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To meet the need for a high quality scientific publishing platform in its field, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries is publishing a quarterly peer-reviewed research journal.

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A letter from the Editor

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The first issue of the Journal in 2017 is published with some delay and in slightly more modest volume of the pages as usual, with only three research papers published. Attentive readers will notice some changes in typography and design. The Cambria font was chosen, since it provides better legibility on screen, thus fewer problems are expected, specially when writing equations in MS Word Equation Editor program, where very similar Cambria Math is used as default font. The lay-out was also slightly redesigned, changed and improved, so it is now closer to generally established typographic rules.

Small, but significant changes have been introduced in the Guidelines for Authors. I would like to emphasize the respect for ethical rules in the field of publishing in scientific journals. Widely internationally accepted ethical standards adopted by the Committee on Publication Ethics (COPE), whose members are the most important publishers of scientific journals – including Springer, whose ethical rules were taken into account so far – are now accepted as a set of ethical rules also for the Journal of Print and Media Technology Research. The COPE guidelines for authors, peer reviewers and editors, available at <https://publicationethics.org/resources/guidelines> are the backbone of ethical scientific research and publishing of the research results. A brief summary of these rules is published in the Guidelines for Authors of the Journal, so we may reasonably hope and expect that basic ethical standards will be consistently taken into account by the authors, peer reviewers, editors and all those who are in any way linked to the research and publication of their results. Firmly established ethical standards are a prerequisite for recognition of the Journal and its classification in the list of scientific journals.

Similarly, an important part of each article is an overview of the theoretical background from previous publications and research results of other authors, which is evident from the references. At the Journal, the Harvard system of referencing is used, which exists in several versions. During editing we have been leaning on the version used by the Anglia Ruskin University, and now we have also obtained their consent for the use of the *Guide to Harvard style of Referencing, 6th edition*, 2016, available at <https://libweb.anglia.ac.uk/referencing/files/Harvard_referencing_2016.pdf> for further and consistent use.

The application of a uniform system of referencing enables the access and processing of the bibliographic data from the references that allows evaluation and classification of the Journal as an important source in the research field of print and media technology. The Journal is currently listed in several national and international lists of scientific journals, but also it is in the evaluation process at Scopus and Web of Science, which calculate and publish important and in academic circles internationally and well known Journal Impact Factor. Only the quality of the papers published in the Journal, their citation frequency in other recognized scientific journals and citations of the papers from the Journal in other Journals can improve the positioning of the Journal in different indexing systems.

The currently published research papers have dealt with challenges in the field of quality of printed holograms, print quality and accuracy of colour reproduction and the use of statistical methods for evaluation of varnish for textured effect. They have a common approach in objective evaluation of the quality of prints and their effect on the observer – the end user, using a variety of measurement and statistical methods. Improvement of the quality of prints and analysis of user experience is a research area that remains interesting together with the dominant direction of research in the fields of printed electronics, functional printing and 3D printing.

Associated editor Markéta Držková (marketa.drzkova@jpmtr.org) has again prepared an overview of innovations in the field, including the review of developments relating to drupa fair, new patents and interesting books within the areas of nano-materials, infographics, colour reproduction, packaging and from other areas of printing technology. In the academic Bookshelf three doctoral theses are presented, all in the field of printed electronics and sensors, which is obviously a very topical research area. The review of events shows on the intense interest for cooperation and knowledge exchange of the professionals and researchers from the industry and academic institutions in the field.

The Journal of Print and Media Technology Research is the leading international publication in the field, even though it does not reach recognition comparable to established journals from the border areas in papermaking industry, colour science, imaging, packaging and advanced materials. Finally, recognition and inclusion on the lists of recognized journals can only be achieved in cooperation, particularly through the publication of high-quality scientific and research papers that will be referenced and cited in other journals. Call for papers is open and I hope that more authors will decide for submissions to the Journal, giving us, editors and reviewers an opportunity for fast and high-quality publication.

Ljubljana, April 2017

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Quality control of embossed holograms by measuring gloss and color values

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Abstract

Embossed holograms are increasingly often used for the decorative refinement of printed products. So far, there has not been much scientific research about quality control of embossed holograms as well as research about the influence of the background color on the quality of embossed holograms. For this purpose, hologram samples with different background colors were produced in a laboratory setup, using the principle of UV embossing. At first, the quality of the samples was evaluated through a visual experiment. The conceptual design of that experiment was part of this research. Second, gloss and color values were measured with conventional hand-held measuring instruments used by the graphics industry. Color measurements were conducted with an X-Rite MA98 multi-angle spectrophotometer and measurements of gloss values with a BYK micro-TRI-gloss gloss meter. The comparison of the results of the visual experiment and the color measurement led to the conclusion that conventional color measuring instruments can evaluate the influence of the background color on the quality of embossed holograms. It was found out that calculating the color difference ΔE^*_{ab} between background color and sample can be used to recreate the results of the visual experiment, whereas the samples' chroma C^*_{ab} is not suitable for evaluating the influence of the background color. The number of provided measuring geometries is a limitation of this approach. Moreover, the comparison of the results of the visual experiment and the gloss measurements showed that conventional gloss meters cannot evaluate the influence of the background color. However, conclusions concerning the UV embossing process can be drawn from a sample's gloss. This suggests the usage of gloss measurement for process control.

Keywords: micro embossing, UV curing, visual experiment, nickel shim, multi-angle color measurements

1. Introduction

Embossed holograms are well known from banknotes, identification cards or other security documents where they serve as complex anti-counterfeit elements, but they are also used for decorative refinement, e. g. for the refinement of product packaging. Production processes for embossed holograms have become high-speed mass production processes. Consequently, a need for quality control arises.

Another reason for an upcoming need for quality control is the following. For some years, a new scope for design is available through the production process UV embossing, which allows the choice of an arbitrary background color for the embossed hologram (Masuda, 2006). Before this, only metallic background colors were possible, which provide the desired brilliant effect of the classical embossed hologram. The free choice of the background color opens up new possibilities but also new challenges. Which background color can be used to achieve a strong holographic effect? How can the quality of an embossed hologram be measured?

So far, there has not been much scientific research about quality control of embossed holograms and the influence of the background color. In general, one can say that quality control of holograms is difficult because of the great angle-dependency of the holographic effect. Similar difficulties can be found when investigating effect coatings (Hupp and Dörsam, 2007; Kehren, Dörsam and Hupp, 2009).

The goal of this research is to find out, if conventional hand-held measuring instruments for gloss and color values used by the graphic industry can evaluate the quality of embossed holograms. A part of the research was presented at the 43rd International Research Conference of iarigai held in Toronto, Canada (Brumm et al., 2016).

For this research, several experiments are conducted (section 2). We prepare hologram samples with different background colors in section 2.1 and conduct a visual experiment, which has the aim to evaluate the samples' quality, in section 2.2. The development of the visual experiment is also part of this research. In section 2.3, we conduct gloss and color measurements and in section 3, the results of the visual experiment and the measurements are presented and compared to each other. Finally, conclusions are drawn in section 4.

2. Experimental

2.1 Sample preparation

This chapter is about the production of hologram samples with different background colors, using the principle of UV embossing.

2.1.1 Pre-printed substrates

Five types of pre-printed substrates in the colors blue, red, black, white and silver with a size of approximately 135 mm × 330 mm were used (Figure 1).

For the blue, red, black and white pre-printed substrates, Fasson MC Offset 2S-90 (SV4565) with a thickness of 71 µm and grammage of 90 g/m^2 was used as paper substrate. For the UV coating, Saphira UV-Coating U8730 (Heidelberger Druckmaschinen AG) was used. The silver pre-printed substrate differs from the others, because it is produced by cold foil transfer using silver cold foil. Moreover, another paper substrate with a grammage around 180 g/m^2 was used. Table 1 shows CIELAB color values and gloss values (measured in GU-gloss units) of the five types of pre-printed substrates.

2.1.2 Embossing master

To produce an embossing master, we poured a conventional transparent silicone onto a nickel shim (Iliescu, Necşoiu and Comănescu, 2011) and then hardened it in an oven (Vötsch Industrietechnik VTL 60/90) at 42 °C for about three hours. Afterwards, we left it at room temperature for about 60 hours, before gently peeling of the replica (Figure 2). Thus, we produced a transparent silicone shim (thickness approximately 3 mm), which we later used as an embossing master for the UV embossing of our hologram samples.

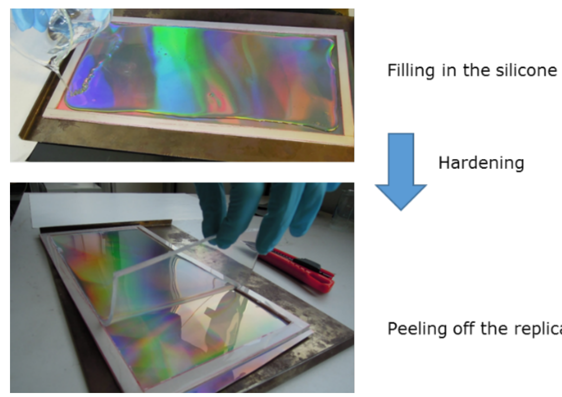

Figure 2: Production of transparent silicone shim

There do not exist clear specifications for nickel shims. They are chosen by visual characteristics like the 'rainbow effect'. We used a commercially available 'rainbow effect' nickel shim, provided by Heidelberger Druckmaschinen AG. It has a double sine wave surface microstructure that creates a rainbow effect due to light diffraction. That means that in different viewing angles different colors of the rainbow (red, orange, yellow, green and blue) appear. We chose the rainbow effect, because it is a simple holographic effect, which is the base of many complex embossed holograms. The depth of the surface microstructures is approximately 130 nm to 140 nm and the period length is approximately 1.02 µm in one direction and approximately 1.25 µm in the perpendicular direction. We measured these values with an atomic force microscope (Nanosurf Nanite

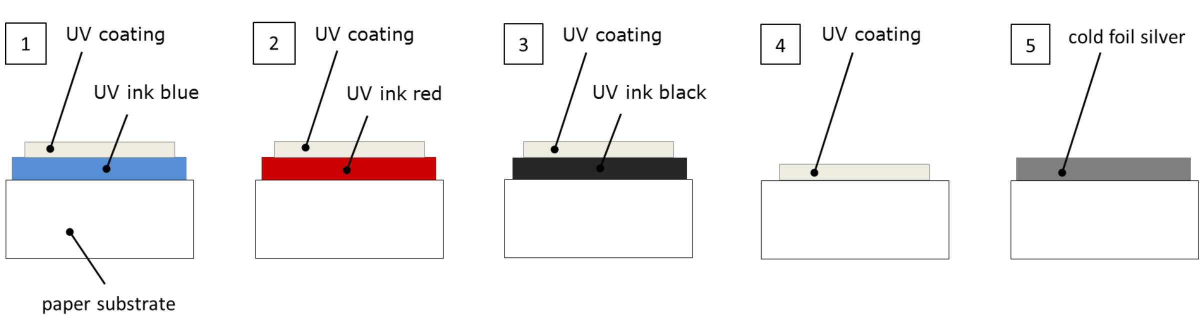

Figure 1: Types of pre-printed substrates. 1 – Blue, 2 – Red, 3 – Black, 4 – White, 5 – Silver

Table 1: CIELAB color values L, a* and b* of pre-printed substrates (X-Rite MA98, measuring geometry 45°/0°, illumination D65, 10° observer, n = 10) and gloss values of pre-printed substrates (BYK micro-TRI-gloss, 20° and 60° measuring angle, n = 10) measured on one pre-printed substrate*

Pre-printed substrate	*L**	*a**	*b**	Gloss (GU)	
				20°	60°
Red	31.3	61.9	40.2	57.3	91.4
Blue	31.2	−15.2	−44.9	45.2	83.9
Black	7.4	−0.1	−1.8	49.6	91.3
Silver	12.8	−0.6	−3.4	1056.7	669.8
White	88.1	−0.2	−0.9	60.1	93.9

B System). Since direct measurements on the nickel shim are technically difficult, we measured the surface structure of one of our hologram samples, which theoretically shows the identical surface structure of the nickel shim.

