***Frank J Maile***, Schlenk Metallic Pigments GmbH, Germany and ***Jiri Filip***, Institute of Information Theory and Automation of the Czech Academy of Sciences (UTIA), discuss how the latest effect pigments allow for the realisation of semi-smart surfaces in interior architecture and design

# New applications for polychromatic effect pigments

Pigments that generate special effects like angle-dependent colour or decorative texture, have a growing economic significance and can be found in various industrial products and end-user applications. In decorative uses, special effect pigments provide three major advantages: (a) they can create an illusion of optical depth; for example it can be observed when applying pearlescent pigments in car paints; (b) they can generate subtle to startling angle-dependent eye-catching colour effects, which can be used in car paints or decorative printing; (c) they have the ability to imitate the effect of natural pearls in buttons, plastic bottles and many other decorative objects[1].

This paper provides an insight into the recently discovered new applications of MultiFlect® and Alegrace® Spectacular polychromatic effect pigments.

These effect pigments allow the creation of surfaces, which exhibit polychromatic light sparks under directed lighting, in various coating, printing or cosmetic applications. When used in interior architecture, eg in coil or powder coatings, different surface textures and interference colour effects can be perceived when exposed to different spectra of light, ie to create semi-smart surfaces[2].

## INTRODUCTION

Every design action causes an emotional reaction. To choose among two similar products, emotional design[3] may influence consumers to make their decision. A product must not only have haptic appeal, ie be easy to use (known from usability research[4] but also offer an attractive colour, texture and shape.

Coatings which allow the development of high-quality, value-added and customised product design and which, also, make it possible to visually communicate the functional properties of a product, are increasingly sought after in today's market. They allow products to be positioned in a way that helps them to stand out from the rest. In this respect, effect pigments give rise to unique opportunities.

Their application in powder coatings, as well as coil coatings, leads to unique optical effects, which are visible on façades even at a great distance. By bringing effect pigments into play, designers and architects will be able to create new colour compositions in architecture.

Surfaces that change colour, depending on the viewing angle, are not smart materials but are of interest in the field of architecture. These types of material include dyes with special effect pigments[5]. Originally used to direct light through optics, holographic optical elements (HOE) were developed as a potentially new means of directing light.

As it is possible to change dramatically the optical appearance of surfaces equipped with diffractive elements, we decided to develop effect pigments including these physical properties. For example, MultiFlect effect pigment can be easily incorporated into coil and powder coatings. Two products frequently used to manufacture coated panels in interior architecture and product design. Other applications include plastics and printing. We consider these surfaces to be semi-smart as their diffractive property can be used to switch the on-and-off effect using the appropriate light source as shown in **Figure 1**. Another interesting field of application is the use of the Alegrace Spectacular effect pigment in cosmetics, especially in nail lacquers as shown in **Figure 2**.

## SPECIAL EFFECT PIGMENTS

Effect pigments have been widely used for decorative and functional applications in products, such as paints, plastics, printing inks and cosmetics for several decades. Their unique ability to achieve eye-catching optical effects, angle-dependent interference colours, pearl lustre or multiple reflection, has made them irreplaceable.

Effect pigments show a number of advantages when compared to extended films. Some of them include the wide variety of achievable optical effects, the ease of incorporation in all relevant application systems, the possibilities of blending them with other colourants and the impression of

**Figure 1. Switchable optical effects in interior architecture and design with the use of MultiFlect polychromatic effect pigments in powder coatings[2] (© pictures by Schlenk Metallic Pigments GmbH)**

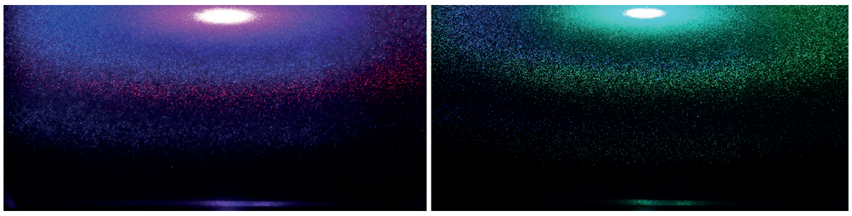

Figure 2. Left: Photograph of a motor-bike helmet: Realisation of chrome-like effects without using chromium[9] by using vacuum metallized pigments (VMPs, Decomet) plus MultiFlect effect pigments in the paint formulation. Right: Alegrace Spectacular effect pigments in nail lacquers (© pictures by Schlenk Metallic Pigments GmbH)

