MEASUREMENT AND VISUAL EVALUATION OF METALLIC GLOSS OF PRINTS.

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Abstract: Metallic gloss is increasingly used for simulating high quality of a product. Since the methods used for producing metallic gloss widely differ, e. g. bronzing, offset, gravure and flexo-printing, they also effect a different appearence. Therefore it is desirable to have a measuring technique at hand the application of which allows to numerically specify the size of the visually perceived metallic gloss. Using gonio-spectrophotometry, it is possible to evaluate colour and lightness of the light reflected from metallic prints at different angles. Plotting the lightness and/or the colour values of the reflected light as a function of the measuring angle results in an indicatrix, the form of which is given by the character and strength of the gloss of prints. Using this measuring technique, metallic gloss can clearly be differrentiated from surface gloss and the ranking of the visually perceived metallic gloss of a variety of printed samples could be confirmed by the measurement results.

Introduction

Metallic effects are increasingly used for printed products because metallic lustre gives an impression of particularly high product quality. There are various techniques for achieving metallic effects. One possibility, with which a very strong effect is achieved, is bronzing. In this process, small flakes of brass or aluminium are dusted or brushed over an adhesive gold primer.

In offset, gravure and flexo printing there are printing inks that contain brass or aluminium powder as pigment in order to achieve a gold or silver effect. Alloys of copper and zinc with increasing zink content are referred to as pale gold, rich-pale gold and rich gold. In the mentioned series the colour of the gold shifts from yellowish to reddish.

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“Gold inks“ without any heavy metals (copper and zink) based on aluminium powder dispersed in the vehicle together with transparent yellow pigment have also been developed.

High surface gloss may be achieved by application of transparent varnishes, so that a smooth upper surface is created evening out the irregularities of the layer. The metallic appearance, on the other hand, is effected through the reflection of light by the metal particles on the surface of a print or in the printed ink layer.

A generally applicable and reliable method that would allow the measurements obtained from metallic samples to be numerically ranked in accordance with the visual perception is currently not available. Therefore, after investigation of the surface properties of different kinds of metallic prints and their reflection behaviour a research project was carried out to develop an assessment method for metallic lustre.

Method of evaluation

Goniospectrophotometer

A gonio-spectrophotometer (Fig. 1) was used for the measurement of metallic lustre. This fibre optic equipped device enables the reflexion spectrum of the samples to be measured across a broad range of angles of illumination and measurement. The samples were each illuminated at angles of 30°, 45° and 60°, and the spectral values were measured and recorded at angles between 0° and 75° in steps of 5° (Fif. 2).

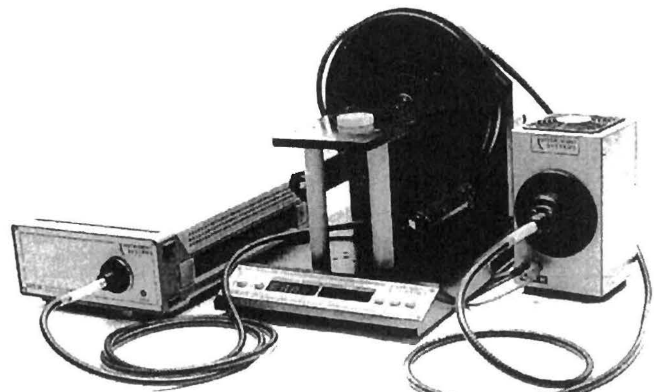

Figure 1: Gonio-spectrophotometer (Instrument systems Inc.)