2.1.3 UV embossing

For the production of our hologram samples, we used the principle of UV embossing (Figure 3). To produce one hologram sample, we coated one of the pre-printed substrates with UV lacquer (holographic lacquer from Heidelberger Druckmaschinen AG) using an automatic film applicator coater (Zehntner ZAA 2300) and a doctor blade (Zehntner ZUA 2000) with the gap height of 50 µm. Then, our transparent silicone shim was pressed into the still wet UV lacquer and exposed to UV light, using an UV curing system (IST Metz M-40-1-URS-WIR-TR-SLC). Lastly, the transparent silicone shim was removed. Before using the transparent silicone shim again, we cleaned it from UV lacquer residuals with a strip of strong adhesive tape.

For each type of pre-printed substrate (background color blue, red, black, white and silver), ten hologram samples were produced and numbered in the order of their production (sample #1, #2, #3, ... #10). Preliminary tests had shown that each silicone shim could only be used 12 times on average for UV embossing before it becomes brittle and eventually gets torn. In the following, this behavior is referred to as the aging of the silicone shim. A similar behavior is known from Theopold et al. (2012) where the influence of solvents on flexo printing forms is investigated. Fine cracks already appeared after approximately eight times of use and could be detected in the sample surface as well (Figure 4). For this reason, we used a new silicone shim (100 mm × 140 mm) of the same properties for each background color.

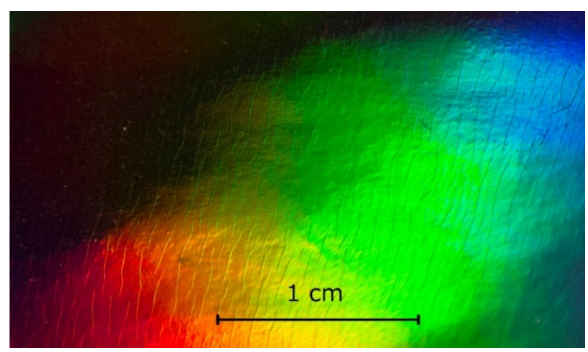

Figure 4: Cracks in the surface of black sample #10

We would like to emphasize that we prepared the hologram samples in a laboratory setup. There also exists an industrial process for the UV embossing of holograms,

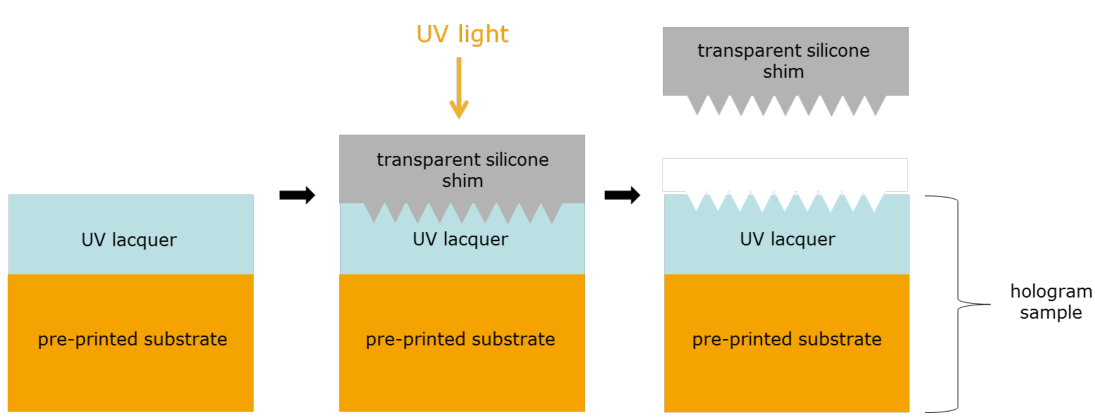

Figure 3: UV embossing of hologram samples

which is commercially referred to as 'UV Casting'. Other names are 'UV Film Casting' or 'Cast and Cure'. Instead of using a transparent silicone shim as in this research paper, the industrial UV embossing process uses a transparent plastic film which has a transparent lacquer coating with imprinted micro- or nanostructures on one side (Kaule and Grauvogl, 1999). It is to mention that the contact time of embossing master and UV lacquer is much shorter in the industrial UV embossing process than in our laboratory flatbed setup.

2.2 Visual experiment

There hardly exist any scientific approaches for the visual inspection of embossed holograms, yet. For this reason, we developed our own visual experiment.

2.2.1 Equipment

Samples #1 and #10 of each background color were used. For better handling and a uniform look, a black frame (70 mm × 70 mm window size) made from cardboard was added to each sample. Besides, we used a viewing booth Macbeth SpectraLight III covered with black velvet inside, a self-made sample display, which can be tilted ± 5° around its basic adjustment of 45° to the horizontal (Figure 5), and a chin rest.

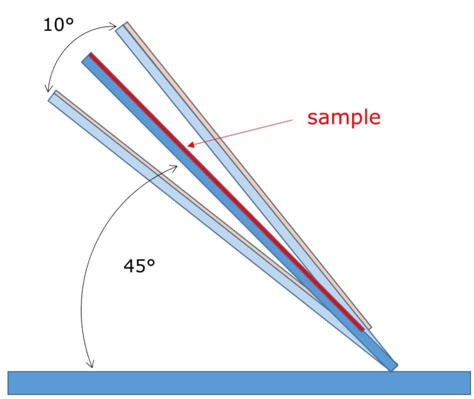

Figure 5: Sample display

2.2.2 Assessment criteria

Aiming to evaluate the quality of our samples, we first had to find appropriate assessment criteria. To start with, the reader needs to know that embossed holograms produced by UV embossing – like our hologram samples – are rather used for decorative refinement than for security applications. This is due to their easily damageable open holographic structure. Often, the purpose of decorative refinement is to attract the viewer's attention. Presuming that quality is the fitness for a special purpose (Teschner, 2010), we therefore assume that the samples' quality depends on certain sample properties that are responsible to attract the viewer's attention, e. g. color properties.

In this research, we choose the sample properties 'intensity' and 'variety of colors' as assessment criteria for our samples' quality, assuming that great intensity and great variety of colors notably attract the viewer's attention. Please note that the visual experiment is conducted in German language, using the German terms 'Leuchtkraft' (intensity) and 'Farbvielfalt' (variety of colors) as assessment criteria, whereby the German and English expressions may have slightly different meanings.

2.2.3 Subjects

26 test persons participated in this research, 17 of them male and 9 female, from age 22 to 65 (average 32). All were normal or corrected-to-normal sighted. No color vision deficiencies were found according to the Farnsworth-Munsell 100 Hue Color Vision Test. Ten of the test persons were classified as experts, which have experience in colorimetry or visual experiments.

2.2.4 Procedure

The experiment is part of a broad series of visual experiments. Only the experiments directly relevant to the topic of this research paper are described further. All visual experiments are conducted in the so-called 'Black Room' at the Institute of Printing Science and Technology, Darmstadt, Germany. This room is almost entirely furnished black, so that as little scattered light as possible gets into the viewing booth. The viewing situation in the viewing booth is shown in Figure 6.

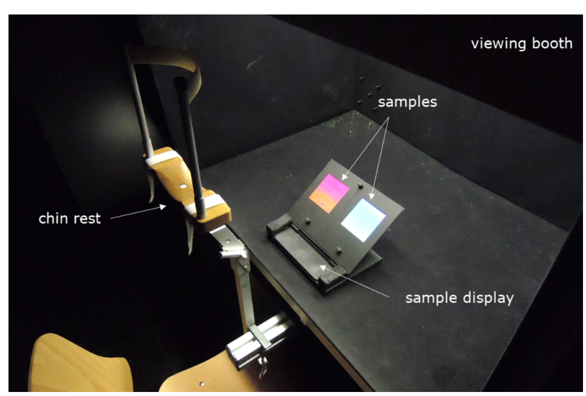

Figure 6: Viewing situation in the viewing booth

To create a ranking of the different samples, paired comparisons are conducted. We chose this approach, because the human eye is better in comparing simultaneously than successively (Hunter and Harold, 1987). The order of the paired comparisons and the samples' arrangement on the sample display is random.

In the first experiment, each sample #1 is compared to every other sample #1 with respect to intensity and variety of color, which means that ten comparisons must be done by each test person. The sample with the highest intensity scores one point and the sample with the highest variety of color scores one as well. In Figure 7, you see a scene from the first experiment from the view of a test person.

Figure 7: First experiment from the view of a test person (exemplary scene; left – red sample #1, and right – silver sample #1)

In the second experiment, sample #1 and sample #10 of the same background color are being compared. The test persons must decide, whether they see a difference between the two samples and if yes, they shall describe it. They do not know which is #1 and which is #10. The purpose of this experiment is to find out if the quality of the samples is visibly changing within the production process.

In both experiments, the test persons were told to tilt the sample display back and forth several times so that they could see the rainbow effect in its full range. At this point, we want to emphasize that the test persons were always asked to compare solely the samples' rainbow effect and not their background colors. Besides, all test persons were told to decide spontaneously and subjectively. All instructions to the test persons were given orally.

2.2.5 Illumination and geometry

The first experiment was conducted twice, once with illuminant TL84 and once with illuminant D65 aiming to simulate the viewing conditions in a shopping mall (TL84) and in daylight (D65). Both illuminants are built into the Macbeth SpectraLight III viewing booth by default. The second experiment was conducted with illuminant TL84 only.

The height of the chin rest, where the test persons had to lay their chin on during all experiments, and the position of the sample display within the viewing booth determine the geometry of the visual experiment. The experimental setup was chosen so that the light of the selected illuminant strikes the sample approximately at an incident angle of 45° to the sample's normal and the emergent angle is approximately 0° to the sample's normal (45°/0°). We chose this geometry according to the recommendation of the nickel shim manufacturer. Of course, the viewing geometry changes by the tilting of the sample display in its tilting limits. To create a reproducible visual experiment, we preferred this relatively specified geometry to a free geometry.

