The HP Indigo White Ink for Industrial Applications

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Abstract

Being a leader in the industrial digital printing market, HP Indigo provides its industrial customers with a comprehensive value proposition to enable a smooth transfer from the conventional to the digital presses. Our revolutionary HP Indigo ws4500 digital web press makes extensive use of all 7 color stations (4 for process colors and 3 for special colors including white). This helps our customers capture the short run and the variable print market of the traditional offset and Flexo, while providing similar look and feel. HP Indigo white ink serves as an excellent backing color and enables printing on a broad range of colored, dark, metalized or transparent substrates. With HP white ink, a silky, smooth, professional appearance to labels, shrink sleeve and flexible packaging is obtained.

In this paper we will show how the white ink, in particular, supports the industrial portfolio of HP-Indigo. We will cover the basic white ink performance requirements and demonstrate the flexibility of using the white ink in the HP-Indigo digital industrial press for direct printing, reverse printing and even printing two sides of an image on a single side of a media. We will show that applications printed with conventional flexography process implementing white ink can be reproduced easily by the digital printing process, being a driving factor in the growth of digital printing industrial market.

Introduction

In the Industrial printing market the look of the printed product, might it be a flexible package or a label, is one of the major factors influencing the consumer to choose a product and eventually enhancing the ability to sell a specific product. To achieve this goal many industrial presses use more than the standard 4 colors used in commercial printing. The ability to digitally print special colors is one of HP Indigo's significant differentiators [1,2]. HP Indigo digital presses allow for up to three more ink systems to be added to the 4 basic process colors, making the presses capable of printing with up to seven colors. Beside the 4 process colors, one of the most important colors used is white. In digital industrial production ,a significant part of the printing goes on clear substrates. The range of applications using clear substrates is growing every day with flexible packaging, labels and shrink sleeves the top 3. For these applications the white ink is usually used as a backing color for the process and other special colors , creating and enabling a vibrant image on the clear substrate.

The fundamental requirement of a white ink is to serve as an opaque layer, meaning it should reflect back the light penetrating the ink layers on its one side from getting through the white ink layer to the other side. In order to quantify the sensation of opacity there are several definitions: contrast ratio, hiding power or covering power. All terms basically supply a measure for the ratio of amount of light reflecting back to the viewer if the layer is placed over a complete absorbing layer (black) to the complete reflecting (white). In order to better understand the phenomena of opacity the optics, chemistry and physics of the formulated ink should be taken into account.

Basic properties of white pigment

The opacity of a pigment particle is a function of its surface reflectivity, refractive index relative to its surrounding matrix, its light scattering power (depended also on its particles size) and light absorbance [3-5]. In contrast to colored pigment, where opacity is achieved via absorption of some part of the energy spectrum, the white pigment does not absorb the visible wave length range, as can be seen in figure 1, and the opacity is achieved via scattering.

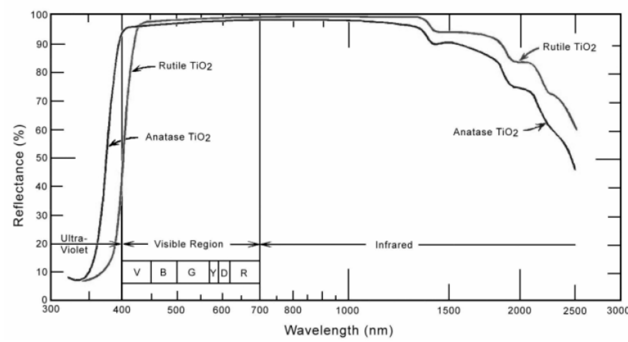

Figure 1. Reflectance of anatase and rutilr titanium dioxide through the near UV, visible and IR regions [4].

To understand better the optical properties of a white ink we need first to look at the interaction of a particle with an incident light. Figure 2 shows some possible interactions of a particle with an incident light.

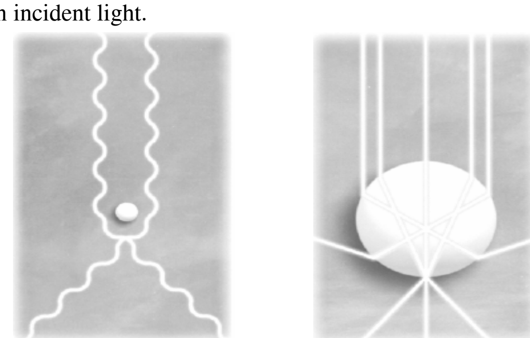

Figure 2. Interaction of Incident light with pigment particle [5].

