Articulation of Facade Graphics and Techniques of its Implementation

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Abstract. The article deals with issues at the boundary of architecture and technology, related to visual articulation. The facade graphics is a relatively new phenomenon that has arisen over the last two decades. Some of the image implementation techniques it uses have been known for a long time. Some of them are derived from stained glass (e.g. the technique of manual enamel application), some are related to the already known techniques of workshop graphics (screen printing). One of the latest technological achievements is the development of digital printing technology. Each of the aforementioned techniques has specific artistic possibilities and means of expression, which influences the articulation of the image in the external partition and has a significant impact on a number of compositional aspects. The image placed in the façade supports the building's form, underlining its shape, emphasizing important places in the building. The work examines the relationship between the applied techniques of implementation and the properties of the image on glass. An important part is to determine to what extent the construction of the image and the applied plastic measures affect the visual range of the glass partition and the functional properties. Particularly interesting projects are those made with several techniques, and those in which a new technique was discovered, which is later copied in other projects. The research can make a strong case for using artistic glass in the facade of a building and provide guidance for designers and investors. The publication will present examples of implementations placed in the facade of the building. The phenomenon will be investigated on the basis of buildings constructed over the last two decades. Due to the global nature of plastic phenomena, there is no limited research territory.

1. Introduction
Incorporation of art glass into a building’s envelope has a significant effect on a number of aspects of how that building functions. The scope of articulation is determined by several factors, the most important of which include: the properties of materials used; execution techniques; and the structure of the outer surface. Through the artistic layer, the envelope affects the perception of the building as well as the properties of the light that passes through it. To some extent, it may also affect the functional properties, sunlight protection, and the integration between the external and internal space.

In their work, both the architect and the façade designer, aiming to achieve integration between the image and the architectural surroundings, determine – by choosing an execution technique – what the articulation will be within a given architectural space. Therefore they affect several aspects which are not only visual but also connected with the layer’s functional properties.
2. Materials vs image articulation

An important thing in image articulation are the visual properties of the applied materials. Regardless of the type of material, it is the transparency that is essential for a glass façade, as it largely determines the range of image articulation.

Transparent materials, such as coloured transparent glass, enamels, and films, are adapted to be viewed when backlit. In daylight, images composed of such materials function mostly inside of the building (Figure 1a); while, after dark, when lit inside, they can be viewed from the outside. Opaque stained-glass enamels, patinas, and non-transparent glass are adapted mainly for viewing when lit from the front, e.g. from the outside.

Figure 1. Façade made in the screen printing technique [1], a) Transparent image, illuminated from the front, glazing with religious themes, church of the Sacred Heart of Jesus, Munich (Alexander Beleschenko, Allmann Sattler Wappner Architekten, 2000) b) Image from a distance of 0.5 m, illuminated from the back, c) Botanica residential and service complex, Wrocław, Poland (arch. Dziewoński & Łukaszewicz, 2014), fragment of the facade seen from the facade, illuminated from the front, d) Part of glazing seen from the inside, illuminated from the back, photos by Alina Lipowicz-Budzyńska.

The search for a method to create layers that would have a broader articulation scope has led to the emergence of several strategies used to make layers that can be viewed from both sides, i.e. independent of whether they are being lit from the back or the front. This allows an image to fully function visually within a façade, both on the outside and inside of the building. One of the methods of forming this type of layers is to combine materials of varying degrees of transparency in an image. Currently, thanks to the use of suitable media, screen-printing materials, despite their opaqueness, enable the observer to see a colour in the printed surface that can be viewed both when lit from the back and front (Figure 1b, c).

The colour of an image is key to the building’s perception. When viewing the façade from the outside, image articulation increases with the use of layers having high luminance. White and light colours reflect light (Figure 7), which means that an image can be perceived not only as part of an architectural context, but also an urban context. When a single colour is used, it focuses the viewer’s attention on the form of the image, and it is also conducive to the use of simpler media, which in turn positively affect the integration of the image with its architectural surroundings.

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1 The enamel and patina materials available today are divided into many categories, taking into account the chemical composition, firing temperature, transparency, and the possibility of combining with various media.

