GLASS IN THE BUILDING CONSTRUCTION: BEYOND THE TRANSPARENCY

A. DE VECCHI, S. COLAJANNI, S. SAMMATARO, A. MARCECA
Dipartimento di Progetto e Costruzione Edilizia, Università degli Studi di Palermo, Vile delle Scienze, 90128, Palermo, Italy,
Email: devecchi@unipa.it; simcola@dpce.ing.unipa.it; s.sammataro@dpce.ing.unipa.it

ABSTRACT

Glass, since its earliest use in the construction industry, has been used to maintain a separation whilst allowing both transmission of natural light and vision.
In the last decades, the evolution of the methodology of the glass manufacturing processes has created the opportunity to craft external frames that include integrated multifunctional elements which enable the user to fully control different functions.
The evolution of glass - from being a basic see-through material to becoming a system with high-tech potentiality - has given the designer the opportunity to satisfy different needs.
These can be fulfilled without altering the structure of the material and without affecting its relation with the frame it is built for.
The paper will submit the findings of a research of the Dipartimento di Progetto e Costruzione Edilizia dell'Università degli Studi di Palermo.
The aim of the research was the analysis, classification and verification of the performance of the translucent products currently available in the marketplace and of the ones still at an experimental stage.
As well as allowing their main function - the transmission of natural light and vision.
These products are designed to control energy flows in order to manage the level of illumination and thermal insulation.
The use of dedicated filtering methodologies, decreases and/or modifies the effect of the solar energy.
Firstly, the performance and cost of the different translucent products were compared in order to set the standard.
Afterwards, new avenues were investigated in order to elucidate some issues affecting the products currently on the market, including the cost/benefit ratio which is currently not advantageous.

INTRODUCTION

Over the last few years, laminated glass has become of very common use; it is used to reduce this medium's fragility, to improve its acoustic insulation and its transparency and also to increase its fire resistance.
We will pay attention to those see-through materials which, in the last few years, have became object of a vast research and which have been utilized to control the use of solar energy, specifically with regards to the possibility of decreasing and/or modifying their capacity to transmit the solar energy.
The effect of solar lighting decreases and/or it's modified by the use of particular filters, the use of which gives us differently glass or system types.
Firstly we collected the information available on the differently known typologies through the consultation of a limited bibliography and the cooperation of business operating in the sector.
This research permitted to identify two principal types of components affecting the control of the transparency: dynamic components (chromogenic technology) and static components.
For each typology we brought to the fore the performances relating to light control.
The main constituent materials and the various fields where they have been applied or they are still at the testing stage.

