PEARLESCENT PIGMENTS IN PRINTING

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Abstract
In order to stay competitive in publishing market that strives toward electronic publications, print service providers are putting much effort into creating products that are visually impressionable and appealing. Pearlescent pigments are often employed for such purpose since they provide both natural pearl shine and the effect of goniochromism. This paper provides an overview of the use of pearlescent pigments in print production, briefly discusses their properties, as well as the ways of their practical application.
Keywords: *pearlescent pigments, printing, goniochromism*

Introduction

With respect to their interaction with light, the pigments used in printing inks can be divided into absorption and effect pigments [1, 2]. The latter have become increasingly important in graphic arts industry because of their ability to create the range of optical effects – the effect of metals, shine, change of perceived colour with the change of viewing angle or the angle of illumination (effect knows as goniochromism) etc. Pearlescent pigments belong to the special effect pigments due to their goniochromatic properties, as well as the possibility to produce the effect of pearl lustre.

The structure of natural pearls, which is determined by the layers of transparent materials with different refraction indexes [2], served as an inspiration for creating the multilayer pearlescent pigments. In such composition, natural or synthetic muscovite (mica) is used as a base substrate, on which layers of different materials (titanium dioxide, iron(III) oxide, chromium(III) oxide, silicon dioxide and so forth) are deposited. The commercial success of pearlescent pigments started in the 1970s and reached its peak in the 1990s when the way to synthesise more layers of different material onto the base substrate was found [3].

The multilayer structure of pearlescent pigments determines their optical properties since the incident light is both reflected (to some extent), and dispersed in the layers' boundaries. The progressive decrease of reflected

lights leads to the pearl lustre, the specific kind of sheen which appears to arise from the object surface [2]. Also, different refractive indices of the layers lead to the constructive interference - the reason why pearlescent pigments exhibit goniochromatic properties. In practice, pearlescent pigments are often defined by their interference colour – the dominant wavelength of the light reflected in the specular angle [1]. By increasing the angle of illumination and not changing the position of the observer, the dominant wavelength of reflected light shifts toward the short wavelengths, i.e. the colour is perceived bluer (as seen in Figure 1). The range of colours that can be observed by changing the position of illumination or the observer depends principally on the material of the pigment layers, as well as their arrangement and thickness.

Figure 1. The change in the appearance of green colour enhanced with pearlescent pigment (Iriodin® 221 Rutil Feinblau) with the change of the illumination angle (angle was increased in the steps of 30°)

The main properties of pearlescent pigments

Besides their optical properties, pearlescent pigments possess high resistance to water, acids and alkali, poor electrical conductivity and are stable up to temperatures to 800°C [4]. Also, they can safely be used in packaging since they are eco-friendly, odourless and tasteless, do not migrate and contain only small amounts of metals [4].

It is also stated that pearlescent pigments possess very good light resistance [2-4], a feature that can be quite useful for printed products intended to be displayed under the strong light or outdoor. However, it seems that this property depends on the application. It was shown that in flexographic printing pearlescent pigments improve light-fastness of printed products when mixed with the absorption pigments [5], while in the case where they overprinted the ink-jet prints quite the opposite behaviour was reported [6]. In later work, it was also noticed that the light-fastness highly depended on the base colour, i.e. colour of the absorption pigment that was formerly printed [6].

Application of pearlescent pigments in printing

In printing, pearlescent pigments can be mixed with the absorption pigments or applied as separate colour [1, 7]. If mixed with absorption pigments their concentration depends on the desired effect and is usually in the range of 0.5-20%. In such an application perceived hue of the printed colour depends on the absorption pigment, while pearlescent pigments contribute to the final appearance by enabling very subtle goniochromatic and pearl lustre effect.

If the intent is to create the more prominent visual effect, pearlescent pigments should be dispersed in the transparent ink base or different types of varnishes. Their concentration is determined on the basis of the viscosity necessary for the particular printing technique and the intensity of the effect. While adding the pigment to ink binder or varnish, it is important to avoid aggressive mixing, since it can alter the pigment structure [7]. Once prepared, the mixture can be used in the same manner as conventional printing ink – as the first colour in a sequence or to overprint previously printed products. Products printed with pearlescent pigments can easily be overprinted, coated, embossed, folded etc.

Pearlescent pigments dispersed in UV varnishes can be used to create the visual effect of embossing – an interesting solution presented by Merck (VE3D – Virtual Embossing) [8]. 3D printed effect is achieved by printing the layer of pearlescent pigments dispersed in the UV varnish over the previously printed image and, after the sheet is transported to the second printing unit without curing, pressing the desired shape using a 3D polymer plate. Pearlescent pigments retain their position and, after drying, the illusion of the embossed surface is created [8].

It is important to note that in the case when pearlescent pigments overprint previously printed products the resulting colour highly depends on the base colour. Since the pigment particles are (semi)transparent, the light of the colour complementary to the interference colour is transmitted to the printed product surface [1]. If the surface is black – the light will be absorbed and the colour observed in the specular angle will be the pure interference colour (as seen in Figure 2a, which shows the appearance of the colour observed in the angle very close to the specular). In the case of white surfaces, the complementary colour is scattered from the surface, meaning that in the specular angle and the angles close to specular the effect of interference colour is reduced since it is combined with its complementary colour (Figure 2b). In any other case, the hue of the interference colour is highly determined by the base colour (as can be seen in the Figure 2c-e).

