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# APPLICATION OF DICHROIC GLASS IN THE ARCHITECTURAL DESIGN OF BUILDINGS

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**Abstract**. *The application of coloured and optical glass in architecture is of great importance in terms of creating spatial dynamics and uniqueness of space. Dichroic glass is a type of glass coated with a thin layer of metal, which causes the glass surface to change in colour depending on the viewing angle. The colour of the glass depends on the incidence of different wavelengths of light passing through or bouncing off the glass surface, thus creating different effects of colour refraction. Created effects provide different possibilities in the design of buildings and improvements in the aesthetic quality of the interior space. This paper deals with the analysis and application of coloured dichroic glass in architecture and interior design.*

**Key words**: *Dichroic glass, coloured glass, colour refraction, optical glass*

## 1. INTRODUCTION

The transparency and translucency of glass has historically given an aesthetic quality to architecture like no other material. It gives a building the ability to change, to move, and to create certain environments. The way in which light passes through a piece of glass in a building can be a powerful design tool for an architect. The glass can reflect, bend, transmit, and absorb light, all with great accuracy (1). Combined with modern technologies and materials such as steel, concrete, aluminum and other materials, this ancient building material has become one of the most important materials in architecture (2). The material properties of glass and its ongoing technological development offer particular opportunities. Modern types of glass, because of their ability to change their characteristics and the ability to adapt to different space, replace other types of materials, thus creating a new kind of aesthetics (3). Dichroic glass, which, in addition to all

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standard features, has the ability to change colour depending on the angle of observation, is one of the new, modern types of glass. The constant change of colour, as well as the three-dimensional structure, gives many possibilities for architects to create very dynamic, colour effects in the object when designing buildings using Dichroic glass. This paper deals with the characteristics and types of Dichroic glass as well as case studies of its application in facade design and interior design.

## 2. DICHROIC GLASS

Dichroic glass is modern, composite, opaque glass composed of a layer of glass and micro layers of metal or oxide that show a change in colour depending on the lighting conditions, time of the day or season. Although it is commercially known as "Dichroic", this glass can have a coating or overlay in three - "trichroic" or more colours - "pleochroic". Dichroitic filters applied to glazing are of particular interest to architects. These filters consist of perhaps 10 to 20 alternately low and high refractive layers of various thickness. The typical thickness of these layers is between 45nm and 110nm. The layers are applied by using the SOL-Gel process. Therefore, they are suitable for application on surfaces curved in two dimensions, but on surfaces and bodies with three-dimensional curvature it is usually not possible to achieve an adequately even coating (4).

Dichroic glass first appeared in the 4$^{th}$century AD, as a piece of Roman glass, a transparent glass structure containing colloidal gold and silver particles arranged on a matrix of glass in certain proportions, so that the glass had the ability to transmit certain wavelengths of light that were passing through the glass, and thus the projections and refractions of different light colours (5). In the 20$^{th}$ century, in 1950s and 1960s, NASA began to develop dichroic glass, a technology in which extremely thin metal films were vacuum deposited on the glass surface. The aim of developing such glass was to protect the aircraft from the harmful effects of cosmic radiation, as well as to protect people from the flash of sunlight (5). Further development of dichroic glass has led to commercial applications in art and architecture, in which the process of coating glass with thin layers of metal allows some wavelengths of light to bounce off the surface while other wavelengths pass through the surface of the glass, resulting in discoloration depending on the light being absorbed or reflected, thus producing different visual effects of (5).

In architecture, dichroic glass was first used in 1985 on the Sweeney Church design in Indianapolis, USA by the architectural bureau of James Carpenter Design Associates (15). The glass was mounted on the largest window (dimensions 9.35 x 3.06 m), which is divided into five parts by vertical elements made of ordinary glass, fixed by horizontal stiffeneres made of dichroic glass. The light across these glass bands falls in different colours, influenced by the reciprocal effect of the transmitted and reflected rays along the wall. Depending on the time of the day or year, with the change in the position of the sun and the angle of the incident rays, different light changes occur. As a result, there are four qualities of light occupying the space: 1) the original light which has not been manipulated by any instrument, 2) the reflected light which is reflected by the mirrored panels, 3) the non-light (shadows) which is blocked by the mirrored panels, 4) the transmitted light which passes through the clear glass boards. The four qualities of light interact with one another, except 1) and 3) for they are parallel in space and generate five effects: 1) +2), 1) +4), 2) +3), 2) +4 ), 3) +4), projecting different sizes of parallelograms with various brightness on the

back wall and floor, which are opaque smooth passive screens. Thus, the properties and geometry of the light and the intervening grid are seen on the screens of the wall and floor. With the use of dichroic glass, the simple, white space of the chapel has been completely transformed by the play of light and colour (7).

**Fig. 1** Sweeney church Indianapolis, USA, James Carpenter Design Associates

## 3. Characteristics and Types of Dichroic Glass

There are different types of dichroic films that can be used in architecture. Their division is based on the colours and the three-dimensional effects that are reflected on a smooth, flat texture and a relief, wavy structure.

1. Dichroic glass of a smooth, flat texture is called "red or green" because of the different colours that refract into two colours and the final colour that is reflected; it is composed of layered glass, which also has the effect of a mirror which is reflected in its flat surface (8).

- Transmission colour for “Red” at the right angle viewing will be aqua blue/green, shifting through deep blue, then magenta at the skew angle viewing, while reflection colour will be copper / red shifting through yellow / gold and into green at skew angles (9).

**Fig. 2** “Red” Dichroic glass of a flat texture

**Fig. 3** Cohen, Children's Medical Center, Thomas Morris

- Transmission colour for “Green” at the right angle viewing will be magenta / purple, shifting through orange, then yellow at the skew angle viewing, while reflection colour will be green shifting into deep blue at skew angles.
- Colours for the Black Sea do not need colour spectrum as the dichroic films used are always “Blue”, unless specifying special runs of “Green” or “Red” (10).