2 Ang. Luminance, a photometric quantity, determining the amount of light that passes or is emitted through a specific surface. A value that specifies a measure of the brightness of a surface [2]
Multicolour images are characterised by more variety, and are often used as part of a narrative. In coloured layers, depending on the colours used and the degree of transparency of the materials, the glass partition acts as a filter for the light that passes through it, and by reducing certain spectrum bands it influences the colour of the light.

Figure 2. Kendrew Quadrangle Café, Oxford, UK (Alexander Beleschenko, MJP Architects, 2010): a) view of the facade from inside, b) details of the glass coating, source: [3], photos by Alexander Beleschenko, c) the phenomenon of iridescence observed in dichroic coatings, office complex La Defense Office, Almere, Holandia, (UNStudio, 2004), photos by Alina Lipowicz-Budzyńska.

Apart from traditional coloured layers, creators are experimenting in screen print with reflective and dichroic layers. The use of experimental layers in facades is possible thanks to reflective enamels applied by screen printing. With the surroundings reflected in the layer, a visual collage is created over the view of the space behind it (Figure 2ab). In multilayer surfaces, it acts as the layer reflecting the one in front of it. Mirrors often constitute a base in cold pour laminated glass, used as a background to glazing made using other techniques. Such glazing performs the role of cladding. The mirror reflects light shining on the glazing, brightening the semi-opaque and semi-transparent layer.

Glass covered with a dichroic layer, which is used in art installations and glazing solutions, is increasingly more popular in building facades. Glass shifts colours locally, depending on light parameters and the position of the observer relative to the partition. Colour modifications apply to light that is reflected and passes through; it affects in different ways how the virtual and actual image is perceived. The occurring multicolour light reflections are a result of the movements of phase-structured light beams which occur in thin layers composed of metal oxides with the width similar to the length of a light wave. White light beams, reflected in upper and lower layers of a transparent surface, interfere with each other, resulting in colour transitions. The phenomenon of surfaces appearing to gradually change colour is called iridescence (Figure 2c) [4].

3. Execution techniques

3.1 Manual work on glass surfaces
Traditional manual work to create image on glass is done in several stages and enables the creator to have full control over the image. First, the image is created at a scale of 1:1 and moved onto glass using contour paint. After burning, a single layer or several layers of pigmenting material are applied. In order to obtain a uniform surface, the applied paint is distributed when wet using a wide brush. The paint layer texture depends mainly on the application method, but also on the degree and method of processing performed following the application. Each failed layer can be wiped off prior to burning; and if burning has been completed, it can be removed by sandblasting. Tonal transitions are achieved with the use of wider brushes, by gently taking out excess paint layer. Following the burning of each layer, the process is repeated for subsequent colours, until the image has been impregnated with each of them. This method was devised in response the need to separate individual colours, and using it, the
creator can achieve photographic effects as well as clear, bright colours. By displaying the artist’s movements, the paint layer, applied manually with brushes, can be very expressive (Figure 4c). The use of stencils, e.g. raster stencils, produces a graphical effect on the image implying that screen printing has been used (Figure 5).

![Image](image1.png)

**Figure 3.** a) Façade made using mixed technique; silk-screen printing, hand-coated glass, expansion of the Empire Theater, Liverpool, Great Britain (Martin Donlin, Ellis Williams Architects, 2002), b) close-up view, source: [5], photos by Martin Donlin.

![Image](image2.png)

**Figure 4.** Hand-painted façade a) View of the tower made by the headquarters of Glas + Räume GmbH, Neuenbeken Germany (Alexander Beleschenko, 2010), b) a fragment of hand-painted composition, c) Hagener Feinstahl, Hagen, Germany (Tobias Krammer, 1998), photos by Alina Lipowicz-Budzyńska.

Very often, paint layer complements the elements created with the use of screen printing (Figure 3). In large works, enamels are not applied as a layer over the entire surface, as in stained glass. Often, a section of glass is covered, or a paint layer structure is built which results in a scattered pattern with the remaining part of the glazing left transparent, without any colour (Figure 4b). In large surfaces, spraying methods are used. Similarly to graphical works, enamels and patinas are applied with airbrush pistols or other spraying tools. With these methods, gradual transitions and uniform surfaces can be obtained. Following the addition of the right medium, enamels or patinas become
suitably dense, and enable to obtain thicker layer, which also means that the colours will be more intense.

