Conservation of cultural heritage using nanotechnology applications in glass

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Abstract:

The research aims to provide excretion to nanotechnology applications used on glass and take advantage of them in heritage buildings for its conservations,

The research classify these applications into two categories: indoor applications on glass and outdoor applications on glass in heritage buildings, these applications can be applied to glass windows in cultural buildings for conservation of wallpaintings and minimizing of cultural buildings degradation.

This paper proved its hypothesis that some of nanotechnology application in glass can benefit us in conservation of cultural heritage field, this Through recommendations to apply this application in glass in heritage building ; such as cleaning , protection from sunrays and air purifying applications.

Finally we put forward recommendations to enable the use of applications of nanotechnology on the glass for heritage buildings conservation.

Keywords:

Nanotechnology- Glass- Cultural Heritage- Conservation- Indoor application- Outdoor application.

1- Introduction:

Cultural Heritage is an expression of the ways of living developed by a community and passed on from generation to generation, including customs, practices, places, objects, artistic expressions and values.[1]

Nanotechnology can be defined as 'engineering at a very small scale', and this term can be applied to many areas of research and development. Nanotechnology originates from the Greek word meaning "dwarf". A nanometer is one billionth (10-9) of a meter, which is tiny, only the length of ten hydrogen atoms, or about one hundred thousandth of the width of a hair.[2]

The protection of culture heritage at the national level often remains incomplete because of the scale of the resources which it requires and of the insufficient economic, scientific, and technological resources of the country where the property to be protected is situated.[3]

Some of nanotechnology applications in glass can benefit us in conservation of cultural heritage in historical buildings such as cleaning of glass, protection of pigment, destroying air-borne pollutants and taking advantage of the solar transmission.

This search asks research question "how can nanotechnology applications in glass benefit us in conservation of cultural heritage?"

The search aims to present a proposed to use nanotechnology applications in glass in conservation of historical buildings and reduce degradations in cultural heritage in historical buildings

This search depends on **theoretical hypothesis** represented in that nanotechnology applications in glass can be used in historical buildings to reduce the degradation in these buildings and that by classifying the applications into two main categories:

- **Indoor application**
- **Outdoor application**

2- Nanotechnology:

Nano- which comes from the Greek word for dwarf indicates a billion. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. One nanometer is a billionth of a meter, or 10^{-9} of a meter. Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering. Nanotechnology is not just a new field of science and engineering, but a new way of looking at and studying.[4] The ideas and concepts behind nanoscience and nanotechnology started with a talk entitled "*There's Plenty of Room at the Bottom*" by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used. In his talk, Feynman described a

[1] http://www.cultureindevelopment.nl/Cultural_Heritage/What_is_Cultural_Heritage, last visited 25-3-2014.

[2] http://www.nano.org.uk/what-is-nanotechnology, last visited 25-3-2014.

[3] **Convention concerning the Protection of the world cultural and natural heritage,** The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) ,1972, seventeenth session, p1.

[4] **What is nanotechnology?, last** visited 12.05.2014, http://www.nano.gov/nanotech-101/what/definition.

process in which scientists would be able to manipulate and control individual atoms and molecules. Over a decade later, in his explorations of ultra precision machining, Professor Norio Taniguchi coined the term nanotechnology. It wasn't until 1981, with the development of the scanning tunneling microscope that could "see" individual atoms that modern nanotechnology began. [1]

Fig1: The scale of a nano molecule compared to a football is the same as the football compared to the world [2]

3- Glass:

The term glass refers to materials, usually blends of metallic oxides, predominantly silica, which do not crystallize when cooled from the liquid to the solid state. It is the non-crystalline or [i]amorphous structure of glass that gives rise to its transparency.[3]

Glass made from sand, lime and soda ash has been known in Egypt for 5000 years, although it probably originated in Assyria and Phoenicia. The various colors within glass derived from the addition of metallic compounds to the melt. Blue was obtained by the addition of cobalt, whilst copper produced blue or red and iron or chromium produced green. In the fifteenth century white opaque glass was produced by the addition of tin or arsenic, and by the seventeenth century ruby-red glass was made by the addition of gold chloride. Clear glass could only be obtained by using antimony or manganese as adecoloriser to remove the green coloration caused by iron impurities within the sand. In the late twentieth century, with the advent of fully glazed facades as illustrated by the Faculty of Law building at the University of Cambridge, the construction industry has become a major consumer of new glass, and a proactive force in the development of new products. [4]

The current state of the art in cladding is an active system which tracks sun, wind and rain in order to control the building environment and contribute to sustainability, but this is unreliable and difficult to calibrate and maintain.[5]

3-1. Glass in construction:

Most of glass in construction is on the outdoor surface of buildings and the control of light and heat entering through building glazing is a major sustainability issue and on the indoor of buildings in furniture or mirrors and for decorations.