The particle may scatter light by direct reflection, refraction (bending of the light) diffraction of light passing near it and by absorbing a portion of the energy. As the reflected light is only a small part of the energy (usually about 4%) [5] and white pigment is almost non absorbing, it immediately becomes clear that the most important properties of a pigment are the ability to bend light (nature of material) and diffraction (particles size and dispersion in its surrounding matrix).

The ability to bend light is depended on the difference between the refractive index of the pigment and its surrounding matrix. The material RI (refractive index) is defined as the ratio of speed of light in vacuum divided by the speed of light in the medium of the specific material. The refraction of the incident light is caused by the fact that as light is traveling from medium with one density to a different medium with different density it will change its velocity and that will cause a change in its angle of propagation. Figure 3 demonstrates the difference in opacity when using pigment with low and high RI in the same matrix surrounding. In case a low RI pigment is used, part of the light will be able to penetrate through the pigment layer to the back of the layer so the viewer will see some of the energy absorbed by the backing layer and opacity will be low. In the case were a high RI pigment is used, the incident light is refracted back to the surface so the layer will appear completely opaque.

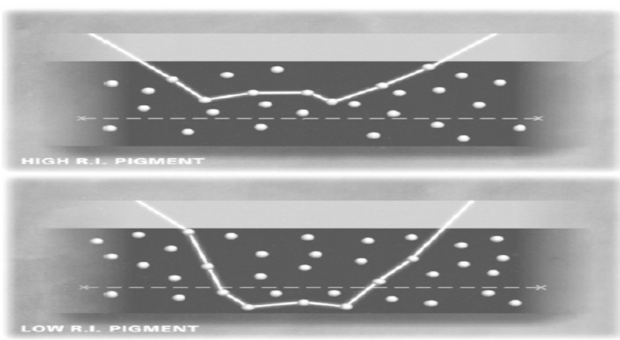

Figure 3. *Path of light in white paint films [5].*

By looking at figure 3 it is evident that in order to formulate a high opacity ink, the choice of pigment material is crucial. Table 1 lists the RI of several pigments and resins. As can be seen, all resins have more or less the same RI. For the pigments, there is a very big range of RI, with the highest RI found for titanium dioxide in rutile form. Taking into account that ink layers are relatively thin (in comparison to coating or plastics) it is not a surprise that the rutile form of titanium dioxide has become the natural choice. The effect of difference in RI can be demonstrated by preparing formulations of the same thickness, with pigments having different RI, figure 4.

Formulation of white opaque ElectroInk

As was shown in the previous paragraph, when coming to formulate a white opaque ink, the formulator is limited by the selection of raw materials. However there are still many parameters in the ink formulation and preparation that can influence the opacity of the final formulation. It was indicated in figure 3, that the ink layer thickness is as important as the choice of raw materials. In order to have an opaque ink layer, the light should be scattered from the white layer itself without penetrating it. So the optimization of the layer thickness is vital. The thicker the layer the less concentration of pigment is needed. In printing the layer is usually very thin (below 10 micron) so the immediate question is "how thin can you go?" Well with the HP-Indigo white ink it can be pretty thin.

Table 1 – Refractive index of TiO2, fillers and binders [4].

Material	*Refractive Index*
Rutile TiO_2	2.76
Anatase TiO_2	2.52
Lithopone	2.13
Zinc oxide	2.02
White lead	2.00
Calcium carbonate (chalk, whiting)	1.57
'China' clay	1.56
Talc	1.50
Silica	1.48
Alkyd/Polyester resins	1.54
Acrylics	1.50
Polyethylene	1.51 – 1.54
Polystyrene	1.59
Polyvinyl chloride	1.52 – 1.55
Water	1.33
Air	1.00

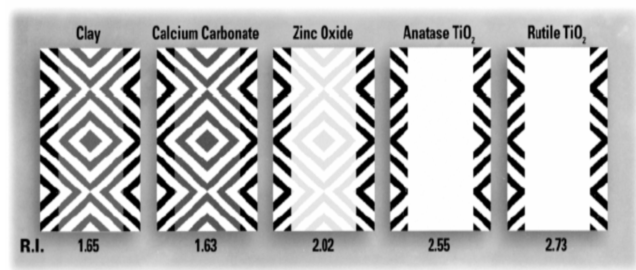

Figure 4. *Effect of refractive index on opacity [5].*

To access the limits of opacity as function of layer thickness the Kubelka-Munk [6] theory can be used. Although the theory has some major limitation: all light is either backscattered or absorbed, only one direction of propagation, it usually gives a good estimation for the layer properties and it is widely used in the industry [3,7].