Images applied manually, due to the many stages of the process, have a limited area compared to the area of the entire building. Strong articulation resulting from the decorative nature of the image determines local effect. It is used to emphasise important elements of the building, such as entrances (Figure 3a), its corners (Figure 4b), and dominant features (Figure 4a). It has a decorative function and, depending on the transparency of materials used and image structure, is also used to block the view of something.

Figure 5. Decorative wall cladding made by hand with sponge stencils and applicators, private house, Zurich, Switzerland, (Alexander Beleschenko, 2008) a) entrance part view, b) glazing detail, source: [6], photos by Raffaella Sirtoli.

3.2 Screen and digital printing
Graphic techniques are currently the most frequently used methods of enamel application on façade glass. Their high efficiency is linked to the ability to copy the image multiple times, and then use it to create large-scale works composed of repetitive elements. The two most commonly used techniques are screen printing and digital printing.

Figure 6. Two-color screen printing, University Library in Utrecht (Wiel Arets Architects Studio, 2004): a) glass facade in combination with decorative concrete panels, b) papyrus motif reflected on glass, c) screen printing raster, photos by Alina Lipowicz-Budzyńska.

Each technique has its typical features. There are numerous advantages of screen printing, such as easy repetition in subsequent applications and the possibility to select from many different materials.
With the right media, a wide range of enamels of varying degree of transparency can be applied, and the paint layer can be worked on after burning. It is possible to apply paints imitating metallic surfaces [8] which produce reflective finish or, after burning, imitate blasted surfaces, frosted surfaces, or surfaces with water drops. The main limitation of screen printing is the difficulty in creating multicolour layers; therefore it is used chiefly in monochromatic works. In order to incorporate several colours, one needs to properly prepare the image and have screens ready; enamels need to be applied in several layers, and each layer is burned separately. In this technique, coloured paint layers must fit precisely one on top of the other. The calibration process requires utmost precision, which is hard to achieve with large formats. In order to simplify the process, screen printing is often combined with manual application of paint. Following this, glass undergoes heat treatment.

![Figure 7. Two-layer image realized with screen printing [7], The Cottbus Technical University Library (Herzog & de Meuron, 2004), a) building view from a distance, b) Façade seen from 5 meters away, c) Visual interferences occurring in a double-glazed façade, photos by Alina Lipowicz-Budzyńska.](image)

In the case of solid colour prints, a proper preparation is required. In this technique, the image is built of a raster, which results in a number of visual and functional benefits. In screen printing, due to high luminance, the most frequently used enamel is white (Figure 7). And if sunlight protection needs strengthening, another colour is used, for instance, black (Figure 6).

Application of screen print in a façade is connected with a need to put together the image on the glazing out of repetitive elements; resulting in facades of simple structure, decorated with an image based on the same motif used over and over again in a linear fashion (Figure 6ab), or a more complicated one, where the repetition is hard to discern (Figure 7ab). In two-layer arrangements, consisting of images built of a raster, and set in a certain order, graphical processes of interference can be seen – these are line and shape arrangements that result from the overlapping of small elements (Figure 7c). The image changes depending on the viewing angle, making the layer come alive by being sensitive to the observer’s position relative to the façade.

Screen printing, due to its high efficiency, is most often used on large elevation surfaces and in fully glazed buildings. It enables optimisation of energy inside such buildings. Application of large scale glazed facades in buildings such as libraries is one of the trends seen in contemporary projects. This tendency results from energy-related calculations as well as reductions in the use of electricity connected to lighting. It is a technology that ensures maximum daylight penetration, as well as full utilisation of waste heat for heating in winter and ventilation in summer. The distance between the two separated glass layers acts as a buffer. Ventilated area stabilises temperature inside the building, protecting the interior against temperature fluctuations caused by excessive penetration of sunlight in

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3 A modern office building consumes around 30 percent of the total energy consumption for electric lighting. However, in a public library, the illumination index can be as high as 45 percent [11].
warm weather or sudden temperature drops occurring as a result of quick cooling outside in winter. Due to the buffer area between glass layers, the reduction of sunlight and protection against overheating inside the rooms is much more effective compared to single-layer surfaces. There is also an additional function in the form of sound insulation.

