Dye Sublimation: An Image Quality Comparison Between Pre-coated and Self- coated Non-traditional Substrates

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Keywords: dye sublimation, sublimation coatings, non-traditional substrates, image transfer, color gamut

Abstract

This study examined pre-coated substrates as well as three additional self- coating products to determine which substrate and coating combination provided the best image transfer across different types of photography using the dye sublimation printing process. The substrates included in this study were wood, glass, metal, and tile. Different sublimation coatings were used for each self-coated substrate. Some coatings increased challenges with burning, paper sticking, and inconsistent ink transfer. A color target was printed on all substrates and a spectrophotometer was used to record LAB and density readings. Once all color readings were gathered, a comparison of each substrate across coatings was made. For example, we compared wood to wood, tile to tile, and so on between the different coatings and the pre-coated blanks. Based on a combination of visual observation and Delta E calculations, we found that each coating performed differently based on the substrate being tested. In general, pre- coated along with Coatings B and D performed the best overall.

Introduction

Moving into digital replication of photographs, two processes are commonly used for photographic reproduction: dye sublimation and inkjet. Dye sublimation was introduced in the mid-1980s and is commonly used today for printing on polymer or polymer-coated substrates (Ohno, 1996). Dye sublimation, also referred to as heat transfer printing, is frequently used to transfer designs onto plastics, polymers, and textiles and has also been used to print on metal packaging (Turner, 1998). The process involves drafting the design, printing it onto transfer paper using special sublimation inks, preparing the substrate for printing, and applying the heat press to the substrate with the affixed transfer paper. Once the sublimation occurs (solid

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ink becomes gas), the material becomes permeated with the gas, the paper carrier is removed, and the image adheres to the substrate (Digital Technology Group, n.d.). The penetration of the ink into the polymer substrate or coating provides a scratch- and environmentally resistant final photograph. Mass produced spray and liquid-based polymer coatings allow for printing on a wide range of flat substrates and multidimensional surfaces such as hats and glassware (Xu, 2017).

In order for ink to adhere during the transfer process, the substrate must contain polyester or a polymer coating. These non-paper substrates, often referred to as sublimation blanks, can be purchased pre-coated or coating can be applied manually to any uncoated, non-plastic substrate. There are many pre-coated substrates available however, for more non-traditional surfaces such as wood or stone tile, self-coating may be required. Sublimation coatings are available in both liquid and aerosol forms with liquid being most common for hard, inflexible substrates. When dye sublimation is used on alternative substrates color accuracy becomes a factor because there is no longer a “paper white” base for the image and without an application of a white base coat, the color and texture of the substrate itself becomes a part of the resulting photograph.

Some advantages of dye sublimation printing are full color with a single pass unlike traditional screen printing, flexography, and lithography, high quality prints, print durability, versatility, and ease of replication and use (Apo, 2020). Printing of a 300ppi source image actually results in an effective ppi of 2400 due to the transformation of the ink into gas during the heat press process (Makenji, 2011).

Building on a previous study examining the durability of color when exposed to environmental conditions such as humidity and UV full- spectrum light (Walker & Bridges, in review), this study will focus on different brands of liquid coatings and examine application processes to ensure even coverage across substrates. By examining both pre-coated substrates as well as three additional self-coated products, we will determine which substrate and coating provides the best image transfer across different substrates.

Methods and Procedures

The purpose of this project is to determine which dye sublimation self- coating provides the best image quality across four different substrates: glass, metal, tile, and wood. Four different self-coatings were tested as well as pre-coated blanks. Pre-coated substrates, in general, provide more consistent results however users are limited in terms of size and type of substrate. This study sought to answer the following research questions:

1) Of the four self-coatings, which one provides the best overall image transfer for glass, metal, tile, and wood 2) Which coating, including pre- coated substrates, provides the best color representation for different types of photography: landscape, portraits, and black and white? and 3) Based on this study, what are the recommended coatings and dye sublimation settings for each substrate and type of image?