2.3 Measurements

For the measurements of gloss and color values, we used conventional hand-held measuring instruments used by the graphic industry. All samples (sample #1 to #10) of each background color were measured.

For the gloss measurements, we used the following equipment: gloss meter BYK micro-TRI-gloss, software Easy-Link for data handling and black cardboard as a measuring underlay. We measured each sample ten times on random spots (measuring angles 20°, 60° and 85°). The measuring instrument was always oriented longitudinal to the sample to eliminate possible anisotropy.

The following equipment was used for the color measurements: multi-angle spectrophotometer X-Rite MA98, software X-Color QC for data handling and black cardboard as a measuring underlay. Just like at the gloss measurement, we measured each sample ten times on random spots and we always oriented the measuring instrument longitudinal to the sample. Measuring angles, illumination and CIE standard photometric observer were chosen consistent with the visual experiment (see section 3.2.2).

3. Results and discussion

In this chapter, both the results of the visual experiment and the measurements are presented and compared to each other.

3.1 Results of the visual experiment

3.1.1 First experiment

In the first experiment, each sample #1 is compared to every other sample #1 with respect to intensity and variety of colors. The maximum total score to be reached by a sample is 4 × 2 × 26 = 208, since every sample is compared to four other samples, gains maximum two points per comparison for the two assessment criteria and is assessed by 26 test persons in total.

Figure 8 shows the results of the first experiment at illumination TL84. It displays the score reached for the criteria 'variety of colors' and 'intensity' as well as the total score reached by samples of all background colors. The silver samples gain the highest score, closely followed by the black samples. The red and blue samples are ranked third and fourth, as they gain rather similar scores for their variety of colors. However, the red samples were given twice the score for their intensity than the blue samples. The white samples gain the lowest score since they gain no points for their intensity and only a few for their variety of colors.

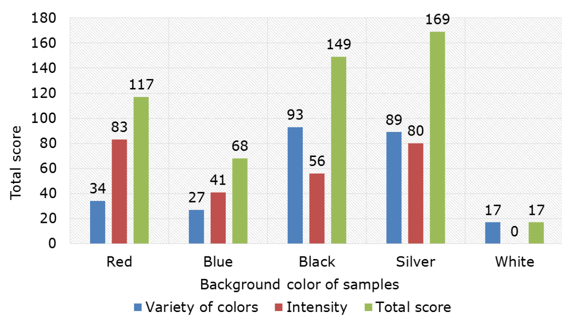

Figure 8: Results of the first experiment at illumination TL84 and geometry 45°/0°, where the maximum total score is 208

The results of the first experiment conducted at illumination D65 are shown in Figure 9. In comparison to the results in Figure 8, similar scores and nearly the same ranking of the samples can be found. Only the first and second placing are inverted, since the black samples gain a slightly higher score than the silver samples. Thereby we would like to add that those test persons who were considered as experts on average still assigned more points for the silver samples than for the black samples.

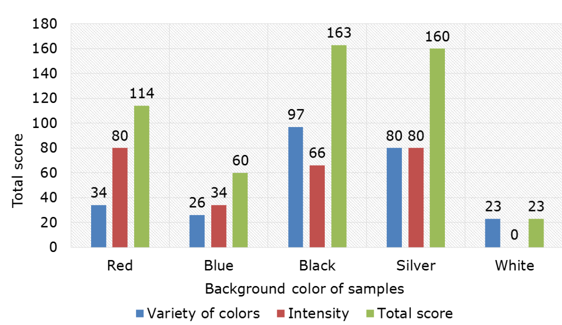

Figure 9: Results of the first experiment at illumination D65 and geometry 45°/0°, where the maximum total score is 208

3.1.2 Second experiment

In the second experiment, sample #1 and sample #10 of the same background color are being compared. The major results of the second experiment are presented in Figure 10, which shows how many test persons saw a difference between sample #1 and sample #10 of the same background color. We want to remind the reader that the samples were named in the order of their production. It appears that for all background colors most of the test persons saw a difference between the samples #1 and #10. While all test persons saw a difference between the white samples, a difference between the silver samples was most seldom discovered. This implies that the appearance of the silver samples is most constant during the production process.

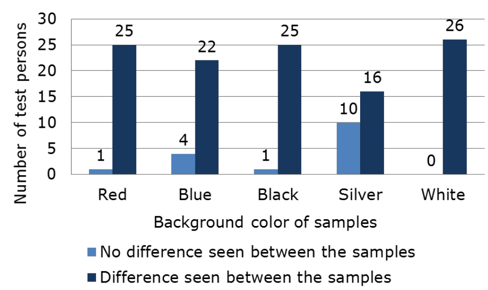

Figure 10: Results of the second experiment at illumination TL84 and geometry 45°/0°

Other results of the second experiment are the following. Those persons who named 'intensity' or 'variety of colors' as a difference between the samples, always – except once – related the greater intensity and the greater variety of colors to sample #1. This means that the samples #1 are of a better quality than samples #10. Moreover, it became apparent that a very frequently named difference between the samples was the shape of the rainbow, which is influenced by the samples' waviness (Figure 11).

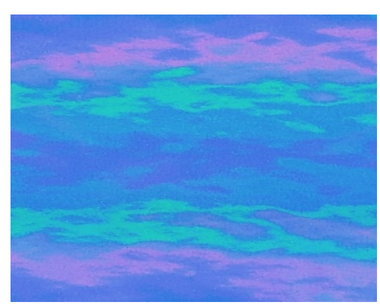

Figure 11: Detail of a blue sample with wavy surface structure that influences the shape of the rainbow

3.2 Results of the measurements

3.2.1 Results of the gloss measurement

In the following, the blue, red, black and white samples will be referred to as non-metallic samples. The 60° measuring angle is chosen for evaluation, because the non-metallic samples' gloss values at a 60° measuring angle lie between 10 GU and 70 GU (Deutsches Institut für Normung, 1982). Figure 12 shows the gloss values from sample #1 to sample #10 of all background colors at 60° measuring angle. The silver samples take on a special position concerning gloss measurement since they have more than six times higher gloss values than the non-metallic samples. In contrast, the non-metallic samples nearly all have the same gloss values.

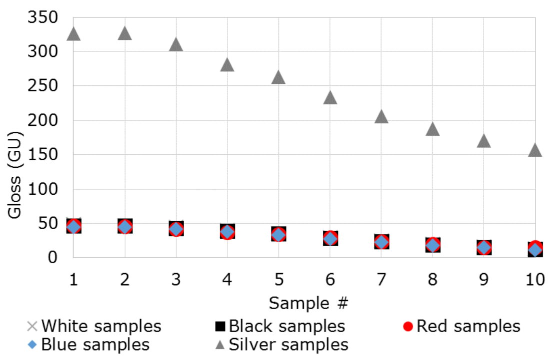

Figure 12: Gloss measurement of samples at 60° measuring angle

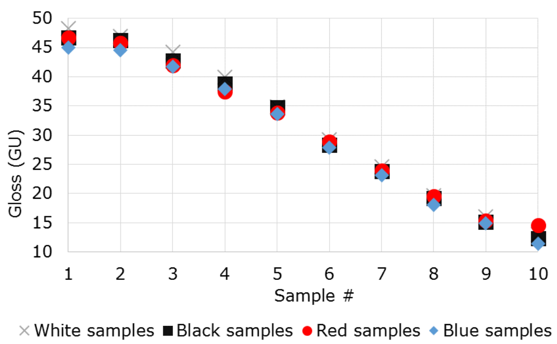

Figure 13: Gloss measurement of samples at 60° measuring angle without silver samples

Taking a closer look at the non-metallic samples' gloss values (Figure 13), it can be detected that the imaginary gloss curves, which are the imaginary connecting lines between the measuring values of one background color, cross each other. Consequently, the gloss measurement is not able to provide a ranking of the samples. This implies that gloss measurement is not able to evaluate the influence of the background color on the quality of embossed holograms.

However, Figure 12 clearly indicates that conclusions concerning the UV embossing process can be drawn from a sample's gloss. Irrespective of the background color, gloss values are constantly decreasing with increasing sample number. In total, the silver samples lose about 75 GU and all non-metallic samples about 35 GU. Comparing this to the results of the visual experiment (second experiment, see section 3.1.2), which showed that the samples #10 are of worse quality than the samples #1, we conclude that the loss of quality is accompanied by decreasing gloss values. Therefore, gloss measurement can be used for process control of the UV embossing process as conducted in this research. For example, gloss measurement can be used as an early warning system for the aging of the silicone shim. This can be realized by defining a lower limit of gloss that indicates that the silicone shim must be replaced.

3.2.2 Results of the color measurement

The multi-angle spectrophotometer X-Rite MA98 offers different measuring geometries (Kehren et al., 2011). Due to the angle-dependency of the holographic effect, analyzing several measuring geometries is reasonable. We chose to analyze the measuring geometries 45°:as25°, 45°:as45° and 45°:as75° because these are the measuring geometries provided by the X-Rite MA98 spectrophotometer that lie closest to the geometry used for the visual experiment. The first number, 45°, represents the incident angle in respect to the surface normal. The second number represents the viewing direction in respect to the specular angle. Accordingly, 45°:as45° represents the geometry used for the visual experiment (45°/0°). As illuminant, we chose D65 and as CIE standard photometric observer, we selected the 10° observer because in the visual experiment the samples are regarded at an aperture angle of more than 4° (Deutsches Institut für Normung, 2009).

Figure 14 shows three chromaticity diagrams, one for each of the selected measuring geometries, where the CIELAB color values a^* and b^* of sample #1 to sample #10 of each background color are plotted. It is to notice that the displayed colors in the chromaticity diagrams serve only for visualization purposes and do not conform to the real colors of the samples. This is because the value of the lightness L^* is chosen as 60 within the chromaticity diagram although each sample has a different L^*-value. The dotted lines between the measuring values serve as a guide for the eye only. Samples #1 are marked with the number '1'. As can be seen in all diagrams, samples of different background color show distinctly different color values a^* and b^* although they were prepared with the same holographic surface structure. This implies that the background color has influence on the holographic effect.