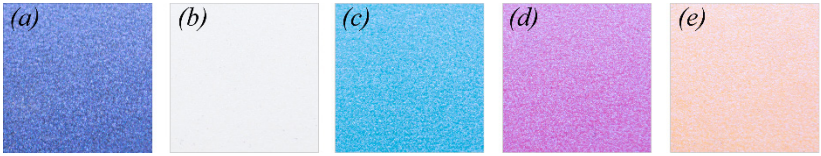

Figure 2. The appearance of the ink-jet prints enhanced with pearlescent pigment (Iriodin® 221 Rutil Feinblau) in the case where the base colour was (a) black, (b) white, (c) cyan, (d) magenta and (e) yellow. Images were made to capture the reflection in the angle very close to the specular angle (15° aspecular).

Products printed with pearlescent pigments

Pearlescent pigments can be applied to almost all the substrates: paper and cardboard (coated and uncoated), plastic, textile, glass, wood, metal etc. [7]. Therefore, they can be used to produce a full range of printed products, where many of those fall in the domain of packaging, security- and commercial printing.

Luxurious and decorative packaging are produced in flexography or gravure by overprinting the coloured cardboard with pearlescent pigments coating (normally applied in the form of a thick layer to produce more accentuated visual effects) [9]. Since the effect of goniochromism is very hard to counterfeit, pearlescent pigments are also used for creating security elements in printed products [7].

Putting an accent to a specific part of design can be achieved when printing magazines and promotional materials by applying the pigments partially (commonly in offset printing), while the various visual effects on the wallpapers can be achieved in flexography [7]. Since the pearlescent pigments are heat- and moisture resistant, they are often used for printing sports clothing, as well as the home textile (using the screen printing technique).

Special concerns regarding the printing process

In order to reduce problems in printing, it is important to fulfil basic requirements regarding the application of pearlescent pigments (with respect to the specific printing technique).

In flexography, pearlescent pigments should be mixed with transparent inks with low viscosity solvents, as well as with water-based inks. The concentration of the absorption pigment should not extend 3%, while the concentration of pearlescent pigment can reach 30% (in case of the pigments with very fine particles) [7].

Adequate choice of the printing plate and the anilox roller enables good transfer of pigments to the printing plate and their uniform deposition on

the substrate. Very good results can be achieved using soft photopolymer plates with low surface tension [7], as well as the laser engraved ceramic anilox rollers with hexagonal screen (60° or hachure) [9]. The line screen of an anilox roller depends on the size of pigments (smaller particles require higher line screen), as well as the printing substrate. More emphasised visual effects can be achieved if the printing is performed on flat, uniform surfaces, while for the rough and absorbent substrates the line screen has to be smaller.

Regarding the gravure, the screen count of a gravure cylinder is the main factor that determines the transfer of the pigments into the printing substrate. Same as in flexography, it is recommended to use laser engraved cylinders and to adjust the viscosity of the printing ink to the materials being printed and the printing speed [9].

Pearlescent pigments are suitable for offset printing as well, where they can be used as a conventional ink or in the form of a coating. In the first case, due to the ink layer thickness and the line screen of the printing plates, pigments of size up to 25 μm should be used [10]. Larger particles cannot be appropriately transferred to the surface, which can lead to the loss of the details in prints.

Also, it is recommended to use special rubber blanket to prevent the accumulation of pigments on the surface of the blanket [10], as well as the FM screening since it emphasises the visual effects. To ensure good reproduction of details dot size should not be smaller than 30 μm [9]. In the cases when AM screening is used, screen count should not exceed 85 lines/inch (34 lines/cm) [10].

Regarding the application, pigments can be printed *wet-on-wet* or after drying the previously printed material. Printing in a sequence ensures very fine reproduction but lowers the goniochromatic effect since the pigments adhere to the formerly printed ink. When pearlescent pigments are printed as the first ink, appropriate drying is necessary since it reduces the possibility of sticking the sheets together.

If the pigments are used for enhancing the printed products, they are applied via coating unit. In this case, pigments whose particles exceeds 25 μm are normally used, and the selection of appropriate plate and anilox roller is essential. More detailed recommendation for the practical use can be found in [9].

To achieve optimal results in screen printing, mesh size must be adapted to the size of a pigment particle. More specifically, mesh size should be 1.5-2.5 times larger than the largest pigment particle [8, 9]. The mesh material should be chosen in such a manner that it prevents blockage and adherence

of pigments to the mesh, while the hardness of a squeegee should be lower so that the pressure does not affect the pigments structure [10].

The limitation of the printing process impedes the use of pearlescent pigments in ink-jet printing. To be properly printed the diameter of a pigment particle should be 50-100 times smaller than the diameter of the ink-jet head nozzle. Since the typical nozzle diameter is approximately 25 μm, the particle size should be 0.5-0.25 μm – far smaller than the smallest pigments currently available in the market (with a particle size distribution of 1-5 μm) [11]. The solution for overcoming this problem presented in [12] has still not been widely applied. Therefore, it is to be seen whether in the near future the application of pearlescent pigments in ink-jet will be possible.

Summary

Taking into account the characteristics of pearlescent pigments and the effects they produce, it is no wonder that they are quite present in the graphic arts industry. The fact that they can be used in almost all printing techniques and applied to almost any surface makes them a very attractive choice for decorative and functional purposes. For the designers, the possibility to change the perception of the printed colour by different application of the pigments opens up a full range of possibilities for creative expression. Taking into account the rapid entry of these pigments into the printing market in the past decades and the increased offer by the ink-suppliers, the continuation of their development is most surely to be expected in the future.

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