Activation of photoluminescence glass in public squares

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Abstract

A square is one of the most important visual and functional elements of cities. It is a vacuum that reflects the identity of civilizational and cultural societies and it works to strengthen bonds among members of society. In recent times, many squares have lost their influence due to their lack of functional and aesthetic aspect and their inability to be environmentally compatible. Therefore, the research is developing types of smart glass materials that sustain architectural formations and reduce the energy consumed in it for the purposes of lighting, and take advantage of its characteristics in the development of public fields, by designing a monument of photoluminescence glass that is saving light energy in an innovative style. The research problem can be identified in the following points:

Research problem:

The need to provide new glass technologies that raise energy efficiency.
Weakness of some Public squares regarding functional and aesthetic factors.

Research aims:

How to take advantage of photoluminescence glass to achieve sustainability? Raise the efficiency of lighting at night, and rationalize its consumption in public squares.

Research hypotheses:

The research assumes that the study of modern technologies of glass helps in reaching new functional and aesthetic solutions to enrich and develop the field of architectural glass.

Research importance:

Contribute to raising energy efficiency by means of modern glass technologies and activating them to develop public squares.

Research Methodology:

Descriptive and experimental method.

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The following steps were studied:

A study on the concept of environmental design, its philosophy and requirements.

A study on smart materials and their classification according to their characteristics.

Preparation of photoluminescence glass in the laboratory.

Contemporary design process using photoluminescence glass technology for application in public squares.

Environmental design:

It is the integrated and specialized design to solve environmental problems, conserve its resources and employ them to serve mankind to perform the expected job without disturbing the balance between the environmental elements used in an aesthetic consensus standard characterized by simplicity and harmony.

Environmental design philosophy:

The environmental design philosophy depends on the creation of an inclusive design language represented in combining design decisions for both the natural environment and architecture, fulfilling design considerations (social, aesthetical, and functional ... etc.) while preserving the identity of the place to achieve creative values in design, where environmental design is considered at the architectural level. It is a systematic process of design that aims at having mutual influence between architecture and its environment in a positive way.

The concept of environmental design is determined in the study of the surrounding environment in terms of climate, available natural resources, the prevailing culture and its impact on the final outputs of the design process.

Environmental design requirements:

Environmental design has technological, economic and creative requirements (functional, aesthetical), in which the design process begins with the development of a set of requirements that affect the construction of the built environment systems and within them, and the analysis of the structural elements and their link to the overall system.

The traditional energy is from limited resources as it is considered polluting sources of the environment, and that was behind the main motivation for interest in renewable energies, so the trend was to employ (sun, wind and air) as they are sources of renewable energy and achieve sustainability, which we can call design for the environment (Design for Environment (DFE), where energy is one of the main entry points towards achieving environmental design principles.

Smart Materials:

Smart materials are materials that can be used in the field of design, because they are materials interacting with the surrounding environment, they are dynamic materials that can perceive the surrounding environmental variables and respond to them in a specific way in advance, and they have the ability to automatically transform their physical properties as they can change their sizes, shapes and colors in response to physical and chemical influences, as a change in shape, color, etc., without an external source of energy to achieve its desired goals.

The great diversity of smart materials and their multiple applications in buildings has led to the necessity to develop their classification system to help in selecting materials, and one of the important classifications of smart materials is the author's classification (Axel Ritter) in 2007, where smart materials are sectioned to the following groups:
(Property changing smart materials), (Energy exchanging Smart Materials).

Application of smart glass materials in lighting:

Created by the Icelandic artist Olafur Eliasson in the central foyer of the Copenhagen Opera in 2004 AD, transparent glass smart lamps consist of three identical spherical chandeliers of luminous safety glass in which there are optical filters (Dichoritic Filter) that allow natural light to pass through and filter it and reflect it with storing part of its energy to radiate it at night, as a smart material, each chandelier consists of several pieces of glass, which are bisectable, allowing some light to pass through, and some of them are reflected, also the patterns change when viewed from different angles.	 **Picture No. (1) shows smart glass lamps designed by the artist Olafur Eliasson in Copenhagen's opera**

Luminescence:

It is the light emitted by the particles of the material upon its return from the state of excitation to the state of stability. If the energy falling on the surface of the material then stimulates the action of the emission of light, the material is called (Photoluminescence material) and it is currently used as a paint for walls and floors and it is divided into two types depending on the characteristics of their behavior with respect to time as in Table No(١) .