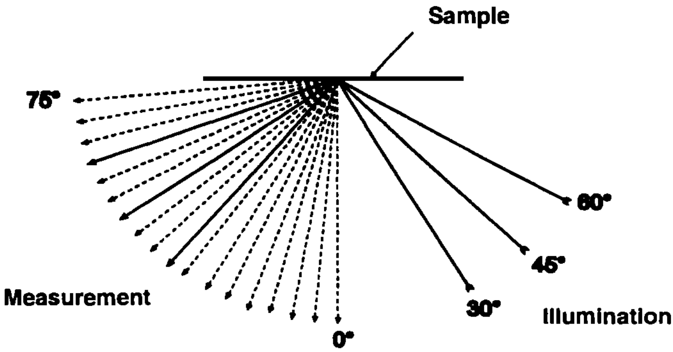

Figure 2: Illumination and measurement geometry of the gonio-spectrophotometer

Colourimetry

The colorimetric assessment of metallic prints primarily differs from that of process colours in that one cannot use the "ideal white diffuser" as the reference for colour assessment, as in conventional colour measurement of prints using a 45°/0° or sphere measurement geometry. The reason for this stems from the need to measure the light reflected by the metallic print at the angle of reflection, and that this is many times brighter than the light scattered by a white diffuser. Therefore, the spectral curve produced by the light source and measurement system is used as the reference to define 100 % reflection (Fig. 3).

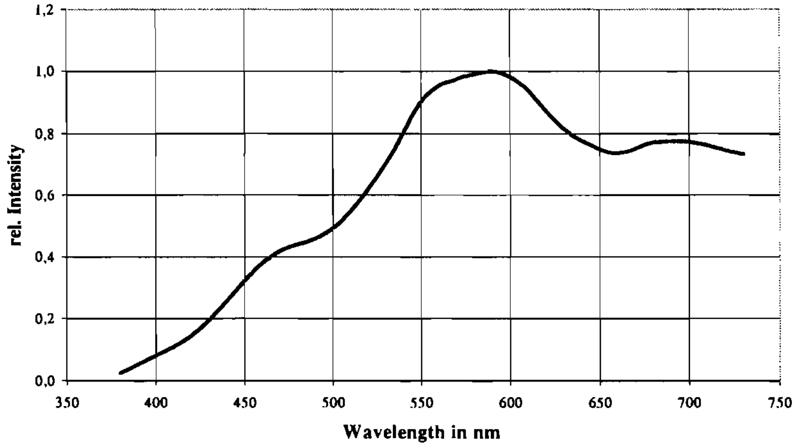

Figure 3: Reference curve of the illumination and detection system of the goniospectrophotometer

After measurement of each individual metallic print sample at different illumination and measuring angles the spectral data was evaluated with reference to this spectral curve and in a first approximation the X,Y,Z tristimulus values of the CIEXYZ colour space were calculated. In a second step the L*,a*,b* values of the uniform CIELAB colour system werde calulated from these tristimulus values and used for specifying the colour of the light reflected from the metallic prints, since this system turned out to be highly suitable for clearly revealing the different factors that influence metallic lustre.

Microstructure of metallic print surface

In the following a selection of micrographs of the surfaces of different metallic prints is shown together with the indicatrices obtained from these prints.

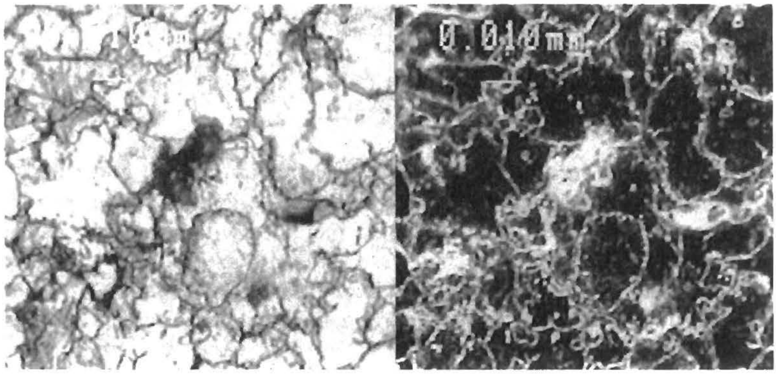

Figure 4: Micrograph of bronzed rich gold print under different angles of illumination (left 0°, right 45°)

Fifure 4 shows micrographs of the surfaces of bronzed rich gold. The flake like structure of the leaving pigment can clearly be seen, and one may look at these flakes as small individual mirrors that create the high metallic lustre. The micrographs were taken under both perpendicular illumination (left) and at an angle of 45° (right), in order to reveal differences in reflection by the pigment particles, which are related to their arrangement. When illuminated at 45° the metal flakes appear dark, since their predominantly horizontal arrangement causes the light to be reflected at an angle that misses the aperture of the sensor.

