodied Carbon Indexes of Materialities

Every material that is deployed within the construction, consumes a great amount of energy through its entire life cycle, starting with processes of manufacturing, then in use, operation and deconstruction. It is important to note that, these stagesencompass, raw material extraction, transportation to factory, processing and manufacturing, transportation to site and construction, installation as well as its disassembly, deconstruction and decomposition. All these consumed energy throughout the materials or products life cycle is defined as the “embodied energy”, whereas pursuing this cycle emerges the energy consumption and carbon emission (Cabeza et al, 2012). Likewise, the notion of “embodied carbon” refers to carbon dioxide emitted during the manufacture, transport, construction of building materials and end of its’ life (Url 13). By highlighting that, in mentioned perocess not only carbon dioxide, but also other related gasses are emmited which contributing to climate change in the world (Url 13).

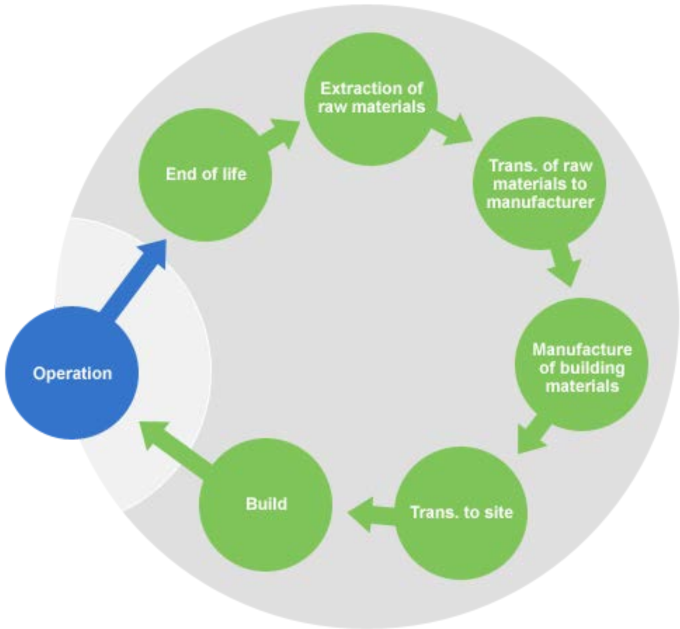


Figure 2.12: Embodied energy and embodied carbon of materials during the construction lifecycle

With increase of awareness about environmental issues, such as green-house gas emissions and natural resource shortages, the importance of embodied energy and carbon issues in building materials has gained a great importance in order to operate on favor of better energy performance in the buildings (Cabeza et al, 2012). Referring to the statements mentioned in previous sub-section, almost 40 % of produced energyand materials in the globe are consumed by means of buildings (Cross Cain, 2007). Therefore, the built environment accounts for the largest share of greenhouse gas emissions and waste stream in terms of energy and usage (Url 14). By taking these issues into consideration, the quantity and type of materials used in the construction industry could have major effect on sustainability and reduce climate changing impacts which are related to the named industry (Url 15). According to Gonzalez and Navvaro, building materials with high-embodied energy, could possibly result in more carbon dioxide emissions than to the materials with low-embodied energy (Cabeza et al, 2012). For this reason, in construction industry, architects, interior designers and engineers need to be conscious of the embodied energy of the materials, so that they can select products that help reduce the overall energy footprint of buildings. In order to maintain the most appropriate impact factor that is compatible with the global environmental issues, designers need to be aware of material selections in their design processes on behalf of lower embodied energy levels, higher durability, lower levels of toxicity, and overall favorable life-cycle impacts (Url 16).However, there has been a keen presumption shared by many people that, higher amount of energy is required for producing nanomaterials because of their long lifecycle; yet being argued that these products have higher global warming impact when compared with conventionalmaterials and their process of produce. However, the studies of Kim and Fthennakis have proved that, the cradle-grave energy demand and global warming impact from nano-enable products are lower than conventional materials and technologies because nanomaterials are typically used in a small amount to improve functionality and the upgraded functionality offers more energy efficient operation (Kim and Fthennakis, n.d). By highlighting that, in some cases maybe the energy used for producing and montage of some of nanomaterials could be more than conventional ones, but it is undoubtable that, they will be more sustainable during their lifecycle (Kim and Fthennakis, n.d).

For this purposes, in fourth chapter, the embodied energy and embodied carbon of implemented nanomaterials are analyzed in three cases from Istanbul to compare with conventional materials to understand the potentional of nanomaterials in interior architectural design.

3. Types of nanomaterials Deployed in Architectural Design and Implementation

Nanotechnology has been an essential and the foremost technological step in 21st Century, it is worthwhile to notice that, particularproperties of nanomaterials and their characteristic attributes in return environmental factors clearly indicate vast promise in numerous fields especially in architecture and interior design. Rewi (2006) highlights the importance of material selection in design, by referring to Maregatti, and she quotes that "If designers did not have to be so concerned about how materials perform and maintain, they could spend more energy developing new concepts and ideas for improving people's lives through design solutions", (Rewi, 2006, p.19). So, taking Maregatti's statement into account, it could be clearly observed that how nanotechnology have affected architecture and interior design field and as a final point affected people's life in all aspects. The presence of this materialist approach, not only vanishes the borders in the way of architects' and designers' ideas and creation, but also maintains numerous possibilities to them to design specially, public places such as hospitals, restaurant, hotels and etc. with excellentperformance in energy efficiency, durability and sustainability.

For example, in 2002 Commonwealth Scientific and Industrial Research Organization (CSIRO) and Sydney's University of Technology were collaborated to establish the implementation of nanotechnology and how they cooperate with conventional buildings and interior materials, lunched the nano-house research. (Rewi, 2006) (Muir 2004)(Figure 2.12).

The first nano-house, by architect James Muir, so-called, The Glass House Project, (2004), is enveloped with huge glazed façade, and designed with nano-based products such as, UV/IR filtering and reflecting windows to control unwanted solar heat; self-cleaning TiO_2 coated glass; UV protective coatings on furniture; self-cleaning tiles; cold lighting systems for harvesting daylight; and heat-absorbent nano-particulate paints that are light-colored in the visible part of the spectrum" (Rewi,2006).

Figure 2.13: The Glass House Project (2004) by architect James Muir, in Nano-house Research Group, CSIRO-Industrial Research Organization and Sydney University of Technology, Dr.Michael Cortie (co), Sydney, 2002.

Experiments like these, have proven that, a nano-house with its particular shape, performance, controlling system and facilities, is a sample for smart shelter, which could save energy for one million dollar each year, while terminating the diffuse of 12500 tone carbon dioxide to the atmosphere (Pir Mohammadi, et al., 2014). On the other hand, in another experiment, by James Muir, The Glass House Project 2004 also explores the potentials of the nanomaterials (Muir, 2004) (Figure 2.13). This smart house consists of two different layers, where each has different role in relation to environmental issues. The first layer, which is defined as a nano-layer saves physical information, while the second one, which is considered as a logical-layer analyses raw information and does essential changes for environment compatibility (Figure 2.14 and 2.15). (Pir Mohammadi, et al., 2014). In addition to nanomaterials that are used both in exterior and interior design of the house; the roof of the house also accommodates vents, which mediates the airflow through glass lures (Muir, 2004). This forms a natural heat siphon that pulls the air through the pavilion and keeps it cool (Muir, 2004).

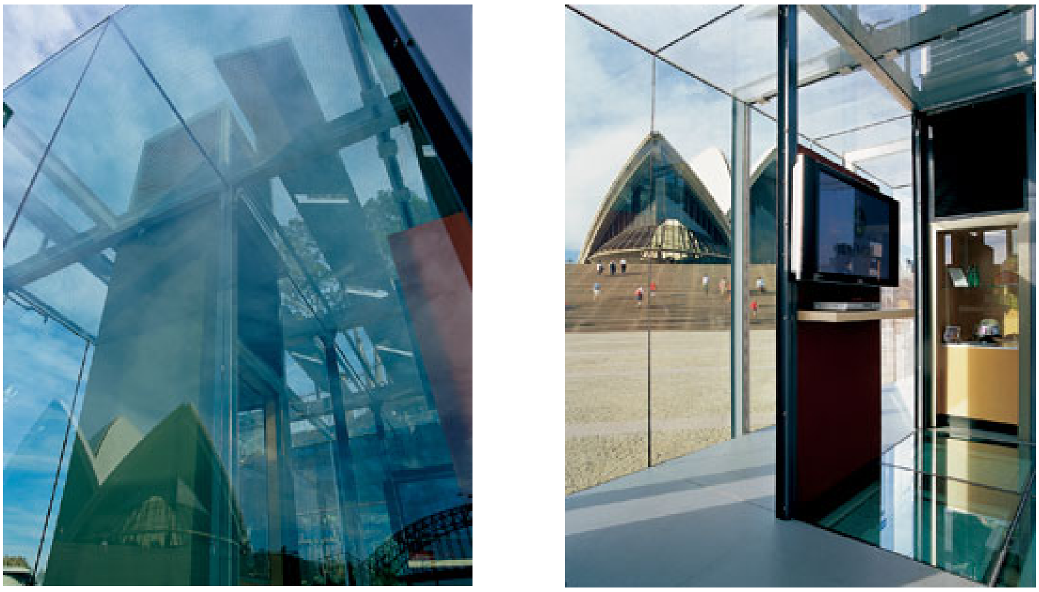


Figure 2.14 and 2.15: The Glass House Project (2004) by architect James Muir, in Nano-house Research Group, CSIRO-Industrial Research Organization and Sydney University of Technology, Dr.Michael Cortie (co), Sydney, 2002.

In the light of these very initial examples, and pursuing with the more recent ones, it is observed that, in terms of nano-context, nanomaterials are the most significant relevance between the term of economy and ecology with sustainability. Like Veith (2008) affirms; "One should not forget that, nanotechnology is an enabling technology, it helps to improve existing products rather than creating completely new products." (Veith, 2008, p.10-11).In relation to this principle, we observe quite great amount of supplementary use of nanomaterial, which are targeted/oriented to enhance the material qualities on behalf of improvement, long term use and maintenance purposes such as: self-cleaning (Lotus Effect and Photocatalysis); air purifying; anti-fogging; thermal insulations (Aerogel); temperature regulation (PCMs); solar and UV protection; protection; fire-proof; anti-graffiti; anti-reflective; antibacterial; anti-fingerprint; scratchproof and abrasion-resistance, which all can be summarized in the Table 2.3 below.

Departing from these varying qualities, this sub-chapter briefly focuses on each nanomaterial enhancement that are mostly deployed in interior design.

Table 2.3

Table 2.3 arka Sayfasi

3.1 Self-Cleaning Qualities

3.1.1 Lotus-Effect

Lotus effect is one of the best-known means of designing surfaces with nanomaterials. Self-cleaning behavior is normally achieved using hydrophobic surfaces with nano-structured features (Anous, 2014).These products are inspired by the lotus flower leaves that combine a surface roughness at the nano-scale and the water repellent wax at the same time (Leydecker, 2008). The leaves of Lotus plants are coated with minute wax crystals around 1nm in diameter, which repel water droplets falling onto them bead up and, if the surface slopes slightly, will roll off (figures 2.16 and 2.17), (Leydecker, 2008).

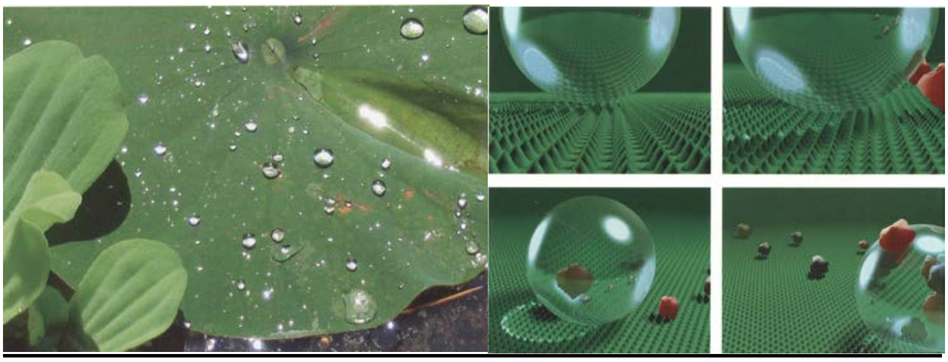


Figure 2.16 and Figure 2.17: Lotus Plant and a microscopic view of a water droplet resting on a super hydrophic knobbly surface, (Leydecker,2008).