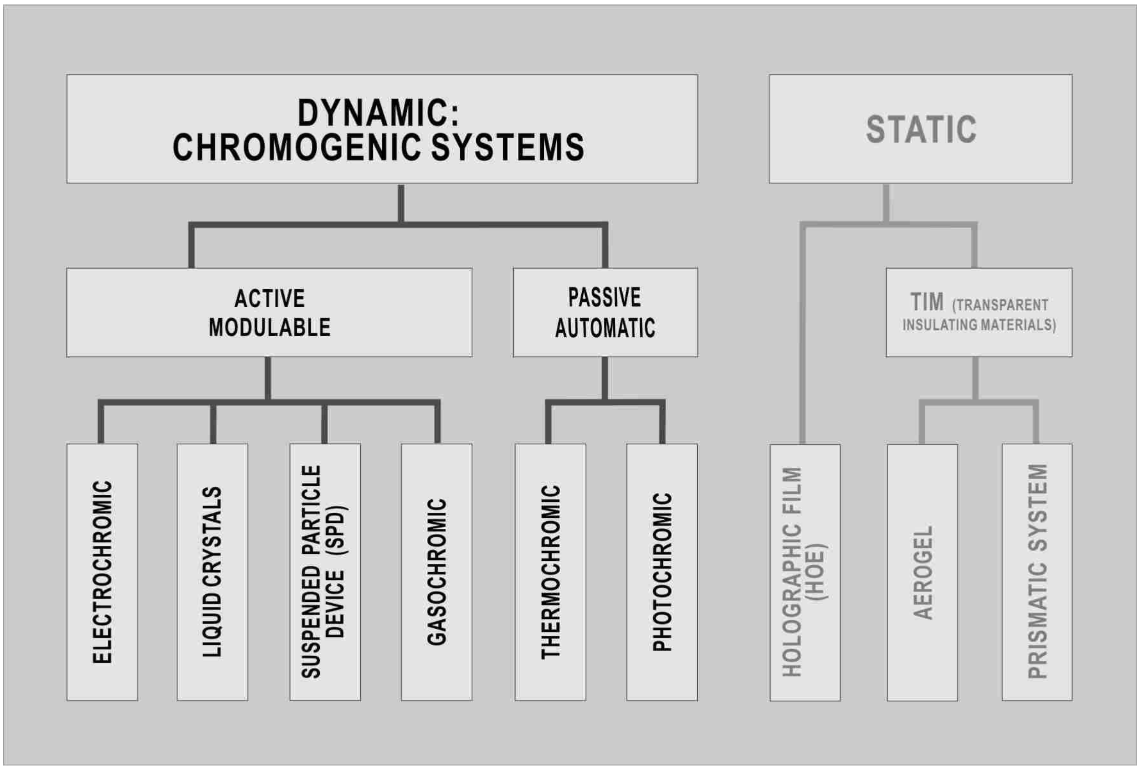

Fig. 1 – Chart of the developed components for light control

DYNAMIC COMPONENTS

The dynamic components (Chromogenic technology) possess the ability to change the light intensity by altering their optical properties, in particular the transmittance, according to various parameters and depending on the technology used. They are separated into either active (modulable) or passive (self-adjustable) categories.

The active categories change the optical properties under the effect of electric field: they are activated by the user through on/off switches or through potentiometers.
There are four kinds of active systems: electrochromic, liquid crystals, suspended particle devices and gaschromisms.
The passive categories change the optical properties automatically according to sunlight; they are not affected by the user. There are two kinds of passive categories: thermochromic and photochromic.

The **electrochromics** are modulable transparency systems that, under the influence of electric fields, change the chemical properties of the active layer.
The active material is an electrochromics film; when the voltage is applied across the coated film, this becomes darker and reduces the transmission of visible light and solar heat; reversing the polarity returns the film to its original state.
The main uses of this system are in the automotive and electronic sectors; they are still being tested in the building industry.

The **liquid crystals technology** uses modulable transparency systems which, under the stimulation of electric fields, change the physical properties of the active layer.
This system uses a polymeric film which contains molecular bars.
Without voltage, the bars are randomly oriented inside the material (the system is opaque), while with voltage they are oriented in a one-way direction (the system is transparent).

The use of this system in the building industry is limited to interior partitions, interior design, shop windows and bank counters.
The **SPD (Suspended Particle Device)** are modulable transparency systems which, under the voltage, change the physical properties of the active layer in a variable way.
Microscopic light-absorbing particles are dispersed within a thin film. When no electrical voltage is applied to the film, these particles absorb light, making the end-product dark; when the voltage is applied, the particles align and allow light to pass through.
The system is modulable but not widely applied other than, rarely, in windows.

The **gasochromics** are modulable transparency systems where - through an electrical field - a catalysis process is produced in the active layer.
The active material is a coat of WO3 which, when in contact with hydrogen varies its chemical composition and becomes darker; oxygen allows the system to return transparency.
The oxygen and the hydrogen necessary for this process are obtained from water contained in a small electrolytic cell inside the system. This systems are still being tested.

The **thermochromics** systems are self-adjustable ones which change their optical properties according to the variation of the surrounding temperature. The thermochromics elements can be a polymeric aqueous solution or a oxide. These materials can change from clear to opaque when the temperature reaches a certain set point (between 10° and 90°C). In buildings, its uses are limited to panels for greenhouses or skylights.