**Figure 8.** The facade made with digital printing, a) Harlem Hospital, New York, USA (Vertis Hayes, HOK Architects, 2013), source: [9], photos by Paul Warchol, b) Hotel in Cancun, Mexico (Rockwell Group, 2012), source: [10], photos by Rockwell Group.

With digital printing, the creator can use colours freely and make either a monochromatic or multicolour image. One can use screen print technology to create a varied image without the need to repeat a single sequence, as is the case with screen printing. For this reason, it is often used in transferring figurative images, photographs, or even artwork reprints (Figure 8). Depending on the technologies used, it is often difficult to make an accurate copy. It is also not uncommon for the quality of the surface to be lower compared to traditionally applied stained-glass enamels. The colour obtained in this way may be less intense, and it may be hard to obtain satisfactory quality of transparent and semi-transparent surfaces. Currently it is not possible with digital printing to create different transparency levels within a single image as can be done when working on glass surfaces manually.

With the use of digital printing the creator can obtain an impenetrable uniform layer (Figure 8a) or partial covering with enamel (Figure 8b). Wide availability of this technique means that it is used for large-scale glazing projects. Strong articulation, which results from the decorative nature of an image, ensures that it has a powerful effect on the surroundings. It is used to emphasise key elements of a building. Its purpose is decorative, and depending on the transparency of materials used and the image structure, it also functions as a covering and sunlight protection.

### 3.3 High-temperature relief techniques

Relief techniques are differentiated based on the range of applied temperatures and the obtained artistic and spatial effect. The most commonly used relief techniques include: *kiln casting* (Figure 9), *fusing* and *slumping*. A glass partition made using relief techniques has distinctive properties which can be used both in contemporary architecture as well as in the adaptation of historical buildings. Relief-based projects have a characteristic texture (Figure 9a), and each work is unique. The subtle image that appears due to changes in the shape of glass (Figure 9b) is modified, as the direction of light and the viewing angle change. What we see is a result of several subtle images overlapping: the one on the outside of the glass surface, plus light reflections and refractions occurring on the back surface. In semi-spatial glass projects with significant width\(^4\), apart from the image visible on the surface of a partition, we are also dealing with the image inside of glass. These are trapped air bubbles of various sizes, occurring in glass in the form of round shapes with the size of less than 1 mm. They

\(^4\) Above about 2 cm.
form organic streaks in glass. There are also spatial shapes inside glass resulting from the use of coloured glass or dyeing materials (Figure 10).\footnote{These include: enamels, frits, glass flakes.}

![Figure 9. a) Structure of the facade, view from ul. Krawiecka, Justin Center, Wrocław, Poland (Tomasz Urbanowicz, ARCH-E Biuro Pracownia, 2009): glazing structure, b) detail, c) structure of a raster image on glass, St. Agaty, chapel, Lennestadt (Thierry Boissel, 2011), photos by Alina Lipowicz-Budzyńska.}

Relief partitions made of colourless glass are used to discreetly separate two areas so that light is not obstructed but at the same time the space is not visible from the outside. In some cases, the light passing through the glass layer is visually duplicated. When making such a partition, it is important to select glass with the right type and quality. Its purity is determined, among other things, by low content of iron compounds and lack of greenish glow, which is especially important in projects characterised by significant breadth.\footnote{Solid or loose forms leave micro-deformations on the glass surface, which on one side matt the surface of the glass.}

For the most part, relief glass is used in interiors; however, some architectural projects are known in which, despite disadvantages connected with these techniques, relief glazing has been put in the building’s façade. With relief techniques, one does not obtain transparent layers\footnote{Type, intensity and angle of incidence.}. A glass partition made of pure transparent glass will form a transparent and translucent layer depending on the size of deformations on the glass surface and relief depth. Colouring is done using high-temperature enamels or metal oxides (Figure 10ab). Relief techniques are characterised by especially subtle means of impacting the surroundings. Their intensity depends on the depth of the relief, purity of glass, the properties of light\footnote{Type, intensity and angle of incidence.} that penetrates it, and the viewing angle. These methods are used to create abstract images as well as realistic and photo-realistic ones (Figure 9ab) with the use of a raster (Figure 9c). A partition made using relief techniques unifies and modulates the passing light, and enables only partial visual integration of spaces on both sides of the glazing.
3.4 Laminated glass