So, lotus effect surfaces with water-repelled property could clean the organic dirt,while water droplets are rolling down. For this reason, these products is better to apply on the materials which have more contact with water such as building facade, bathroom, toilet, swimming pool and etc.

For instance, the facade of Ara Pacis Museum is designed with glass, large blocks of travertine and white surfaces, which are painted in white with Lotusan self-cleaning paint (Figure 2.18 and 2.19). Here a self-cleaning coatings has been invisibly integrated into the white color to ensure the durability of the color. For this reason, it remains white for a long-term in the heavy polluted city (Leydecker, 2008).

Figure 2.18 and Figure 2.19: white facade of Ara Pacis Museum, Rome, Richard Meier & Partners, 2006

3.1.2 Photocatalysis

Photocatalytic self-cleaning is the property of surfaces coated with titanium dioxide (TiO_2) nanoparticles. Its properties are super-hydrophilic of the surfaces witch are created by oxygen gaps on the TiO_2 surface (Anous, 2014). By highlighting that, the term “Self-Cleaning” does not mean that, the product, with this property can clean itself. In fact, this substance significantly decrease the number of cleaning times by extending the intervals between cleaning periods (Leydecker, 2008), As a result, fewer detergents will required, which lead to less wear and tear of materials and less environmental pollutants and saving personal costs. It is also important to notice that, for the means of functioning the material a correct ratio of UV light, oxygen and air humidity levels are required. The level of UV light present in normal daylight is sufficient to activate the photocatalytic reaction (Leydecker, 2008). When the sunlight reach to the material, the existing organic dirt on the surfaces decomposed with the help of catalyst reaction and dirts are cleaned by means of rains water (Figure 2.20) (Inas Hosny, 2014). Self-cleaning photo catalysis substances are invisible nano-based products, could be added into concrete or could be applied onto façade panels made of glass and ceramic or to membranes (Leydecker, 2008), For this reason, these products are more effective at outdoors use such as facade design and glass patios than indoor environments.

Figure 2.20:photocalysis process on self cleanin photocatalysis surfaces, (Leydecker,2008).

In another example again by Richard Meier and his partners, Jubilee Church (Figure 2.21), which is known because of its long-term white and clean concrete façade (Url 17). To preserve the whiteness of the building company Italcementi developed a new cement containing Carrara marble and titanium dioxide, TX called Millennium, which guarantees the whiteness of the concrete, despite the pollution, rain and weather effects (Url 18). These additivets not only provide long-term clean surface in urban environment with heavily polluted exhaust gases, but also, combat pollition by considerably reducing the amount of volatile organic compounds (VOCs) and nitrojen oxide (NO) in the air (Leydecker, 2008).

Figure 2.21: White and clean concrete facade of Jubilee church, Rome, Richard Meier, 2003

3.1.3 East-to-Clean (ETC)

Easy-to-clean surfaces, which are mostly confused by other self-cleaning functions are water-repellent products (Leydecker, 2008). Yet, when material qualities are examined, it is observed that there are major differences between ETC with *Lotus-Effect* and *Photocatalysis* surfaces (Leydecker, 2008). In one hand, ETC surfaces, at the microscopic scale are smoother rather than rough, and because of their smooth surfaces, easy-to-clean coatings do not have adhesive properties; and furthermore this causes water to be repelled by forming droplets and running off (Figure 2.22 and 2.23) (Leydecker, 2008).

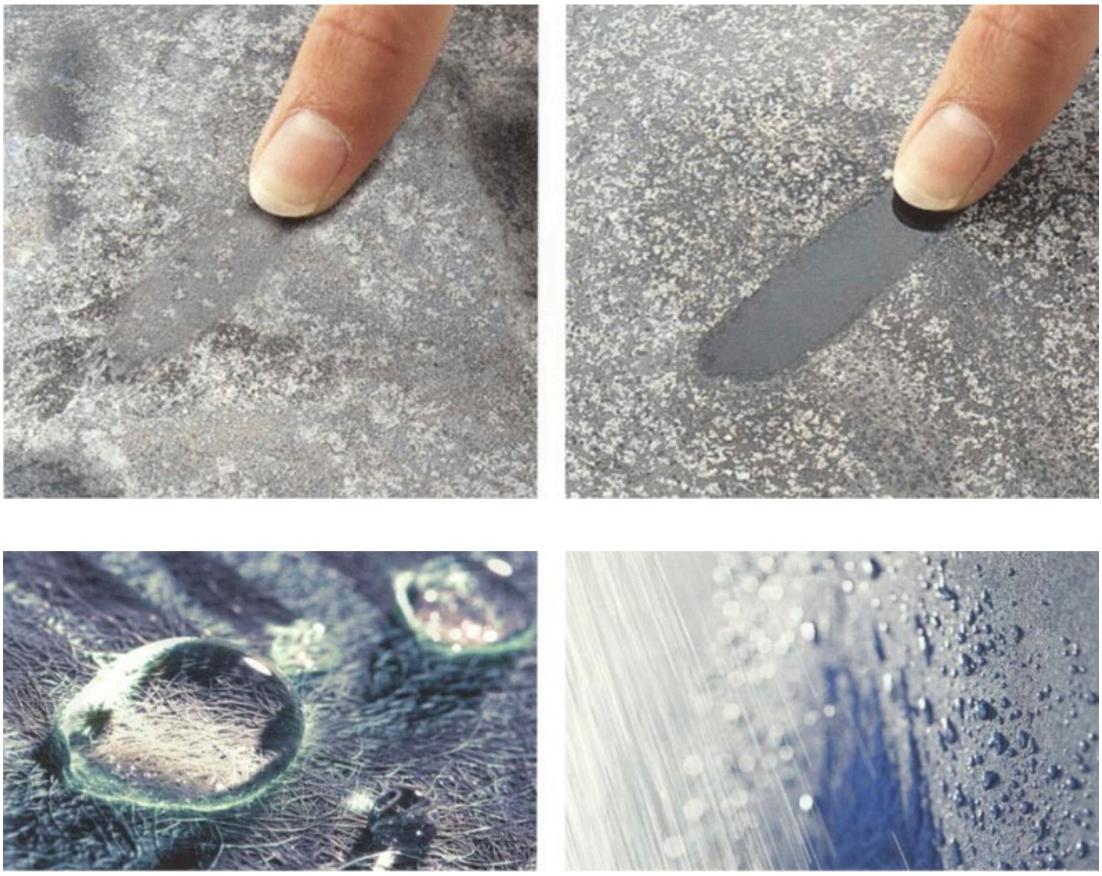


Figure 2.22 and Figure 2.23: A comparison of ceramic surfaces – left without ETC coating, right with ETC coating Flexible ETC ceramic wall coverings, similar to wallpapers, can withstand direct exposure to water, such as that in a shower cubicle, thanks to their highly water-repellent surface, (Leydecker, 2008).

In addition to water-repelled function, oil-repelled is also another important property of these products (El-Samny, 2008). For this reason ETC surfaces are appropriate for using in bathrooms and toilets that are open to diverse threats of water. Moreover, the main differences between ETC and Photocatalysis surfaces is, there is no need of UVlight and/or an excessive amount of water to activate the easy-to-clean coatings (El-Samny, 2008). Therefore, ETC products are suitable for both outdoor and indoor environments. Super-hydrophobic materials and coatings are also beneficial, where dirt accumulation needs to be kept to a minimum and water repellence is ensured (El-Samny, 2008). Figure 2.24 indicates the comparison of ETC surfaces with other conventional surfaces and hydrophilic photocatalytic nano-surfaces, which are activated by UV light. Image on the left shows the behavior of a water droplet on a conventional surface, while the image in the middle shows droplets on hydrophobic ETC or Lotus Effect surface from spherical shape, and the image on right displaces a hydrophilic photocatalytic surfaces activated by UV light (Leydecker, 2008).

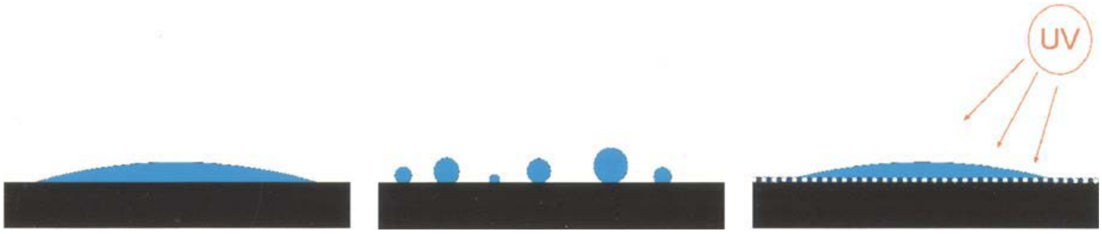


Figure 2.24: A comparison of surfaces with different wetting properties, (Leydecker, 2008).

Figure 2.25: Ultra clean white surfaces of poolside with ETC quality, (Leydecker, 2008).

Figure 2.26: Yachtinteriors with self-cleansing qualities, (Leydecker, 2008)

ETC products are stress free and save time and costs. There is a common misconception among people that, by using easy-to-clean or self-cleaning materials, there is no need to clean anyway, but it is important to mention once again that, these kinds of materials reduce the counts and period of cleaning (Figure 2.25). As such, ETC surfaces are most commonly found in interiors, but can also be employed outdoors for better weather protection (Figure 2.26). As an example, Mohen

DesignInternational group, characterized their Chinese office with combining classic and contemporary design elements. The used elements both have decorative and functional properties. Special wall coatings with ETC, anti-bacterial and warming properties and hydrophobic natural stone stairs, not only looks aesthetic, but also the nano-based ETC coatings function to improve their durability (Figure 2.27 and 2.28) (Leydecker, 2008).

Figure 2.27 and Figure 2.28: Interior of Mohen Design International Office, China, Mohen Design International Group, 2006, (Leydecker,2008).

3.2Air Purifying Quality

Unfortunately, unplanned technological enhancements of Late-Industrial Era further caused environmental pollutions and destruction of natural resources; where as a clean and healthy air has become one of the most basic and precious needs at both outdoor and indoor environment at this present age. For this purpose the air-purifying nanomaterials are basically developed to response this vital problem. However, these productshave not yet replaced thoroughly the clean air, but it is examined that they have significant impact on improvement air quality and are beneficial in both cases, and play an important role both for indoor, as well as increasingly for outdoors environments (Fahmy, 2010).

Indoor air quality has a direct relationship withhuman's general feelings of well – being (Leydecker, 2008). This means that, the better the indoor air boosts, enhanced feeling of peace and serenity of the environment; even the most beautiful spaces will not feel comfortable if the indoor air quality is disagreeable. Indoor air quality has been an important issue particularly in industrialized nations, who have recently developed this awareness. Because, people spend most of their times in enclosed areas, therefore, this approach could also be respond to counteract the *Sick Building Syndrome* (*SBS*) which has been discussed in the previous sections (Leydecker, 2008). For this reason, it is essential for interior designers to consider indoor air quality in their design process, due to its long-term effect on human health. In the operative realm of nanomaterials, the air-purifying nano-surfaces not only reduce the unpleasant smells from environment, but also they could decrease air-pollution, such as pollution from smoking or unpleasant food smell etc. (Fahmy, 2010).But, it is also worth to mention that, this system will function properly, if the volume of implementation of these product be proportional with the volume of environment, which will designed for this purpose and these surfaces should be in contact with air (Figure 2.29) (Fahmy 2010).