The **photochromic** are self-adjustable systems which are capable of varying their light transmission characteristics according to changes in sunlight. The photochromic material may be anorganic or inorganic compound containing metals. They change the initial transparency and colour when exposed to the sun and return to the original state only when the exposure ceases. The sunlight affects the photosensitive material and activates the electrochromic film through the displacement of ions and electrons. While used in other fields, their use in the building industry is still at the testing stage.

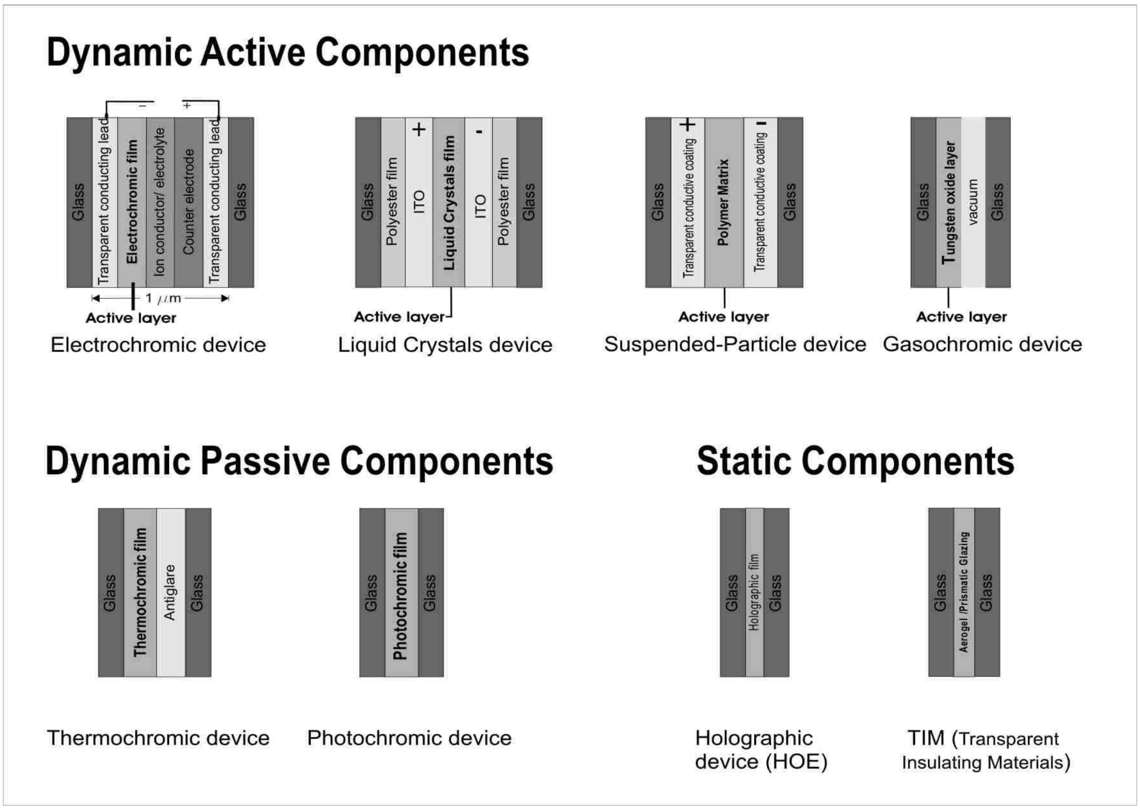

Fig. 2 – Constitutive elements of static and dynamic components

STATIC COMPONENTS

The static components include elements such as thin films inserted between layers of glass which modify the passage of sunrays. They include holographic films and the TIMs.

The **holographic films (HOE)** are static systems utilizing the diffraction of a luminous flux directing it to a particular point or reflecting the undesired light.
It is a material with angular selection constituted by an invisible prismatic structure obtained by "printing" with holographic method.
These thin films, applied in the glass within a frame, permit the homogeneous distribution of the day-light inside internal space. In building, they are employed in the bioclimatic construction.