There are a wide range of coatings on the market including both liquid and aerosol options. Four coatings (3 liquid, one spray application) were selected for the project. Ingredients for two of the liquid coatings were identical and were comprised of acrylic, pigment yellow, glycerol, copper phth alocy anine, and deionized water. Ingredients for the other two coatings were not provided. A different sublimation coating was used for each self-coated substrate. Uncoated substrates were purchased from Lowes Hardware or found as scraps and the pre-coated blanks were purchased from a dye sublimation retailer.

To begin, two coats of polymer coating were applied to the samples using a sponge brush applicator, the second coat was applied one hour after the first to allow for dry time. The spray coating was applied using a spray bottle then evened out with the same type of applicator. The substrates then dried for no less than 24 hrs prior to curing. The sublimation blanks were then heat cured according to manufacturer guidelines (16x20 Geo Knight heat press).

A color target was then prepared in Adobe Illustrator and printed on Epson Dye Sublimation Transfer Multi Use Paper using an Epson SureColor F570 printer. The color target included 72 patches to represent a wide range of tints, hues, and skin tones often produced in photographic imagery. Thirty-one patches were representative of tones commonly found in landscape photography, twenty-two patches were of skin tones, and nineteen covered levels throughout the grayscale printed with black only and the equivalent cyan magenta, and yellow builds. Transfer paper was then placed on each sublimation blank (self-coated and pre-coated) and pressed, Table 1. Once the cured samples were cooled, the target was attached and placed in the heat press to print, Table 2.

	Time	Temperature	Pressure	Parchment
Glass	5 min 10 sec	350	0	Paper Parchment
Metal	1 min	360	2	Paper Parchment
Tile	5 min	350	0	Paper Parchment
Wood	2 min	400	1	Paper Parchment

Table 1. *Dye Sublimation Settings for Curing.*

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Table 2. *Dye Sublimation Settings for Printing.*

Results and Discussion

We measured each color patch using an X-Rite Spectrophotometer set to M1 daylight to record density and CIElab values. Then using the DE76 formula, we determined the difference between the initial color values in the target and the printed patch. This resulted in individual patch DE values, an "all target" DE average value, and an average for each of our sets of patches: landscape (n=31), skin tones (n=22), and neutrals (n=19), Table 3.

Coating	**Substrate**	**Average DE for all**	**Landscapes (1-7, 10-16, 19-35)**	**Skin (8-9, 17-18, 37-54)**	**Neutrals (36, 55-72)**
A	G	43.76	56.46	41.65	26.55
B	G	**14.55**	**14.98**	**16.63**	**11.37**
C	G	16.65	16.81	19.28	13.37
D	G	15.01	15.51	17.15	11.62
PC	G	46.19	52.80	44.82	36.50
A	M	40.08	45.34	36.22	35.21
B	M	**29.12**	**28.82**	27.93	31.20
C	M	30.14	29.80	30.10	30.76
D	M	29.54	30.80	28.88	28.05
PC	M	29.63	35.30	**25.41**	**25.30**
A	T	48.37	59.05	42.99	38.77
B	T	5.75	7.21	**3.54**	5.74
C	T	6.65	7.19	6.32	6.21
D	T	**5.50**	7.00	3.55	**5.18**
PC	T	7.82	9.97	6.45	5.88
A	W	30.67	38.20	19.92	30.06
B	W	32.74	38.11	24.98	32.01
C	W	35.38	39.67	27.44	36.66
D	W	**26.54**	**28.58**	**19.13**	31.20
PC	W	26.70	30.23	21.93	**25.95**

Table 1. *Dye Sublimation Settings for Curing.*

Glass

Glass had no absorbent qualities, which provided a challenge during application but all the coatings dried as expected. On glass, this resulted in minimal image transfer for Coating A and texturing across all the self- coated samples, especially Coating C which showed major texturing beneath the print. There was sticking of the paper with both Coatings A and C during the heat transfer process. After printing, pre-coated had a matte finish, whereas all other substrates were shiny and maintained a reflective quality common for glass. Color measurements revealed that if printing landscapes, portraits, or black and white photos, Coating B is best on this substrate, Figure 1.