Figure 2.29: Products with air-purifying nano-coatings, (Leydecker, 2008).

Air-purifying technologies are mostly applied on paints and textiles (figures 2.30, 2.31, 2.33 and 2.34), (Fahmy, 2010). Obliged to point out once again that, “this technology does not produce healthy air, it just enhance the quality of air by chemically decompose odors into their harmless constituent parts; where the molecules are cracked, giving off steam and carbon dioxide” (Leydecker, 2008). Therefore,by using air-purifying nanomaterials, it would be not accurate to assume that, natural ventilation is not required and regular ventilation is necessary to allow to CO^2 to escape (Leydecker, 2008).


Figure 2.30 and Figure 2.31: In the call-center of "die fabrik" in Cottbus, Germany, the surfaces are both air-purifying and sound insulating, (Leydecker, 2008).


Figure 2.32 and 2.33: Air- purifying materials such as plasterboard oracoustic panels (Leydecker, 2008)

In addition to the indoors, building façades, road surfaces etc. are equipped with appropriate coating of air purifying nanomaterials to counteract the effect of industrial and vehicle exhaust. As an example, a hospital building designed in Mexico City “eats smog” (Figure 2.34) (Zimmer, 2013). The Manuel Gea González Hospital in Mexico City with double skinned decorative façade emerges as an innovative example that becomes both functional and fashionable at the same time (Figure 2.35 and 2.36). It is made up of elegantly designed Prosolve370e modules with anti-microbial and de-polluting properties, which have been installed for helping to soak up air pollution and creating a better quality of life (Zimmer, 2013). Prosolve tiles are coated with very thin layer and of titanium dioxide, which fights and retains pollution with neutralizing emissions and other toxins when activated by ambient daylight (Salla, 2014). By highlighting that, no high UV radiation levels are needed to activate the coating

electrons, so that they "break down nitrogen oxides and other compounds, transforming them into water and calcium nitrate [$Ca(NO_3)_2$], that will be washed off by the rain" (Salla, 2014).

Figure 2.34: Façade of the Manuel Gea González Hospital, Mexico City, 2013.

This system cleans the neighboring air and the air that goes to the building. Another advantage of these tiles is filtering sunlight, which lead to saves air conditioning energy and avoids polluting emissions (Salla, 2014). It is important to notice that, this façade, is estimated to be able to neutralize the nitrogen oxides emissions of 1,000 vehicles every day (Salla, 2014).

Figure 2.35 and figure 2.36: Prosolve tiles coated with TiO2, Mexico City, 2013.

3.3 Anti-Fogging Quality

As it is commonly observed, in the environments open to the threat of damp such as bathrooms, toilets, swimming pools and etc., when the moisture in the air has condenses, it settles on the glazed surfaces like mirrors and glass separators. This action creates spots, which causes cloudy surfaces. The common methods of removing these spots are cleaning or heating those surfaces, by various heating methods, so that the settled moisture on panels evaporates and spots on the surfaces fade away, however, always remaining for the next round. Therefore, in terms of maintaining a more permanent solution to keep glazed surfaces clean from fogging, but rather than not to consume excessive energy for heating; anti-fogging nano technological coatings are emerged to respond to these problems. By means of nanotechnology, permanently clear view ispossible without requiring to energy or electricity.

The solution is ultra-thin coatings of nano-scalar titanium di oxide, which exhibits a high surface energy and therefore, grater moisture attraction (Leydecker, 2008). On these hydrophilic coatings, moisture forms as an ultra-thin film instead of water droplets, which causes spots on surfaces (Leydecker, 2008). These films still settle on the surfaces, but remains invisible. Thus, as the film is transparent, it creates fog-free clear appearance. Particularly in indoors, especially bathroom mirrors and glass panels are the ideal surfaces to apply such coatings (Figure 2.37). These coatings are also suitable for glass surfaces of air-conditioned rooms in the tropic climates, which tend to cloud as soon as outdoor air streams into a room.

Figure 2.37: Mirrors with anti-fogging nano-coatings, (Leydecker, 2008).

Scientist and researchers at the Massachusetts Institute of Technology (MIT) in 2005 has discovered another method to solve mentioned problems, a glass like nano-porous surface coating made of several layers, containing minute holes made by nanoparticles (Fahmy, 2010). This super hydrophilic surface appears like a flat surface, but with a great potential of efficiency. If these products are applied as coatings in damp environment, moisture is drawn down into its tine pores, thereby stopping water droplets from forming (Fahmy, 2010). A thin invisible layer of water forms and the surface remains clear.

So, taking these two products into consideration, a notable aspect of all anti-fogging nano-coatings is that, clear sight of the surface would be possible at all times, without necessitating heating, or wiping down. By using these products, condensation itself is not stopped, but instead it remains transparent and therefore appearing invisible, it does not interfere with the sight.

3.4 Insulation Qualities

3.4.1 Thermal Insulations (Aerogel) Quality

Nano Thermal Insulation, which is known as nanogel (a form of Aerogel), not only, provides high performance in thermal insulation, but also performs as an effective sound insulation at the same time (Leydecker, 2008). Aerogelcomposed of air (about 95-99.9%) and silicon dioxide (silica) (Leydecker, 2008).

This material has been used as an insulating infill material in various kinds of cavities between glass panels, U profile glass or acrylic glass multi-wall panels, and therefore it is well suited for the advanced use in the external envelopes of buildings (Figure 2.38) (El-Samny, 2008). Aerogel thermal insulations are used in both exterior environments such as facade panels, and interior environments such as separators in conference areas in offices. The main goal of producing this nano-based product is attaining energy efficiency, which reduce life expenses of the built systems in order to reach sustainability.

Figure 2.38: Glass sample with black edging and aerogel-filled glazing cavity. (Leydecker, 2008).

On the other hand, by highlighting its translucent property, aerogel also performs as a good light transmitter; therefore it can spread light evenly and pleasantly (Fahmy, 2010). This product, can transform the straight sun light to the glance-free soft light; and for this reason, it further eliminates the necessity of using curtains and heating/cooling systems (Fahmy, 2010). In addition to all, because of the regular distribution of light there is no need to use artificial lighting systems during cloudy days, and in those moments, indoor environments, look brighter and comfortable (El-Samny, 2008).

Moreover, in terms of sound insulation, the air molecules trapped in the gaps of Aerogel, perform as a barrier in front of sound waves passing (Leydecker, 2008). Due to hydrophobic property of the material moisture and mold also will not an issue. This product is mostly use in factories, sports hall, zoos and schools. As an example, Milwaukee County Zoo, designed by Zimmerman Design Group, made up of stone, concrete and aerogel-filled glass panels to provide glare-free natural daylight whilst ensuring greater thermal performance and energy efficiency and, because better natural lighting is an essential key to improve conditions for the big cats and could have a positive effect on the reproductive cycle of the animals (Figure 2.39 and 2.40) (Leydecker, 2008).

Figure 2.39 and Figure 2.40: Milwaukee County Zoo designed with aerogel-filled glass panels, USA, Zimmerman Design Group, 2005 (Leydecker, 2008).

3.4.2 Temperature Regulating Quality

As it is known, regulating the temperature of buildings in both processes of heating and cooling requires quite much more energy. Doubtlessly, the excessive consumption of energy cause to Greenhouse Gas Emission and other non-sustainable affects. For this reason, apart from thermal insulators, nanotechnology has also produced temperature-regulating products to reduce the energy consumption in the field of architecture and interior design (Fahmy, 2010).

Latent heat storage, which is known as Phase Change Material (PCM), can be used as effective means of regulating indoors temperature (Fahmy, 2010). Thermal retention of PCMs could be applied not only on new constructed buildings, but also to the old ones (Leydecker, 2008). These products alsoactas athermal insulationandpreventunwantedairinfiltration and exfiltration. The main substances of PCMs are paraffin and salt hydrates (Leydecker, 2008).“Minute paraffin globules with a diameter of between 2 and 20 nm are enclosed in a sealed plastic sheeting”, which could be injected into typical building materials (Leydecker, 2008). In summer, this material, could receive and store the heat without changing its real-time temperature; then the received heat causes the change and transforms the paraffin material from phases of solid to liquid then gas (Leydecker, 2008).“During [this] phase changes, the warmth is retained latently for as long as is required to change from on physical state to another, during this process, the PCM absorbs a particular amount of heat, the specific latent heat equivalent to the amount of energy require to melt paraffin” (Leydecker, 2008). For this reason the temperature level of the material, which PCM is applied to, remains constant. Also, in winter, the reverse of this process could occur (Leydecker, 2008). It is important to mention that, the amount of energy, which are gained or released by means of PCMs aresignificantly more than being assumed. So that, any smallest amount of PCMs may have great effect on buildings temperature. The PCM has far greater thermal capacity, as an example, a concrete wall warms up much more quickly, whilst the temperature of a PCM remains unchanged (El-Samny, 2008).These products could be also considered as additives in the construction industry and interior design field, into conventional building materials such as plasters, plaster-boards (Figure 2.41), and aerated concrete blockers (Fahmy, 2010). Not to forget that, the existing paraffin inside PCMs is a flammable material, therefore, PCMs are not fireproof products (Leydecker, 2008). In addition to these, building materials, which are consisted of PCMs could also perform good thermal insulations, by ensuring rapidly transferring the heat to PCMs; so that the paraffin has a relatively low thermal conductivity (Leydecker, 2008). Although its side-effect of inflammability, PCMs have valuable advantages, which are listed such as, improving indoor climate, reducing energy costs, obtaining the need for air conditioning and providing a further nanotechnology based opportunity to reduce CO^2 emission (Leydecker, 2008). It is important to notice that these materials are also very recyclable and biologically degradable (El-Samny, 2008).

Figure 2.41:PCM plaster applied on interior walls provides thermal insulation, (Leydecker, 2008).

Figure 2.42: Glazed south façade of Sur Falveng with PCM Quality, Zurich, Dietrich Schwarz, (Atwa, 2015).

For instance in the project “Sur Falveng” (Figure 2.42), which is a housing complex for elderly people located in Swiss Alps, is characterized with a latent heat storing glass (Figure 2.43 and 2.44). Considering the climate and the geographical settings, the south facade of the building is designed with a massive positioning of glazed surface. This product allows the thermal insulation through the flats, and heats the space actively, or in fact from the passive solar gain, yet regulates the indoor temperature, providing a significant energy saving in heating and cooling facilities. “The central of three cavities of an 8 cm thick composite glass element contain a salt hydrate fill material that functions as a latent heat store for solar heat and protect the rooms from overheating” (Atwa, 2015). Like Atwa mentions, this latent heat store has a thermal absorption capacity, almost equivalent to a 15 cm thick concrete wall (Atwa, 2015). When exposed to heat, the salt hydrate melts, causing the product to look likea transparent glass; but whet it is frozen, and the product looks like a milky-white glass (Atwa, 2015). Both the function and the aesthetics of the material are inseparable, meaning that the function also reflects on the building's facade appearance (Atwa, 2015).

Figure 2.43 and Figure 2.44: Interior and Exterior view of glazed façade with PCM quality, Zurich, Dietrich Schwarz, (Atwa, 2015).

3.5 UV and Solar Protection Qualities

In the field of architecture and interior design, the use of sunlight is one of the most crucial points of design process. It is also important to notice that, sunlight is not always beneficial; yet there are harmful radiations in UV sunrays, whichinvisibly damage both humans and consumed materials in building industry. UV rays not only, fades out the colors of furniture, textures, wall coverings, artworks, fabrics, flooring and etc. and destroys them, but it also causes harmful diseases in humans such as skin cancer.As an example, painted wood, when it is exposed to the sunlight, harmful radiation of UV sunrays destroys the color pigments and coloring of it. Therefore, it is obviously clear that, these radiations not only has disadvantage effect on the appearance of materials, but alsohas negative impact of their durability (Leydecker, 2008). Thus, lasting protection against the damaging ultraviolet spectrum of light is desirable. For this purpose, nanotechnology offers UV-protection coatings to solve these problems.