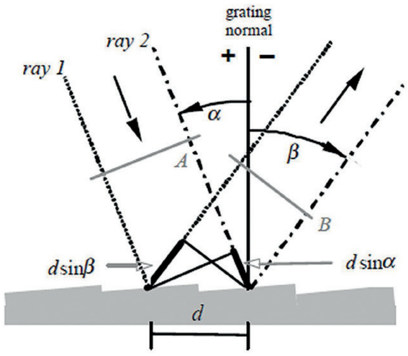


Figure 3. Explanation of the diffraction by a plane grating. A beam of monochromatic light of wavelength l is incident on a grating and diffracted along several discrete paths. The triangular grooves come out of the page; the rays lie in the plane of the page. The sign convention for the angles $\alpha$ and $\beta$ is shown by the + and – signs on either side of the grating normal: A reflection grating: the incident and diffracted rays lie on the same side of the grating[12]

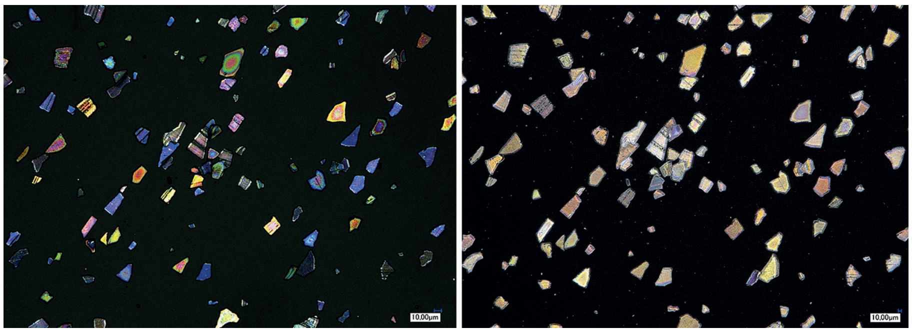

Figure 4. Light microscopy of polychromatic effect pigment particles: bright field (left); dark field (right) at a magnification of 500x (© pictures by Schlenk Metallic Pigments GmbH)

'vivid' colour effects[6]. Effect pigments are made up of either substrate-free pigments or substrate-based structures.

A property not possessed by conventional organic and inorganic pigments is what is frequently referred to as the flop. This is the change in colour and/or gloss with respect to the viewing angle. The origin of the effect lies in the almost two-dimensional, anisotropic nature of effect pigments[7]. The anisotropic morphology of the particles explains why their use particularly affects the appearance because a change in processing technology results in a modified standard deviation of the flake orientation[8].

Effect pigments can be classified into two groups:

- platelets, which consist of only one optically homogeneous material (substrate-free pigments);
- platelets, which have a layered structure and consist of at least two optically different layer materials

## METAL EFFECT PIGMENTS

The well-known metal effect pigments are materials without a layer structure, for example, aluminium or copper–zinc platelets. Similarly, transparent effect pigments, such as single crystalline BiOCl or polycrystalline $TiO_2$, in the form of flakes, belong to this group. These non-metallic flakes need to be very thin to achieve the interference colour effect. This can lead to lower mechanical stability than flakes based on a substrate platelet.

Metal effect pigment flakes are produced by treating metal granules with stamping machines. The most common method employed is the ball mill, which use the dry milling (Hametag[9]) or wet milling (Hall[10]) processes. During the treatment, a lubricant is added to prevent cold fusion and to achieve the desired leafing or non-leafing properties. Standard aluminium pigments are produced as 'cornflake' and 'silver-dollar' types depending on the quality and shape of the untreated granules and on the milling conditions.

One special type of metal effect pigment is the PVD aluminium, also known as VMP (Vacuum Metallized Pigment, please refer to **Figure 2**). This is produced by a vacuum process where the aluminium is deposited on a web. After releasing the deposited aluminium from the web, very thin flakes are obtained. When incorporated in coating systems, they give an improved mirror-like effect.