4- cultural heritage:

Cultural heritage is the legacy of physical artifacts (cultural property) and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations. Cultural heritage includes tangible culture (such as buildings, monuments, landscapes, books, works of art, and artifacts), intangible culture (such as folklore, traditions, language, and knowledge), and natural heritage (including culturally significant landscapes, and biodiversity). The deliberate act of keeping

[1] **How it started,** last visited 12.05.2014, http://www.nano.gov/nanotech-101/what/definition.

[2] **Nanotechnology,** Last Update: 12.05.2014 http://en.percenta.com/nanotechnology.php, Last Update: 12.05.2013

[3] **Materials for architects and builders,** Third edition, 2007, Arthur Lyons, p210

[4] Reference**3, p211**.

[5] **Nanoforum Report, Nanotechnology and Construction**, 2006, Surinder Mann, p16.

cultural heritage from the present for the future is known Conservation, though these terms may have more specific or technical meaning in the same contexts in the other dialect.1

4-1. Conservation of cultural heritage:

All measures and actions aimed at safeguarding tangible cultural heritage while ensuring its accessibility to present and future generations. Conservation embraces preventive conservation, remedial conservation and restoration. All measures and actions should respect the significance and the physical properties of the cultural heritage item.[2]

The World Heritage Convention aims to promote cooperation among nations to protect heritage around the world that is of such outstanding universal value that its conservation is important for current and future generations.[3]

Preventive conservation is all measures and actions aimed at avoiding and minimizing future deterioration or loss. These measures and actions are indirect – they do not interfere with the materials and structures of the items. They do not modify their appearance.[4]

5- Historical background of glass in nanotechnology:

Although modern nanoscience and nanotechnology are quite new, nanoscale materials were used for centuries. Alternate-sized gold and silver particles created colors in the stained glass windows of medieval churches hundreds of years ago. The artists back then just didn't know that the process they used to create these beautiful works of art actually led to changes in the composition of the materials they were working with.[5]

Fig2: Medieval stained glass window courtesy of Nano BioNet [6]

The Lycurgus Cup demonstrates a short-lived technology developed in the fourth century A.D. by Roman glass-workers. They discovered that glass could be colored red and unusual color change effects generated by the addition of a precious metal bearing material when the glass was molten. We now understand that these effects are due to the development of nanoparticles in the glass. However, the inability to control the colorant process meant that relatively few glasses of this type were produced, and even fewer survive. The Cup is the outstanding example of this technology in

[1] http://en.wikipedia.org/wiki/Cultural_heritage, last visited 25-3-2014.

[2] **Terminology to characterize the conservation of tangible cultural heritage,** 15th Triennial Conference held in New Delhi in September 2008, ICOM-CC.

[3] **The World Heritage Convention,** Last updated: Thursday, 24-Apr-2008, Australia, http://www.environment.gov.au/heritage/about/world/convention.html

[4] Reference 2

[5] **Nanotechnology,** Last Update: 12.05.2013 http://en.percenta.com/nanotechnology.php.

[6] Reference 5

very respect – its outstanding cut work and red-green dichroism render it a unique record.[1]

Fig3: The Lycurgus Cup 1958, 1202 in reflected light [2]

Fig4: The Lycurgus Cup 1958,1202 in transmitted light [3]

Scene showing Lycurgus being enmeshed by Ambrosia, now transformed into a vine-shoot. Department of Prehistory and Europe, The British Museum. Height: 16.5 cm (with modern metal mounts), diameter: 13.2 cm. © The Trustees of the British Museum.[4]

6th-15th Centuries: Vibrant stained glass windows in European cathedrals owed their rich colors to nanoparticles of gold chloride and other metal oxides and chlorides; gold nanoparticles also acted as photocatalytic air purifiers. [5]

Fig5: The South rose window of Notre Dame Cathedral, ca 1250.[6]