The first produced nano-based UV protection building materials, which applied in the form of a protective lacquer, are organic substances (El-Samny, 2008). These coatings absorb UV sunrays and filter out the harmful rays before contacting with material itself (El-Samny, 2008). These products could be applied on both new and already damaged materials.In case of applying on already damaged materials, UV protection additive impregnated in material itself and prevent the continued degeneration of an already damaged material, by reacting with the free radicals that form and converting them to inert compounds. It is important to note that, these products could not expose enough durability and lasting protection, due to its organic structure (El-Samny, 2008). So that UV light could degenerate these products and reduce their impact over time. For this reason, new non-organic version of UVprotection are emerged, which provides a more lasting protective effect, becausethey will not degenerate by means of harmful rays of UV light (Leydecker, 2008).

Titanium di Oxide (TiO_2), Zinc Oxide (ZnO), Cero Oxide (CeO), are the main three elements of these products, which arewell suited for this purpose and each of these combination have their own task (Leydecker, 2008), and provide protection against powerful and harmful UV-A (Ultraviolet long rays) and UV-B (Ultraviolet short rays) which damage building materials and also, causes sunburn and skin cancer. (Url 19).

UV protection products, like other nano-coatings are transparent, so the coloring and structure of material beneath is restored (Leydecker, 2008). This product could be a proper selecting for exteriors such as facades and interiors like, patios, atriums, exhibition areas, offices and etc.

Figure 2.45 UV protecting glasses are used in the facade of Ferrari Factory Store, Italy, Iosa Ghini Associates, 2009.

As an example, Ferrari Factory Store is (Figure 2.45) characterized by a large glass gallery to permit total visibility inward and outward. The glass gallery is highly innovative with a curved face which supported with ultra-light clips which guaranteesthe perception of material continuity between the plate glass and provide lightness to the whole system (Figure 2.46 and 2.47). For this purposes, special UVprotection films are suited as well as screen prints for energy saving and reducing sun rays and protect the exhibition objects and visitors (Url 20).

Figure 2.46 and Figure 2.47:outside and inside view of UV protection facade panels of Ferrari Factory Store, Italy, Iosa Ghini Associates, 2009.

In addition, nanotechnology offers integration electrochromic nano-based solar protection glass panels (Figure 2.48). These products, not only, be responsible about solar protection and energy efficiency but also, provides glare-free light and partial shading rather than complete enclosure, which causes further relationships between outside and inside. Accesing to different levels of light transmission with various darking effects could be controlled by single switch. For this reason, solar protection glass pannels, could be a suitable choices for façades and office interiors specially in computer work stations.

Figure 2.48: Facades with Solar protection Quality, (Leydecker, 2008)

3.6 Fire-Proof Quality

Nanotechnology researchers have also developed fireproof glass panels with 3mm thickness, which resist to flames with a temperature of more than 1000 degrees centigrade for more than 120 minutes (Leydecker, 2008).The mainelement of this product, which causes to emerge fireproof quality, is *Flerosil* (pyrogenic silic acid), and this element is injected between two glass panels (Leydecker, 2008). In case of fire, the fire resistant layer between the two glass panels expands in the form of foam, to prevent fire spreading and keeps the roots accessible for people and firemen (Leydecker, 2008). It is also important to note that, this gel is transparent, for this reason, it does not create any visual barriers (Leydecker, 2008).

The main advantage of this product could be listed such as lightweight of the glass, the slender construction, accompanying optical appearance and long duration of fire resistance (El-Samny, 2008). In addition to all, the improved noise insulation is another positive-effect of this product. Therefore, this mentioned advantages are beneficial for building construction, insulation, transportation, aesthetic and of course, safety of users (Fahmy, 2010). Moreover, apart from building construction facilities, this product is also known as a proper material for interior design, especially in exhibition stands, foyers, corridors, meeting areas and places, where fire safety is of utmost importance. For instance these sequential examples like, Dubai International Airport by Paul Audreu (figure 2.49); or Deutsche Post Headquarters in Bonn by Murphy Jahn (figures 2.50 and 2.51); or the Waverly Gate in Edinburg by SMC Hug Martin Architects (figure 2.52), are remarkable examples that all utilize fire-proof panels in their designs.

Figure 2.49:glazed facade with fireproof quality of Dubai International Airport, Dubai, Paul Audreu, 2008.

Figure 2.50 and 2.51: Deutsche Post Headquarters, Bonn, Murphy/Jahn, 2005.

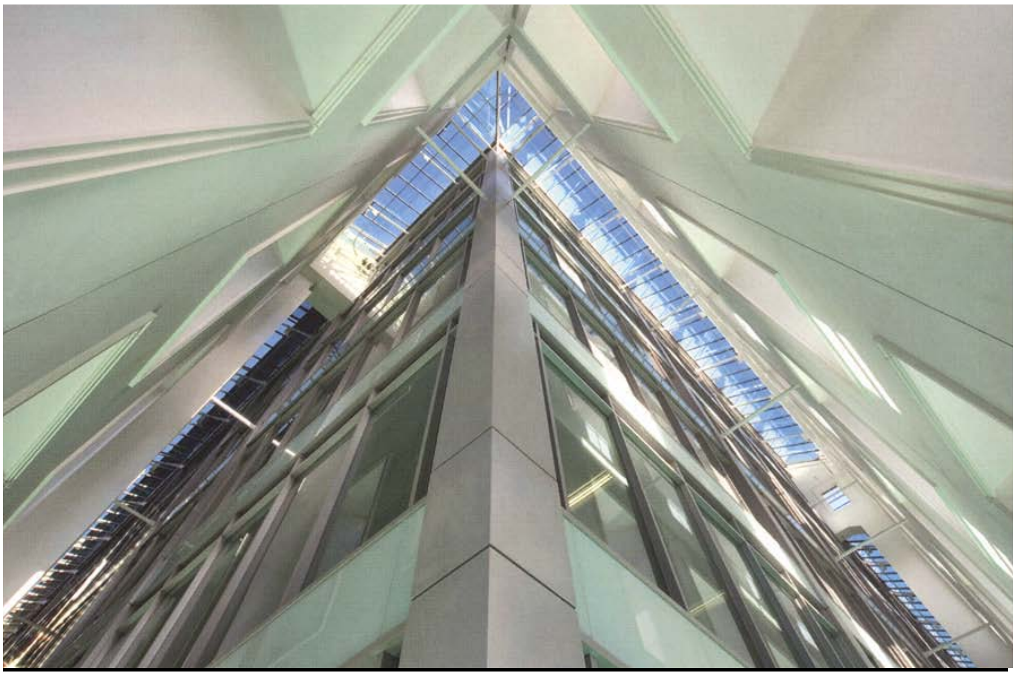


Figure 2.52: Waverly Gate designed with fire-proof panels, Edinburg, SMC Hug Martin Architects, 2005, (Leydecker, 2008).

3.7 Anti-Graffiti Quality

Anti-graffiti nano-coatings are intended asa protective layer on materials to prevent unsightly graffiti on buildings or constructions such as noise barriers, walls, and bridge piers. These materialswhen applied on other existing surfaces, are sealed with object material and it is impossible to remove it again (El-Samny, 2008). This act causes to emergence water-repellent (hydrophobic) and anti-graffiti material (El-Samny, 2008). This extremely hydrophobic property means that graffiti could be removed more easily with appropriate detergents. It is worth to highlight that the best application of anti-graffiti non-coatings are the porous surfaces like brick, lime sandstone and concrete, which all have the highest absorbing characteristics, and these anti-graffiti coatings are effectively an impregnation, unlike other systems (Leydecker, 2008). Yet, it does not close the pores of the material, by allowing the target material to retain its vapor permeability. Therefore the material do not cause additional damage to the original surface that is applied. In addition to, mentioned properties of anti-graffiti nano-coatings, they also reduce the dirt accumulation on the applied surface (Leydecker, 2008). And for this reason, it could be suitable to apply on floor surfaces indoor and outdoor environments (Figure 2.53). In this situation, rain will have a certain rinsing, self-cleaning effect.

Anti-graffiti nano-based materials have permanent effect and they are transparent like other nanomaterials, but could be possible to add color pigments if it is desired.

Figure 2.53: Brandenburg Gate, Germany

3.8 Anti-Reflective Quality

Recently, it is observed that, anti-reflective glasses are utilized in larger amounts in the construction realm in order to benefit from the increased solar transmission resulting from broadband spectral de-reflections (Leydecker, 2008). Transparent nano scalar surface structures, consists of minute 30-50nm large silicon dioxide (SiO2) balls, which offers not only an innovative but also a cost effective and efficient anti-reflective solution (El-Samny, 2008). These products could be an appropriate selection for the places such as patios glass atriums and in exhibition design for glass cabinets or in treatment rooms for those who need more sunlight like the specialized spaces in hospitals that need to prevent the spread of radiation (Leydecker, 2008).

As an example Pilkington OptiView™ is a laminated glass with anti-reflective coatings on surfaces (both outer surfaces of the laminated glass) (Figure 2.54 and 2.55), which reduces interior and exterior visible light reflectance to less than 2%. Improved safety, enhanced security, durability and acoustic are the main properties of this product. Furthermore, it provides protection from UV radiation (UVA and UVB) by blocking over 99% of UV transmittance, helping to reduce fading of the contents and interiors of a building (Url 21).

Figure 2.54 and 2.55: President’s House, Philadelphia, Kelly/Maiello Architects and planners

3.9 Anti-Bacterial Quality

It is undoubtedly determined that,bacteria are omnipresent and a part of everyday life, although not always desirable. For this reason people use hygienic substances to deal with them in every situation. With the rise of understanding of this topic among people, the use of hygienic materials has been raised gradually in the last decades, reciprocal to the inventions. These materials are sometimes not capable to exclude the level of bacteria in the desired degree. Thus, nanotechnology also offers anti-bacterial nano-surfaces, which are emerging as the best options to destroy bacteria and expand sustainability to save our environment.

The effect of antibacterial nano-products, whether in the form of ultra-thin and invisible coatings, or materials to which the particles have been added, are more than antibiotic to ward of bacteria (Leydecker, 2008). It is important to mention that, the antimicrobial property of silver have been known for more than 3000 years, and are in essence nothing new (Url 22). As a simple example, silverware is used in pasts and also currently is a case in point.For this reason, emergence of quantitative silver nanoparticle is sufficient to reach antibacterial property (Leydecker, 2008). The major difference between the current use of silver and that of the past is one of scale, so that, in the past silver was used in its classic form as a metal alloy and was comparatively coarse in structure (Leydecker, 2008).

Antibacterial nano-products based on silver nanoparticles, by destroying microbes and bacteria causes emergence of a layer of bacteria on the materials, for this reason, for preventing this act which new bacteria could eventually grow, it is recommended that, to equip surfaces with an anti-stick function (Leydecker, 2008). In addition, antibacterial nanomaterials not only reduce the need of chemical disinfectants, but also decrease the amount of cleaning time period (Fahmy, 2010). It is also worth to mention that, the antibacterial effect is itself permanent; it does not wear off after a period of time (Leydecker, 2008).

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Figure 2.56 and 2.57: Light switches and washbasin with Antibacterial properties, (Leydecker, 2008).

In interior design field,all interior surfaces, such as walls, ground; ceiling, furniture, finishing and textures are suitable for being covered by antibacterial nano surfaces (Figure 2.56 and 2.57). Especially healthcare centers are more appropriate cases to use these products, because in these places, harmful bacteria abound in one hand, and weaken patients are on the other. For this reason it is important to cover the surface of the most clinic materials and also medicine equipment with germ-free surfaces (Figure 2.58).