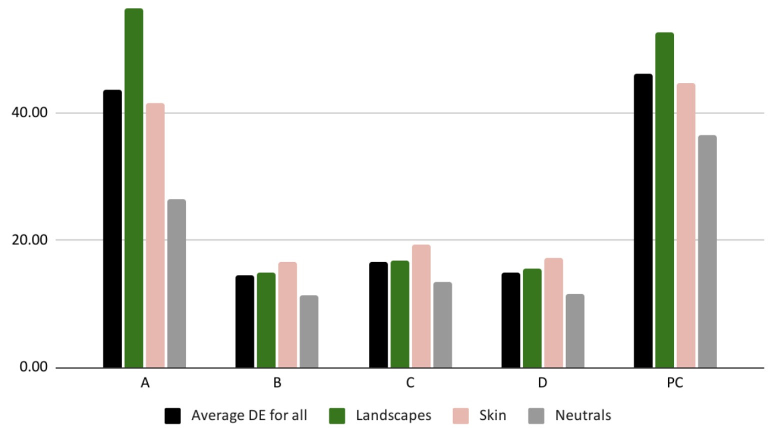

Figure 1. *DE results for glass reveal that Coatings B, C, and D result in more accurate color transfer compared to Coating A or the pre-coated glass.*

Metal

Similar to glass, metal does not have absorbent qualities. Coating A produced poor image transfer and Coating C resisted a smooth coat on this substrate. Based on visual observation after printing, self-coatings provide more sheen and vibrance but could produce an uneven texture due the coating application process when compared to the pre-coated substrate. The recommendations for metal are dependent on the type of photograph being reproduced. If printing portraits and black and white photos, pre-coated substrates are best overall, but if you prefer self-coated, Coating D is best for black and white photographs. For self-coated landscapes or portraits, Coating B is best, Figure 2.

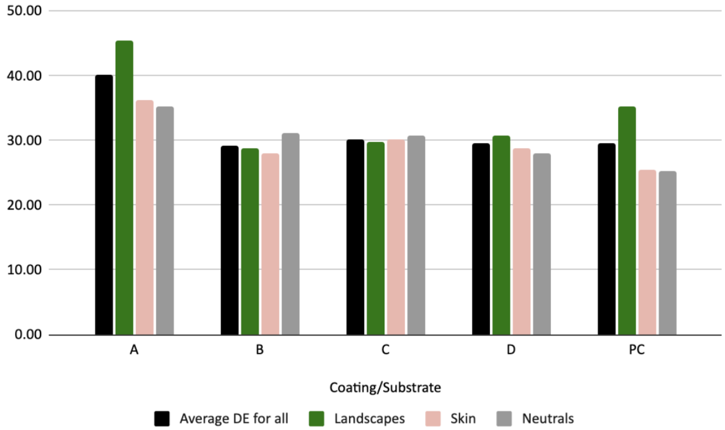

Figure 2. *DE results for metal reveal that pre-coated substrates provide a color transfer advantage for portraits and black and white photographs whereas Coating B is best for landscapes.*

Tile

Although tile is normally not absorbent due to the gloss coating, tile does have the advantage of being bright white and therefore best able to color match the original patches. Coatings B and D display minimal noticeable texture under the print and once again, Coating A had poor image transfer. The transfer paper had sticking issues with Coatings A and C. Overall self-coated with Coatings B, C, and D provided the best color transfer compared to pre-coated tile. If printing landscapes, portraits, or black and white photos, coatings B and D are best. Black and white photographs transfer similarly across pre-coated and Coatings B, C, and D, Figure 3. Note that these results change dramatically across different types and colors of tile.

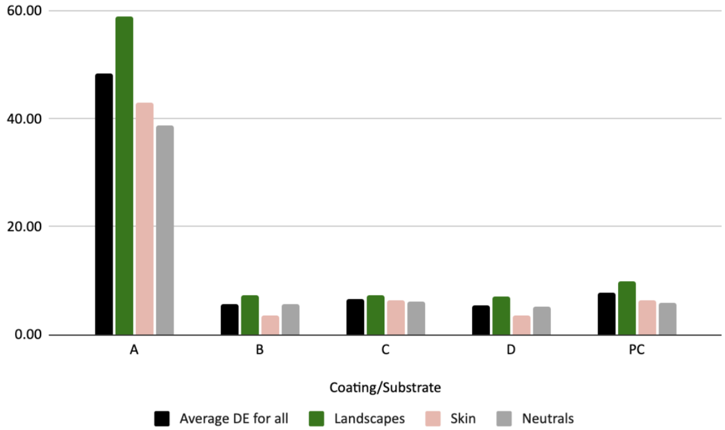

Figure 3. *DE results show that self-coated white tile can very successfully match colors compared to the other substrates in this study, with the exception of Coating A.*

