Gloss Colour Effects in Inkjet Printing – Attribute, Artefact or Defect?

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Abstract

Inkjet printing technology continues to advance. One of the drivers for this has been the customer need for increased resistance to fading and physical durability. Whilst these needs have in many respects been met by the use of pigmented inks this has resulted in the appearance of other effects, notably gloss colour.

This presentation will describe and demonstrate the issue of gloss colour in inkjet printing. Methods of measurement and visualisation will also be described.

It will be shown that depending on the application gloss colour can be an attribute, artefact or defect. Possible applications and customer benefits will also be described, particularly in terms of brand identity, personalisation and security.

The Optics of Gloss and Gloss Colour

The reflection from the surface of an ideal glossy surface can be considered with reference to Figure 1.

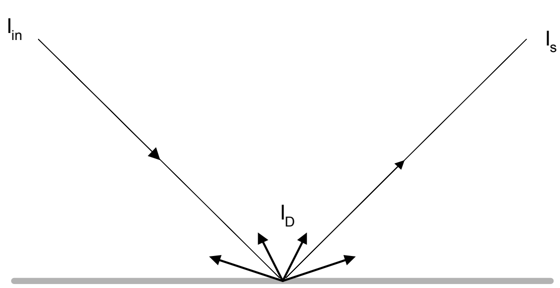

Figure 1. Reflection from an ideal glossy surface

The incident light I_{in} will be split into a specular reflected component I_S and a diffuse component I_D. The diffuse component is subject to absorption by the colorants in the print. However, the specular reflection component I_S closely retains the spectral properties of the illuminant I_{in}. With white light incident the specular reflection will in turn look white. In more general terms, I_S will have a similar hue angle and shade to I_{in}.

In reality an observer viewing the specular component along I_S will view light over a finite cone angle and will therefore collect a portion of the (coloured) diffuse light in addition to the white specular component. The result is that the gloss as viewed by an observer will always have a slight hue contribution from the colorant.

Differential Gloss and Gloss Colour

A number of practical printing technologies exhibit the phenomenon known as Differential Gloss.[1-4] This is a change in gloss level as a function of printed density. A viewer can see this as a difference in gloss level as a function of both printed density and colour. Differential Gloss is a well-known phenomenon associated with inkjet[1] and electrophotography prints.[2] Indeed printed matter often displays different reflective and diffusive characteristics depending on the orientation of the incoming light.[3]

In a number of practical situations gloss colour is associated with Differential Gloss. Gloss colour is the effect that is observed when the specular reflection I_S is a different colour to the incident light I_{in}. Images printed with some pigmented inks show this effect. Images printed in black ink can look black by diffuse reflection but silver, gold or green by specular reflection. This phenomenon is sometimes known as "bronzing".

Gloss colour should not be confused with Metamerism. Metamerism occurs when two samples match under one type of illuminant but do not match under another. It is commonly seen with textiles when clothes bought under store lighting don't match when viewed under another light source. It is also a known issue with pigmented inks. Gloss colour is a different phenomenon to metamerism but it is easy to see why these two effects become confused. Whilst metamerism is a change in colour with different illuminant *type* gloss colour is a change in colour with different illuminant *gloss angle*.

Gloss effects can be attribute, artefact or defect, depending on the application. Whilst a uniform high gloss is necessary to give a photo-realistic look gloss effects can find a use in security printing.[7]

Measuring Differential Gloss

The easiest way to measure this is with a gloss meter. The experiments described here used a DR LANGE Refo 3 gloss meter measuring to DIN 67530 / ISO 2813.[5] This measures visually weighted gloss to Illuminant C (representing indirect sunlight). ISO 2813 reference standard A, a sheet of black glass was used to set 100% gloss. DIN 67530 / ISO 2813 allows for measurements of gloss to be made at 3 angles of incidence. The gloss test patterns consisted of CMYKRGB stripes printed with ink coverage in steps of 0, 5, 10, 20, 30 ... 100% in line with published work.[6] The variation of gloss with density can then be measured and plotted as illustrated in Figure 2 from a previous paper.[7] Results such as these can be used to derive metrics of gloss variability.[8]

Initial measurements were made at 3 angles of incidence (20º, 60º and 85º). Only the 20º and 60º measurements were of interest as the 85º results showed little if any correlation with visual perception.

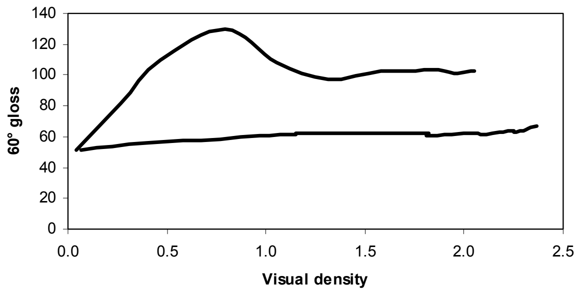

Figure 2. Gloss of 2 black pigmented inks on glossy media

However, in order to investigate these issues further a method to *visualize* differential gloss was required.