Figure 2.58: Furniture which are coated with Antibacterial nano coatings, (Leydecker, 2008)

As an example, Interface Company produces modular carpets for hospitals and buildings specialized in areas of health care, which are also emerging as excellent options for high traffic spaces (Figure 2.59 and 2.60). Beside possessing anti-microbes protection, these products are also effectively threw all the carpet's useful life, providing the end of odors produced by humidity and bacteria, offering better air quality, where its installed. On the other hand, the Base GlasBac system provides great dimensional stability, and avoids that dirt, dust and liquids pass through the carpet into the floor, which further facilitates its maintenance (Url 23).

Figure 2.59 and 2.60: Interface's modular carpets in healthcare centers and public places.

3.10 Anti-Fingerprint Quality

Steel and glass are popular and the most used building materials in both architecture and interior architecture realm. But, as it is known that, stain and fingerprints, which are not aesthetic (and also hygienic) could be easily appear on these materials. For this purpose, nanotechnology offers anti-fingerprint nano-coatings to disappear finger prints.

Anti-fingerprint surfaces are ultra-thin steel coatings that could be easily applied on to objects without any breaking and fracturing (El-Samny, 2008). These product, “alters the refraction of light in the same way the fingerprints itself does, so that new fingerprints have little effect – one can think of the coating as a kind of enlarged fingerprint” (Figure 2.61) (Leydecker, 2008). The light reflections on the coating make steel or glass surfaces appear smooth, giving the impression of cleanliness that many users have come to expect. These products could be favorable selection for both outdoor and indoor environment, where easy to touch such as; facades, kitchens, bathrooms, hospitality and healthcare centers and furniture.

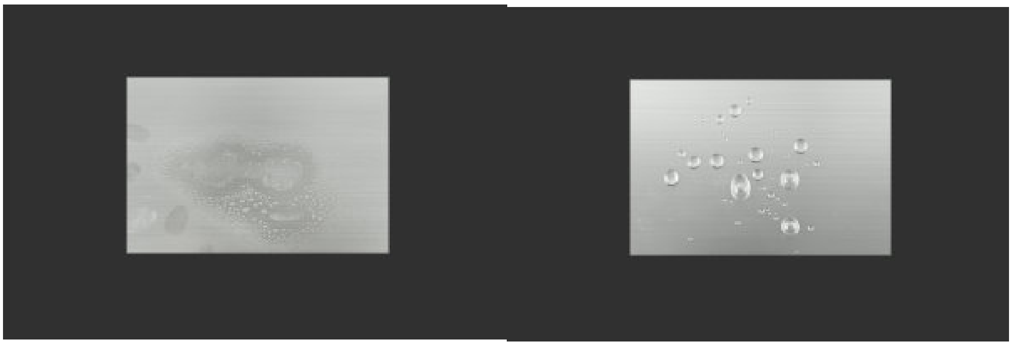

Figure 2.61: Comprehensive of AFP coating with conventional coating, right picture shows a coating with anti- fingerprint property and left picture displays a coating without anti-fingerprint property.

3.11 Scratch-Proof and Abrasion-Resistance Qualities

Materials usually are wear and tear by being walked on and scrubbing by cleaning or similar acts. For this reason nanotechnology produced nano-based transparent scratch-proof and Abrasion-Resistance coatings to solve this problem. These product could be applied on different kinds of materials such as wood, metal and ceramics and also are resistant against corrosion and abrasion. (El-Samny, 2008)

In the architectural context, scratch-resistant stainless steel coatings are also available in transparent or colorful form (Figure 2.62) (Leydecker, 2008). The most desirable products are scratch-proof paints that varnishes to protect the surfaces of parquet flooring or other gloss lacquered surfaces. These nano-based products make materials durable, and maintain their original appearance. But, it is also worth to note that, scratch resistance does not mean protection from major mechanical impact such as scratches caused by keys or other damaging implementations (Leydecker, 2008).

Figure 2.62: Bank of America during installation of scratch resistant, exterior window film from Madico. The right side of the building has the new film installed, Florida.

4. NANOMATERIALS IN HEALTHCARE DOMAIN AND CASE STUDIES

4.1 Importance of Nanomaterials in Healthcare Domain and their Emergence in Patient's Room Design and the Methodology of the Study

Healthcare centers are the public facilities, which everyone in the society could be a possible user, without exception of age, gender, socio-economical status and accessibility. Therefore, both physically and psychologically creating a healthy place for all users is essential. Medicine and healthcare alone, may not always provide complete physical and mental well-being, therefore especially from the stage of material selection until the final product, the design has a major role on the healing process (Mitrione, 2007). For these reasons, in terms of architecture and interior design, health care centers also emerge as one of the most complicated building type, which require specialized design processes.

According to a research done in USA, healthcare buildings are the most energy and source consuming commercial buildings after the food industry (Karakas & Altin, 2015). These public amenities, operates 24 hours and 7 days a week, therefore, they consume myriad amount of power and energy, which also means producing CO^2 emulsions and toxic gases, both to its inside and outside environments. Byconsidering environmental issues, architects and designers, should be careful about the stage of selecting materials, which have great impact on both sustainability and patients health.

As a simple example, healthcare settings require intensive and frequent cleaning with a wide range of products to provide hygienic, safe environments and aesthetic benefits for its users. For this reason, cleaning and disinfection play an essential role in healthcare settings and highlights a serious responsibility and critical factor in this domain. By highlighting that nearly all of the cleaning products are complex mixture of chemicals and hazardous ingredients, which affect human health and environment. These products, have potential to cause adverse health effect such as serious respiratory ailments, eye and skin irritation, central nerve system disorders, reproductive disorders, blood disorders and even cancer (Markkanen & Galligan, 2009). Possible environmentally impacts of cleaning products could be listed such as indoor and outdoor air pollution; water pollution including drinking water quality and stratospheric ozone depletion (Markkanen & Galligan, 2009). For this reason self-cleaning, ETC and antibacterial surface qualities of nanomaterials would be the accurate solution for this purpose. These surfaces, reduce the number of times needed for cleaning and the amount of chemical detergents, and extends the cleaning period, which cause CO^2 emission and damaging to building materials and in some cases, are not healthy for the patients. In addition to this, Carling's research in 2008, through which 23 random patients room had been examined from different acute-care hospitals further approved that some parts for example toilet handholds, bedpan cleaners, light switches, door knobs, patient phones, nurse call devices, and bedside rails were poorly cleaned because they were forgotten (Markkanen & Galligan, 2009). These parts of the room are the places, which the patients have most contacts with and it is better to use nanomaterials in these parts in order to guarantee the hygienic atmosphere in all parts of the room.

Besides, another basic urge for the deployment of nano-based air-purifying materials in most parts of care centers is the indoor air in hospitals, which contains fungi, bacteria and viruses, usually caused and distributed by poor ventilation and over-heating (Url 24). As CO^2 accumulates due to lack of ventilation in rooms and corridors, it is examined that this leads to all kinds of complains from patients, staff and visitors. In addition to that, considering the patients, who are immune-compromised or have respiratory problems, it is also important to select nano-based air-purifying materials to get along with proper ventilation and improve air quality, because good air quality and a pleasant temperature improve the recovery of a patient and also staff and visitors (Url 24). After all, as it is known the daylight has tremendous impacts on the recovery of a sick person or on the mood and comfort of an elderly person. Moreover, it is important for a patient to always maintain the contact with the environment. For this reason, it is important to use UV and Solar protection glass panels to not only, filter the dangerous radiations of ultra violet light which damage both building materials and human body specially patients, but also makes a patient to use enough sunlight.

By taking all these into account, using nanomaterials in such facility not only provides great support in making it sustainable, but also could have healthier impact on patients, staff and visitor's environment. These materials, reducing the use of natural resources and cause energy conservation on heating, cooling, lighting systems and etc.

Besides, in terms of financial figures for the maintenance purposes, approximately 350,000 liters of water and 7,000 liters polish of are used per year (Url 25). As it has been reported that, about 8% of the total cost of floor finishing is related to the initial price and montage; where as 92% of the total costs are related to maintaining the material through its lifecycle (Url 25). Thus, as it may observed clearly throughout the figures, by using nanomaterials, the long-term costs of maintaining the materials could be reduced drastically.

Therefore, within the framework of this study, in reciprocal to the growing potential of the nanomaterials in various fields of architecture and interior architecture, the emergence of them in healthcare centers, are examined in detail. So, LIV HospitalUlus, Kolan Hospital and Medicana Bahçelievler Hospital which are all located in Istanbul, are selected as case studies to identify the nanotechnology applications in interior space, specifically narrowing down the focus to the utilization of particularly deployed nanomaterials and their properties within the patients' room. On the other hand, the secondary reason for the selection of the mentioned hospitals as case studies, is to draw out a basic comparison of embodied energy and embodied carbon of nanomaterials and conventional materials and to analyze their environmental impacts. Because this office, in most of their designs, complementary to the deployment of natural materials, the design team tries to use technological manufactured materials such as composites or nano-based materials, which are environmentally friendly, recyclable, non-carcinogenic with air-purifying, anti-bacterial, fire-proof properties and etc. to provide not only healthy environments for patients, staffs and visitors, but also to reach the level of sustainability (Url 26).

Thus, in terms of examining the qualitative and quantitative use of nanomaterials in all cases, the related data have been collected through the close contact with the related design office, via obtaining the first hand information both through theproject documentations and the targeted interviews with the leading architects of the projects: Levent Çırpıcı and Atilla Kuzu. The collected information has been blended with the onsite examinations for each cases, and then synthesized accordingly. The goal of the evaluation process is to demonstrate the materials deployed in each design; their essential properties, the specific location of use as well as the amount of use, of the nanomaterials that are utilized in the patient rooms of each hospital, while at the same time, depicting the repetition of the deployed materials in various healthcare projects of the same practice.

On the other hand, as it is widely-known, in addition to nanomaterials, composite and natural based materials are also commonly used materials in healthcare interiors. However, since this study focuses on the use of nanomaterials in the healthcare spaces, the research content is limited to the investigation of the mentioned material used. To draw a more coherent perspective, the features of each material are also associated with the literally assigned material brand, whereas further explanations of the brands' have been captioned in the manuscript through their official websites and brochures. In addition, the embodied energy and embodied carbon of implemented nano-enable materials in mentioned cases are retrieved from official product catalogues, where the physical and chemical properties are listed, as well as through companies' websites yet interviewing the product representatives. On the other hand, embodied energy and embodied carbon of conventional materials are retrieved from the catalogues of 'Inventory of Carbon & Energy (ICE) Version 2.0', which are studied and listed by Prof. Geoff Hammond and Craig Jones, who work at Sustainable Energy Research Team (SERT) in the Department of Mechanical Engineering University of Bath, United Kingdom (Url 27).

4.2 Case Studies

4.2.1 Case Study 1: LIV Hospital Ulus, Istanbul

LIV Hospital Ulus is located in the center of Istanbul; Ulus, Besiktas, providing a distinctive concept in hospital design, treatment and care focusing for both national and international patients (Url 28). The hospital is best known for its expertise on the services of cardiology, oncology, orthopedics and traumatology, neurosurgery, general surgery, and the treatment of eye diseases (Url 28).

This Hospital is designed with a patient-based approach, consists of 154 beds, 8 operation rooms and 50 departments in 30.000 m² indoor area(Url 29). In addition to the general information, by focusing on its architectural aspects, LIV Hospital Ulus, is designed by ZOOM Office in 2012, under supervision of head architects, Levent Çırpıcı and Atilla Kuzu. The implemented design concept of the hospital is inspired from miraculous "self-recovering" ability of human body diseases (Url 30). Designating impenetrable internal fronts due to human body's tremendous self-protection and analyzing the tissue and cell behavior of the scenes of the journey to the human body in the movie "Fantastic Voyage", geometry of the organics and forms was obtained and applied to the architecture structure in terms of cosmetics and function as a visual theme for the group's hospital for higher segments (Url 30). Furthermore, the interior of the hospital is characterized with natural, conventional and nano-based materials, not only to provide healthy environments to patients, staff and visitors, but also to reach a level of sustainability. In this section, by focusing on a standard patient room (Figure 2.63 and 2.64), the identification and the use of the nano-based building materials within the room and their properties have been unfolded and asserted through a comparative structure (Table 3.1).