The **transparent insulating materials** (TIM) are low density transparent materials.
They have a high tolerance to transmission of the heat and they also allow the diffusion of solar radiation removing the annoying effects of dazzling.
There are two kinds of TIMs, according to their geometrical structures: the Aerogel and the prismatic systems.

The **Aerogel** are static systems which allow the total diffraction of luminous flux. They are constituted by a transparent siliceous and highly porous structure; because of a specific manufacturing process, the spatial disposition of this particle determines a microcellular porous structure producing an optical and energetic high-performance.
Because of the porous structure there are phenomena of the light transmission diffusion which create a milky vision with unusual colours.

The **prismatic systems** are static systems which allow the reflexion and refraction of the light flux.
The prismatic windows take advantage of the reflexion and the refraction of light's phenomena. They distort the entering light through refraction and reflexion: they have different geometric shapes and deflect sunrays depending on their angle of incidence allowing to direct the light where needed. In building, over the last years, the TIMs are employed in the "daylighting", maximising the use of natural light in internal lighting.

COMPARISON AMONG DIFFERENT SYSTEMS

The systematisation of the acquired information allows to compare the optical properties, the operational requirements, the use in building and, where possible, the cost.
It was found that among the active modulable systems in production, these with better performance are the Suspended Particle Device because they pass from total transparency, in the active condition, to opaque in the disconnected through voltage control.
The change of light transmission coefficient is rather wide (0,35% - 60%).
They have a low electricity consumption, consequently their running cost is more economical than others systems because they have an energy requirement of 0,5 W/mq to maintain the transparency.
Their low market share does not give sufficient information to quantify costs.
Among the active modulable systems, the liquid crystals devices and the electrochromics offer the best performances.
The power required by the electrochromics is quite limited whilst the liquid crystals have a higher energy requirement.
The latter, as well as a greater energy consumption, has higher maintenance costs than other systems.
With reference to production costs, it was possible to find the unit price of both devices per square metre.
Although this cost was not comparable to others systems' because their cost was not known, it appears to be too high to allow its widespread commercialisation for use in external casing.
The passive systems do not allow the user to control the transparency and are subject to external lighting alteration; for these reasons, they are not easily usable.

In a separate category are the static systems because they distort the quantity and quality of incoming light without giving the user the chance to control the transparency.

			DYNAMIC : CHROMOGENIC SYSTEMS						STATIC		
			ACTIVE : MODULABLE				PASSIVE: AUTOMATIC			TIM	
			ELECTROCHROMIC	LIQUID CRYSTALS	SUSPENDED-PARTICLE DEVICE (SPD)	GASOCHROMIC	THERMOCHROMIC	PHOTOCHROMIC	HOLOGRAPHIC FILM (HOE)	AEROGEL	PRISMATIC SYSTEM
OPTICAL PROPERTIES	TRANSPARENCY	ON	SOFTEN	TOTAL	TOTAL	SOFTEN	SOFTEN	SOFTEN	?	SOFTEN	SOFTEN
		OFF	TOTAL	NULL	SOFTEN	SOFTEN	SOFTEN	TOTAL			NULL
	COLORATION	ON	COLOURED	TRANSPARENT	TRANSPARENT	COLOURED	COLOURED	COLOURED	TRANSPARENT / COLOURED / OPAQUE	TRANSPARENT	WHITISH
		OFF	TRANSPARENT	MATT WHITE	COLOURED	TRANSPARENT	TRANSPARENT	TRANSPARENT		OPAQUE	
	LIGHT TRANSMISSION	ON	15%	80%	0,35%	10%	90%	26-89%	?	2 - 70%	11- 54%
		OFF	50%	75%	60%	75%					
OPERATIONAL REQUIREMENTS	OPTICAL PROPERTIES CONTROL		ON / OFF	ON / OFF	MODULABLE	MODULABLE	AUTOMATIC	AUTOMATIC			
	SWITCHING TIME		< 10 M''	< 10 M''	< 10 M''	~ 1 M'	<1 M'	<1 M'			
	POWER CONSUMPTION		2 W/mq	35 W/mq	< 5 W/mq	?					
	POWER INPUT		1 - 5 V	80 V	?	?	SOLAR ENERGY	SOLAR ENERGY			
APPLICABILITY A TO BUILDING	DURABILITY		2 - 4 YEARS	4 - 6 YEARS	5 YEARS		5 YEARS	>10 YEARS			
	COST		1000 €/mq	1800 €/mq	?						
	PRODUCTION		YES	YESI	YES	NO	NO	NO	YES	YES	YES
	BEING TESTED		YES	NO	YES	YES	YES	YES	NO	YES	NO