Lightness

Plotting the lightness L* as a function of the measurement angle records the reflection behaviour of the surface as perceived by the eye and produces a lustre curve that is termed an "indicatrix". This shows how bright a sample would appear to the eye for a particular angle of illumination and measurement. A lustre curve is characterized by its height and half width.

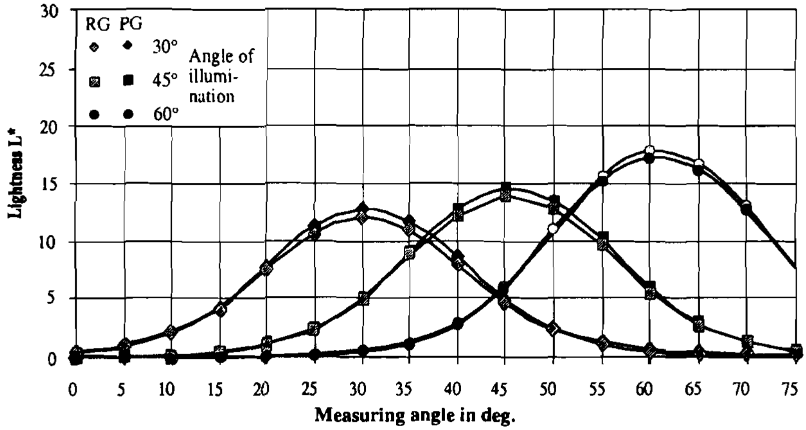

Figure 5: Lustre curves (lightness L*) for bronzed rich gold (RG) and pale gold (PG) prints at different illumination angles

Fig. 5 shows lustre curves (lightness L*) measured at three different angles of illumination for bronzed prints of rich gold and pale gold. As usual for gloss measurements the peak height of the curve increases with increasing angle of illumination. However, the lustre curves are comparatively broad. The high half width may be looked at as a consequence of the surface structure of bronzed prints. The pigment flakes mentioned above act as individual mirrors and vary a little in their alignment, so that the light is reflected very effectively from the surface but over a broad range of angles.

The almost identical curves for the greenish yellow rich gold and the reddish pale gold shows that it is primarily the alignment of the metal pigment particles and the associated surface structure of the print that is responsible for the reflection behaviour.

Colours

Plotting the respective colour values a* and b* as a function of the measurement angle results in colour indicatrices. The a* indicatrix shows the change in the red/green component, and the b* indicatrix shows the change in the yellow/blue component of the samples when measured at different angles of reflection.

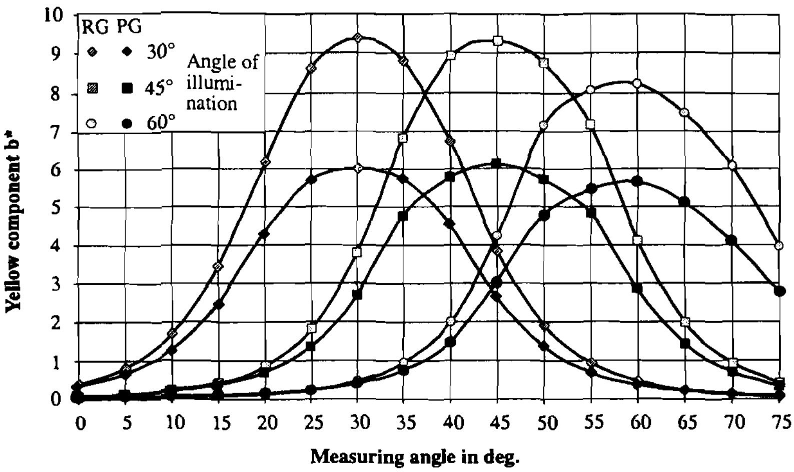

Figure 6: Colour indicatrices (yellow component b*) for bronzed rich gold (RG) and pale gold (PG) prints at different agles of illumination