## MULTIFLECT AND ALEGRACE SPECTACULAR EFFECT PIGMENTS

Angle-dependent optical effects of pigments are derived from submicron structures in the pigment and are caused by interference at the thin layers. Such effects can also arise from light diffraction on periodically structured surfaces[1], as shown in **Figure 3**.

MultiFlect and Alegrace Spectacular effect pigments are based on a structured polymer film which is metallized and ground to particles of the desired particle size distribution. **Figure 4** shows light microscopic pictures of the structured (diffractive) pigments. The macroscopic appearance of the effect pigments in basecoat layers is shown in **Figure 5**.

Figure 5. Photograph of car shapes coated with basecoat layers containing MultiFlect (left) and Alegrace Spectacular effect pigments in nail lacquer (right) exhibiting polychromatic light sparks (© pictures by Schlenk Metallic Pigments GmbH)

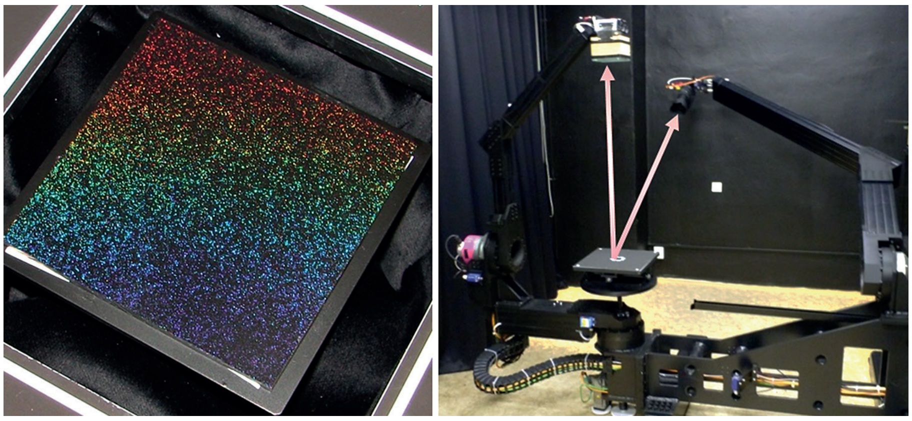

**Figure 6. Left: measured MultiFlect effect pigment sample captured by camera using a flashlight. Right: UTIA gonio-reflectometer setup used for capturing of its gonio-apparent behaviour (© pictures by UTIA)**

## CHARACTERISATION OF OPTICAL PIGMENT PROPERTIES

We have measured the gonio-apparent behaviour of planar MultiFlect 35 holographic pigment sample (**Figure 6** – left) using the UTIA gonioreflectometer shown in **Figure 6** – right. The pigment's particle size distribution (D50 value) was ca 35µm. In total 81 illumination and 81 viewing directions were used providing 6561 spatial configurations of arms holding camera and light. For each configuration one high-dynamic range image of the sample was taken.

**Figure 7** depicts the angle dependent, polychromatic appearance of pigment flakes within the in-plane measurements for an illumination angle of 45° with respect to the normal. One can observe a reduction of chromaticity as the viewing angle approaches specular reflection. A total shape of reflectance lobe is shown in the inset in the top-left corner.

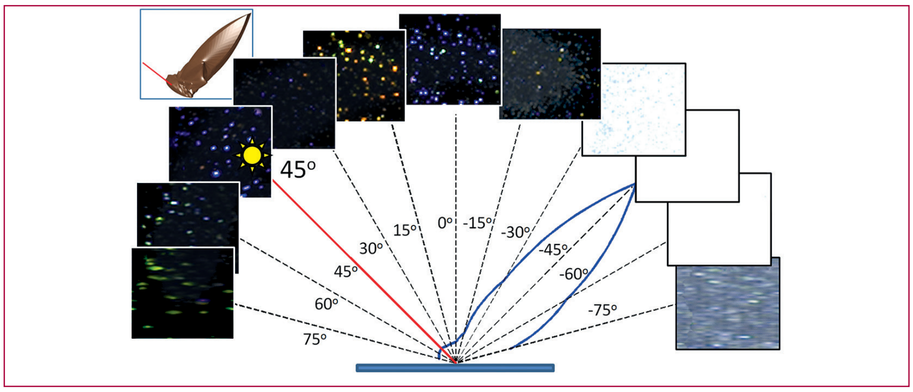


**Figure 7. In-plane measurements of MultiFlect polychromatic effect pigments for illumination angle 45° from normal (© pictures by UTIA)**