Taking a closer look at the samples' color locations (Figure 14), it becomes apparent that at all measuring geometries the red samples' color locations rather lie in the red area whereas the blue samples' color locations rather lie in the blue area. In contrast, the silver samples appear rather blue at 45°:as25° and rather red at 45°:as45° and 45°:as75°. This leads to the conclusion that chromatic background colors (blue, red) in contrast to non-chromatic background colors (e.g. silver)

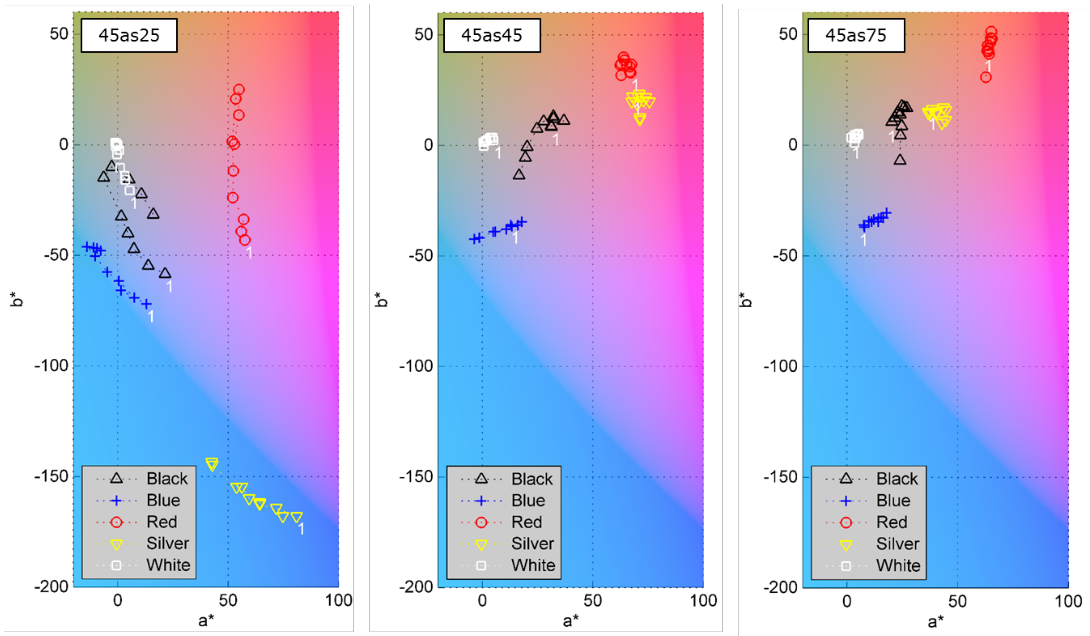

Figure 14: Chromaticity diagrams of hologram samples at L = 60 (illumination D65, 10° observer); measuring geometries from left to right: 45°:as25°, 45°:as45°, 45°:as75°*

overlay with the colors of the rainbow effect so that they shift them into the direction of the background color.

Moreover, Figure 14 shows that the color measurement is not able to characterize the rainbow effect in its full range, since the three selected measuring geometries represent only bluish and reddish parts of the rainbow. However, the rainbow of the applied rainbow effect contains more than these two colors. To represent all colors of the rainbow or at least more than two colors, ideally, a color measuring instrument with continuously adjustable measuring geometries must be used.

In Figure 15, we investigate the development of the chroma C^*_{ab} from sample #1 to sample #10. In general, the dipping and rising of chroma values can be explained by the aging of the silicone shim and by the waviness of the pre-printed substrates which negatively influences the preciseness of the color measurement. Taking a closer look at the development of the chroma values, it becomes apparent that, at measuring geometry 45°:as25°, the chroma values of all background colors tend to go down with increasing sample number. This fits to the results of the second visual experiment, which shows that the samples' rainbow effect loses intensity from sample #1 to sample #10. However, at the other measuring geometries (45°:as45° and 45°:as75°), we cannot recognize any evident trend regarding the samples' chroma values.

Investigating the samples' chroma C^*_{ab} and comparing it to the visual experiment, one could assume that the samples' chroma values represent the samples' quality, since the white samples have the lowest chroma and the silver samples have a rather great chroma at all measuring geometries (Figure 15). However, it contradicts the

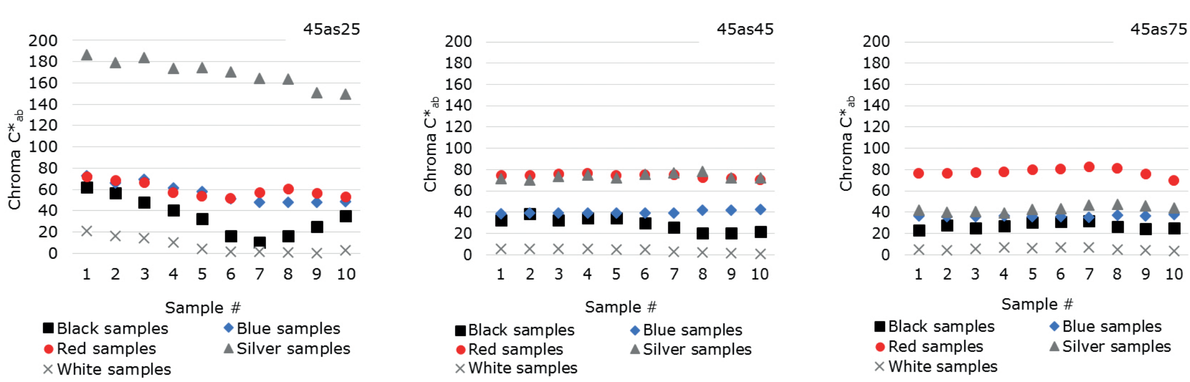

Figure 15: Chroma C^*_{ab} of all samples at measuring geometries 45°:as25°, 45°:as45° and 45°:as75°, at D65/10°

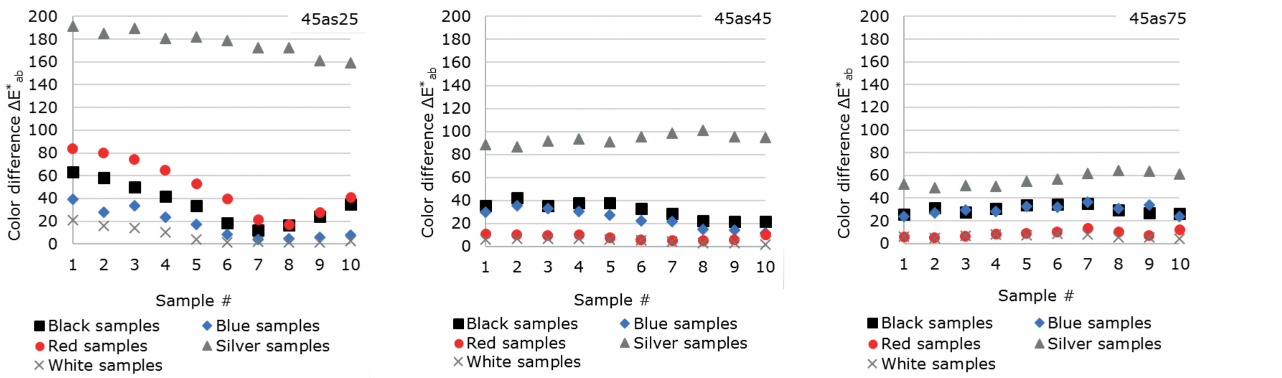

Figure 16: Color difference ΔE^*_{ab} between pre-printed substrate and hologram sample at measuring geometries 45°:as25°, 45°:as45° and 45°:as75°, at D65/10°

visual experiment that the black samples have only the second lowest chroma, whereas they gained a rather high scoring at the visual experiment. Consequently, the investigation of chroma values is not a suitable method to evaluate the influence of the background color on the quality of our samples.

In the following, we therefore chose another approach; we calculate the color difference ΔE^*_{ab} between the pre-printed substrate and the hologram sample (Figure 16). The consideration behind that approach is that color appears in interaction with its surrounding (Berns, 2000) – in our case the background color, which appears at some viewing angles alongside the rainbow effect. Whereas the chroma C^*_{ab} is an absolute measurement variable, the color difference ΔE^*_{ab} is a relative measurement variable which can consider the background color. Assuming that a greater color difference stands for a stronger holographic effect, Figure 16 clearly states that the black samples have a rather strong holographic effect. This fits better to the results of the visual experiment than the results from Figure 15.

To make a combined statement about the color difference, we calculated the arithmetic mean of the color differences at all three analyzed measuring geometries (Figure 17). This step is reasonable since the measuring geometry 45°:as45° – which is the geometry used for the visual experiment – represents only one color of the rainbow effect.

However, the test persons saw the full rainbow because the setup of the visual experiment (size of samples, tilting of sample display) was chosen according to that. Consequently, using only the measuring geometry 45°:as45° does not lead to a sufficient statement. Taking a look at the combined statement in Figure 17, it becomes apparent that – except the relative positioning of the red and blue samples and the big gap between the silver and black samples – Figure 17 well represents the results of the visual experiment.

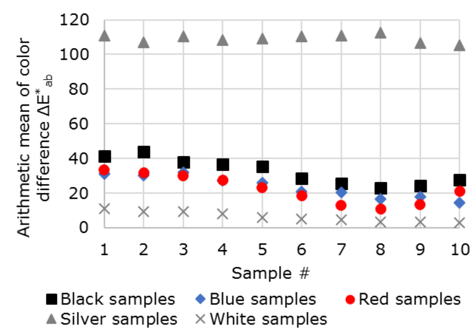

Figure 17: Arithmetic mean of color difference ΔE^*_{ab} between pre-printed substrate and hologram sample at measuring geometries 45°:as25°, 45°:as45° and 45°:as75°, at D65/10°

3.3 Accuracy of the measurements

Statistical data for the gloss measurement can be found in Table 2, which shows that the standard deviation of gloss values lies in the same scale, both for the 'normal' pre-printed substrates and the hologram samples. This means that the gloss measurement of hologram samples can be regarded as a rather precise measurement. However, the hologram samples' relative standard deviation tends to be a little higher than the pre-printed substrates' relative standard deviation since the hologram samples' gloss values are at least about two times lower (samples #1) and up to seven times lower (samples #10) than the pre-printed substrates' gloss values.