Photoluminescence	
They are materials that depend on the properties of light behavior and its relationship to time, as their internal orbits are excited through a part of the light such as ultraviolet rays, so these materials can emit light from them during the excitation period, as they absorb ultraviolet rays to emit visible rays that illuminate dark rooms, and they are divide into Two types are:	
Fluorescence materials	**Phosphorescence materials**
Substances whose molecule is excited by ultraviolet radiation and the return of a substance from an excited state to a normal state is accompanied by the emission of light at approximately the same time of 10-8 seconds, Picture No. (**3**),(4).	They are the substances whose return from the excited state to the normal state is accompanied by the emission of delayed light, Picture No. (2). One of the glass tables that glow in the dark, where the upper surface is covered with a layer of phosphorous glass-ceramic material by printing technology so that the paint stores daylight and artificial light and releases it in the dark.

Picture No. (3) Shows one of the windows that was sprayed with "Christina Kubisch" using fluorescent paints in Germany.

Picture No. (٤) shows one of the plastic works of the German artist "Ruth Handschin" using fluorescent paints.

Picture No. (2) shows one of the glass chairs that was covered with a glass-ceramic phosphorescent material.

Table No. (1) shows the materials transformed into energy (Photoluminescence)

Laboratory experiment to develop varieties of Photoluminescence glass:

This part deals with the laboratory experience, and the scientific properties of raw materials for preparing optical emission glass to evaluate the chemical composition in terms of their ability to be applied in the field of spectral emissions and provide adequate information on methods of preparation and treatment, and the possibility of using them in the formation of new innovative glass mixtures from spectral emission glass.

Laboratory experiment to prepare optical Photoluminescence glass
The goal of the experiment: Preparing a new type of silicon phosphate glass that contains oxides of heavy elements such as barium or bismuth as a host medium for the rare earth dyspepsia oxide in order to reach a light emitting glass that gives a green phosphorescent color**.**
Primary raw materials: Silica sand (SiO2), zinc oxide (ZnO), dry barium carbonate (BaCO3), bismuth oxide (Bi2O3), sodium phosphate (Na3PO4), the transition element manganese oxide (MnO2), the rare earth element dyspericium oxide (Dy2O3).
Preparing the glass mixture: **Measuring weights:**

1. The weights of the raw materials used in the mixture were calculated by a percentage.
2. Packing the primary raw materials in bags intended for preservation after weighing to avoid moisture.

Measuring density:

The density was measured for the first group of the mixture to check the quality of the glass. The measurement procedure was carried out using a sensitive balance with an accuracy of 0.001 and using water as an inert liquid. This is according to Archimedes' standard principle by using the following formula: $\rho = [\ \frac{a}{a-b}\ ]\rho_x$

Where (a) is the weight of the glass sample in air, (b) is the weight of the glass sample when immersed in water at a density of 1 g / cm3 (ρx).

Smelting and molding:

1- The first mixture of the glass was prepared using chemicals that were weighed, Picture No. (5).
2- The chemicals were placed in alumina covered crucibles under normal atmospheric conditions.
3- The mixture was melted in Vecstar-brand silicon carbide furnaces, at a temperature of 1250 degrees Celsius for a period of 120 minutes.
4- The crucible inside the molten melted was turned repeatedly every half an hour to obtain full transparency when pouring.
5- Two stainless steel molds, size 20 x 30 mm, were heated ready to pour the molten glass.
6- After the specified melting time (120 minutes), the molten mix. was poured into two preheated stainless steel molds.
7- Samples were transferred immediately after the molding process to the cooling oven, after setting it at a temperature of 350 degrees Celsius.
8- The glass samples were filled after the cooling process was completed and placed in bags designated for preservation, ready to be prepared for the chemical and physical measurements stage, Picture No. (3).

Picture No. (5) shows the process of weighing the raw materials used in the mixture

Picture No. (6) shows the shape of the glass samples for the first group after completing the cooling process according to their chemical composition

Discussion and results:

Spectral emission methods depend on the excitation of the particles of the substance by the radiation energy and then measuring the intensity of the rays emitted from these atoms or molecules after returning to the steady state. Pictures No. (7) Illustrate the spectral emission process for samples grafted with dysprosium and for glass samples grafted with manganese and samarium, which resulted in light energy in green color.

Picture No. (7) shows the spectral emission process of the glass samples in phosphorescent green

Table No. (2) Illustrates the laboratory experience

A contemporary design idea proposal using light-emitting glass technology and its application in architecture:

Suggested design: monument (field sculpture)	
Architecture type	External architecture
Space	Its height is 17 meters, and its width is up to 7 meters.
Regional climate	A proposed design for a monument to suit a public square.

Identify the memorial:

The monument is designed to be placed on a total area of 6000 square meters, with a height from the base to its highest point of 28 meters, and is based on a granite base of 1000 square meters, and the monument is surrounded by a yard for pedestrians to see it and places to sit.