6- Nanotechnological solutions strategies:

Nanotechnological solutions have four different strategies to block light and heat coming in through windows:

1. **The first strategy: thin film coatings strategy:** thin film coatings are being developed which are spectrally sensitive surface applications for window glass which filter out unwanted infrared frequencies of light and reduce the heat gain in buildings[7] as Easy-to-Clean (ETC), Anti-fogging, Self-cleaning: Lotus-Effect

2. **The second strategy: thermochromic technologies:** an active solution which react to

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[1] **The Lycurgus Cup - A Roman Nanotechnology**, 2007, Ian Freestone, Nigel Meeks, Margaret Sax, Catherine Higgitt, Gold Bulletin 40/4, p276

[2] Reference 1,p 271

[3] Reference 1, p270.

[4] Reference 1, p270.

[5] http://www.nano.gov/timeline, last visited 17-5-2014.

[6] Reference 5.

[7] **Nanoforum Report, Nanotechnology and Construction**, 2006, Surinder Mann., p15.

temperature and provide thermal insulation to give protection from heating whilst maintaining adequate lighting[1] as Smart glass coatings.

3. **The third strategy: photochromic technologies** producing a similar outcome by a different process, involves photochromic technologies which are being studied to react to changes in light intensity by increasing absorption[2] as UV protection.

4. **The forth strategy: electrochromic coatings** are being developed that react to changes in applied voltage by using a tungsten oxide layer; thereby becoming more opaque at the touch of a button[3] as solar protection, Self-cleaning: Photocatalysis.

All these applications are intended to reduce energy use in cooling buildings and could make a major dent in the huge amounts used in the built environment.

7- nanotechnology application of glass:

We can classify nanotechnology application of class into two main classifications:-

1- **Indoor nanotechnology application of glass.**
2- **Outdoor nanotechnology application of glass.**

7-1. Indoor nanotechnology application of glass:

These applications, which are applied to the glass in the building internally such as the following applications:

7-1.1. Easy-to-Clean (ETC):-

Easy-to-Clean surface coatings creates a thin protective film that facilitates removal of dirt, oily substances, lime, algae and other wastes and protecting from dirt and bacteria.[4] ETC surface coatings do not require UV light to function and their hydrophobic surface properties - as opposed to hydrophilic - cause water to run off in droplets rather than forming a thin film of water. Water that runs off inclined ETC surfaces forms droplets, washing away surface grime in the process. The benefit: stress-free and easy cleaning saves time and costs. When only a small amount of water is involved, droplets of run-off water can form runways.ETC surfaces are most commonly found in interiors, but can also be employed outdoors for better weather protection.[5]

ETC surfaces are hydrophobic making them well suited for use in bathrooms. Etc coatings can be applied on mirrors, window glass, interior, glass shower cubicles, glass shelves and glass display cases.[6]

7-1.2 Anti-fogging:-

"Nanotechnology Anti-Fog for Glass" is a glass cleaner, which by its hydrophilic effect significantly delays the fogging on applied glass surfaces. The nanostructures also cause a significantly improved cleaning action.[7]

There are two methods for antifogging to be employed:-

The first method:-

The solution is an ultra-thin coating of nanoscalar titanium dioxide, which exhibits a high surface energy and therefore greater

[1] **Nanoforum Report, Nanotechnology and Construction**, 2006, Surinder Mann. , p15

[2] Reference 1,p16

[3] Reference 1,p16

[4] **Nanotechnology Glass & Ceramics Sealant, Last Update:** 12.05.2013, http://nanotechnology-solutions.com/nanotechnology-glass-ceramics-sealing.php.

[5] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG,p91-95

[6] Reference 4

[7] **Nanotechnology Anti-Tanish for Glass,** Last Update: 12.05.2013 http://nanotechnology-solutions.com/anti-tanish-glass.php

moisture attraction. On hydrophilic surfaces moisture forms an ultra-thin film instead of water droplets. It still settles on the surface but remains invisible. The film is transparent, creating a fog-free clear appearance.[1]

The second method:-

A glass like nanoporous surface coating made of several layers containing minute holes made by nanoparticles. The surface appears flat to the naked eye but is in fact super-hydrophilic. Moisture is drawn into the tiny pores thereby stopping water droplets from forming. A thin invisible layer of water forms and the surface remains clear.[2]

The new "multifunctional" glass, based on surface nanotextures that produce an array of conical features, is self-cleaning and resists fogging and glare.[3]

These coatings are suitable for use in bathroom mirrors, and glass surfaces in wet and surfaces in air-conditioned rooms in the tropics, which tend to cloud.