The basic concept of the K-M theory assumes that for a given unit thickness of a coating layer, light is going either upward (j) or downward (i) this depends on the material scattering coefficient (S) and absorption coefficient (K). The total reflection (R) is then a function of the material properties and the layer thickness (X). For an infinitesimal layer thickness, the K-M equation can be then written as [6]:

$$-di = -(S+K)idx + iSdx \quad (1)$$

$$dj = -(S+K)idx + jSdx$$

For an ideal white (on ideal black substrate) there is no absorption so K=0 and the K-M equation can be solved in the following manner [6]:

$$R = SX / (SX+1) \quad (2)$$

In order to validate this assumption, a plot of 1/R vs. 1/X can be made [8]. The fitted line should be linear and intercept the 1/R axis at value of 1. In figure 5 such plot is shown for a rutile pigment in a PE plastic film, thickness of 150-940 micron [9]. As can be seen the K-M theory is valid.

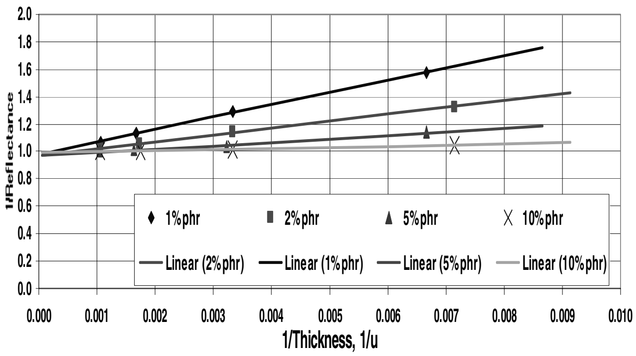

Figure 5. *K-M plot of rutile pigment in PE.*

Figure 6 shows a similar plot for an HP-Indigo ink. It can be seen that K-M is indeed valid for layer thickness above few microns, but for layer thickness in the order of ~ 1 micron, as is the case for the HP-Indigo ElectroInk, the K-M theory is not valid.

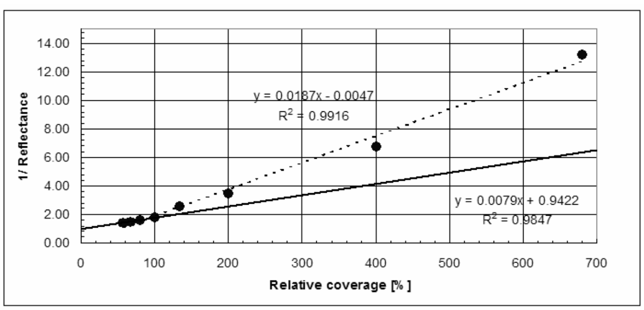

Figure 6. *K-M plot of rutile pigment in HP-Indigo white ink.*

This means that for a layer with thickness of ~ 1 micron a full calculation of the scattering should be made in order to access the exact limit. However based on these calculations, and practical measurements, opacity of at least 60% can be easily achieved in a thin layer. For example one can find a patent [10], describing a white toner for dry electrophotographic copier, reporting to achieve opacity of 60% for a 0.75 - 1.5 mg/cm^2. Dry electrophotography (DEP) is based on transferring powder toner particles through air to a photoconductive drum or layer and from there to a substrate (directly or by using a rubber blanket). After the toner is transferred to the substrate it is fused for final adhesion. In liquid electrophotography (LEP), the toner particles are suspended in a liquid medium. The particles are transferred to the photoconductive layer through the liquid medium and then to a rubber blanket. On the blanket the liquid toner is heated to form a uniform layer. The layer is then transferred to the substrate where it immediately solidifies. The ability to move particles in a liquid medium enables the use of smaller toner particles and more control of where the particles end up - either on the developer roller or on the image area on the photoconducter. This results in printing of vibrant colors in a very thin layers ~ 1-3 microns (similar to analog offset) whereas for DEP the layer thickness is 5-7 microns. So the opacity of white DEP toner can be matched or even surpassed by white LEP toner with a thinner layer.