Figure 2.63 and 2.64: Patient room and bathroom of LIV Hospital, Istanbul, designed by ZOOM/TPU, 2012

Like it is examined and also indicated in the Table 3.1, in addition to composite material, extensive use of nano based materials with the properties mentioned in previous section is observed within the room. As it is detected from Table 3.1, not all parts of the room are enriched with nano properties and some are missing. As anexample the fire proof or easy to clean properties are missing from most materials. There are no doubts that there are alternates to prevent accidents and hazards of a fire situation, but if this property was considered during the design and material selection, there would be no need for an alternative solution to this problem. In addition, however the air-purifying quality has been the essential demand in the healthcare centers, especially in a patients' room, it is observed that this property adjusted mainly on the flooring surface. Asides of these, it is worth mentioning that one of the most important properties for materials in the case of health care facilities is anti-bacterial which in this case is used flawlessly, creating a hygienic atmosphere for the users. Moreover, nano-based glass panels with heat and sound insulation as well as solar protection properties, are also deployed as other complementary elements of the patients' room design.

In addition to furniture and finishing elements, acrylic immobile furniture, as well as the curtains with anti-bacterial and fire-proof properties are also selected as nano-based materials throughout the design process.

On the other hand, when focused on the bathrooms within the patient rooms, like indicated on the Table 3.1 once again, all finishing elements in patients' bathrooms are characterized with nano-based materials with common anti-bacterial and easy-to-clean properties. Acrylic finishing with anti-bacterial, easy-to-clean, fire-proof and easy-to-maintain properties are used in most area of this place. And ceramics with anti-bacterial, easy to maintain and wear-proof qualities decorate the bathroom. In addition to finishing elements, the team has selected the nano-based furniture with common anti-bacterial, easy-to-clean, anti-fingerprint and wear-proof properties. Bathroom are the places which require more cleaning and disinfecting effort with more chemical detergents, therefore, using nano-based with the mentioned properties will reduce the period of cleaning time and the amount of hazardous chemical used detergents which have negative impact on patients and environment.

In addition to the definition of nanomaterials and their properties within this room, according to table 3.2, it is explicit that, the mentioned nanomaterials, in comparison to conventional ones has lower embodied energy levels. And also by checking the embodied carbon figures, it is recognizable that the lower figures are related to the nano-enable materials. This means that, these materials are sustainable and environmental friendly, which need less energy and produce less CO^2 or other related gasses, which damage environment, during their lifecycle.

There are no doubts that this case is not one step, maybe way ahead of the conventional rooms and offers far more features than a room built with conventional materials. But this does not mean that there are no progress left to be made. This case is a pure example of what difference using nano based materials can make.

Table 3.1

Table 3.1 Arka Sayfasi

Table 3.2: Embodied energy and embodied carbon figures of implemented nano-enable materials in case study 1: LIV Hospital patient room interior.

		EMBODIED ENERGY Mj/Kg	**EMBODIED CARBON KgCo2e/Kg**
Acrylic finishing	LG HI-MACS	22.17	0.94
Wallpaper	Matrix	34.52	1.02
Paint water-borne	Jotun Majestic	NA	2.33
Glass	Saint-Gobain	20.84	NA
Vinyl finishing	Tarkett	NA	0.20
Ceramic	Villeroys & Boch	10.81	0.66
Acrylic surfaces	LG S001 satin white	23.17	NA
Curtains	Creative bauman	NA	NA

4.2.2 Case Study 2: Kolan Sisli Hospital, Istanbul

Kolan Hospital is located in Şişli, Istanbul provides relaxing and healing environments for its patients with its modern interior design. It is best known for its cardiology, pediatric cardiology, general surgery, heart and vascular surgery, internal and eye dieses' healthcare services (Url 31). This hospital is distinguished not only with its patient-oriented approach, medical staff, modern medical technologies, but also with its modern interior design, sustainable and healthy environments, considering patient, staff and visitors comfort (Url 31).

The Kolan Hospital consists of 174 beds, 6 operating rooms, internal surgical, coronary and cardiovascular surgery intensive care units with a total capacity of 58 beds, neonate intensive care unit with 31 incubators more than 40 departments in 20.000 m² indoor area (Url 31). Kolan hospital Şişli, is designed by Zoom Office in 2013 by head architects, Levent Çırpıcı and Atilla Kuzu. The main concept of this design is transforming the existing structure by use of technological manufactured materials such as nano-based materials in addition to natural and composite ones, to an environment designed as a "flora", where makes patients relax and sure about they are in a healing place. (Url 32) (Figure 2.65 and 2.66).

Figure 2.65 and 2.66: Patient room and bathroom of Kolan Hospital, Istanbul, designed by ZOOM/TPU, 2013

As it is examined and also indicated in the Table 3.3, natural and composite materials, nano-based wallpaper with anti-bacterial and scratch-proof properties, nano-based PVC finishing with anti-bacterial, easy-to-clean and anti-fingerprint qualities, nano-based laminate finishing with anti-bacterial, easy-to-clean, fire-proof and scratch-proof properties have been utilized in this patient room. Unfortunately inthe mentioned case air purifying property is been missing. The lack of this feature in this place not only requires more ventilation inside the room but also, supports the need of artificial ventilation systems in most cases which leads to consuming more energy and finally increases the costs. In some cases this systems are not healthy for patients also, because it requires fresh filters on the system constantly and dirty filters would increase indoor pollutions which directly affect the patient's health. In addition to finishing elements, just acrylic part of immobile furniture with anti-bacterial, easy-to-clean and fire-proof properties is selected as nano-based materials.

As it has been summarized on the Table 3.3 most of the finishing elements in patient's bathroom are natural materials, but the team has selected the nano-based furniture with common anti-bacterial, easy-to-clean, anti-fingerprint and wear-proof properties. As mentioned in previous case, bathrooms require more attention when it comes to disinfection and hygiene. However, natural materials are appropriate for bathrooms in terms of organic factors but, these places are moisty and shady areas which are suitable sources for bacteria and mold growth. For this purposes it is recommended to use nano-based materials at least with anti-bacterial and easy-to-clean, properties to kill bacteria, reduce the cleaning periods and the amount of chemical detergents used, which have negative impact on both the environment and patients health.

On the other hand, as it is examined from the Table 3.4 the embodied energy and the embodied carbon figures of implemented nano-enable materials in this room are once again lower than conventional ones. As it is noted, although in some instance some figures are missing, but in overall reading, most of the figures are verifying the general statement. As an example, the embodied energy of Gerflor is unknown, in this case, by focusing on its embodied carbon figure compared with conventional one, it could be said that, this material by lower embodied carbon figure, is appropriate to use in finishing specially in healthcare centers. As another example, because of missing information about the embodied carbon of nano-based Gentas wood laminate strip, just by comparing the embodied energy figure (9.5 Mj/Kg), of this material with the embodied energy figure (16.30 Mj/Kg) of conventional laminate, it could be said that, this material is more sustainable than conventional one.

Last but not least about this case, if it is to be compared with a conventional patients' room again it has more features and provides more comfort and requires less energybut to compare it for instance with the previous case, it has less features. In this case mostly natural and composite materials are chosen. This selection of materials may differ from one costumer from another. The reason behind this kind of selection mostly lays behind economical aspects. It is also worth mentioning that even though compared to previous case, this room has lack of nano features but again even by using for instance floors with easy to clean feature, the costs of cleaning are reduced. In this case it is recommended that although most of used materials are natural and composite, in most parts as mentioned in previous chapter, it is possible to add nano coatings with anti-bacterial, easy to clean or air purifying features.

Table 3.3

Table 3.3 Arka Sayfasi

Table 3.4: Embodied energy and embodied carbon figures of implemented nano-enable materials in case study 2: Kolan Hospital patient room interior.

		EMBODIED ENERGY Mj/Kg	**EMBODIED CARBON KgCo2e/Kg**
Paint water-borne	Ral 9003	53.31	NA
Wallpaper	Vycon Y46399	33.16	1.18
Pvc finishing	Yaktas Gerflor	NA	3.04
Wood laminate strip	Gentas	9.5	NA
Acrylic zenith unit	Corian	NA	2.54

4.2.3 Case Study 3: Medicana Hospital, Bahcelievler, Istanbul

Medicana Bahçelievler Hospital, which is located in Bahçelievler, Istanbul, was established in 2003, in 1000 m² indoor area (Url 33). This hospital with the 100 bed capacity consists of 6 operating rooms, 2 delivery rooms, coronary cardiac and general intensive care units, a cardiovascular intensive care unit, neonatal intensive care unit and a dialysis unit with 30 beds and etc., which include all the recent requirements and technologies. This hospital is best known for its cardiology and angiography, cardiovascular surgery, physiotherapy, kidney transplantation, dialysis, obstetrics and IVF Unit, medical oncology and laser treatment center for varicose veins and intensive care units (Url 34). Moreover general information, this hospital is designed by GroupMedicana's in-house design team. By focusing on the patient room, and by interviewing it could be stated that, the room is designed with conventional materials, which are mentioned in Table 3.5 and there is not any nano-enable materials in this room (figures 2.67 and 2.68). The main goal of selecting this hospital as a case study is to comparing the implemented materials and their embodied energy and carbon figures which are listed at Table 3.6 between this case with the used materials in LIV and Kolan hospitals.

Figure 2.67 and 2.68: Patient room and bathroom of Medicana Bahcelievler Hospital, Istanbul, designed by Medicana design team, 2003

Table 3.5

Table 3.5 Arka Sayfasi

Table 3.6: Embodied energy and embodied carbon figures of implemented conventional materials in case study 3: Medicana Bahcelievler Hospital patient room interior.

		EMBODIED ENERGY Mj/Kg	**EMBODIED CARBON KgCo2e/Kg**
Acrylic finishing	Conventional	25.04	2.58
Wallpaper	Halley	36.40	1.93
Paint water-borne	Dyo	59	2.54
Glass	Isicam	23.5	0.91
Vinyl finishing	Conventional	68.60	3.19
Ceramic	Çanakkale	12	0.78
PVC finishings	Azen	77.20	3.10
Laminate (Wood Strip)	Çamsan	16.30	NA
Cotton Fabric	Evren perde	143	6.75

5. CONCLUSIONS AND RECOMMENDATIONS

In this present time, where energy-time-cost-saving-environment and natural sources are the subsets of sustainability, they are all considered as an important issue in all aspects. In this regard, the role of nanotechnology and nanomaterials is crucially emerging in all sectors especially in architecture and design discipline. Doubtlessly, the main goal of deploying nanotechnology in architectural realm is about getting more function and efficiency on less space. This act could be a bridge to achieve sustainability and higher benefits to humans, environment and economy. The benefits of nanomaterials in design and construction industry are appealing as providing lighter buildings, resistant and robust in front of natural phenomena's, provide a greater economy, saves a flat earth for future generation, maintain the natural resources by reducing the consumption of raw materials and energy, minimize waste and pollutions and comfort.

Departing from the extensive benefits of the nanotechnology in design and construction industry; with a specific emphasis, this study focused majorly to unfold the range of the nano-materials and their properties deployed in the interior architecture, particularly their current use in healthcare domain and the patients' rooms. The key reason behind this decision is that, healthcare centers are the most energy consuming building type after food industry, which consume more material and resources. For this purposes the role of embodied energy and embodied carbon getting important in this case. In this regard, by citing tables, 3.2, 3.4 and 3.6, table 3.7 is prepared to create a comparison matrix of embodied energy and embodied carbon of all implemented materials in all case studies.

Table 3.7: Comparison matrix of embodied energy and embodied carbon figures of all implemented nano-enable and conventional materials in case studies interiors.