Fig6: Mirrors with anti-fogging coating do not steam up.[4]

[1] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p117

[2] Reference 1, p117,118

[3] **Making nanotextured glass that's anti-fogging, self-cleaning and free of glare,** Apr 26th, 2012,David L. Chandler, Nanowerk, http://www.nanowerk.com/news/newsid=25028.php

[4] Reference 1, p118

7-1.3 UV protection:-

Protection against harmful UV sunrays is in demand in architecture. UV light destroys the color pigments and colorings for example woods and the material itself is also affected. UV protection using organic compounds prevent the continued degeneration of an already damaged material, by reacting with the free radicals that form and converting them to inert compounds.

A disadvantage of protection using organic compounds: [5]

1- They simply lessen the effect of UV light and delay its impact.

2- The protective effect decreases over time.

3- The material degeneration advances more rapidly – first discoloration, then embrittling and finally chalking.

A new means of UV protection using inorganic substances represents an innovation. Their primary advantage is that they do not themselves degenerate and therefore provide a lasting protective effect. A prerequisite of protective coatings is that they are transparent so that the coloring and structure of the material beneath is preserved. To achieve this, the individual inorganic UV-absorbing particles in the formulation must be smaller than 15 nm in size. Below this size they no longer scatter visible light and become effectively invisible.[6]

7-1.4 Solar protection against heat gain from solar radiation:

Nanotechnology has provided a new means of integrating electrochromatic glass in buildings.

[5] Reference 1, p141

[6] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p142.

Advantage of electrochromatic glass with an ultra-thin nanocoating:[1]

1- A single switch is required to change the degree of light transmission from one state to another one switch to change from transparent to darkened, and a second switch to change back.
2- The electrical energy required to color the ultra-thin nanocoating is minimal. The switching process itself takes a few minutes.
3-Photochromatic glass is another solution for darkening glass panels. The sunlight itself causes the glass to darken automatically without any switching.
4-Blinds or curtains may no longer be necessary. This provides partial shading rather than complete closure so that a degree of visual contact to the world outside always remains. Nanotechnology has made it possible to provide an energy-efficient means of solar protection that can also be combined with other glass functions.

Glare-free light and shading is particularly important for office interiors with computer workstations.

Fig7: Electrochromatic glass with an ultra-thin nanocoating needs only be switched once to change state, gradually changing to a darkened yet transparent state. At present the maximum dimension of glazing panels is limited.[2]

7-1.5 Anti-fingerprint:

Fingerprints show very clearly in glass when used in interiors. An anti-fingerprint coating can offer a suitable solution for this problem. These coatings make fingerprint marks are practically invisible. The nanocoating alters the refraction of the light in the same way the fingerprint itself does so that new fingerprints have little effect. The light reflections on the coating make glass surfaces appear smooth, giving the impression of cleanliness that many users have come to expect. The coating is used mainly for applications such as lifts, cladding and furniture.[3]

a silicon coating is usually applied to the sandblasted glass surface which when cleaned acquire a typical cloudy appearance. An anti-fingerprint nanocoating ensures the lasting optical appearance of the glass and reduces the impact of fingerprints and dust and they lead to a reduction in cleaning costs.[4]

1 Reference 6, 143.

2 **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p144.

3 Reference 1, p171

4 Reference 1, p173

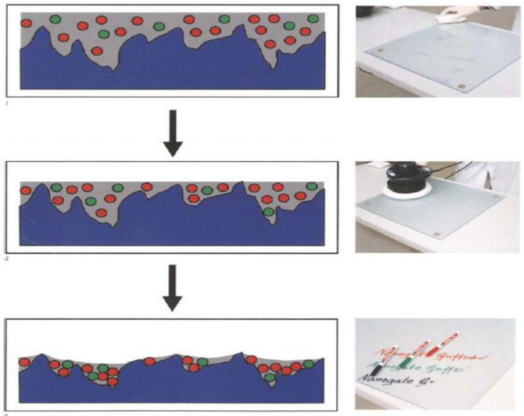

Fig8: the functional principle of a colored protective coating retrofitted to a glass surface:
1- The coating material is applied with a slight excess to the glass (shown in blue). Color pigments (red) and stabilizers (green) are contained within the matrix of the coating (shown in grey).
2- Removal of excess material by hand or machine.
3- Fully hardened protective coating.[1]