Another important parameter for the ink formulator is the pigment loading, or pigment volume concentration (PVC) and the pigment crystal size. It is well known that the scattering power of the pigment depends on the crystal size and should be about half of the incident wavelength. It is also know that due to crowding effect the scattering coefficient is decreased. In other words, depending on the specific system, there is an optimum pigment loading that will contribute to the opacity. Beyond this optimum concentration the addition of pigment will not increase the opacity (or may even reduce it). For thick coatings, increase of the pigment loading beyond the critical pigment volume concentration (CPVC) can result in increased "dry hiding power" meaning the dry film will contain air (not enough resin to wet all pigment particles) and it will increase the difference between the RI of the pigment and its surrounding to increase opacity. This is illustrated in figure 7.

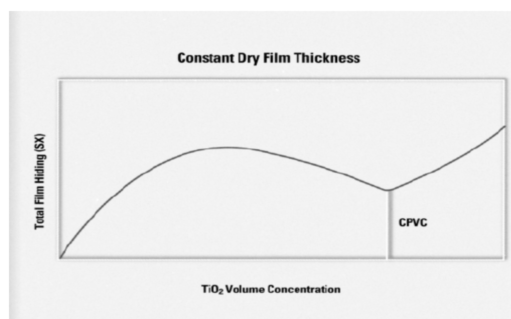

Figure 7. *Film hiding with constant film thickness as a function of TiO2 pigment volume concentration[5].*

Figure 8 shows the relative reflection of HP-Indigo dry film as function of relative pigment loading (the optimum pigment loading and reflection are used as a reference point value of 100%. i.e. 150% pigment loading is 50% more pigment loading then the optimum value). Similar to the general graph for coatings it can be seen that there is an optimum for the reflection (opacity) for the pigment loading.

In order to optimize the formulation performance given these limitations, one can formulate an opaque white ink by carefully choosing an optimal pigment grade with known crystal size and surface treatment. Many grades exist in the market to allow an optimized formulation taking into account the resin system, system limitation and grinding procedure.

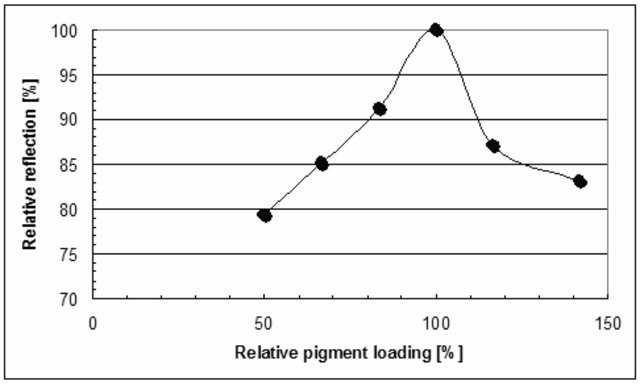

Figure 8. *Relative reflection vs. relative pigment loading for white Electrolink.*

Printing with HP-Indigo white ElectroInk

Digital Presses and HP-Indigo are transforming the analog printing world into digital. To reach this vision the HP-Indigo industrial press WS4500 is providing customers the capabilities and flexibility to convert jobs from the traditional flexo and offset presses to the digital era. Along with the ability to print 7 spot colors and specially mixed colors, the white ElectroInk provides the customer an important capability to capture more of the short runs in many application areas such as: labels, shrink sleeves, flexible packaging, heat transfer labels and others. This helps the Digital press owners to achieve truly innovative applications and solutions for their customers.

The most common need for white ink is when application requires printing on clear substrate. In the simplest application a white layer is needed as a part of the label design. This can be achieved by simply printing the white and CMYK colors. An example of such an application is shown in figure 9. The print sample on the right is printed with the white as dominating color of the background and on the left the white is only printed in selected areas according to designer specification.