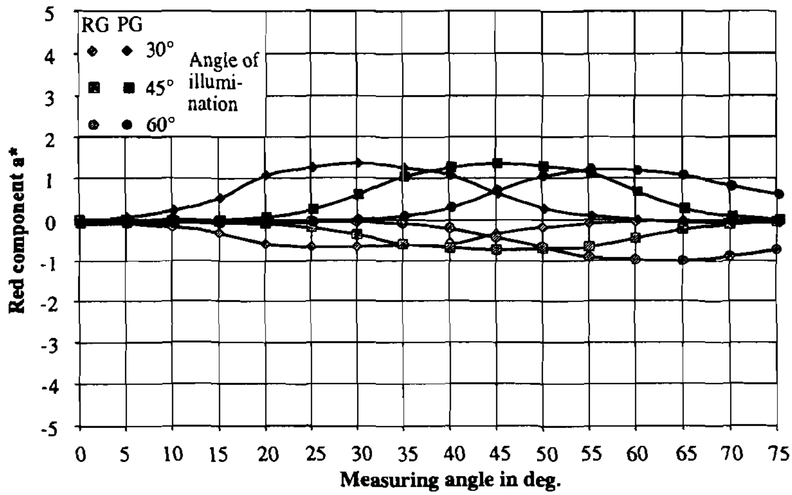

Figure 7: Colour indicatrices (red component a*) for bronzed rich gold (RG) and pale gold (PG) prints at different illumination angles

The indicatrices for the yellow component b* of a bronzed rich gold print and a pale gold print differ only slightly for the three different angles of illumination (Fig. 6). Similar as the lustre curves (Fig 5) the colour indicatrices display a broad maximum which is an indication that at either side of the gloss angle, the chromaticity of the lustre light changes little and distinctly diminishes only at greater distances from the gloss angle .

The colour indicatrices of the red component a* (Fig. 7) for rich gold are very slightly negative as a result of the somewhat greenish yellow. In contrast, the colour-indicatrices for the reddish pale gold display higher values in the red component a*, as expected.

Corresponding measurements for rich-pale gold and silver in principal gave similar results.

Offset prints

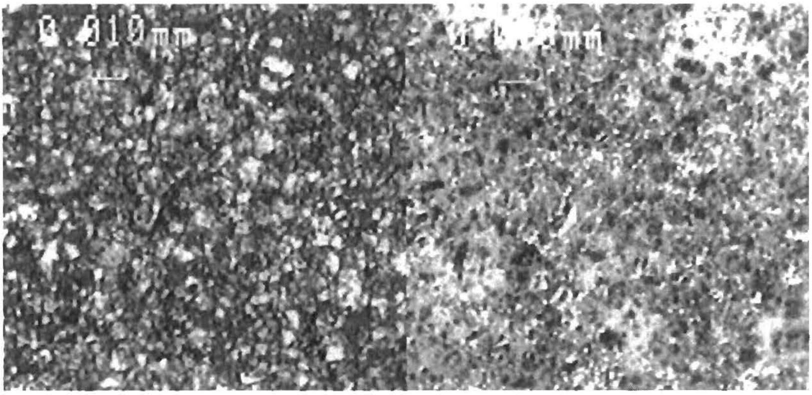

Figure 8: Micrograph of a rich gold offset print under different angles of illumination (left 0°, right 45°)

In the offset printed rich gold sample (Fig. 8) the pigment particles are much smaller than the leaving pigments shown in the previous micrograph. Some of them are positioned in a manner that allows them to act as mirrors with the given direction of illumination and observation of the microscope, and therefore give a metallic lustre even at the 0° observation angle. On the other hand, the horizontally arranged pigment particles that create a metallic lustre when the sample is observed at the angle of reflection, appear dark when illuminated from 45°. In addition, the offset prints show quite areas of paper, which means that the coverage of the surface is clearly poorer here than with the bronzed print.