Fig. 3 – Comparison among different systems

The majority of the systems described are based on rather advanced technology which provide a wide enough performance range (with reference to transparency, control, consumption, light transmission coefficient and durability) but the cost factors were not easily identified.
Where it was possible to know the cost of the product, it was found that there the costs were much higher than the common glass, mainly because of the difficulty in finding material (films, layer, gel, etc.).
It was also proved quite expensive to produce these materials in the wide dimensions required by the construction sector.

IMPROVEMENT OF THE PERFORMANCES

Comparing the different systems it was noticed that the factors which most influence the use of this innovative technology in the construction sector are:

- maintaining the transparency in the glass up to low range;
- the possibility to control and to change the transparency of the glass with low energy consumption;
- the use of materials which allows the production of wide dimensions sheets at a competitive price compered to the standard glass for casing already available;
- the possibility to obtain vertically a variable transparency along the glass surface, in such a way that the layers would be modulable with the light conditions according to time of the day and the type of usage of the room.

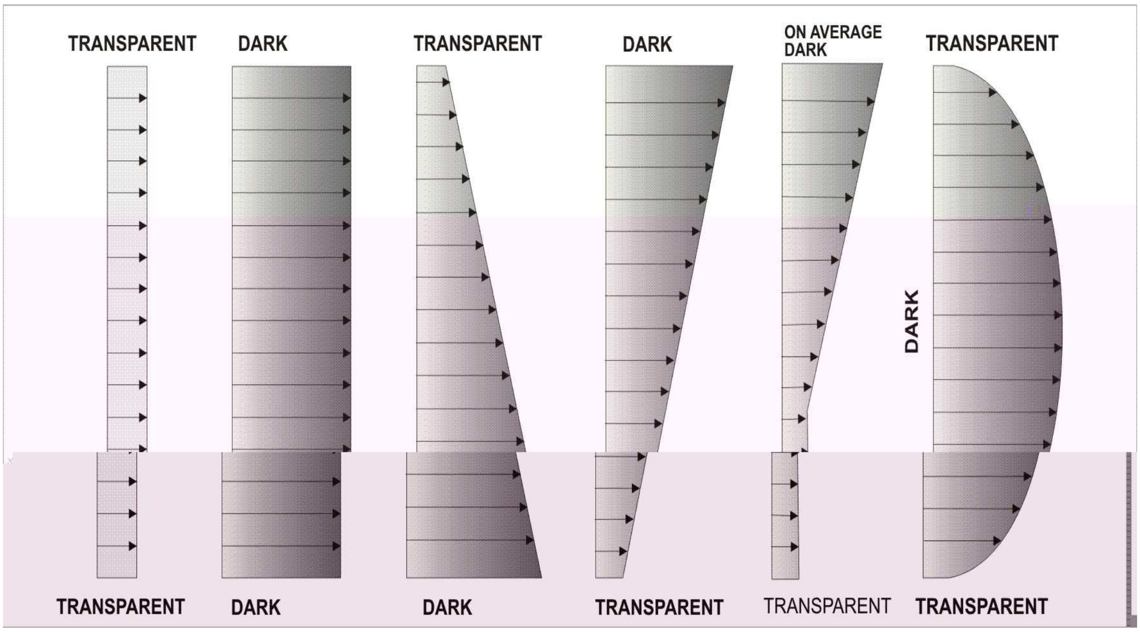

Fig. 4 – Scheme of different possibility of ideal transparency

The schemes listed above, offer different possibilities of transparency applicable to the application of the systems according to every user's requirement.

