Paper D27

Structural Colours like Chameleon for Leather

Dr. Alois G. Püntener[1] and Dr. Fritz Dannenhauer[2]
[1] VESLIC: Verein Schweizerischer Lederindustrie-Chemiker und –Techniker (Association of Swiss Leather Chemists and Technologists)
[2] ex. Daimler R&D Germany: (Retiree); Home address: Gartenstr. 1, D-79686 Hasel (Germany)
Correspondence: VESLIC, Postfach 505, CH-4016 Basel (Switzerland); e-mail: VESLIC@hotmail.ch; Web: http://www.veslic.ch

Abstract
How does a chameleon change his colour? What is the structure? Does it work on leather?
Structural colour is a common occurrence in nature, and is responsible for the colouration of some birds, butterflies, beetles and some other animals including chameleons. Sophisticated processing techniques have been devised to replicate the structures and produce the same effects.
Our investigation considered the visual effect relates to pigments with different colours dependent on the viewing angle. These structural colours work on the basis of light interference in the layers of material that are dispersed in the paint.
This paper describes the newest developments in this field and how they are applied in paints especially for leather. It discusses paint coating and pigments, which have crosslinking substances with liquid-crystalline structure.

1. Introduction

Colour is essential. It has a significant place in our lives. On the one hand there are psychological associations related to colour and this can vary from culture to culture. Whereas in physics, colour is described through electromagnetic radiation with its wavelength (or frequency) and its intensity.

We know that colour consist of three important factors: the light, a coloured object and the eyes. When we alter one of these parameters, the colour stimulus changes. If we consider leather, the application of light absorbing dyestuffs and pigments is well known and has been described in many books, as well as in technical and commercial papers. However, structural dyestuff for leather is a new and an innovative technique. Some objects not only reflect light, but also transmit light or emit light themselves in order to contribute to the colour. At present, researchers are working with a variety of these materials, which includes introducing innovative application processes. This applies particularly in the security sector like credit cards and banknotes but also more recently to the coatings and consumer industry.

2. Structural Effect Colours in Nature

The colour in nature is undoubtedly fascinating; remember a rainbow which is caused by light being reflected in droplets of water. Also animals are capable of producing colour with the help of optical refraction. The colour alteration in chameleons is carried out by pigment dilution and concentration in the cells and by guanine in order to break and reflect the incoming light. The optical appearance of effect pigments based on reflection and interference in nature and is already known by butterflies, beetles and others.


Figure 1: Chameleon (source: wikipedia.org)

In biology, a colour created by an optical effect is often named “Schemochromes”. “Structural Colours” is the general term for an object capable of producing colour by interacting with electromagnetic radiation, pressure, pH, electricity, friction, heat and other physical forces. If this effect is caused by pigments, they are called “Effect Pigments”.

3. Absorption and Effect Pigments

3.1 Absorption Pigments

The colour of an object like leather depends on the light leaving their surfaces, which normally depends on the wavelength within the visible spectrum of approximately 390 nm to 750 nm, and the reflectance properties of the surface. The physical basis of a standard absorption pigment is based on the selective reflection and absorption of certain wavelengths of visible light. As an example, the blue cobalt pigment absorbs red and green light and reflects blue, creating the blue viewing colour.

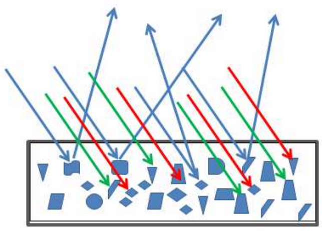

Figure 2: Absorption Pigment

3.2 Metal Effect Pigments

Metallic Pigments comprise of small platelets of aluminum, copper, zinc or other metal. They reflect the light almost completely and thus produce a gloss and mirror effect, so called metallic look. The conventional technique of colour design is based on mixtures of absorption pigments with metal effect pigments: This produces a bathochromic glossing shift of the reflected colour.

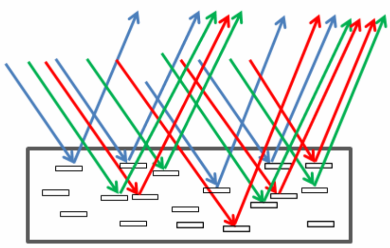

Figure 3: Metal Effect Pigments.

3.3 Pearlescent Effect

3.3.1 Naturel and artificial Pearls

Pearlescent pigments are similarly to natural pearls. The refractive index difference by pearls is caused through alternating transparent layers: calcium carbonate and proteins. The requirement for this effect is the specific relation of to the thickness of each layer to the wavelength of incident light. Pearlescent is defined by multiple reflections.

Natural pearl essence consists of 75 to 97% guanine and 3 to 25% hypoxanthine. In 1656, François Jaquin, a France rosary maker, started the execration of fish scales to receive the so-called “Natural Fish Silver Essence”. His commercial target was to produce synthetic pearls.

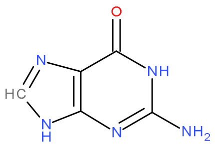

Figure 4: Guanine

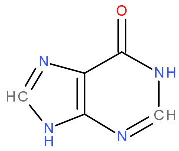

Figure 5: Hypoxanthine

Jaquin’s pearls consist of small, delicate glass beads, which are coated inside with pearl essence and then filled with wax. Today, this technique is still successfully used and utilised for costume jewellery.