Scanning electron microscopy

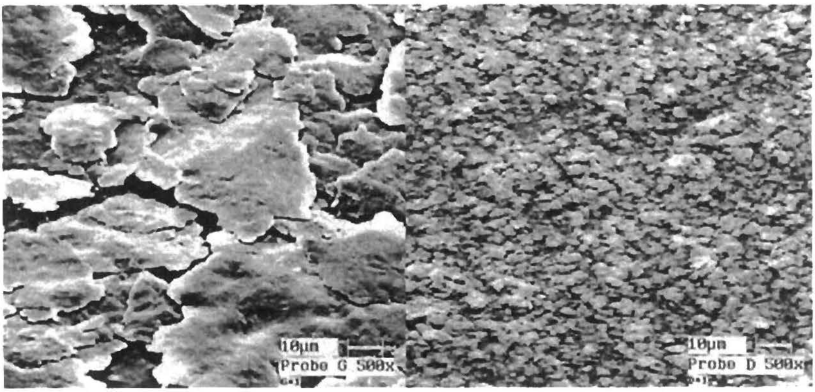

Figure 9: Scanning electron micrograph of a bronzed (left) and of an offset print (right)

Scanning electron micrographs of the same surfaces (Fig. 9) reveal essentially the same structures as the light micrographs, but the surface and arrangement of the flake like leaving pigments in the bronzed print and the very much smaller pigments as well as the uncovered areas of the offset print.

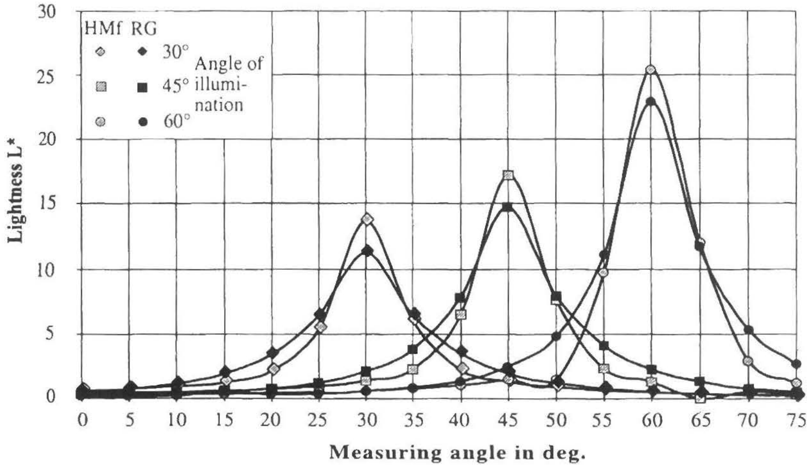

Figure 10: Lustre curves (lightness L*) of rich gold (RG) and offset prints with heavy metal free (HMf) ink at different angles of illumination

Fig. 10 shows the lustre curves of of rich gold and heavy metal free (HMf) inks printed in offset. The metallic lustre of both is visually classified as middle to weak. It can be seen that compared to the bronzed prints, which are visually classed as having a high metallic lustre, the lustre curves reach a high peak but are not as wide as those of the bronzed prints.