Wood

Wood is the most absorbent of all the substrates used in this study but it also tends to darken and even crack during the heat press process due to the water content natively present in this material. This moisture might also have also been a factor in the transfer paper sticking, as was seen in Coatings B, C, and D with C showing significant sticking. The stuck paper was removed with water and gentle scrubbing which did not negatively impact the final image. When considering the reflectance after printing, Coating A and C had minimal sheen and B and D were quite shiny. Pre- coated had no shine on the resulting image. Coating A was somewhat successful at transferring the image onto wood, most likely due to this coating being made for absorbent materials like cloth. If printing landscapes or portraits, Coating D is best for color accuracy but if printing black and white photos, pre-coated is best followed by Coating A, Figure 4.

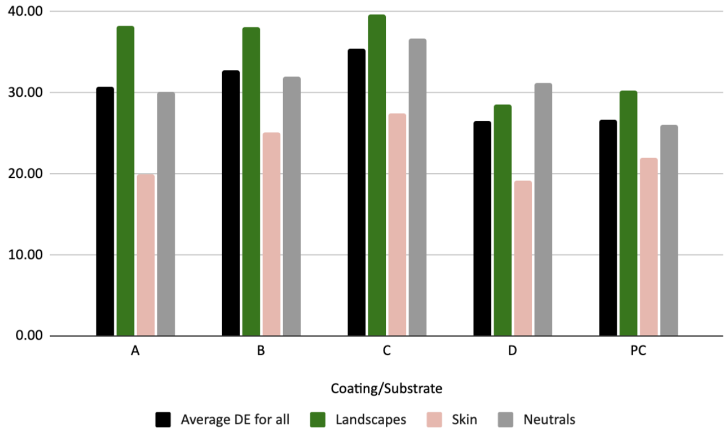

Figure 4. *DE results show that wood significantly impacts color match, even on the pre-coated sample.*

Conclusions

We anticipated Delta E values that would be unacceptable in traditional color-managed printing because the substrate was not traditional "paper white" and therefore contributes undertones to the resulting color in the print. In fact, the substrate itself became a contributing part of the artistic result adding both natural texture and color to the resulting printed photograph. If the intent is to reduce that impact, it is recommended to add an undercoating of white beneath the printed image, a commonly employed process for professional prints on these substrates.

For this investigation, we wanted to maintain the impact of substrate on the resulting artistic piece. Therefore, we decided to use DE combined with visual observations to focus our investigation on which coating is preferable if an artist wants to print on a non-traditional substrate and capitalize on the substrate's natural characteristics.

Using the resulting measurements, we compared across coatings and the pre-coated sample within a single substrate. Results show that if a photographer is focusing on only one type of substrate or subject, more specific recommendations (Table 3) can be made but if they prefer the flexibility to use self-coated across multiple substrates, we recommend Coatings B or D, which performed best, in general, across all the tested substrates.

Some limitations of this study included the constrained options for substrates available in pre-coated blanks, which hindered our ability to make additional side-by-side comparisons of other substrates or to

expand the size of the color target used. We also did not use a reflectance standard on the spectrophotometer when measuring the metal substrates, which could have skewed our Delta E values. In addition, Delta E was an appropriate measure for this study since the intent was not necessarily to reproduce exact color patches. However, this measurement may not be suitable for showing how the substrate color interacts with the printed color, and how it impacts the color measurement.

Recommendations for future research include utilizing ISO 12040:1997 standards (International Organization for Standardization) when analyzing light fastness. Finally, it may be beneficial to utilize a color proofing software with individual substrate baselines factored in to ensure that color profiles can accurately predict results when printing on different substrates.

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