Picture No. (8) illustrates the first applied idea of the monument

The expressive side of the design idea:

The monument is considered one of the few types of architecture whose primary function is not shelter, but rather a feeling and remembrance. Therefore, the discovery and adaptation of modern materials such as light emission glass works on creating new and bold designs in formation and sculptural creativity, and can be presented within the ideas of modernity in the field work that provides innovative plastic values, to create a highly effective monument with high aesthetic values, it can be used for a long period of time and save energy on the long run.

Design Idea Sources:

Man, and movement are two sides of one positive coin, which is health, culture, creativity and the percentage of enjoyment of life. Art and the culture of movement are an elevation and progression in human life. The enormous amounts that can be used as a source of energy generation for our civilization system, as it was found that the human body is a diverse and effective resource for producing energy and spreading it to the surrounding environment all the time, which can be harvested of all kinds.

Picture No. (9) illustrates (the movement of the human body) from which the design thought is inspired

The structural configuration of the design:

The monument is a structure of smooth curves that express a mathematical movement of the human being, and it is divided into two parts, the upper part in which the hands join to form an arc embracing within it a ball that represents the head, while the lower part is represented by two large arcs, but they are open inward, expressing the rest of the body, and the sculptural work is balanced and streamlining, and the design of the memorial in its interactive form aims to store solar energy during the day and use it at night in the form of light energy with a phosphorescent green color.

Picture No. (10) the structural configuration of the design is shown

Sources of creationist thought in the monument:

The monument is a steel frame structure that carries colored glass panels and light-emitting glass distributed according to the design designed for the most functional and aesthetic, the upper and lower parts are divided by long horizontal and vertical black columns that intersect with each other forming the steel structure, so that the upper part wraps around a blown glass ball to be the center of the memorial.

The idea of distributing the columns in the vertical direction and in the horizontal direction made the structure appear coherent, and it also gave freedom of formation and simplicity in the external form, the yellow, green, blue and pink colored glass were distributed repeatedly on the entire steel structure of the monument in a fixed pattern, forming a network of multiple colors.

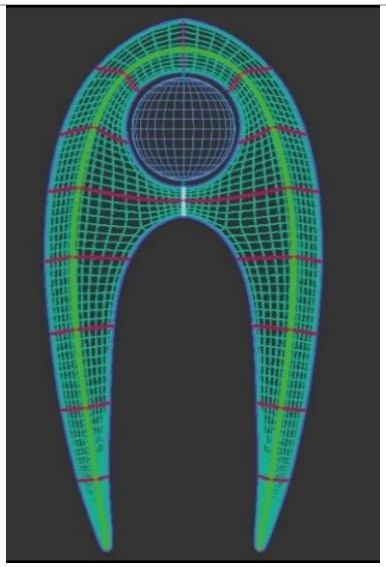

Figure No. (11) shows a vertical section of the monument

Architectural trends in energy consumption:

The researcher suggested using the green entrance in the design of the monument, as it is based on energy efficiency and the use of renewable energy such as solar energy and reliance on storing as much solar energy as possible to meet the needs of photovoltaic energy.

Principles and standards for architecture:

• The integration of the abstract shape of the monument, where the form, function and structure led to integrated solutions through their organization represented in the innovative concept of field sculpture.

• The monument is characterized by an increase in energy efficiency due to the use of light-emitting glass, as it is energy-saving, and this is what gave it the characteristic of sustainability.

• The memorial's use of environmentally friendly materials that are locally available, represented by recyclable steel and colored glass, which were manufactured well in order not to leave negative impacts on the environment to reduce pollution.

The ability of the photoluminescence glass to store a lot of natural light by day and artificial light at night, and to generate electrical energy reduces the demand for electrical energy sources needed to light up the square.

Type of environmental design strategies:

The application of solar energy strategy: by using photoluminescence glass because of its ability to store solar energy throughout the hours of the day and transmit it at night in the form of photovoltaic energy, i.e. converting solar radiation directly into electrical energy.

The materials used in the monument:

The monument is an iron structure of steel covered with a colored glass cover, its sculptural style is characterized by the dependence on large areas of multicolored glass in the decoration of the sculptural form, which in turn increased its expressive strength and gave it unique characteristic, as it achieved transparency in the design, and the emission glass Photosynthesis in repetitive areas in the design, which meet many environmental requirements, the most important of which is power generation. The steel structure is characterized by great formability, high flexibility, and its resistance to rust.

Picture No. (12) shows the type of materials used in the monument

Optical properties:

the color:

The monument is colored by a mixture of bright cold and hot colors, stemming from the merging of colored glass with photoluminescence glass in its yellow and white transparent colors in a repetitive engineering system, which aims to achieve joy and happiness by creating a mental connection relationship for the viewer to achieve a beautiful visual sequence, the design in its diversity is attractive and dynamic.