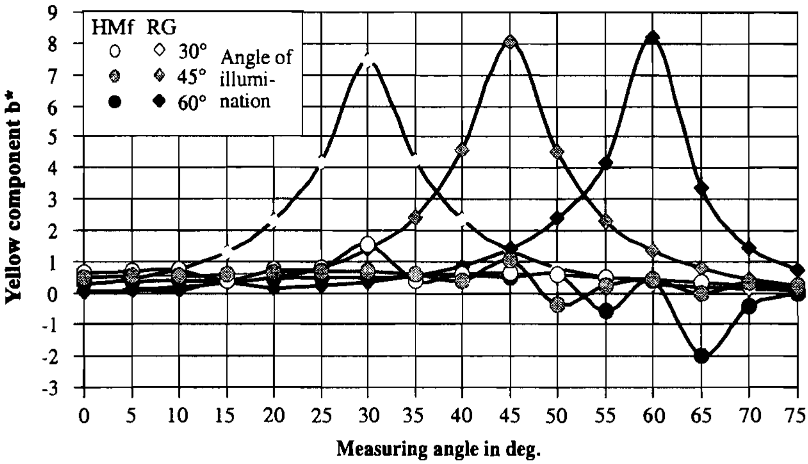

Figure 11: Colour indicatices (yellow component b*) of offset prints of rich gold (RG) and heavy metal free (HMf) ink at different angles of illumination

Looking at the colour indicatrices of the yellow component b* for of rich gold offset prints (Figure 11) displays rather high values of b* at the gloss angle that fall away steeply on either side of the gloss angle.

The yellow component b* of the lustre light of the print with heavy metal free ink, on the other hand, displays very low values of b* which means that lustre light reflected by these prints displays very little of the yellow character of the gold lustre. This permits the conclusion that the lustre curves in Fig. 9 are overwhelmingly due to the surface gloss resulting from the vehicle and paper. This is confirmed by the fact that, with an angle of incidence of 60°, the maximum reflexion amounts to 3,8 % which almost corresponds to the highest possible reflexion due to surface gloss of a transparent reflector (e. g. glass).

Laboratory prints

Ink layer thickness

The influence of the printed ink layer thickness on the visually perceivable metallic lustre was investigated by means of printed samples with a range of known different ink layer thicknesses produced with the help of a prüfbau printability tester. Fig. 12 shows a selection of these printed samples.

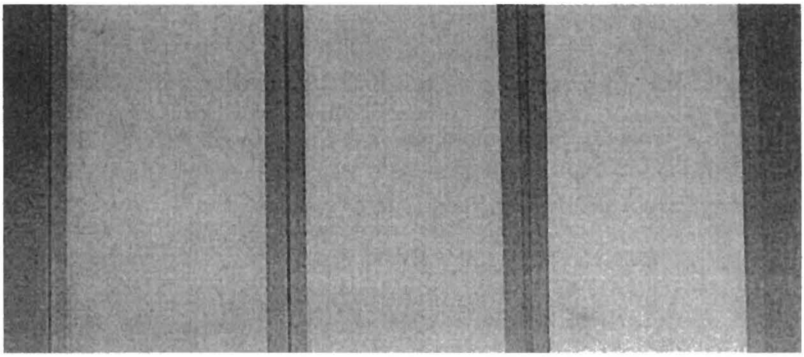

Figure 12: Rich gold laboratory print samples with varying ink layer thickness (left 0.8 μm, middle 1.0 μm, right 1.9 μm)

Apparently these printed samples display a very similar metallic lustre at the gloss angle despite considerable differences in the ink layer thickness. If the samples are declined to such a degree that the observation is made outside the gloss angle the chromaticity of the reflected yellow light clearly decreases with lower ink layer thickness. Under these conditions of observation the samples with thick ink layers are dark yellow to brownish, the samples with thin layers appear increasingly grey (achromatic).

Fig. 13 shows micrographs of the laboratory prints of rich gold ink printed at an ink layer thickness of 0.8 μm and 1.9 μm resp. on a gloss coated paper. As was to be expected, the thinner ink layer show greater gaps in the ink coverage.