7-1.6 Air purifiers with glass:

Stained glass windows that are painted with gold purify the air when they are lit up by sunlight, a team of Queensland University of Technology experts have discovered. Numerous church windows across Europe were decorated with glass colored in gold nanoparticles.[2]

People appreciated only the beautiful works of art, and long life of the colors, but little did they realize that these works of art are also, in modern language, photocatalytic air purifier with nanostructured gold catalyst. Tiny particles of gold, energized by the sun, were able to destroy air-borne pollutants like volatile organic chemical (VOCs), which may often come from new furniture, carpets and paint in good condition. These VOCs create that 'new' smell as they are slowly released from walls and furniture, but they, along with methanol and carbon monoxide, are not good for your health, even in small amounts.[3]

The magnetic field on the surface of the gold nanoparticles can be enhanced by up to hundred times, which breaks apart the pollutant molecules in the air. This technology is solar-powered, and is very energy efficient, because only the particles of gold heat up. [4]

7-2 Outdoor nanotechnology application of glass:

8 These applications, which are applied to the glass in the building externally such as the following applications:

8-1.1 Self-cleaning: Lotus-Effect:

The lotus plant is revered in Asia for its exceptional cleanness. Although it grows in muddy waters, its leaves always appear immaculately clean. The plants' leaves are super hydrophobic, i.e. drops of water roll off free of residue, taking any impurities with them. Investigations into the surface using reflection electron microscopy (REM) have shown that the surface of the leaf is characteristic roughness systematically arranged; water-repellent, nano-size wax crystals form three-dimensional structures, similar to small nipples, which are no greater than a few nanometers or micrometers in size.[5]

[1] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p, p172
[2] **Stained glass church windows - nanotechnology air purifiers**, August 21 2008 ,Zhu Huai Yong, Queensland University of Technology, Nanowerk, http://www.nanowerk.com/news/newsid=6868.php
[3] Reference 2.
[4] Reference 2.
[5] **Nanotechnology solutions for self-cleaning, dirt and water-repellent coatings**, January 11, 2011, By NanoTrust, Austrian Academy of Sciences, *nanowerk*, http://www.nanowerk.com/spotlight/spotid=19644.php.

Fig9: The Lotus plant with its natural self-cleaning qualities lends its name to the "Lotus-Effect".[1]

When combined with the waxes' water-repellent chemical properties, these structures make the lotus leaf extremely non-wettable, a state called ultra hydrophobia or super-hydrophobia, and they give it its self-cleaning properties. Dirt particles only sit on the tip of the wax crystals and as a result only a very small surface area comes into contact with the plant's surface. If waterfalls onto a leaf surface like this, the interplay of the surface tension and the low attraction force between the surfaces and the water produce a spherical water drop which only sits on the tips of the wax structures. If the leaf tips in the slightest, the water drop immediately rolls off, taking the dirt particles with it. [2]

The Lotus-Effect is most well suited for surfaces that are regularly exposed to sufficient quantities of water, e.g. rainwater Small quantities of water may leave a surface looking dirtier rather than cleaner. [3] These properties are not practiple for use in most interior.[4]

The Lotus-Effect is long lasting: five years later a painted façade remains as fully functional as ever.[5]

Various products such as Lotusan façade coatings are allowed, as are some roof tiles. At present no Lotus-Effect textiles are available on the market, although they are expected to launch soon. The advantages are self-evident: a cleaner appearance and considerably reduced maintenance demands. [6]

Fig10: Water channels formed by water droplets running off natural surfaces and a building facade.[7]

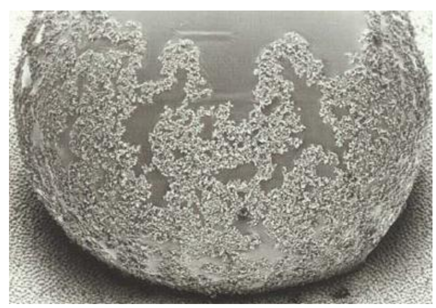

Fig11: Water droplets running off a superhydrophobic surface of a leaf wash away dirt deposits, as can be seen in this image of the cultivated oriental Coiocasia esculenta plant. The fine knobbly structure of the leaf's surface is also clearly visible.[8]

[1] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p58

[2] **Nanotechnology solutions for self-cleaning, dirt and water-repellent coatings**, January 11, 2011, By NanoTrust, Austrian Academy of Sciences, *nanowerk*, http://www.nanowerk.com/spotlight/spotid=19644.php.