Visualising Differential Gloss

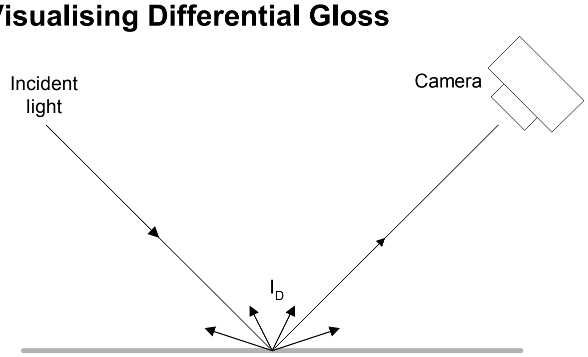

Figure 3. Visualising gloss effects

Following on from published work[9] a simple, pragmatic solution was used, as illustrated in Figure 3. An extended light source (an outside window) was used as this would be a typical "real world" illumination condition. By judicious positioning of the sample various angles of incidence can be selected. The gloss image was acquired using a commercial digital camera, in this case a Canon Powershot A40. Pictures of the 2 step wedges printed with black ink used to construct Figure 2 are illustrated in Figure 4, taken at an angle of incidence close to 60º. For the purpose of this illustration, this image was recorded in monochrome – see below.

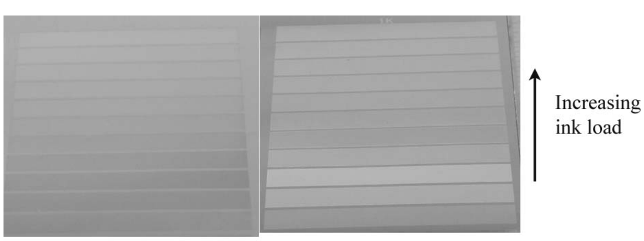

Figure 4. Pictures of the gloss of black ink step wedges

This image shows that the very different gloss behaviours of these 2 black inks can be adequately visualised using the simple apparatus illustrated in Figure 3.

Figure 4 also shows that differential gloss effects can be made machine readable using simple apparatus. This offers the prospect that such effects could be made into overt or covert security features that are machine readable.

Visualising Gloss Colour

The apparatus illustrated in Figure 3 is also very effective in recording gloss colour. This work used a consumer colour digital camera and samples that produce gloss colour can therefore be imaged directly with this apparatus.

One of the samples used to generate Figure 2 and Figure 4 generates gloss colour at certain illumination angles. This is the sample with the highest gloss in Figure 2 and the right hand image in Figure 4. This effect can also be used for machine readability, as illustrated in Figure 5. This shows the gloss image in Figure 4 viewed as separate red, green and blue components. It can be seen that the gloss characteristics are perceptibly different. Once again this raises the possibility that these gloss artefacts could be used as a machine readable security feature.

Measuring Gloss Colour

The images shown in Figure 4 and Figure 5 can be used to generate a crude measure of gloss colour. The digitised images can be analysed in various software programs and CIELAB information generated. However, as consumer digital cameras do not necessarily make good colorimeters an alternative method was sought.

A Pye Unicam PU8800 UV/Visible spectrophotometer was used fitted with a specular reflectance accessory (Part # 9423 179 082521). This accessory allows the specular reflectance of a sample to be measured over the entire visible spectrum over a range of angles of incidence from 10º to 75º. The resulting data could then be used to accurately calculate CIELAB colour data.

Baseline reflectivity was set to 100% on a front surface aluminium mirror and the following spectra were then recorded.

Figure 6 shows the specular reflectance spectra of the black ink used to generate Figure 5, measured at 20, 30 40 and 100% ink loads.

These spectra illustrate the fact that the gloss colour varies with ink load as the curves are substantially different across the spectrum. This makes for an objectionable defect in photographic applications but a potentially valuable attribute in security printing, particularly for machine readability. A colour filter could be used to render the detector sensitive to only one area of the spectrum.

Figure 7 illustrates one further artefact of this system, the issue of angle dependence.