3.3.2 Pearlescent Effect Pigments

Nevertheless, even though the pearlescent effect has been known for several centuries, it is only in the last 50 years that significant development in the pearlescent effect pigments has taken place. The most important class of pearlescent pigments is composed of mica flakes, which are coated with a thin transparent metal oxide like titanium, iron or other metallic components. Depending on the thickness of the metal oxides different colours can be created. In the technique are two different principles to consider: Silver white pigments and interference pigments.

Silver White Pigments
Silver white pigments are covered with a thin metal, like titanium oxide, surface of ca. 40-60 nm and reflect the whole wavelength spectrum. Depending on the particle size, the gloss effects can be adjusted from silk mat to high glittering.

Interference Pigments
Thicker metal oxide layers create the interference phenomena. In physics, interference is the addition of two or more waves which result in a new wave pattern. Countless varieties of colour effects are possible by combining different metals and controlling the metal layer thickness of the mica flakes.

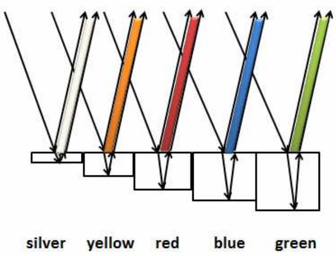

Figure 6: Interference caused by thickness difference.

4. Effect Pigments based on Liquid Crystal Polymers (LCP)

4.1 Background and Discovering

A very attractive new category of structural colours is based on liquid crystal structures. In 1888, it was seen by the Austrian botanical physiologist Friedrich Reinitzer, but at first not understood. He observed interesting colour effects when cooling cholesterol derivatives just above the freezing point. They had two melting points. His academic friend Otto Lehmann reported him seeing liquid crystallites. This liquid crystal shows interaction with polarized light. Today, “Liquid Crystal Displays” (LCD) are used in almost all computer monitors, television and other electronics devices as the visual display.

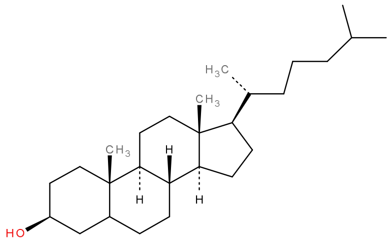

Figure 7: Cholesterol

4.2 From Liquid Crystal to Pigment

In order to produce paints with liquid crystal they should have a solid form corresponding to pigments. Therefore it is necessary to fix the liquid crystalline phase or stabilize it mechanically. It can be done by incorporating this liquid crystal in solid polymers. However, we have to consider that the appearance of the liquid crystalline phase often depends on temperature, namely as the liquid crystalline phase is heated or cooled, different wavelengths are reflected. Therefore liquid crystal polymers (LCP) should avoid this effect. Appropriate chemical connecting to a solid matrix polymer is the crucial point for this type of effect pigments.

4.3 Selective Angle-dependent Reflection

The key point for liquid crystal polymers (LCP) is chirality. This is a substance that is non-superimposable on its mirror image, laterally reversed. Molecules that are chiral are optical active and rotate and turn around polarised monochromatic light.

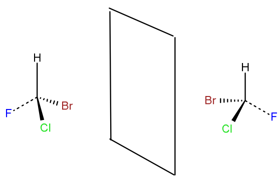

Figure 8: Example of a Chiral Molecule

Furthermore, if these molecules have a twisted structure and if the pitch corresponds to the wavelength of the light; then the light is reflected selectively and angle-dependent. This is called the “Flip-Flop Effect”. As a result, the reflected colours depend on the viewing angle.

4.4 Construction of LCP

Many of the LCP with angle reflection properties are based on polysiloxanes. The core of the siloxane oligomer consists of a silicone–oxygen eight membered rings with some silicone having reactive groups, often an acrylic type, to form stable polymer chains that can be processed to thin solid LCP films. The standard method for continuous foil production is the roll-coater technique. After the formation of the film they are ground to small transparent platelets. The resulting flakes have a thickness of ca. 6 µm and a particle size of ca.40 µm. Thus they have the same properties as a pigment but are colourless. These designed LCP's are able to achieve angle-dependent viewing effects.

5. Application

There is no substantial application difference between the conventional pigments and the use of effects pigments including LCP. The incorporation of these LCP pigments into a coat is based on the usual manufacturers and users knowledge. This is true for all treatment irrespective of the substrate. It can be a rigid (e.g. metal plate) or a flexible (e.g. leather) material. However, one has to use his own substrate specific lacquer composition.

These pigments have been successfully applied and tested on cars. Also the application on leather could be made with a clear top coat system. However a black dyeing or black base coat is highly recommended. It is required to avoid unwanted reflection of scattered light on the bottom, which results in a reduction of the colour efficiency. Carefully dispersion and a parallel orientation of the LCP particles in the layer are also highly suggested.

6. Conclusion and Outlook

In general, the final colour design for all the effect pigments are influenced by the length / thickness ratio of the individual particles, the concentration and the optic properties of the matrix (refractive index, opacity). Interesting new bright, shiny and glossy colour effects as in nature can be achieved.

Figure 9: Leather finished with Angel Reflection Pigments

Of course, like all other new developments, many detailed questions need to be answered before the new paint will be suitable for mass production application. Not surprisingly, these unusual paints focus on luxury and fashion consumer goods. Never the less, this technique is already used for credit cards, banknotes and electronics and successfully tested and used on cars. One can be sure that luxury leather goods will be an attractive target to be painted using the same natural principle like rainbow, butterflies and chameleons.

Literature sources and recommended reading

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