In Table 3, statistical data for the color measurement – using the blue sample #1 and a blue substrate as an example – is provided. As can be seen, the standard deviation of the hologram sample is about one or two magnitudes higher than the pre-printed substrate's standard deviation. Consequently, the color measurement of our hologram samples cannot be considered as precise as a measurement we know from the printing industry. The reason for the high standard deviation is the waviness of the samples, which changes the appearance

Table 2: Gloss (GU) values with standard deviation and relative standard deviation (in brackets) at 60° measuring angle, for an exemplary pre-printed substrate of each background color and for all hologram samples #1 to #10, measured ten times (n = 10) on different spots

Background color	Red	Blue	Black	Silver	White
Pre-printed substrates	91.4 ± 1.5 (± 1.6 %)	83.9 ± 1.0 (± 1.2 %)	91.3 ± 1.7 (± 1.8 %)	669.8 ± 8.4 (± 1.3 %)	93.9 ± 0.9 (± 0.9 %)
Hologram samples					
#1	46.7 ± 0.7 (± 1.4 %)	45.0 ± 1.5 (± 3.3 %)	46.7 ± 0.6 (± 1.3 %)	326.4 ± 6.1 (± 1.9 %)	48.3 ± 0.6 (± 1.3 %)
#2	45.7 ± 1.0 (± 2.1 %)	44.6 ± 0.4 (± 0.8 %)	46.2 ± 0.9 (± 2.0 %)	326.8 ± 8.1 (± 2.5 %)	47.0 ± 0.4 (± 0.9 %)
#3	42.0 ± 0.5 (± 1.1 %)	41.7 ± 1.1 (± 2.8 %)	42.8 ± 0.5 (± 1.2 %)	310.7 ± 11.4 (± 3.7 %)	44.2 ± 0.4 (± 1.0 %)
#4	37.5 ± 2.8 (± 7.5 %)	37.9 ± 0.5 (± 1.3 %)	38.8 ± 1.0 (± 2.5 %)	281.9 ± 7.3 (± 2.6 %)	40.0 ± 0.9 (± 2.3 %)
#5	33.9 ± 1.1 (± 3.2 %)	33.6 ± 0.7 (± 2.1 %)	34.8 ± 0.5 (± 1.5 %)	263.2 ± 5.7 (± 2.2. %)	34.9 ± 0.6 (± 1.8 %)
#6	28.9 ± 1.0 (± 3.3 %)	27.9 ± 1.5 (± 5.3 %)	28.4 ± 0.6 (± 2.1 %)	233.8 ± 4.7 (± 2.0 %)	29.2 ± 1.0 (± 3.4 %)
#7	23.9 ± 0.8 (± 3.1 %)	23.1 ± 0.8 (± 3.4 %)	23.8 ± 0.5 (± 2.1 %)	206.3 ± 3.0 (± 1.5 %)	24.6 ± 0.6 (± 2.6 %)
#8	19.5 ± 0.8 (± 4.1 %)	18.1 ± 1.6 (± 8.9 %)	19.2 ± 1.0 (± 5.1 %)	187.5 ± 3.2 (± 1.7 %)	19.7 ± 0.8 (± 4.0 %)
#9	15.4 ± 1.6 (± 10.2 %)	15.0 ± 0.5 (± 3.5 %)	15.1 ± 0.4 (± 2.6 %)	170.6 ± 4.1 (± 2.4 %)	16.1 ± 0.3 (± 2.1 %)
#10	14.6 ± 1.4 (± 9.3 %)	11.5 ± 0.8 (± 6.8 %)	12.3 ± 0.6 (± 5.1 %)	157.4 ± 1.7 (± 1.1 %)	13.1 ± 0.3 (± 2.7 %)

Table 3: CIELAB color values with standard deviation at 45°:as25° and D65/10° for both the pre-printed substrate and the blue hologram sample #1, measured forty times (n = 40) on different spots

Parameter	L^*	a^*	b^*
Blue pre-printed substrate	31.2 ± 0.4	−14.7 ± 0.2	−45.0 ± 0.5
Blue hologram sample #1	42.3 ± 3.0	0.3 ± 16.2	−66.3 ± 8.5

of the holographic effect and thus the measured color values. Please note that the measurements in Table 3 were conducted for closer examination, irrespective of the other color measurements. We did forty measurements instead of ten like in the other examples because of the rather high dispersion of the measuring values.

Regarding the rather high measurement errors of the color values, it is important to investigate, if the measurement error influences the samples' ranking as given in Figure 17. Therefore, a Gaussian error propagation was done exemplarily for samples #1, based on the measuring values in Table 4. The pre-printed substrates' standard deviations for L^*, a^* and b^* were neglected. Please note that the measuring software X-Color QC, which was used for the color measurements, provided only the standard deviations for L^*, a^* and b^* for one defined illumination/observer combination for each background color.

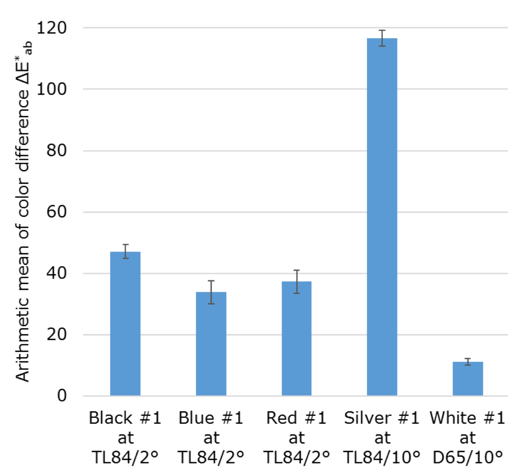

Figure 18: Standard deviations for arithmetic mean of color difference ΔE^*_{ab} for samples #1 resulting from Gaussian error propagation

Table 4: CIELAB color values and standard deviations (n = 10) at 45°:as25°, 45°:as45° and 45°:as75°, used for the Gaussian error propagation

Background color **Illumination and observer**		**Red** **TL84/2°**	**Blue** **TL84/2°**	**Black** **TL84/2°**	**Silver** **TL84/10°**	**White** **D65/10°**
Pre-printed substrates						
*L**	45°:as25°	35.5	17.4	7.1	34.7	89.0
	45°:as45°	35.3	17.6	7.2	12.6	88.1
	45°:as75°	35.7	17.3	7.8	10.8	87.4
*a**	45°:as25°	59.9	14.6	0.2	−1.1	−0.1
	45°:as45°	60.1	13.8	0.2	−1.1	−0.2
	45°:as75°	60.4	15.0	0.0	−0.8	−0.3
*b**	45°:as25°	45.7	−67.2	−2.4	−5.0	−0.5
	45°:as45°	46.1	−67.1	−2.3	−3.8	−0.9
	45°:as75°	47.8	−67.6	−1.9	−1.9	−0.9
Hologram samples #1						
*L**	45°:as25°	39.6 ± 0.6	24.7 ± 1.6	18.3 ± 1.3	76.3 ± 3.0	91.5 ± 0.3
	45°:as45°	40.9 ± 1.5	29.2 ± 3.5	21.4 ± 1.3	65.6 ± 3.7	89.6 ± 0.2
	45°:as75°	41.9 ± 1.9	28.3 ± 2.3	18.9 ± 2.0	42.9 ± 1.5	88.9 ± 0.3
*a**	45°:as25°	66.3 ± 5.8	42.2 ± 10.5	32.4 ± 5.5	71.5 ± 6.6	5.3 ± 2.1
	45°:as45°	63.3 ± 1.6	34.2 ± 6.1	28.3 ± 2.5	57.1 ± 3.8	5.1 ± 0.8
	45°:as75°	63.7 ± 1.4	32.9 ± 5.4	22.7 ± 3.3	39.0 ± 2.7	4.0 ± 0.9
*b**	45°:as25°	−48.1 ± 11.0	−99.7 ± 7.4	−73.4 ± 5.6	−198.9 ± 6.2	−20.6 ± 3.2
	45°:as45°	37.6 ± 3.3	−48.8 ± 6.8	9.3 ± 2.4	25.4 ± 6.1	2.3 ± 0.6
	45°:as75°	48.5 ± 2.1	−48.5 ± 3.2	12.1 ± 2.7	18.2 ± 2.2	3.2 ± 0.6

The result of the Gaussian error propagation carried out in this research is the standard deviation for the arithmetic mean of the color difference ΔE^*_{ab} for all samples #1, shown in Figure 18 in form of error bars. Figure 18 demonstrates that the measurement error has no great influence on the samples' ranking. Only the blue and red samples' measurement error slightly influences the ranking.

4. Conclusion and outlook

The visual experiment conducted in this research serves as a guideline for the design of UV embossed holograms. We found out that the background colors silver and black achieve the strongest holographic effect. In comparison, red and blue background colors only evoke a mediocre and white background colors evoke the weakest holographic effect. Besides, we learned that the waviness of the pre-printed substrates influences the samples' appearance.

The comparison of the visual experiment and the gloss measurements leads to the following conclusions:

- Conventional hand-held gloss measuring instruments cannot evaluate the influence of the background color on the quality of embossed holograms.
- However, the samples' gloss steadily decreases within the UV embossing process due to the aging of the embossing master. Besides, the gloss measurement is very precise. This suggests the usage of gloss measurement for process control of the UV embossing process as conducted in this research.

The comparison of the visual experiment and the color measurements leads to the following conclusions:

- Conventional hand-held color measuring instruments can evaluate the influence of the background color on the quality of embossed holograms.
- Calculating the color difference ΔE^*_{ab} between pre-printed substrate and sample is a method to recreate the results of the visual experiment.
- The number of provided or analyzed measuring geometries is a limitation of color measurements; in this research three measuring geometries (45°:as25°, 45°:as45°, 45°:as75°) lead to useful results, but other holographic effects may require far more measuring geometries.
- Besides, the waviness of the pre-printed substrates strongly limits the precision of color measurements; the results of color measurements are rather imprecise in comparison to the results of gloss measurement.

In future research, the following questions may become important:

- What does the quality of embossed holograms need to look like? Are 'intensity' and 'variety of colors' useful and sufficient assessment criteria?
- Does the method also work for more complex holographic effects than the rainbow effect?
- Can the results of this research be equally applied to the industrial UV embossing process?
- Would we get similar results if we calculated ΔE_{00} instead of ΔE^*_{ab}?
- What could a control strip for embossed holograms look like?

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Print quality and color accuracy of spectral and colorimetric reproduction

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Abstract

When reproducing an image by means of printing, the most common concerns are to have good colors and the least perceivable artefacts. These two concerns are most conveniently conveyed via two common reproduction goals: color accuracy and image quality. The goal of this paper is to evaluate how color accuracy aim relates to printed image quality, the attribute usually tight to the method of halftoning. In order to provide a relation between these two different goals, spectral and colorimetric color management workflows are paired with different halftoning methods. Image quality metrics is employed both on the output from the color separation process and on the print output. Overall, spectral reproduction used in this paper showed higher color accuracy but lower image and print quality score, even if combined with state of the art halftoning methods.

Keywords: reproduction workflow, halftoning, image quality, spectral reproduction, multichannel printing

1. Introduction

A reproduction workflow is comprised of processing steps that transform an input, in a form of spectral reflectance or colorimetric values, to the printer binary information. A print oriented reproduction workflow involves calibration and characterization of the printer, gamut mapping where needed, a separation to compute ink amounts, and halftoning. In the best scenario, input signal, whether it is a spectral reflectance or trichromatic value, is perfectly matched by printing specific ink combinations. Specific ink combination and percentage of each ink in the mixture is determined by the separation process.

Typical separation process involves an inversion of the printer characterization model, either analytically or by some search mechanisms (e.g. interpolation or optimization). Which method to use will depend on invertibility of the characterization function and dimensionality difference between input and output. It follows that colorimetric input, being of three dimensions, could be utilized more directly with a printing system having similar degree of freedom (e.g. CMYK). On the other hand, a workflow that starts with spectral reflectance as the input and having printing system on the output will almost exclusively suffer from dimensionality difference. This suggests that more compromises must be made in spectral reproduction process and especially in separation method. Therefore, an ink combination selected by separation process to print input spectral reflectance might be very different from the one otherwise selected to print colorimetric CIE $L^*a^*b^*$ value.