[3] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p59

[4] Reference 1

[5] Reference 2, p59

[6] Reference 2, p61

[7] Reference 2, p59

[8] Reference 2, p62

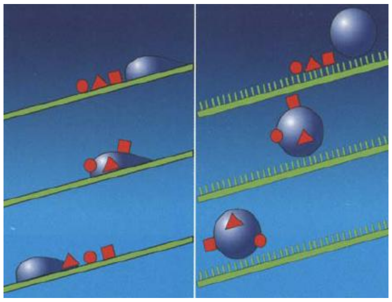

Fig12: The diagrams show clearly the difference between conventional surfaces and the Lotus-Effect.[1]

8-1.2 Self-cleaning: Photocatalysis:

Photocatalytic self-cleaning effect is that it greatly reduces the extent of dirt adhesion on surfaces which lead to savings in personnel costs and the dirts are easier to remove. Advantages of photocatalytic self-cleaning are a low-maintenace and trouble-free solution. [2]

The photocatalytic properties of TiO2 were discovered in 1967 by Akira Fujishima. The first house with self-cleaning exterior surfaces was Fujishima's own. Titanium dioxide is hydrophilic due to its high surface energy, water does not form drops on a surface coated with it, but a sealed water film instead. It is transparent and can therefore also be used on glass. In addition, TiO2 is photocatalytic in the presence of water, oxygen radicals are produced under UV light irradiation which in turn can decompose organic material such as fats, oils, soot or plant materials.[3]

The level of UV light of normal daylight is sufficient to activate the photocatalytic reaction.[4]

In addition to the catalyst, the UV component of light, with a wavelength of less than 390 nm is considered essential for the reaction to occur photocatalytic self-cleaning surfaces are used on building façades. As the self-cleaning effect does not function without water, eaves should be designed so that they do not prevent rainwater or dew from reaching the façade. [5]

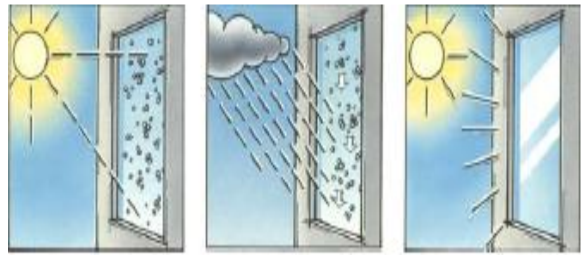

Fig13: The diagrams show the bask process:

- Organic dirt and grime is broken down and "decomposed". Until now UV light, such as present in sunlight, is necessary to initiate Photocatalysis.
- When water impacts on the surface, it spreads to form a film washing away the loose dirt.
- The result: clean surfaces![6]

Due to the hydrophilic property of the surface, the water immediately formed a thin film, which evaporates quickly, absorbing in the process ambient warmth and thereby reducing the indoor temperature noticeably. Initial estimates suggest a potential energy reduction of between10 and 20% in comparison to conventional air conditioning.[7] Photocatalytic self-cleaning only works in outdoor use because it requires UV light and water to remove the residue.[8]

Photocatalytic glass can be combined with other typical functions such as solar-protection glass. Photocatalysis can also be used to achieve

[1] Reference 2, p62

[2] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p71

[3] **Nanotechnology solutions for self-cleaning, dirt and water-repellent coatings**, January 11, 2011, By NanoTrust, Austrian Academy of Sciences, *nanowerk*, http://www.nanowerk.com/spotlight/spotid=19644.php.

[4] Reference 1, p71

[5] Reference 1, p73

[6] Reference 1, p73

[7] Reference 1, p75.