The lamination technique for glass is a method that combines at least two glass layers with the use of an intermediary layer, usually made of film (PVA or PVB) or resins. The key objective of laminating glass is to improve its mechanical strength and to ensure safety in case of damage or breaking. This technique has been used for approximately 30 years to create artistic glazing projects [13]. In the lamination process, it is possible to join glass, film and other materials of specific characteristics. One of the reasons why lamination is used in art glass is to protect the artistic layers. It is applied when glass surfaces prone to damage are directly covered with a digital print, or when film layers with print on them need to be protected. The lamination process also encompasses techniques in which uncoloured as well as multi-coloured chemically bonded resins are utilised. These substances, poured in between two layers of glass, bind to create unique artistic effects (Figure 10). The gap between the two sheets is sealed with spacer tape. Inside the space between glass layers, additional components may be placed, such as pieces of glass or film.

Laminated glass is applied both in building facades as well as in interiors. It is used to create multilayer integrated surfaces. Lamination techniques are the only ones that enable joining various materials, such as glass, film and resins. With the cold pour lamination the creator can make in image set from cut pieces of stained glass (Figure 10b), which means there is no need to apply the stained-glass technique, and therefore one can avoid a strip of lead flashing being visible or having to make a double-sided layer that has a role both in the façade as well as in the interior. Cold pour lamination techniques can be used to produce artistic effects of intertwining colours or create images based on ‘controlled randomness’ (Figure 10a). In the provided research material, only abstract projects can be found; however, the technique does facilitate application of composition elements involving prints on film, and therefore placement of photorealistic items. (Figure 11)

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**Figure 10.** Colorful facade made with slumping technique, Building of the Netherlands Institute for Sound and Vision, Hilversum, (Neutelings Riedijk Architects, 2006): a) view of the building's body, b) close-up view, photos by Alina Lipowicz-Budzyńska.

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8 The glass laminating process takes place at a temperature of 70-140 °C at a pressure of approx. 12 bar, and the temperature depends on the intended use of the glass. In the case of using decorative coatings, the so-called inserts, this process takes place at a temperature of 80 °C [12].

9 For example, gels with a flame-retardant function.
Figure 11. a) An example of the use of the lamination technique with chemosetting resins, Canary Wharf, London, UK (Alexander Beleschenko, 2002) source: [14], photos by Alexander Beleschenko, b) Close-up of one of the walls, New Indianapolis Airport, Indianapolis, USA (Martin Donlin, HOK, 2008) source: [15], photos by Martin Donlin.

4. Conclusion

Based on the collected material, which was synthesised from materials of previous research, it can be said that the artistic values of a glazing play an important part in the image articulation in an architectural space. These values are: its form, dynamics, composition and colours, as well as the means by which the image affects its surroundings that result from selection of the right technique and strategy for formation of the partition.

The selection of techniques has a fundamental effect on the artistic values of the image, the shaping of its properties as well as how it is going to function within the neighbouring space.

Each of the techniques has an individual way of how it is applied, a typical strategy for building transparency, and a special set of artistic means; therefore they all affect image articulation in a different way.

Each of the techniques is connected with a specific method of image implementation, meaning a specific way in which glass layers with a certain artistic form are composed. Some of the techniques are more often used to create narrative images (e.g. screen printing or digital printing), while others (e.g. laminated glass, manually coated glass) facilitate creation of abstract images.

Certain techniques for art glass creation enable the author to at the same time achieve utilitarian objectives, e.g. glass façade covered with pigmenting materials, enamels, or patinas provides protection against excessive penetration of sunlight and building overheating.

The external layer with an image composed of small elements participates actively in the provision of translucency, simultaneously shaping the nature of the visual integration between the interior and exterior of the building. Façade’s transparency depends, for instance, on the size of elements, print density, and the number of its layers.

Having composed a façade of several separated layers of glass or using double-sided print, the creator can achieve a spatial layer effect. In such layers, visual interference phenomena can often be observed. The gap between the sheets of glass may be used as a buffer space for the building.
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