	LIV HOSPITAL		KOLAN HOSPITAL		MEDICANA HOSPITAL	
MATERIALS	EMBODIED ENERGY Mj/Kg	EMBODIED CARBON KgCo2e/Kg	EMBODIED ENERGY Mj/Kg	EMBODIED CARBON KgCo2e/Kg	EMBODIED ENERGY Mj/Kg	EMBODIED CARBON KgCo2e/Kg
Acrylic finishing	22.17	0.94	NA	2.54	25.04	2.58
Paint Water-borne	NA	2.33	53.31	NA	59	2.54
Vinyl Finishing	NA	0.20	NOT USED	NOT USED	68.60	3.19
PVC finishing	NOT USED	NOT USED	NA	3.04	77.20	3.10
Wallpaper	34.52	1.02	33.16	1.18	36.40	1.93
Ceramic	10.81	0.66	MARBLE	MARBLE	12	0.78
Laminate Wood stripe	16.30	NA	9.5	NA	16.30	NA
Glass	20.84	NA	23.5	0.91	23.5	0.91
Cotton Fabric	NA	NA	143	6.75	143	6.75

According to Table 3.7, it is explicit that the acrylic finishing, which is used both in Liv and Kolan hospitals, has lower embodied energy and embodied carbon figures in comparison to conventional one. Moreover, ceramic and vinyl finishings that are also used as nano-enable form in LIV Hospital has lower embodied energy and carbon in comparison to the conventional form, which is used in Medicana Bahçelievler Hospital. In addition to these, water-borne paint, wallpaper, laminate, glass and cotton fabric which are used in all case studies, have lower embodied energy and embodied carbon in comparison to conventional one. This means that, nano-enable materials with the lower embodied energy and carbon need lower energy during their lifecycle, which means low-cost and low-pollution and etc. in comparison to composite conventional materials. Therefore, nanomaterials emerge as more sustainable and eco-friendly materials. However, the importance of sustainability and energy efficiency have been increased these days, but, unfortunately both the designers and the implementers of these types of buildings do not realize the importance of this issue, yet there have not been enough precedents of nanotechnology in use in the realm of architecture especially in developing countries. It is not surprising to observe, how most of the invertors and the contractors seek to reduce the initial building costs, without concerning about the long-term effects.

To broaden the image, envision designing other parts of the hospital like surgery rooms with use of these properties, or entrance and check-in spaces; without a doubt the impact of every single unit would be immense. Even just by adding for instance, the anti-bacterial feature, as demonstrated earlier in the studied cases, the need for chemical detergents are going to fade away.

This leads towards a more sustainable environment and is a more progressive view. It is recommended to use this limitless technology in all aspects of architecture and be more innovative and environmental friendly. With the growth rate of the population in the world and the increase in consumption of natural resources, there are not so many options left. With the features that this technology hands over, as studied, it is possible to add any property to any kind of materials with a little more initial cost at the beginning, but being totally aware of the long term benefits about energy-savings and long-term maintenance costs, where it becomes the definite answer towards sustainability.

To conclude, like Carl Elefante (2007) mentioned; “the ‘greenest’ building is the one that is already been built!” (Url 35). So, taking these words into account, nano-technology increases the life-cycle of buildings by eliminating the need for reconstruction of what is already been built.

REFERENCES

Abdellatif, A. (2011). Innovations And Sustainability In Modern Architecture, The Impact of Building Materials Selection.*4th Urbenviron International Congress on Environmental Planning and Management – CAIRO 2011: Green Cities: a Path to Sustainability*, Date retrieved: 01.05.2015, address: <https://www.academia.edu/3578261/ Innovations_and_sustainability_in_modern_architecture_The_impact _of_Building_materials_selection>.

Antonelli, P. E (1995). *Mutant Materials in Contemporary Designs*. The Museum of Modern Art Publications, New York, Distributed by Harry N. Abrams, Date retrieved: 01.05.2015, address: http://www.moma.org/interactives/exhibitions/1995/mutantmaterials/ MoMAhours.html.

Atwa, M. Al-Kattan, A. Elwan, A. (2015). Towards Nano Architecture: Nanomaterial in Architecture- A Review of Functions and Applications. *Research International Journal of Recent Scientific Research*, Vol. 6, No. 4, pp. 3551-3564, April, 2015, Date retrieved: 01.05.2015, address: < http://www.recentscientific.com/sites/default /files/2274_0.pdf>.

Bacon, L. (2011). *Interior Designer's Attitudes Toward Sustainable Interior Design Practices And Barriers Encountered When Using Sustainable Interior Design Practices*. Graduate College at the University of Nebraska, Master of Science Degree Thesis, Date retrieved: 08.06.2015, address: < http://digitalcommons.unl.edu/cgi/viewcontent. cgi?article=1104& context=archthesis>.

Bechthold, M. Kane, A. King, N. (2015). Ceramic Material Systems: In Architecture and Interior Design, Date retrieved: 08.06.2015, address: < http://www.degruyter.com/view/product/206354>.

Bierman-Lytle, P. (1995). Creating A Healthy Home: Environmental Building Materials—What Are They? Where Are They?*Environmental Health Perspectives*, Journal, Vol 103; No. 6, September 1995, Date retrieved: 08.06.2015, address: <http://www.ncbi.nlm.nih.gov/pmc/ articles/PMC1518908/>.

Cabeza Luisa, F. Barrenche, C. Miro, L. Martinez, M. Fernandez, A. Vorsatz, D. (2012), *Affordable Construction towards sustainable Buildings: Review on Embodied Energy in Building Materials,* The Journal of current opinion in environmental sustainability, 2013, 5:229-236, Date retrieved: 01.8.2016, Address: <www.sciencedirect.com>.

Cross Cain, S. (2007). *Sustainability for Interior Design:Rating the Flooring Materials in a Leed Registered Hotel Using the Bees Evaluative*

*Software for Sustainable Products.*Graduate School of the University of the Florida, Master of iInterior Design Degree Thesis.Date retrieved: 01.05.2015, Address: <http://etd.fcla.edu/UF/UFE0020223/cain_s.pdf>

Dhingra, R., Naidu, S., Upreti, G., Sawhney, R. (2010). Sustainable Nanotechnology: Through Green Methods and Life-Cycle Thinking. *Sustainability 2010*, ***Vol. 2(10)***, doi:10.3390/su2103323, http://www.mdpi.com/2071-1050/2/10/3323.

El-Samny. (2008). *NanoArchitecture Nanotechnology and Architecture.* University of Alexandria, Graduate Schoolof Engineering, Master of Science Degree Thesis. Date retrieved: 01.05.2015, address: < https://www.academia.edu/2367517/NanoArchitecture-Nanotechnology_and_Architecture>.

Elvin, G. (2007). The Nano Revolution: A Science That Works On The Molecular Scale Is Set To Transform The Way We Build. *The Journal Of The American Institute of Architects*, Date retrieved: 01.05.2015, address: http://www.architectmagazine.com/technology/the-nano-revolution_o.

Engelsmann, S., Spalding V., Peters S. (2010). *Plastics: In Architecture and Construction*. Birkhäuser Publications, Basel.

Faten Fares Fouad.(2012). *NanoArchitecture and Sustainability*. University of Alexandria, Graduate Schoolof Engineering, Master of Science Degree Thesis. Date retrieved: 01.05.2015, address: <https://www.academia.edu/1749834/nanoarchitecture_and_sustainability_-_master_degree>.

Fisk, W. & Rosenfeld, A. (1997). Estimates of Improved Productivity and Health from Better Indoor Environments.*International Journal of Indoor Environment and Health*, Vol. 7, No. 3, pp; 158-172. Date retrieved: 01.05.2015, address: < http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.1997.t01-1-00002.x/epdf>.

Freestone I., Meeks N., Sax M., Higgitt, C. (2007). The Lycurgus Cup – A Roman Nanotechnology. *Gold Bulletin 2007*, Vol. 40 (4), pp. 270-277. Date retrieved: 01.05.2015, address: http://www.arne-lueker.de/Objects/work/Surface%20Plamons/lycurgus.pdf.

Guerin, D. (2003). Environmentally Responsible İnterior Design: A Case Study. *Journal of Interior Design*, Date retrieved: 01.05.2015, address: <http://www.ejid.org/jid_issue.cfm?ID=993>.

Haines, C. (2010). The Role of the Architect in Sustainability Education. *The Journal of Sustainability Education*, Date retrieved: 01.05.2015, address: http://www.jsedimensions.org/wordpress/content/the-role-of-the-architect-in-sustainability-education_2010_05/.

Hosey, L. (2003). Why the Future of Architecture Doesn’t Need Us?: What Becomes of Louis Kahn, When Buildings Actually Know What They Want to be. *The Couse of Architecture-An Online Journal of Ideas From Architectural Record*, Date retrieved: 01.05.2015, address:

<http://archrecord.construction.com/inthecause/0602ArchiFuture/archiFuture.asp>.

Hossein Zabihi, Dr. Farah Habib, Leila Mirsaeedie. (2012). Sustainability in Building and Construction: Revising Definitions and Concepts, *International Journal of Emerging Sciences*, Vol. 2 No. 4, December 2012, pp. 570-578, Date retrieved: 01.05.2015, address: <http://www.researchgate.net/publication/236033739_Sustainability_in_Building_and_Construction_Revising_Definitions_and_Concepts>.

Inas Hosny Ibrahim Anous. (2014). Nanomaterials And Their Applications In Interior Design. *Multidisciplinary And Open Access Journal*, International Association of Scientific Innovation and Research (IASIR), USA, Available online at <http://www.iasir.net>.

Johnson, S. (2000). The Economic Case For High Performance Buildings. *Corporate Environmental Strategy*, 7(4), 351-361.

Karakas, G. & Altin, M. (2015). Yesil Bina Degerlendirme Sistemlerinde Saglik Yapilari, *A journal published by Makina Muhendisleri Odasi*, Date retrieved: 01.05.2015, address: < http://www.mmo.org.tr/etkinlikler/tesisat/etkinlik_bildirileri_detay.php?etkinlikkod=262&bilkod=2231>.

Kart, O. (2011). Nano İşlenmiş Beton. *Blogcu*, Date retrieved: 01.05.2015, address: <http://onur-kart.blogcu.com/nano-islenmis-beton/12015468>

Kibert, C. (Eds.). (1999). *Reshaping the Building Environment*. Washington, DC: Island Press.

Kim, H. & Fthenakis, V. (2013).Life Cycle Energy and Climate Change Implication of Nanotechnologies: A Critical Review, *A journal published by Industrial Echology*, Date retrieved: 03.01.2016, address: <http://onlinelibrary.wiley.com/doi/10.1111/j.1530-9290.2012.00538.x/abstract >.

Klassen, F. (2004). Material Innovations: Transparent, Lightweight, Malleable & Responsive. In Transportable Environments 2004. *Proceedings of the Transportable Environments 2004: 3rd International Conference on Portable Architecture & Design*, Ryerson University, Toronto, Canada, 28-30 April Date retrieved: 01.05.2015, address: http://web.deu.edu.tr/metalurjimalzeme/pdf/okumasalonu/Material_Innovations.pdf.

Lawson, B. (2009). Environmental Impacts of Building Materials. *The NSW/RIC Good Wood Guide*, Date retrieved: 01.05.2015, address: http://www.rainforestinfo.org.au/good_wood/env_imp.htm.

Markkanen, P. and Galligan, C. (2009). Cleaning in Healthcare Facilities, Reducing Human health and Environmental Impacts, Date retrieved: 01.05.2015, *publication of Lowell Center for Sustainable production*

University of Massachusetts Lowell, address: < http://www.sustainableproduction.org/downloads/CleaninginHealthcareFacilities.pdf>.

McDonough, W. (2001). *Then Next Industrial Revolution.* New York: North Point Press.