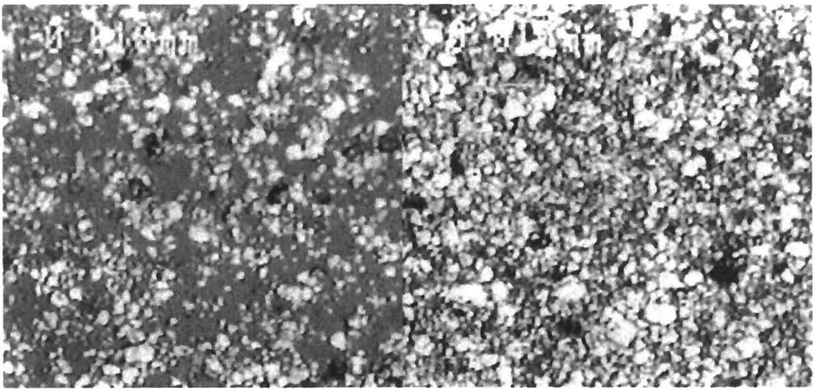

Figure 13: Micrograph of rich gold laboratory prints with different ink layer thickness (left 0.8 µm, right 1.9 µm)

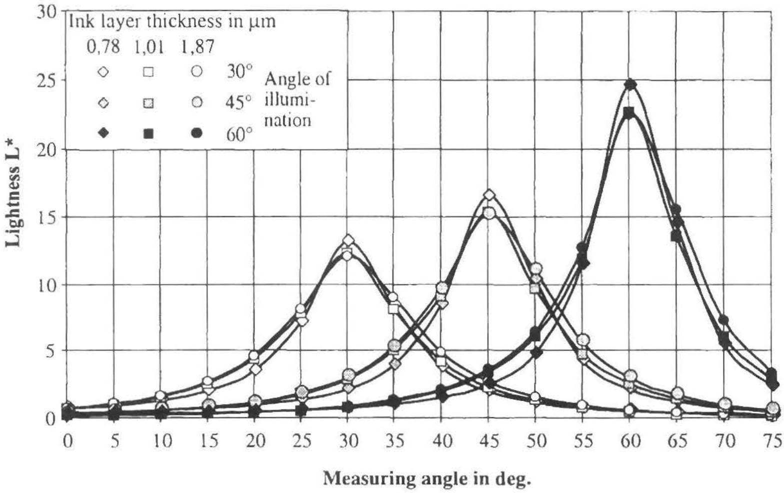

Figure 13: Lustre curves (lightness L*) of rich gold laboratory prints with varying ink layer thickness at different angles of illumination

Looking at the lustre curves of the rich gold samples with thin, medium and thick ink layers they differ only slightly although the ink layer thickness varies across a very wide range. This corresponds to the visual perception shown above. The printed samples with 1.0 µm and 1.9 µm thick ink layers display no differences in the height of the lustre curve, whilst the curve for the thinner ink layer is somewhat higher. The narrow form of the lustre curves, which is similar to that of offset prints (Fig. 10), again points to the influence of the surface gloss, which is caused by the vehicle of the ink layer and the paper background rather than by the metallic pigment. With decreasing coverage of the background, that is with a thinner ink layer, the surface gloss of the paper obviously contributes to a slight increase in the surface gloss.