Figure 9. *Clear substrate printed with CMYK + W ElectroInks.*

In this printing technique the colors are printed as a single CMYK +W separations. Each separation is printed one at a time and transferred from the ink tank to the PIP and then to the blanket. After reaching the blanket the next separation is being printed again from the ink tanks to the PIP and then to the blanket. In this way all 5 separation are first collected by the blanket and only then they are transferred in one pass to the substrate. This process is called the “One Shot“ process. Schematic illustration of the ink layers arrangement in a One shot process is shown in figure 10. In this case the “One Shot” process was used for direct printing. e.g. the image is printed directly on the final substrate and the white is in the back of the image (on the blanket the white ink was the last separation). Another example of direct printing in one shot process is shown in figure 11. This sample shows another white ink application with the HP-Indigo technology as the image was printed with 4 process colors and the 2 hits of white in order to serve as a backing color and enhance image quality. On the left the image see seen as it appear on the substrate. On the right the image is viewed from the back. The white color can be easily seen as a backing color.

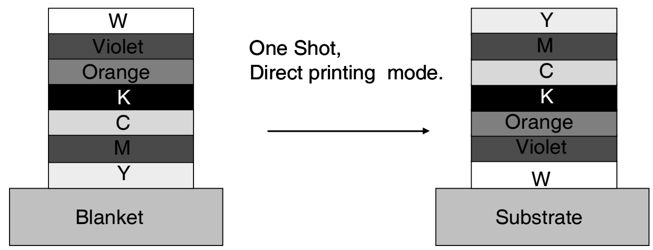

Figure 10. *Schematic representation (not in scale) of ink layers arranged (7 colors) on a blanket and on a substrate in a One Shot "direct" printing mode.*

Figure 11. *One shot direct printing on clear substrate using CMYK+W+W.*

Figure 12 shows the same printing procedure on metalized substrate. Because metalized substrate is reflecting, there is no need for 2 hits and the customers can save on amount of ink they use to print the job.

In some applications there is a need to be able to print with a different order of colors separations. In the case of heat transfer labels, the printed image is later transferred to another substrate. Applications can be: pens, plastic bags or containers. For this purpose the white ink needs to be printed last on the substrate. With the HP-Indigo engine this is a very simple task to accomplish. As the ink separations are collected one at time on the blanket, the operator can choose through the software the order in which the inks will be collected by the blanket. So for reverse printing the white ink will be collected on the blanket first and then all other colors. When transferred to the substrate the white ink will be on top and ready to be transferred to finished substrate. A sample of reverse printing will look like figure 11 on the right.

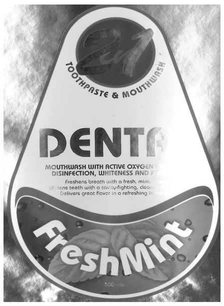

Figure 12. *Direct printing on a metalized substrate with CMYK + W.*

We will now describe a unique set of applications which can be achieved with the HP-Indigo WS4500 press. Some applications demand printing two sides of an image on a single side of a media. This printing process is sometime called "sandwich printing". The idea is to print an image followed by a backing white color to be used as a separator and then another image on top. This can be useful in case there is a need to show on one side an image that sells the product and on the other side, for example, a list of ingredients. As the HP-Indigo printing technology enables more then 4 or even 7 separations per page this is created by adding the needed separations for both sides of the image. All the operator needs to do is to correctly define the order of separations.

A more sophisticated technique is to print (direct, reverse or sandwich) by using the additional 2 stations available in the press. In this way HP-Indichrome on press printing could be done (using orange and violet) or adding spot colors by using the HP IndiChrome Pantone® certified ink mixing system. This flexibility gives the HP-Indigo customers the ability to print and cover about 95% of all Pantone gamut, or unique company logos. As for the industrial market the package or label have a considerable role in selling the product, the ability to print high quality exact colors beyond the 4 process color gamut is a major capability.

Conclusion

As many applications today call for usage of clear substrates, the necessity of a quality opaque white ink is essential for the industrial printer and label converters. We have shown how an opaque white ElectroInk can be formulated by taking into account the physical limitations of available raw materials and optimizing formulation and preparation process. Working with white ElectroInk in the HP-Indigo presses is flexible and can create many opportunities for the printers to produce varying levels of opacity and printing order. The ability to print process colors with white and additional special colors opens the door to any application demanding high quality, wide gamut and fast turn around. It then becomes clear how jobs from the traditional offset or Flexo printing processes such as: labels, shrink sleeves, flexible packaging, heat transfer labels and many more can and are being easily transferred to the HP-Indigo digital presses. Furthermore the combination with the digital on-demand variable printing capability opens innovative opportunities for these Digital press customers. The customers are not simply purchasing another press, but they are generating new profit-making opportunities.

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Author Biography

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