Common goal of any color reproduction is high accuracy. Colorimetric workflow aims to maximize accuracy under one fixed viewing condition, while spectral workflow aims for illuminant and observer independent match (Tzeng and Berns, 1998; Taplin, 2001; Gerhardt and Hardeberg, 2006). Latter is most conveniently achieved by having a spectral match, that is, a copy of the original with the same physical property to selectively reflect input light. It is well known that a single CIE $L^*a^*b^*$ value can be created out of set of different reflectances. All reflectances that sums up to the same CIE $L^*a^*b^*$ value under the combination of viewing condition and illumination form so called metamere set. This set can be large which makes it difficult to match spectral reflectance. On the other hand, if spectral match was possible, the problem of metamerism would be eliminated. However, in majority of the printing applications, spectral match is not possible due to the limited spectral gamut of today's printers (Urban and Berns, 2011; Morovič et al., 2012). This is partly due to the non-optimal ink set for spectral reproduction (Alsam and Hardeberg, 2004), but moreover it is because the available number of inks is yet too small for additive process such as the ink mixing process. As a consequence, the reproducibility of the real world reflectances highly depends on a given application, where one study (Slavuj, Marijanovic and Hardeberg, 2014) suggests that more than a half of the CIE $L^*a^*b^*$ values of the patches to be printed, have spectral reflectance that is non-printable on a current state of the art multichannel printer.

Limitation induced by non-printable reflectances also leads to different gamut mapping strategies that are applied in spectral versus colorimetric spaces. Moreover, a metric commonly used to quantify spectral difference (e.g. spectral root mean squared error – RMS) does not correlate well with the perceptual difference. One of the practical solutions to this problem is to convert spectral data to colorimetric coordinates where conventional color gamut mapping can be applied (Derhak, Green and Lianza, 2015). If spectral information is now converted to colorimetric encoding, the spectral match is then achieved by ensuring that each point is within a gamut constructed under multiple illuminants (Urban and Berns, 2011). If there is a match between the pair of CIE $L^*a^*b^*$ values under any illuminant, then illuminant metamerism is eliminated and it follows that spectral match most probably exists. Problem with pure spectral approach to gamut mapping and of multi-illuminant gamut mapping is that they are pixel based operations that do not account for neighboring pixels. This, in addition to the weak correlation to the perception gives a rise to noisy images as a result of gamut mapping and separation. This problem was addressed by Samadzadegan and Urban (2013) who reported a significant banding that occurred on separation images as a result of multi illuminant gamut mapping and separation. Therefore, the image quality of the separation images suffers due to the nature of the separation process. On the other hand, a print quality or an image quality of the final print is usually attributed to the process of halftoning.

Well-known source of image quality degradation is noise that can be observed in print as a luminance difference of neighboring dots or in the case of low resolution as a disturbing dot placement on the substrate. Dots overlaps are therefore not desirable and multiple solutions are offered in the literature to solve the problem. The most common one is referred to as Minimal Brightness Variation Rendering (MBVR) by Shaked et al. (1999) which reallocates dots so that the pattern becomes the least perceivable. Other solution would be to maximize dot-off-dot printing within processing block (Lee and Allebach, 2001; Agar and Allebach, 2005; Ortiz Segovia, Bonnier and Allebach, 2012a). However, dot-off-dot algorithms are very computationally expensive (Trager et al., 2011) and rarely used in practice. In Slavuj and Pedersen (2015) a different approach is taken where channel independent halftoning is post processed with so called multichannel Direct Binary Search (MC DBS). This halftoning method takes just fraction of the time used by dot-off-dot algorithms and directly enables it to operate in multichannel printing environment. It is also shown that MC DBS improves image quality in comparison with channel independent (CI) DBS halftoning and that it is a good candidate to enhance spectral reproduction workflow.

All parts of the reproduction system generate noise. There can be noise coming from separation process, whether it is a spectral (Samadzadegan and Urban, 2013) or colorimetric separation (Wang, Aristova and Hardeberg, 2010). Likewise, halftoning in absence of separation can be evaluated for similar image quality attributes (Lee and Allebach, 2001; Ortiz Segovia, Bonnier and Allebach, 2012b). However, all these evaluations do not give a full description of the overall system's noise. In this work we quantify noise of spectral and colorimetric separations and overall noise of the reproduction system; that is of separation and halftoning combined.

The evaluation in this paper is made of the two parts. We first evaluate color accuracy of the reproduction using spectral and colorimetric reproductions, then separation's image quality, and then we evaluate print quality of the spectral versus colorimetric reproduction in combination with different halftoning. Note here that print quality is an image quality metrics applied to the actual print while only image quality is a metric applied to digital image (e.g. image of the ink amounts – separation image).

Color accuracy of the spectral and colorimetric workflows is quantified by measuring of reproduced spectral reflectance or colorimetric values of the textile samples. It is followed by an evaluation of the image quality (with selected noise metric) of spectral and colorimetric separation images. The final comparison is made by halftoning separation images (ink amounts) using different halftoning algorithms, and then applying two image quality metrics that evaluate noise.

2. Methods

The overall description of the method is shown in Figure 1. We have compared the performance of the colorimetric and spectral workflows in terms of color accuracy and print quality for a set of spectral images of natural scenes, a painting and real textile patches. Additionally, separations of both reproduction workflows were compared in terms of the image quality. Three halftoning methods were used to test overall reproduction workflow print quality. The spectral images or reflectance factors, obtained either directly from a database or measured, were firstly used to compute the CIE $L^*a^*b^*$ values under D50 and A illuminants.

The D50 rendering was then gamut mapped to the gamut of the printer. Gamut mapping was therefore the same for colorimetric and spectral workflow and it was done by round-tripping with ICC profile. What was different, was the separation from CIE $L^*a^*b^*$ to the CMYKRGB space of used printer where colorimetric separation was performed with the help of pre-built ICC profile (BToA table) while spectral separation was based on a multi-illuminant separation and spectral gamut mapping algorithm (mapping from illuminant D50 to illuminant A). All colorimetric computations were performed using the 2° standard observer. At this stage, the quality of the two separation methods were evaluated in terms of induced noise in the simulated separation image (before halftoning and printing).

In next phase the separation images (in CMYKRGB space) were halftoned in channel independent manner prior to printing. After printing, color accuracy of the colorimetric and spectral workflows was assessed under both A and D50 illuminants using the measured reflectance factors of selected samples and their respective print reproductions. Halftoning method used for this purpose was CI DBS halftoning method. To finalize our evaluation, we varied halftoning methods applied on separation images and showed image quality score of the final print (or print quality) for selected image quality metrics. Following is the detailed description of the samples used for evaluation, explanation of separation strategies and selected halftoning methods used in this paper, and image quality metrics that were selected for our evaluations.

2.1 Material, printing and measuring equipment

One set of images used for testing were spectral images of natural scenes from the Foster database (Foster et al., 2006) while other set of images was selected from Spectral Image Database for Quality (SIDQ) (Le Moan et al., 2015). In addition, we also used a spectral acquisition of a painting to include an image with smooth gradation. As for the SIDQ images, the spectral image of the painting was acquired using a HySpex line scanning hyperspectral camera VNIR 1600 (Norsk Elektro Optikk AS, Norway). The camera has a spectral resolution of 3.7 nm, interpolated to 10 nm steps for further processing. All selected – acquired images are shown in Figure 2 (encoded in sRGB color space for presentational purpose).

For the evaluation of color accuracy we used homogeneous textile samples made of wool and polyethylene (Figure 3). The dyes in colored fabrics have similar

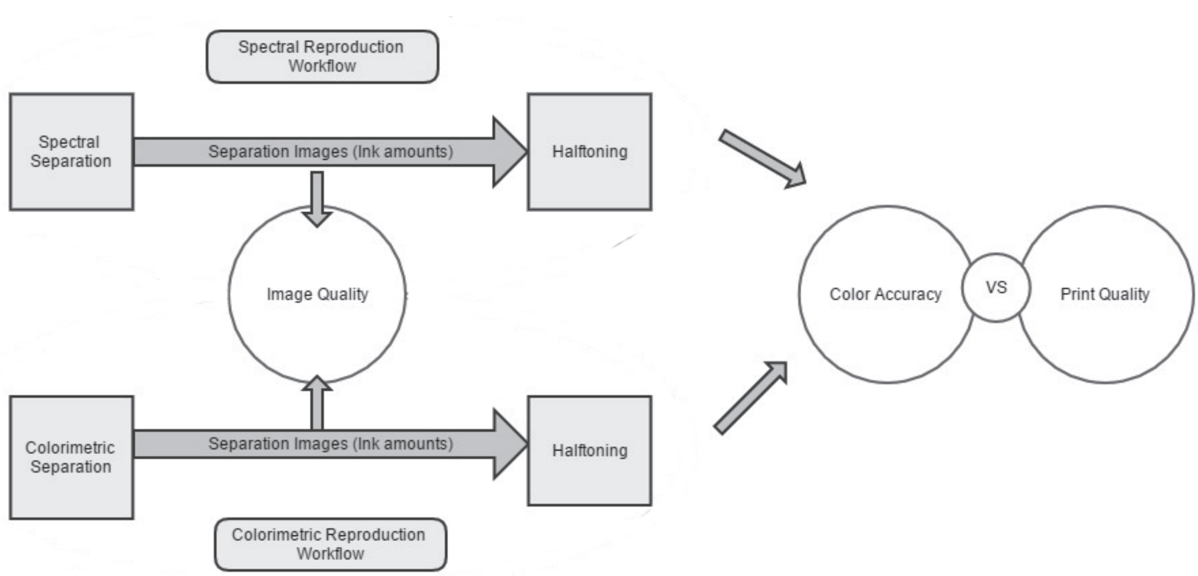

Figure 1: Overview of the analyses done in the paper; spectral and colorimetric workflows are compared in terms of color accuracy and image quality of the final print (print quality)

Figure 2: Spectral images used in experiment: (1) Wool, (2) Painting – section, (3) Flower, (4) Building, (5) Print ramps, (6) Painting – full, (7) Cork, (8) Skin1, (9) Skin2, (10) Orange; (3 and 4) are from Foster database and the others except the painting in (6) are from SIDQ

Figure 3: Textiles sample set used for color accuracy assessment

reflection spectra as the inks used on prints where printability of these reflectances using colorimetric and spectral reproduction is proven to be satisfactory.

The print reproductions were made with a 12 ink Z3200 PS multichannel printer (Hewlett-Packard) using seven Vivera inks (CMYKRGB) that are made for high endurance and large color gamut. For substrate we used HP Artist Matte Canvas which has shown to have optimal absorption balance, large color gamut and pleasing reproductions. The printer was directly controlled by supplying a pre-halftoned 1200 dpi, 7 channel, TIFF binary image, through a Caldera (Caldera, Strasbourg, France) Raster Image Processor (RIP) with all color management features off.

Both the textile samples and their print reproductions were measured with an i1 spectrophotometer (X-Rite, Inc.). The printed images were scanned with an Epson Expression 10 000XL scanner using a custom built ICC profile from a Kodak Q61 IT 8.7/2 target printed on our substrate. All prints were made with a 300 dpi resolution while the scanner resolution was double that of the prints (600 dpi). The scanned images were then converted to CIE $L^*a^*b^*$ space with previously created scanner profile. The scanning method is illustrated in Figure 4 and described in detail by Pedersen et al. (2010).