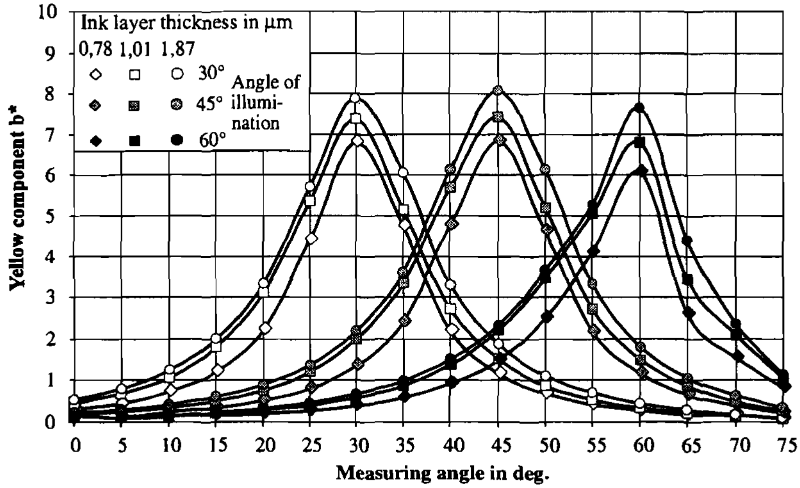

Figure 15: Colour indicatrices (yellow component b*) of rich gold laboratory prints with varying ink layer thickness at different angles of illumination

In the colour indicatrix for the yellow component b* (Fig. 15) the influence of the ink layer thickness is clearer than for the lightness (Fig. 14). Here the yellow component increases with increasing ink layer thickness not only when measured at the gloss angle but also on either side of the gloss angle.

Visual assessment of metallic lustre

The prints shown above were also examined or classified for the strength of the perceived metallic lustre. The comparative examination or classification was carried out at a reading distance under largely diffuse illumination from a colour matching lamp (Just Inc.) and at the sample's maximum angle of reflection.

The samples were ranked as follows on the basis of the strength of the visually perceived metallic lustre.

1. Polished metal plates
2. Bronzed prints
3. Laboratory prints with high ink layer thickness of metal decorating ink
4. Laboratory prints with low ink layer thickness of metal decorating ink
5. Offset prints with metal decorating ink
6. Laboratory prints with heavy metal free ink.

The ranking of the strength of the metallic lustre is independent of the "colour" of the metallic print, that is from silver to rich gold, rich-pale gold, and pale gold to copper.

Conclusions

The metallic lustre that is perceived most strongly by the eye is produced by bronzing, in which the flake like leaving pigments act as mirrors and completely cover the background. The metallic lustre produced by offset printing with metal decorating inks is less strong. This is because the coverage of the background by the smaller pigment particles is less complete and because the metallic lustre is superposed by the surface gloss of prints. The latter also provides an explanation for the observation that subsequent varnishing reduces the metallic effect of printed products.

Whereas surface gloss of colour prints originates from reflexion of the illuminating light by the vehicle film of the printed ink layer as well as the paper surface, metallic lustre is characterized by the fact that the light reflected has the colour of the metal, for example brass yellow or copper red. Therefore, lightness and, except for silver prints, the colour of the reflected light characterize the strength of the perceived metallic lustre.

The eye clearly perceives the metallic effect more strongly with diffuse illumination than with directed illumination.

Both, the surface gloss and the metallic lustre can be assessed by means of an indicatrix. The brightness of the metallic lustre can be colorimetrically characterized by the trisimulus value Y or the L* value in the visually uniform CIELAB space. With the exception of silver lustre, the colour of metallic lustre can be evaluated by means of a colour indicatrix (red component a* or yellow component b*).

An indicatrix is characterized by its peak height and its half width which are closely linked to each other in the transition from polished metals to metallic prints. Both values are to be included in the metric assessment of metallic lustre.

The simplest solution is to multiply them to produce a value termed *F*, which provides an approximate measure of the area enclosed by the curve. The *F* values evaluated in this way for various metals and metallic prints and substrates are shown in Table 1. Their values, or rather the ranking of their values is a good match for the classification of the visually perceived metallic lustre of the individual samples.

Sample	**Metallic lustre *F***
Polished brass	546
Polished copper	471
Bronzed rich gold	460
Bronzed pale gold	460
Laboratory gold print, thick layer	325
Laboratory gold print, thin layer	235
Rich gold offset print	228
Heavy metal free offset gold print	191
Vehicle (for metal dec. ink)*	158
Gloss coated paper*	155

* for comparison only

Table 1: Metallic lustre *F* of various printed products