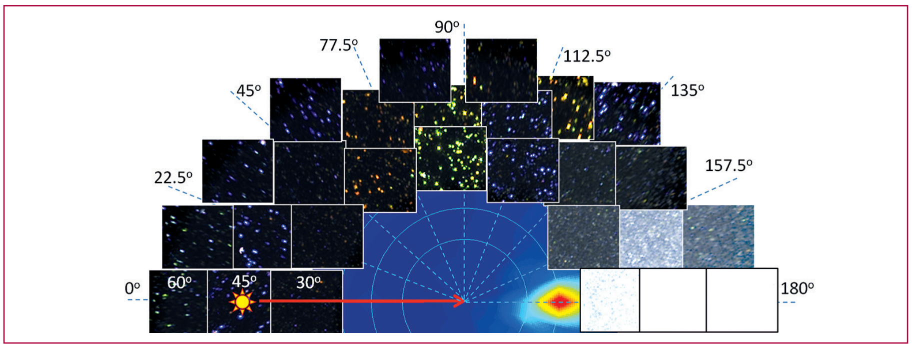


**Figure 8. Out-of-plane measurements of MultiFlect effect pigment sample for illumination angle 45° from normal. It shows its behaviour for viewing angles from normal 30°, 45°, 60° and different viewing azimuths** (© pictures by UTIA)

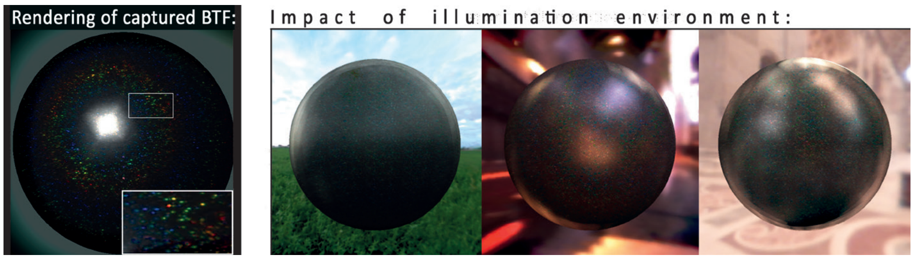


**Figure 9. Renderings of captured MultiFlect effect pigments representing both (1) its gonio-apparent and (2) structural behaviour, for point light (see picture left) showing detail of captured pigment structure and for three different illumination environments** (© pictures by UTIA)

**Figure 8** illustrates out-of-plane measurements obtained for variable azimuths. It includes images for viewing angles 30°, 45° and 60° with respect to the normal. Polychromatic light sparks caused by the effect pigments under directed lighting can be observed.

The captured gonio-apparent effect pigment structure images, represented as BTF (Bidirectional Texture Function)[18], can be used for its visualisation on arbitrary surface geometry and illumination conditions as shown in the point-light and environment illuminations in **Figure 9**. These renderings depict that the pigment's unique visual properties reveal especially for non-uniform illumination, ie having several significant illumination areas only, as shown in the last two images.

## CONCLUSION

Effect pigments have found a wide spectrum of applications for decorative and functional purposes. With their unique possibilities achieving optical impressions such as eye-catching effects, angle-dependent interference colours, pearl lustre or multiple reflection, they can be considered irreplaceable in modern product design. Effect pigments show several advantages in decorative and functional applications in comparison to extended films. Some of the advantages include the broad variety of achievable optical effects, the ease of incorporation in all relevant application systems, the possibilities to blend pigments with other colourants and the impression of vivid colour effects[5].

With MultiFlect and Alegrace Spectacular, new effect pigments based on diffractive elements have been introduced to the industry.

As both generations contain diffractive elements in their pigment design, they allow the realisation of semi-smart surfaces. When irradiated with different spectra of light created from LEDs[12-17], the appearance of surfaces containing MultiFlect and Alegrace Spectacular effect pigments changes dramatically, with respect to interference colours and texture. It is this special property, which amplifies the attractiveness and the use of MultiFlect and Alegrace Spectacular in modern product design. ■

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