2.2 Multi-illuminant separation

We used an implementation of a spectral gamut mapping and separation algorithm (Coppel, 2015; Tzeng and Berns, 2000) that follows the work from Urban and Berns (2011). It is based on a sequence of colorimetric mappings within paramer mismatch gamuts. Given a set of illuminants in a prioritized order, the spectral gamut mapping aims at minimizing the color difference between the printer model estimate and the target under other illuminants (second or third in line),

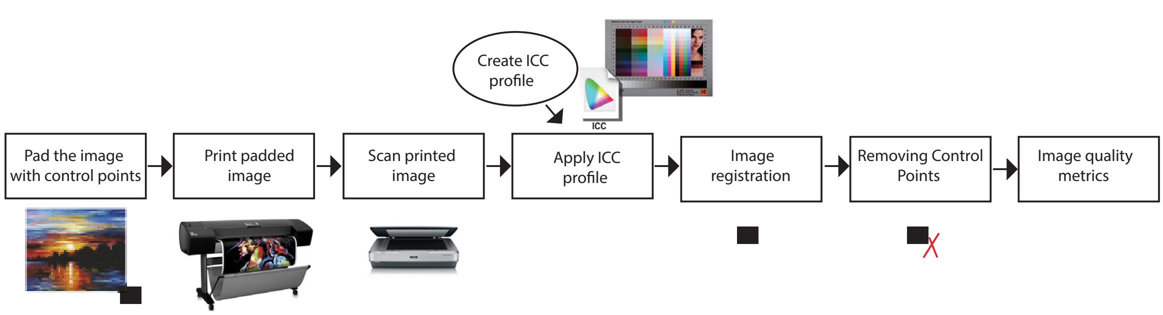

Figure 4: Framework for scanning of the print reproduction

while keeping the difference under the first illuminant below 1 ΔE^*_{ab}. We used ΔE_{94} as a measure of color difference since it is accurate enough for our purpose and less computationally expensive than ΔE_{00}. The printer was modelled with the cellular Yule Nielsen modified Neugebauer (cYNSN) model, described by Wyble and Berns (1999), using four cells. The calibration set included all 4 ink combinations at 5 apparent ink coverages (0–100 % with 25 % step). We considered only 4 ink combinations including K (e.g. CMYK, CKRG or MYKB) since it was observed that 5, 6 or 7 ink combinations do not contribute much to the spectral variability of the printouts (Coppel et al., 2014). In this work, we applied the separation algorithm with D50 as the first illuminant and A as the second illuminant. This means that for each pixel in the images the search was performed for the CMYKRGB combination that leads to $\Delta E_{94} < 1$ under D50 and minimal color difference under A. Note that a gamut mapping was performed under D50 prior to the separation.

2.3 Colorimetric separation

The colorimetric workflow was based on the v4 ICC architecture (ICC, 2010). The ICC profile was made with X-Rite i1Profiler software. We used custom generated chart with 3 000 patches to build a profile which would guarantee high accuracy with acceptable computation time. The profile had a Grey Component Replacement algorithm (GCR) applied but to a lower extent (black starts at 50 % and ends at 100 % with medium GCR level).

2.4 Halftonings

In order to establish a relation between color accuracy (usually associated with color management) and print quality (usually associated with halftoning) of the reproduction, selection of halftoning was restricted to halftoning methods that give the least visible textures and thus high image quality. Therefore the list of selected halftoning methods starts with widely used Floyd Steinberg Error Diffusion (ED) method described by Ulichney (1987), CI DBS developed by Lieberman and Allebach (2000), and channel dependent DBS developed for modern inkjet multichannel printing environment, proposed by Slavuj and Pedersen (2015). The DBS is one of the model based algorithms for halftoning where a printer dot placement model is combined with a model of spatial frequency detection when performing search for optimal solution. Optimization process yields optimal dot distribution in the area of processing (e.g. block of neighboring pixels in the image). The MC DBS uses a hierarchical scale constructed of various dot luminances (Figure 5), starting from a dot of lowest luminance (e.g. of black ink) to the highest luminance dot (yellow ink). Therefore, dots with the lowest luminance are the most visible in contrast to the white paper and their optimal distribution is of highest priority. Each separated channel was firstly halftoned, independently. The four binary images were then summed for identification of the overlaps of CM, CY and MY combinations. These overlaps were replaced with some of RGB inks and the CMY overlaps were changed to one of the BY, RC, or GM complementary color combinations.

2.5 Image and print quality evaluation

As shown in Figure 2, the multi-illuminant (spectral) and the ICC based colorimetric workflows differ only in the separation step. We wanted to evaluate the impact of this separation on perceived image and print quality and of its interaction with subsequent halftoning steps. Noise has many sources but in this work we limited our evaluation to the noise of separation error (e.g. error of interpolation or rounding), pixel-wise processing (in contrast to neighborhood based operations), and halftoning induced noise.

To quantify noise of a reproduction workflow, we used the Noise Quality Measure (NQM) which corresponds to a perceived noise (Damera-Venkata et al., 2000). The NQM was taken from luminance channel only because most of the changes in relation with halftoning are evident there. The metric was computed on the *Y* channel in CIE *XYZ* space, and both original image and scanned print were filtered with HVS model to account for the viewing conditions. The assumed viewing distance was set to 50 cm. For evaluation of the separations we used images number 1–5 and 10 shown in Figure 2. For the image quality of the separation and halftoning, all images from Figure 2 were used. The procedure of the printing, scanning and the metrics application is shown in Figure 4.

To add a halftoning contribution to the noise of a reproduction system, the graininess metric was added (Hains, Wang and Knox, 2003). Graininess is defined as

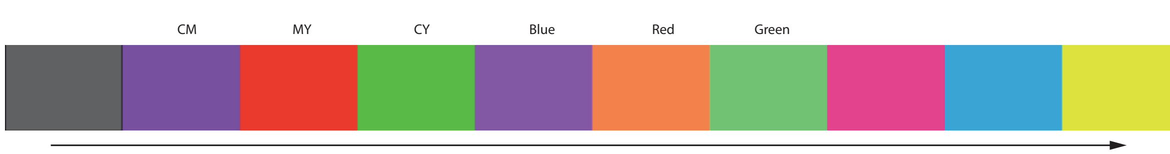

Figure 5: Primary colorants and their overlaps by visibility with decreasing luminance from right to left

aperiodic fluctuations of the optical density at a spatial frequency greater than 0.4 cycles per millimeter in all directions. However, this applies only to monochrome reproductions. For color reproduction, we instead quantify graininess as the standard deviation of the ΔE_{00} differences as proposed by Ortiz Segovia, Bonnier and Allebach (2012b).

3. Results and discussion

3.1 Color accuracy

The CIE $L^*a^*b^*$ values of the textile patches are compared to the gamut of the printer in Figure 6. The sample set had around 30 % samples out of the gamut of the used printer and substrate. The color differences between the textile patches and their reproductions, both spectral and colorimetric are given in Table 1 for both D50 and A illuminants. Color differences in Table 1 point to rather different performance of spectral and colorimetric workflow, where the spectral one was more color accurate. This is true under both illuminations.

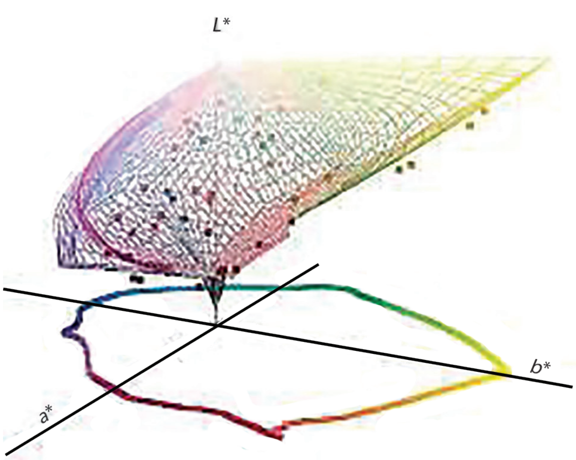

*Figure 6: Gamut plot in D50/2°, CIE L*a*b* space of the HP Z3200 multichannel printer (wireframe) and measurements of textile patches*

3.2 Separation noise analysis

The NQM scores for spectral and colorimetric separations are shown in Figure 7. For the total 5 images used, the ICC separation gave better NQM scores than the spectral separation except for the orange image, which on the other hand had very low score for both separations. Overall, NQM scores were very different for different images, and the difference between different images was larger than the difference between spectral and color separation.

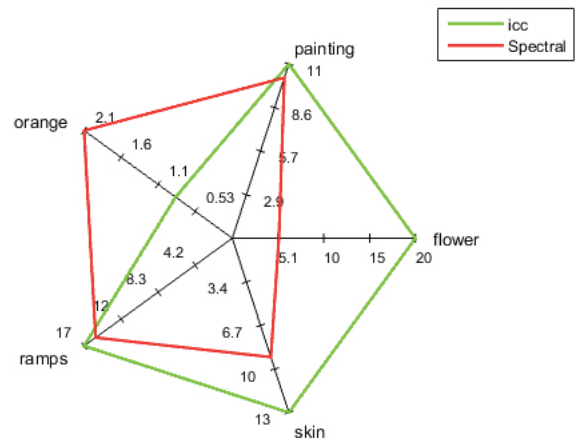

Figure 7: NQM score of spectral and colorimetric separations for five images used

Mean NQM score computed for all images is shown in Table 2. Noise generated in the spectral separation was clearly higher than in the colorimetric separation. From Tables 1 and 2 it is clear that spectral separation had better color accuracy but, because of the choices made in separation process, significantly higher noise, and therefore lower image quality. The source of this noise came mostly as the result of additional gamut mapping (from D50 to A illuminant) but also from constraints imposed to separation.

Table 2: Mean NQM scores of spectral and colorimetric (ICC) separations

Workflow	Mean NQM score
Spectral	6.43
ICC	9.62

Table 1: Color difference between measurements of the textile samples and print reproductions for the spectral and colorimetric (ICC) workflows

	ΔE_{00} at D50				ΔE_{00} at A			
Workflow	**Mean**	**Median**	**Max**	**95th %**	**Mean**	**Median**	**Max**	**95th %**
Spectral	4.04	4.32	6.21	5.61	3.89	4.35	6.66	6.14
ICC	8.73	8.00	23.62	18.05	8.29	7.59	23.89	17.84

3.3 Effect of halftoning on print quality

In this part we evaluate image quality performance of different halftoning methods. In fact, it is also a trial to extract a contribution of the halftoning to the overall system's noise. We tried to achieve this by applying different halftoning on noisy spectral separation. First we have compared widely used CI ED with Floyd Steinberg filter with channel dependent MC DBS.