CONCLUSIONS - RESEARCH APPROACHES DEVELOPMENT POSSIBILITY

From the research that is currently developing, it appears that an optimal control of the transparency can happen through physical-chemical, thermal and mechanic methodologies.

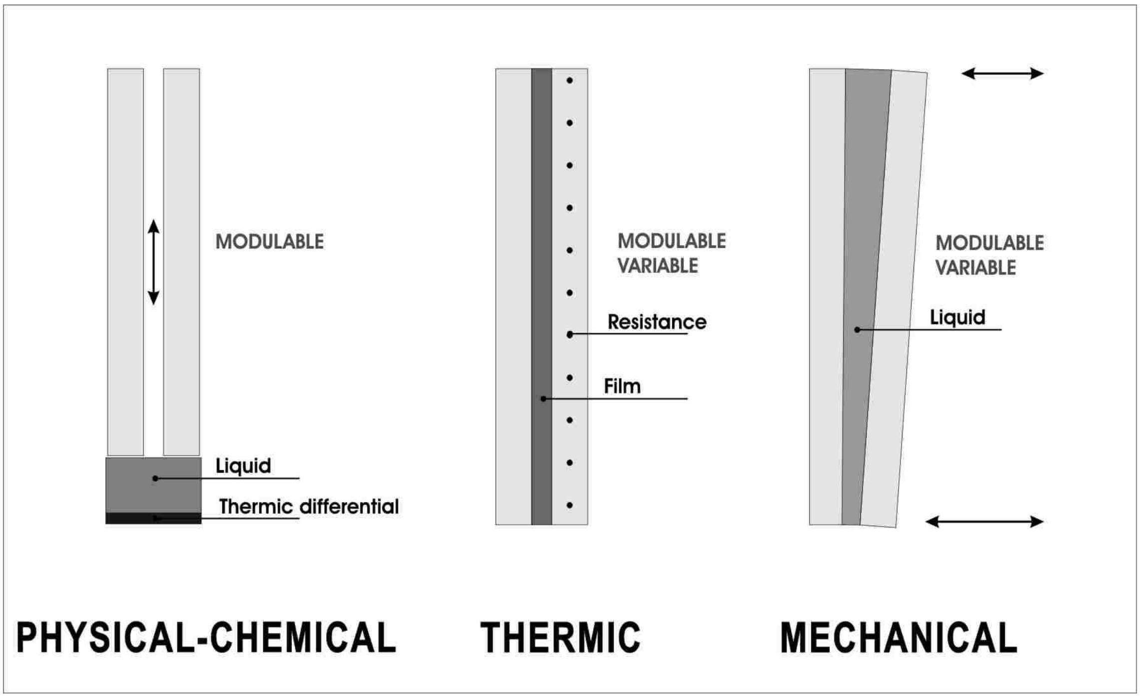

Fig. 5 – Scheme of transparency possibility control

Specifically with regards to the **physical-chemical operation**, the system is essentially constituted by a liquid that is activated by a thermal differential and it changes status and the position of the liquid that is inserted between the two sheets.

The **thermal operation** exploits the quality of some material which to change the state of coloration when are submitted to determinate temperatures so that the user, through the variation of an electric field, can determine the different levels of transparency.

The **mechanical operation** happens through the use of colored liquid inserted between two sheets of glass. The variation of transparency happens mechanically, according to the variation of thickness of the space between the two sheets.

It is forecast that the above systems will reach feasible production costs because they use technology already in use in other fields.

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