Mendez, E. (2006). Nanotechnology the Industrial Revolution of the 21st Century. In *Future Trends Forum Public:*Fundation of Innovation Bankinter’s (Fundación de la Innovación Bankinter), Madrid, Spain. Later Published in *05 Nanotechnology the Industrial Revolution of the 21st Century,* Date retrieved: 01.05.2015, address: http://www.abc.net.au/tv/newinventors/txt/s1343223.htm.

Michelle Addington and Daniel Schodek. (2005). *Smart Materials and Technologies, For The Architecture And Design Professions*. Architectural Press, 2005.Date retrieved: 01.05.2015, address: < https://bintian.files.wordpress.com/2013/01/smart-materials-new-technologies-for-the-architecture-design-professions.pdf>.

Mohamed Hazem Mohamed Fahmy. (2010). Nanomaterials and Architecture Sustainable Nano Architecture.University of Alexandria, Graduate Schoolof Engineering, Master of Science Degree Thesis. Date retrieved: 01.05.2015, address: < https://www.academia.edu/1735829/nanomaterials_and_architecture>.

Muir, J. (2004). The Glass House, Architect James Muir. *The New Inventors,* Date retrieved: 01.05.2015, address: http://www.abc.net.au/tv/newinventors/txt/s1343223.htm.

Peach, J. (2010). Five Sustainable Building Materials that Could Transform Construction. *This Big City,* Date retrieved: 01.05.2015, address: http://thisbigcity.net/five-sustainable-building-materials-that-could-transform-construction/

Pilatowicz, G. (1995). *Eco-Interiors: A Guide to Environmentally Conscious Interior Design.* New York: Wiley.

Rewi, A. (2006). Over Matter. *Perspective,* spring 2006, No. (3), pp. 15-22. Date retrieved: 01.05.2015, address: http://www.iida.org/resources/category/3/1/6/documents/0406mind.pdf

Pir Mohammadi, M., Ahmad, S.M., Mursib, G., Roshan, M., Torabi, M. (2014). Interior Layout Design Parameters Affecting User Comfort In Ee Buildings. *Asian Journal of Microbiological and Biotechnological. Environmental. Sciences,* Vol. 16, No. (3), pp. 1-9. Date retrieved: 01.05.2015, address: https://www.academia.edu/7590559/interior_layout_design_parameters_affecting_user_comfort_in_energy_efficicent_buildings.

Roodman, D. & Lenssen, N. (1995). *Worldwatch Paper #124: A Building Revolution: How Ecology and Health Concerns are Transforming*

Construction. Date retrieved01.05.2015, address:<http://www.worldwatch.org/node/866>.

Salla, F (2014). Rhino Projects: A Smog-Eating Facade, Date retrieved: 10,10,2015, address: <http://blog.visualarq.com/2014/03/07/rhino-projects-asmog- eating-facade/>.

Schodeck, D. (2009). *Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects*. Butterworth-HeinemannPublications, UK.

Sevastean Ianca, Mircea Georgescu. (2015). Architecture Notes. *White*, October 10th , 2015, Date retrieved: 10.10.2015. Address: <http://www.scribd.com/doc/284307034/Architecture- Notes#scribd>.

Spiegel, R., Meadows, D. (2006). *Green Building Materials: A Guide To Product Selection And Specification*. New Jersey: John Wiley & Sons.

Sullivan C. (2012).Nano-Advances behind New Architectural Products. Date retrieved: 01.05.2015: http://www.smartplanet.com/blog/the-astute-architect/nano-advances-behind-new-architectural-products/

Vetter, A., Weston, R., & Martin, S. (n.d.) On Being a Good Neighbor: Moving Towards Sustainable Construction. Carillion, Date retrieved: 01.05.2015: <www.naturalstep.org.uk/hires.pdf>.

Veith, M. (2008). Foreword. *Nano Materials*, ed.Sylvia Leydecker. Birkhäuser Publications, Basel, pp. 10-11.

Wick, P., Nowack, B., Hoet, P., Zuin, S. (2010). Life Cycle of Nanoparticle-Based House Coatings. *Nano House Project* Date retrieved: 01.05.2015, address:<http://www-nanohouse.cea.fr/scripts/home/publigen/content/templates/show.asp?P=55&L=EN&ITEMID=2>.

Zimmer, L. (2013). Mexico City's Manuel Gea Gonzalez Hospital Has an Ornate Double Skin that Filters Air Pollution, Date retrieved: 10,10,2015, address: <http://inhabitat.com/mexico-citys-manuel-gea-gonzalez-hospital-has-an-ornate-double-skin-that-filters-air-pollution/>.

Url-1 Modern architecture is known for its use of new materialshttp://www.next.cc/journey/discovery/modern-architecturedate retrieved 22.04.2015.

Url-2 Bauhaus School. *Art Hut*, Date retrieved: 01.05.2015, address: <*http://www.arthut.co/educational/item/462-bauhaus-school>*, Date retrieved 22.04.2015.

Url-3 (2014) Structures and Technology. *Boundless<https://www.boundless.com/art-history/textbooks/boundless-art-history-textbook/europe-and-america-in-the-1800s-ce-35/the-beginning-of-modern-architecture-220/structures-and-technolgy-782-1085/>*, date retrieved 19.04.2015.

Url-4 It is all covered by nano-based, Sun-Guard glass, address: < *http://023app01.guardian.com/cs/groups/sunguardeurope/documents/web_content/gi_016032.pdf>*, Date retrieved 22.09.2015

Url-5 RolledSteel Is thePrincipalMetalUsed in Construction, address: < *http://encyclopedia2.thefreedictionary.com/Building+Materials>*,Date retrieved 22.09.2015.

Url-6 Polymer Building Materials, address: < *http://encyclopedia2.thefreedictionary.com/Building+Materials>*, Date retrieved 22.09.2015.

Url-7 Nanomaterials Are Expensive Than Other Convertional Materials, < *http://www.nanowerk.com/spotlight/spotid=26700.php>*, To preserve the whiteness of the building

Url-8 Nano. *Wikipedia<https://en.wikipedia.org/wiki/Nano->*, date retrieved 22.09.2015.

Url-9 Artists Were The First Nanotechnologists. *Center for NanoBioSafety and Sustainability<http://www.cnbss.eu/index.php/editorial/item/110-artists-were-the-first-nanotechnologists>*, date retrieved 01.05.2015.

Url-10 Tens of thousands of times smaller than the diameter of a human hair,

<http://www.fda.gov/BiologicsBloodVaccines/ScienceResearch/BiologicsResearchAreas/ucm127045.htm>,date retrieved 22.09.2015.

Url-11 There are 25,400,000 nanometers in an inch, address:

<*http://www.nano.gov/nanotech-101/what/definition>*, date retrieved

20.05.2015.

Url-12 *<http://www.archrecord.construction.com/inthecause/0602>*, Date retrieved 12.01.2015.

Url-13 Embodied carbon refers to carbon dioxide emitted during the manufacture, address: *<https://www.fgould.com/uk-europe/articles/embodied-carbon-q-sean-lockie-director-carbon-and-/>*, Date retrieved 09.01.2016

Url-14built environment accounts for the largest share of greenhouse gas emissions and waste stream, address: *<https://setis.ec.europa.eu/system/files/Scientific_Assessment-EEMBuildings.pdf>*, Date retrieved 09.01.2016

Url-15 the quantity and type of materials used in the construction industry could have major effect on sustainability, address:<*https://upstyleindustries.files.wordpress.com/2014/08/materiallife-embodied-energy-of-building-materials.pdf*>, Date retrieved 09.01.2016

Url-16 They need to select materials with lower embodied energy, higher durability, lower levels of toxicity, address: *<https://upstyleindustries.files.wordpress.com/2014/08/materiallife-embodied-energy-of-building-materials.pdf>*, Date retrieved 09.01.2016

Url-17 Jubilee Church, Richard Meier address : < *http://www.archdaily.com/*

20105/church-of-2000-richard-meier>, Date retrieved 22.09.2015.

Url-18 *<http://en.wikiarquitectura.com/index.php/Jubilee_Church>,* Date retrieved 22.09.2015.

Url-19 UV-A (Ultraviolet long rays) and UV-B (Ultraviolet short rays), address: < *http://www.lukeslocker.com/files/SunProtection.pdf*>, Date retrieved 22.09.2015.

Url-20 Ferrari Factory Store, address: <http://www.archdaily.com/178388/ ferrari-factory-store-iosa-ghini-associates>,Date retrieved 22.09.2015.

Url-21 Pilkington OptiView™ adress: *<http://www.archdaily.com/catalog/us/ products/5837/anti-reflective-glass-pilkington-optiview-pilkington?ad_source=nimrod&ad_medium=article-widget&ad_content=565115>*, Date retrieved 22.09.2015

Url-22 Antimicrobial property of silver, address: < *http://www.hirshfields.com/ designresource/flooring/silverknight.htm>,* Date retrieved 22.09.2014

Url-23 Interface company, produces modular carpets for hospitals, address:< *http://www.archdaily.com/catalog/us/products/1329/modular-carpets-hospital-health-interface>,* Date retrieved 22.09.2015

Url-24 hospitals contains fungi, bacteria and viruses, which are usually caused and distributed by poor ventilation and over-heating, address: *<http://export.renson.eu/solutions-for-ventilation-and-sun-protection-worldwide-ventilation-and-shading-provide-healthier-air-in-hospitals-and-care-centers.html*>, Date retrieved 22.09.2015

Url-25 Approximately 350000 liters water and 7000 liters polish are used in hospitals for cleaning and polishing, address: <*http://v1.raf.com.tr/urun_643_tarkett-pvc-zemin-kaplamalari.html>,* Date retrieved 22.09.2015

Url-26 in addition to use natural materials, try to use technological manufactured materials,addres:*<http://www.ekoyapidergisi.org/1034-nisan-2015-sayimizda-yer-alan-mimar-roportajlarimizi-ingilizce-olarak-da-okuyabilirsiniz.html>,* Date retrieved 22.09.2014

Url-27 Inventory of Carbon & Energy (ICE) Version 2.0, Sustainable Energy Research Team (SERT) Department of Mechanical Engineering University of Bath, UK, *address: <http://web.mit.edu/2.813/www/readings/ICEv2.pdf.old>,* Date retrieved 07.01.2016

Url-28 Leading International Vision, address: *<http://www.intmedtourism.com/en/companies/LIV-hospital-istanbul/>,*Date retrieved 22.09.2015

Url-29consists of 154 beds, 8 operation rooms and 50 departments in 30.000 m2 indoor area, address: <*http://www.patientsbeyondborders.com/hospital/liv-hospital*>, Date retrieved 22.09.2014

Url-30 Fantastic Voyage, address: < *http://uk.archello.com/en/project/liv-hospital-ulus#*>*,* Date retrieved 22.09.20

Url-31 It consist of 174 beds, 6 operating rooms, address:< *http://www.kolaninternational.com/corporate/corporate/*>*,* Date retrieved 22.09.2015

Url-32 Designed in a flora in where make patients relax and sure about they arein a healing place with technological manufactured materials, address:*<http://www.zoom.com.tr/tr/projects/kolan-hospital-sisli>,* Date retrieved 22.09.2015

Url-33 Medicana Bahcelievler was established in 2003, in 1000 m² indoor area, address: <http://www.medicanainternational.com/index.php/medicana-bahcelievler-hospital>, Date retrieved 16.01.2016

Url-34 This hospital is best known for its cardiology and angiography, cardiovascular surgery, address: < http://www.medicana.com.tr/HastaneDetay.aspx?HospitalID=2>, Date retrieved 16.01.2016

Url-35 The 'greenest' building is the one that is already been built, address: <*http://www.fox-arch.com/cate*

APPENDICES

APPENDIX A.1: PATIENT ROOM PLAN AND SECTIONS OF LİV ULUS HOSPITAL

PPENDIX A.2: PATIENT ROOM PLAN AND SECTIONS OF KOLANSISLI HOSPITAL

APPENDIX A.3: PATIENT ROOM PLAN OF MEDICANABAHCELIEVLER HOSPITAL

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