[8] **Nanotechnology solutions for self-cleaning, dirt and water-repellent coatings**, January 11, 2011, By NanoTrust, Austrian Academy of Sciences, *nanowerk*, http://www.nanowerk.com/spotlight/spotid=19644.php

air-purifying, water-purifying as well as antimicrobial properties.[1]

8-1.3 Anti-reflective glass:

The anti-reflective is used in exhibition design for glass cabinets

Fig14: A photovoltaic module with anti-reflective (AR) solar glass coating.[2]

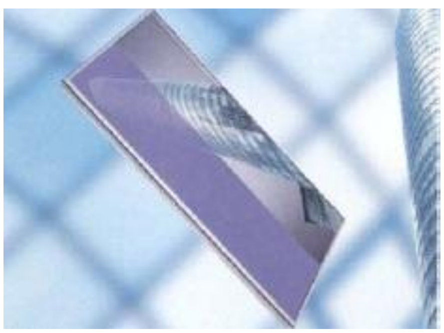

Fig15: A photovoltaic module without anti-reflective (AR) solar glass coating.[3]

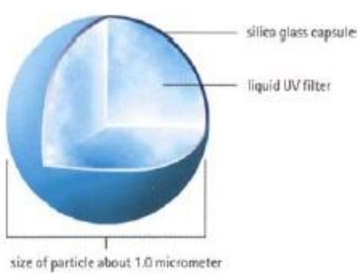

Fig16: Silica glass capsules are used in nanoporous anti-reflective coatings with a thickness of 150 nm that are also able to reflect the invisible spectrum of light.[4]

Transparent nanoscalar surface structures, where the particles are smaller than the wavelength of visible light, offer not only an innovative but also a cost-effective and efficient anti-reflective solution. Their structure consists of minute 30-50nm large silicon-dioxide (SiO_2) balls. A single interference layer is applied by dipping the glass or plastic in the solution and functions across a broadband spectrum of light. A thickness of 150nm is regarded as ideal. The ratio of reflected light reduces from 8% to less than 1%. Another cost effective means of producing anti-reflective surfaces is the moth-eye effect. The cornea of moths, which are active mostly at night, exhibit a structure that reduces reflections.[5]

Photovoltaic panels can lose as much as 40 percent of their efficiency within six months as dust and dirt accumulate on their surfaces. But a solar panel protected by the new self-cleaning glass, would have much less of a problem. In addition, the panel would be more efficient because more light would be transmitted through its surface, instead of being reflected away when the sun's rays are inclined at a sharp angle to the panel. At such times, such as early mornings and late afternoons, conventional glass might reflect away more than 50 percent of the light, whereas an anti-reflection surface would reduce the reflection to a negligible level.[6]

Anti-reflective glass can now be used in large quantities in construction in order to benefit from the increased solar transmission resulting from broadband spectral dereflection. Of particular interest is the increased efficiency of photovoltaic systems as the entire spectrum of

[1] Reference 1, p74.
[2] **Nano Materials in Architecture, Interior Architecture and Design**, 2008, Sylvia Leydecker, Birkhauser Verlag AG, p159.
[3] Reference 1, p159.
[4] Reference 1, p160.
[5] Reference 1, p159-160
[6] **Nanotextured Silica Surfaces with Robust Super-Super-Hydrophobicity and Omnidirectional Broadband Super-Transmissivity**, accepted April 7, 2012, Kyoo-Chul Park, Hyungryul Choi, Chih-Hao Chang Robert Cohen, Gareth McKinley and George Barbastathis, ACS NANO journals.

solar energy from 400 to 2500 nm is now transmitted. By reducing the amount of under-utilized and therefore lost solar energy, the energy gain and efficiency of the photovoltaic systems is improved, resulting in an overall performance gain of up to 15%.[1]

8-1.4 Smart glass coatings for energy-efficient eco-homes:

Vanadium dioxide (VO_2) is a leading candidate material for the fabrication of thermochromic films and coatings that will find special applications in a new generation of 'smart' glass that can change infrared transmittance by responding to environmental temperature, while maintaining visible transparency.[2] 'Smart' windows are expected to play a significant role in energy-efficient homes, ideally by generating energy themselves but at least by allowing light in and keeping the heat out (in hot summers) or in (in cold winters).[3] In addition to its temperature-responsive thermochromism these films also exhibit UV-shielding properties. Flexible vanadium dioxide nanoparticle-based composite foils are especially useful for applying to glass used in the construction industry and the transportation sector.[4]