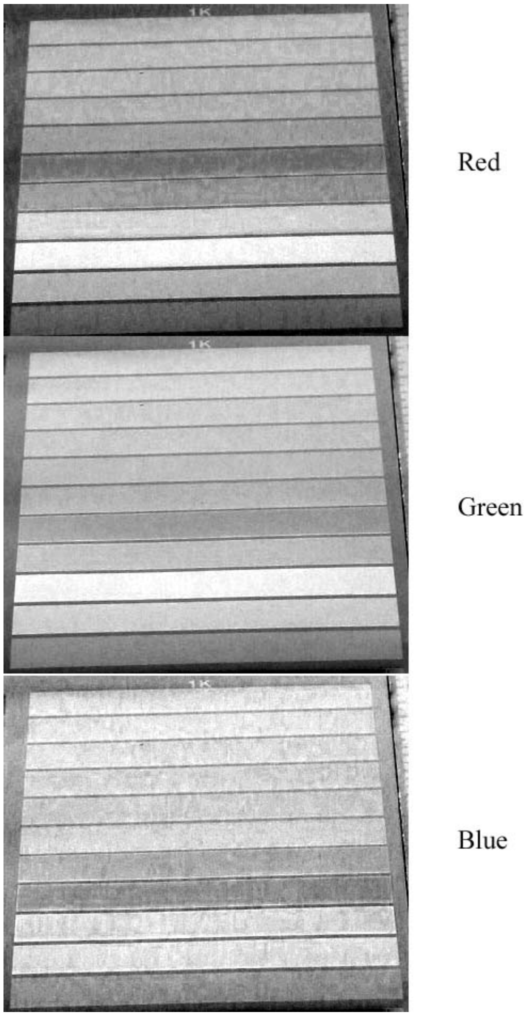

Figure 5. Step wedge gloss imaged in R, G, B

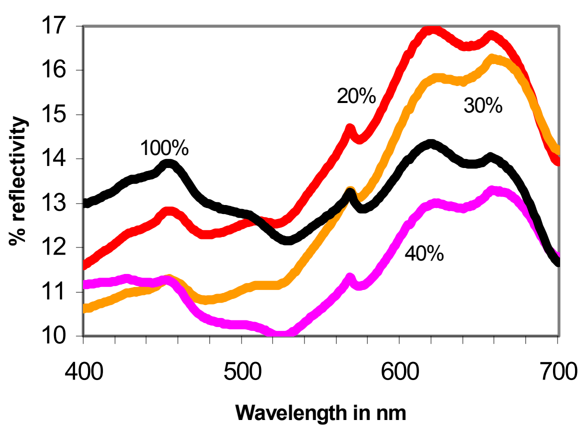

Figure 6. Specular reflectance spectra at 60º

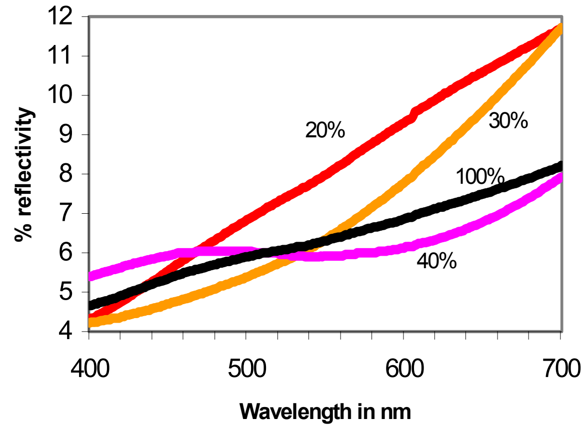

Figure 7. Specular reflectance spectra at 10º

In this case the same samples were measured again, this time at an angle of incidence of 10º. Comparison of Figure 6 and Figure 7 shows that the spectra and the resultant gloss colours are substantially different. Once again, this makes for an objectionable defect in photographic applications but a potentially valuable attribute in security printing as the geometry can be tuned for a particular ink / media machine readable system.

The Use of Gloss Effects in Security

Counterfeiting was once a skilled task. However, with the ready availability of high quality document scanners, PCs and desktop printers it is now comparatively easy to copy various printing techniques previously considered relatively secure.

One way to defeat desktop copying is to embed some machine or visually readable information into the *gloss* of the print. This information is then readable by viewing the gloss information as a specular reflection and as an image separate and distinct from that viewed by diffuse reflection. However a conventional copier or scanner cannot see this specular information.[7] Indeed, these devices are designed to avoid specular reflected light by illuminating at an oblique angle and detecting normally to the print. This is because the specular component normally contains little information of interest and reduces colour saturation.

There are already a number of examples of the use of gloss effects for security applications. One high profile example is the new $20 US banknote, designed to stay one step ahead of counterfeiters. Introduced in May 2003 amongst other security features it contains a “20” that is printed in ink that has a gloss colour that varies with the viewing angle.

Also of interest here is the Xerox Glossmark[3] and clear toner[4] technology. The use of ink jet for gloss effects gives an additional potential solution to the problem of security printing. These technologies can all be used for overt gloss security features but their different attributes enable forensic examination or machine readers to distinguish between them.

The use of gloss effects in this context relies on the fact that inkjet inks can be formulated to give identical colours but different gloss levels. This means that if a print is made using a combination of these inks information can be printed that is readable only in the form of gloss information. It is therefore invisible to the copier and scanner systems mentioned above.

Summary and Conclusions

This paper has described the optics of gloss and gloss colour. Practical ways to measure and visualise differential gloss and gloss colour have also been described with examples. These gloss *artefacts* can be rightly described as *defects* when these systems are used for photo applications but can become *attributes* when applied to security printing. They are particularly applicable to eye and machine readable security systems.

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Author Biography

Alan joined ILFORD Imaging in 1982. After a number of technical support and Sales & Marketing roles his final role was Technical Services Manager at the head office in the UK, covering both traditional silver image and emerging ink jet technologies.

In 2004 he left to become an independent consultant on non-impact printing, specialising in inkjet technology. His particular interests are in image quality and permanence issues and the way in which these can be used as security features.