Lighting:

The lighting of the monument has led to its sustainability and to reduce the light energy required at night by using the light emission glass, the design has been based on the classification of the site and the climate surrounding the monument, where the abundance of natural daylight contributes to providing quantities of the light energy stored inside the spectral photoluminescence glass to cover all parts of the field. The lighting was also distributed around the body of the glass monument and in a way that serves the symbol. Special types of halogen sodium have been taken into consideration that show the details and aesthetics of the monument.

Picture No. (13) shows the phosphorescent lighting emitted by photoluminescence glass at night

Renewable energy sources:

Solar and wind energy:

The interactive shape of the monument is achieved by an extensive study of the general location of the square, the surrounding environmental factors, the wind and the movement of the sun's rotation around the different corners of the monument and its external structure in summer and winter.

Smart material type:

photoluminescence glass was used in the memorial to generate light energy and store natural light as much as possible to take advantage of it in lighting at night in the form of radiant energy, to reduce the need for artificial lighting, and the use of photoluminescence glass repeatedly, with studied angles was the ability to create unique color dynamic scenarios.

Picture No. (14) shows the type of smart materials used in the monument

The design of the memorial encourages gathering and social interaction, as the projections of light emanating from the memorial with its shimmering and flashing colors across the square made a sense of vitality, and it has an important role in communicating with the masses, and the design is also subjected to the peculiarities of the open space and its data to fit with the different angles of the view, evoking hope and optimism in the future, it symbolizes warmth, light and inspiration.

Picture No. (15) Shows the monument's connection with the surrounding environment

Environmental compatibility:

Table No. (3) Shows the proposed design for a monument

Results:

1- Designing buildings that accommodate the concept of environmental design can adapt and accommodate changes in usage, by using smart glass technologies that provide more light by taking advantage of solar radiation according to the seasons of the year.

2- Photoluminescence glass is one of the latest smart materials that can be used in architectural treatments for lighting design, as it is able to significantly raise the level of lighting inside buildings and public spaces at night, to reduce energy consumption, and this is what distinguishes it from other traditional means.

3- The study confirmed that there is a positive relationship between science and innovation in achieving aesthetic and functional values in design, especially when combining environmental design and Photoluminescence glass to express shape in the proposed applied design ideas for contemporary architecture.

Recommendations:

1- Spread awareness of the importance of environmental design and the economic value that can be provided by using spectral emission glass materials, even if the initial cost is high.

2- Applying energy-converting glass materials and integrating them into the architectural design to obtain an interactive and highly efficient architecture.

3- Conducting an economic feasibility study for the use of energy-converting glass materials in Egyptian architecture, and improving technical data by upgrading the level of local manufacturing in terms of quality and diversity in design and implementation techniques, in order to obtain an Egyptian glass building with global architectural and environmental characteristics.

4- Expanding applied studies and encouraging scientific research in the field of glass smart materials technology, its techniques, and introducing its characteristics and capabilities.

References:

1- Ahmed Abdel-Moneim Hamid Al-Qattan, Qasim, Magdy Muhammad "Towards a Contemporary Concept of Environmental Sustainability in Islamic Architecture" Journal of the Engineering Sector. Al Azhar university. Volume 11 No. 39, 2016

2- Asma Ahmad Khader, "The Intellectual Methodology for Environmental Design in Islamic Architecture and Its Impact on the Human Dimension in Contemporary Interior Design", Ph.D. College of Applied Arts. Helwan University 2018

3- Mai Mahmoud Salah El-Din Azzam, "Criteria for selecting local building materials for green architecture in Egypt," Ph.D. Faculty of Engineering. Ain Shams University 2014

4- H. ElBatal, M. A. Marzouk, H. A ElBatal," Crystallization and spectroscopic characterizations of binary $SrO\text{-}B_2O_3$, glasses doped with LiF, NaF, CaF_2, or TiO_2" Journal of the Australian Ceramic Society.doi.org/10.1007/s41779-019-00316-8. 2019

5- I. Kamitsos, A. P. M. A. Karakas sides Patsis, and, G. D Chryssikos "Infrared reflectance spectra of lithium borate glasses, Journal of Non-Crystalline Solids" 126(1-2). (1990) 52–67.

6- M. A. Marzouk, Rasha Mohamed Ali, Doaa Hamed Hussein, Hala Omar, "Reddish orange phosphorescence of some types of zinc borosilicate glasses activated with Mn2+ and/or Sm3+" Journal of Materials Science: Materials in Electronics. (2019) 30:18234–18245