'Such flexible VO_2 nanocomposite foils are able to combine the intrinsic properties of VO_2 nanoparticles with the added functionalities contributed by nanoscale and interface effects, such as increased visible transparency and infrared modulation ability. The researchers found that coating the VO_2 nanoparticles with a thin SiO_2 shell significantly improved their anti-oxidation and anti-acid abilities.' Yanfeng Gao, a professor at the Shanghai Institute of Ceramics, Chinese Academy of Sciences (SICCAS), explains to Nanowerk. [5],[6]

[1] Reference 1, p160

[2] **Smart glass coatings for energy-efficient eco-homes**, February 6, 2012**,** Michael Berger, http://www.nanowerk.com/spotlight/spotid=24176.php

[3] **Porosity of nanocoating improves 'smart' window performance**, December 28, 2011**,** Michael Berger, Nanowerk, http://www.nanowerk.com/spotlight/spotid=23840.php

[4] Reference 4

[5] **Smart glass coatings for energy-efficient eco-homes**, February 6, 2012**,** Michael Berger, http://www.nanowerk.com/spotlight/spotid=24176.php.

[6] **Nanoporous Thermochromic VO2 Films with Low Optical Constants, Enhanced Luminous Transmittance and Thermochromic Properties**, January 26, 2011, Litao Kang , Yanfeng Gao , Hongjie Luo , Zhang Chen , Jin Du and Zongtao Zhang

8. Nanotechnology application of glass suggested to use in historical buildings:

Nanotechnology applications		This application benefit us in historical buildings	benefits	aims
Indoor nanotechnology application of glass	**Easy-to-Clean (ETC)**	yes	• stress-free and easy cleaning saves time and costs	For cleanings
	Anti-fogging	Not important	Not important for using in historical buildings	-
	UV protection	yes	• Reduce the destroying of the colour pigments and colourings for example woods and the material itself is also affected. • prevent the continued degeneration of an already damaged material	For conservation of pigments
	Solar protection against heat gain from solar radiation	Not important	Not important for using in historical buildings	-
	Anti-fingerprint	Not important	Not important for using in historical buildings	-
	Air purifiers with glass	Yes	• Destroy air-borne pollutants like volatile organic chemical (VOCs) • Break apart the pollutant molecules in the air	For pure air
outdoor nanotechnology application of glass	**Self-cleaning: Lotus-Effect**	yes	• cleaner appearance and considerably reduced maintenance demands	For cleanings
	Self-cleaning: Photocatalysis	yes	• Reduce the extent of dirt adhesion on surfaces which lead to savings in personnel costs and the dirts are easier to remove.	For cleanings
	Anti-reflective glass	yes	cost-effective and efficient anti-reflective solution	For benefit from solar transmission
	Smart glass coatings for energy-efficient eco-homes	Not important	Not important for using in historical buildings	-

9. Results:

The new applications, which come from Nanoscience Technology used in glass led to reduce the disadvantages that were associated with the glass; that`s where the glass is one of the basic materials used in buildings which affect directly the building. It should be noted that the physical and chemical properties of the glass has Utmost importance, and when using some applications such as nanoparticles coatings these properties will changing.

The paper answered the research question which put forward at the forefront of research, through emphasizing the veracity of the hypothesis that assumed by research, relating to the possibility of using nanotechnology applications in glass in the heritage buildings for its conservation and reducing its degradation.

10. Conclusion:

Using some of nanotechnology applications in glass in heritage buildings such as cleanings applications (Easy-to-Clean, Self-cleaning: Lotus-Effect and Self-cleaning: Photocatalysis) to clean them and keep a decent appearance of the buildings, Blocking the sun's rays applications (UV protection and Anti-reflective glass) to protect the wallpaintings from degradation and air purifying glass to Maintain a fresh air in the buildings.

11. Recommendations:

In order to be able to benefit from the applications of nanotechnology on the glass in the field of conservation of heritage buildings, it is recommended that using some of these applications in any historical building are based on the following considerations:

1. We should have a full knowledge of all nanotechnology applications on glass in the field of architecture.
2. It should be performed to study ways to conserve the heritage buildings based on determining the causes of its degradation and work to reduce these reasons.
3. We should specify the most appropriate applications of nanotechnology on glass, which can benefit us to conserve the heritage buildings and reduce its degradation.

Finally, this paper is also recommended that we should study the applications of nanotechnology in the field of architecture in general and the importance of using the most appropriate of these applications in conservation of cultural heritage.

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