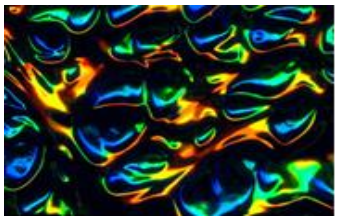

**Fig. 7** Black Sea texture of Dichroic Glass by John Blazy Designs

**Fig. 8** Black Sea Conference Table

- Burl textures are textures with a unique effect of filtration and refraction of wavelengths of light, achieved by a technology where the glass surface is laminated with more than nine separate polymer layers in three separate lamination processes. The ultimate effect of such a lamination process is the glass which creates the optical effect of the colour change in an instant and at the slightest change in the angle (10).

**Fig. 9** Red Burl texture of Dichroic Glass

**Fig. 10** Red Burl texture

## 4. APPLICATION OF DICHROIC GLASS IN ARCHITECTURE AND INTERIOR

Dichroic glass is widely used in architecture and interior design. Its greatest application is for glazing of facades, as well as in areas where the effect of visual dynamism is required through colour change or three-dimensional texture. The use of glass in the interior can be with glass partitions, tiles, different surfaces in commercial and business interiors or it can occur through different details in the space.

One example of the design of facades by Dichroic Glass is the Prairie Museum, designed by Verner Johnson. The building was built in the prairies of Midwest USA, measuring 3800m$^2$, and the idea was to fit the shape of the building completely into the topography of the terrain, evoking the flames of fire spreading through the prairie. This effect required the use of non-traditional materials to evoke the movement of fire. The dichroic glass fulfilled the architect's requirements, evoking the movement of fire in the prairie, while introducing dynamics into the museum's white exhibition space from the inside (11).

**Fig. 11** The facade of the museum

**Fig. 12** Museum Interior

Apartment H is an interior design of a Romanian group of architects Re-Act Now, designed for a 230m$^2$ apartment in the town of Constance on the Black Sea coast in Romania. The design used dichroic glass as a transparent partition to separate the bedroom from the living room of the apartment. The marine environment defined by the white colour which the walls, floors and furniture are treated with, while the dynamics are created by a mounted glass partition made of dichroic glass, which is in a way a "living" element in space and breaks its entire length, thus defining the function, creating dynamics with a continuous change of colour and reflection and creating a completely different experience of moving through the flat (12).

**Fig. 13** Dichroic glass as a partition in the apartment

Spatial structures made of dichroic glass provide new visual identities. An example of a dichroic structure is the design of the Migliore + Servetto architectural studio, which represents an installation in the space designed for the Intesa Sanpaolo skyscraper in Turin. This sculpture is a dynamic work in which light and reflections expand, turning it into a pulsating organism. 16m high panels, alpha-symbol-like, dichroic-coated panels create a sense of monumentality in space, optimizing light diffusion and transforming transparent panels into dynamic light planes (14).


**Fig. 14** and **Fig. 15** Installation, α-cromactive, Intesa, Sanpaolo, Turin, Migliore+Servetto architects

An example of the use of Dichroic glass through various interior details is the Copenhagen Opera House. In this building, the central foyer holds three spherical chandeliers created by the Icelandic artist Olafur Eliasson. Each chandelier has a 2.9 m diameter made of 1480 triangles of laminated safety glass, fitted with dichroic filters that are semipermeable, allowing some light to pass, and some to reflect. The patterns change when viewed from different angles (4).


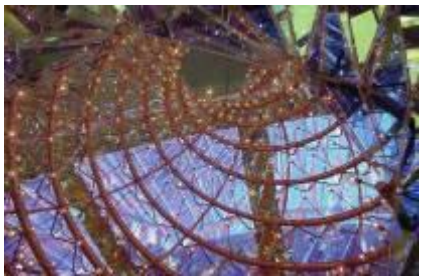

**Fig. 16** and **Fig. 17** Copenhagen Opera house, Denmark, Olafur Eliasson, Designer of chandelier

## CONCLUSION

Based on the above characteristics and analysis of dichroic glass, it can be concluded that in modern architecture and design this glass can have really wide application. The effects of refracting different coatings with changing viewing angles, different from lighting or sunlight can create different perceptions of the living space, but also give a new unique look to the building.

Different textures of the glass, which are presented in the work, achieve different effects that are applicable in the architectural design of the building but also in different interiors such as commercial, residential, public and sacral, creating a unique spatial experience. The constant development of glass laminating technology, with coatings of different materials, leads to the creation of new effects on dichroic glass, giving architects a huge number of possibilities in realization of their buildings.

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# PRIMENA DIHROIČKOG STAKLA U ARHITEKTONSKOM OBLIKOVANJU OBJEKATA

*Primena bojenih i optičkih stakala u arhitekturi ima veliki značaj u pogledu stvaranja prostorne dinamike i jedinstvenosti prostora. Dihroičko staklo predstavlja vrstu stakla koja je premazana tankim slojem metala, zahvaljujući kojem dolazi do promene boje staklene površine u zavisnosti od ugla posmatranja. Boja stakla zavisi od upada različitih talasnih dužina svetla koje prolazi kroz staklenu površinu ili se odbija od nje, stvarajući na taj način različite efekte prelamanja boja. Stvoreni efekti pružaju različite mogućnosti u dizajnu objekata i poboljšanja estetskog kvaliteta unutrašnjeg prostora. Ovaj rad se bavi analizom i primenom bojenih dihroičkih stakala u arhitekturi i dizajnu enterijera.*

Ključne reči: *Dihroičko staklo, obojeno staklo, prelamanje boja, optičko staklo*