To emphasize the differences, prints were made with 150 dpi resolution. Channel independent ED in combination with spectral separation produced banding artefacts while CI DBS have optimized spatial distribution which reduced banding artefacts. For MC DBS, the same as for CI DBS applies, but it also improved texture uniformity in shadow and dark areas and increased level of detail in these areas as well.

Due to its neighborhood filtering, CI ED created artefacts on already noisy separation images (Figure 8). It showed significant artefacts in light areas of the image passing through the area of subtle gradient (a shadow on the wall). Similar behavior was reported by Gerhardt and Hardeberg (2006) where due to error filter passing through the area of rapid light to dark transitions (noise area), error is accumulated and released toward the end of scan line (assuming raster scanning direction). Other halftoning methods also struggle with noisy spectral separation but it seems that MC DBS gives the least artefacts due to its post processing method. Same is true on more smooth images such as image of the painting (Figure 9), but this comes on the expense of slightly reduced image contrast.

Overall, the results confirmed that halftoning plays a significant role in print quality and that the impact of halftoning is higher for colorimetric workflow, which has smoother or less noisy separation. Although colorimetric separation exhibits significantly less noise as a result of separation, after halftoning step, spectral and colorimetric workflow showed similar noise level. Table 3 provides the mean of the print quality score used to compare spectral and colorimetric workflows with different halftoning applied.

As expected, NQM score is lower than that after separation only, for both spectral and colorimetric workflow.

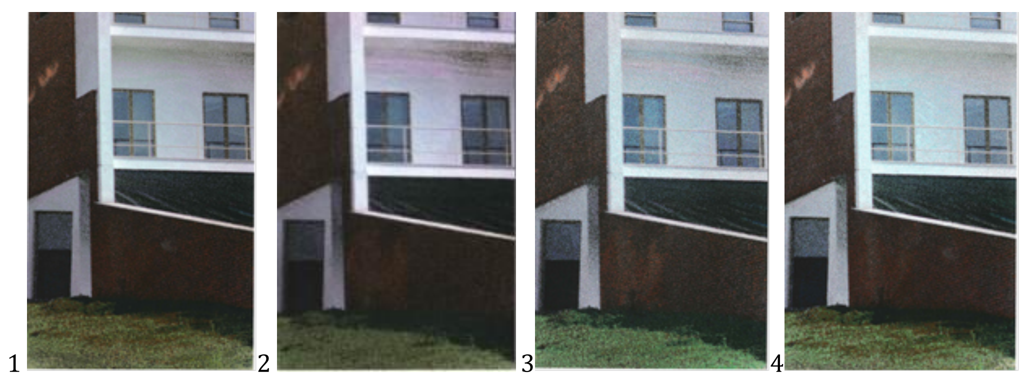

Figure 8: Spectral separation with simulated image (1), channel independent error diffusion (2), channel independent direct binary search (3), multichannel direct binary search (4)

Figure 9: Spectral reproduction of painting using error diffusion halftoning (1) and multichannel direct binary search (2) as multichannel direct binary search replaces overlaps, image on the right looks slightly washed out and with less contrast but it gives smoothness and reduces halftoning noise

The halftoning adds significant perceptual noise which lowers the NQM score, and this is true for all halftoning methods that are evaluated. However, NQM score can be increased by using MC DBS over CI DBS or CI ED.

Table 3: NQM and graininess mean score for all tested images; both colorimetric and spectral separation are combined with all evaluated halftoning methods

Print quality score	NQM	Graininess (halftoning)
Colorimetric + CI ED	5.3	2.8
Colorimetric + CI DBS	6.2	2.5
Colorimetric + MC DBS	7.3	1.6
Spectral + CI ED	4.4	2.9
Spectral + CI DBS	5.8	2.3
Spectral + MC DBS	7.1	1.7

The overall conclusion is that the halftoning has more influence to the NQM score than the separation process (Table 2 and 3). Truly, it is possible to increase the score of the perceptual noise by selection of appropriate halftoning method. The DBS algorithm in all cases shows better performance than ED, both in NQM and graininess score, especially in case of MC DBS.

4. Conclusions

We evaluated image and print quality of a colorimetric and a spectral separation combined with halftoning and their color accuracy. Although spectral separation and halftoning has shown higher color accuracy, the colorimetric separation via commonly used ICC profile combined with halftoning yielded less noise and therefore shown better image quality. Print quality depends mostly on used halftoning but this is even more the case if spectral separation is applied prior to the halftoning. For both colorimetric and spectral workflow, the MC DBS halftoning showed signs of improvement in final print quality. When combined with appropriate halftoning, spectral separation could yield print quality similar to colorimetric separation. As expected, halftoning has much more impact on final print quality, but proper selection of the halftoning algorithm could give an optimal and satisfying reproduction no matter what color management workflow is used.

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Analysis of UV varnish for textured effect

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Abstract

Packaging and especially printing industry is experiencing an exponential growth in terms of customer demands. Owing to these demands, UV varnish is playing a major role, which is preferred over lamination due to environmental issues and cost. The UV varnish can give gloss or matte finish. Textured effect on the surface can be achieved by blending gloss finish over matte. Various textures can be achieved by varying the blend of solutions, ratio, viscosity, surface tension, etc. Among varnishing parameters that affect the results are UV-lamp intensity, speed of varnishing and screen ruling of anilox cylinder. The texture created in such a manner, needs to be evaluated with respect to the topographic index to find an optimum combination of the parameters to achieve a particular textured pattern.

Keywords: surface finish, topographic index, offset printing, coating process parameter, image analysis

1. Introduction and background

The UV varnishing is a technique, widely used in packaging and label printing finishing for protection and enhancement of the printed surface and also for achievement of textured effect. Sanyal (2015) states that flexographic UV printing is proved to give the consistent result as the ink has the right viscosity and amount of the pigment, in comparison to solvent-based and water-based inks. The UV inks cure quickly, meaning that products can be finished more rapidly, enabling higher throughput and fast turnaround, even on two-sided jobs. In-line UV printing is notable for the superior results it can achieve on difficult substrates, from uncoated paper and board to foil and especially plastic, including synthetic papers, static cling vinyl and lenticular. The ability to “lay down” layers of opaque white or metallic ink, and then print over it in a single pass, merely hints at the versatility of the UV process. The UV inks are 100 % solid inks while the solvent-based are 20–30 % solid (Kipphan, 2001) and water-based inks have over 40 % solid content (Verspoor, 2005). So, to achieve the same effect, UV technology uses fewer and less waste of UV inks and consumables. With the help of UV inks, one can reach to higher printing speed and improved production efficiency. In UV printing, specially formulated inks are exposed to ultra-violet radiation, which causes them to harden instantly on top of the substrate. The result produces high levels of gloss or dull coating, vivid color and vibrant detail with superior rub resistance and no post-cure dry back – even on soft, uncoated sheets – making UV the technique of choice for applications like luxury cosmetics and chic wine labels. The UV curing technology is showing an upward trend in printing industry. It is not used only in traditional processes; this technology has also been applied in new techniques such as UV inkjet and hybrid printing.

Modern offset lithographic presses built for packaging and label printing are often equipped with one or two coating units with drying and/or curing systems. Machines with two coating units after the printing units can be used for applying two different varnishes, i.e. glossy and matte; when applying one on the other, it may be coating of waterborne primer and UV varnish over conventional oxidatively drying inks, or coating special types of varnishes to achieve texture effect on the varnished print surface (Kipphan, 2001; Heidelberg, 2008). Coating unit on offset lithographic press is technically based on printing unit in flexography.

Creating a texture effect became market trend and a customer need as packaging had grown up vastly and different printing technology advancements boosted up the growth and implementation of new concepts. Texture effect is best achieved by UV curable inks and coatings. Texture or drip off is the effect obtained by combination of two different types of varnishes, i.e. duct or release varnish and flexo coater gluable varnish. This newly introduced finishing effect is widely appreciated and used as a brand protection feature in the print-packaging houses.

Investigations of texture effect and methods of its characterization are known for decades. Duong (1983) patented surface texture effect obtained by using different UV light sources under different atmosphere conditions, particularly suitable as floor and wall coverings. Texture effect on the surface of paintings was studied and characterized by Cai and Siegel (2002). The texture effect, created on offset press equipped with coater in three different ways is described in KBA publication by Kleeberg (2006), while properties of coatings and substrates are explained by the same author in 2007 KBA publication (Kleeberg, 2007). Surface topography of coated papers was studied by Velho and Santos (2010), using different methods including laser profilometry and scanning electron microscopy with image analysis. Karlović et al. (2012) studied distribution of different particle sizes and their correlation with surface gloss of aqueous coatings in printing. The main goal of our research was aimed to optimize the printing and coating process used to obtain texture effect on offset press with coater and UV curing system and method for characterization of print samples with texture.

2. Materials and methods

Trails were carried out on an offset machine on metallized polyethylene terephtalate film (MET-PET) substrate, coated by UV varnish. The matte varnish was applied on the area where texture is required. Gloss varnish was applied over matte varnish by varying matte to gloss ratio. The effect of anilox screen ruling on texture has been tested by two different screen rulings. The UV-lamp intensity has been varied and the effect was measured and analyzed.

Texture effect on the substrate was achieved by the combinational application of lithographic offset print unit and coating unit with anilox roller responsible for metering of UV-varnish. Printing plate used in print unit consists of solid patch on it, by which the matte varnish was applied firstly on the substrate. Gloss varnish was then applied in coating unit metered by the anilox roller to create texture effect on the substrate surface after curing through UV curing system. Anilox roller plays significant role in texture finish and anilox screen ruling expressed in lines per inch (lpi) is one of the important factors to alter the finishing of textured surface.

A design of experiment (DOE) was conducted with four factors (Table 1) – anilox screen ruling, UV-lamp intensity, press speed expressed as impressions per hour (iph) and dot area. Two levels shall be considered for each factor. Thus, a general full factorial with four factors and two levels each was generated. Thus, 16 runs with two replicates were carried out.

Table 1: Process variables

Factors	Value	
	Low	High
Anilox screen ruling (lpi)	60	80
UV-lamp intensity (W/cm)	80	100
Press speed (iph)	7 000	12 000
Dot area (%)	50	100

Throughout the run, following press parameters have been kept constant:

- Ink and water balance
- Print density
- Color balance
- Printing pressure
- Registration

The evaluation of final results is based on topographic index. The higher is a value of this index, the more textured the finish is.

The overall methodology is as follows:

- Trials were carried out on 6 color KBA Rapida-105 offset printing press with coater, format: 28″ × 40″.
- The initial production runs with predetermined press settings were conducted for a few days to define the reference for the project.
- Printing parameters were set to 10 000 iph speed, 80 lpi anilox screen ruling, and 85 W/cm UV-lamp intensity.
- On the Gray back MET-PET 330 g/m^2 substrate, size: 936 mm × 606 mm, first matte and over it glossy UV varnish Toyo Ink Arets was applied.
- A full factorial DOE was conducted for 4 factors with 2 levels of each: anilox screen ruling, UV-lamp intensity, machine speed, dot area.
- The topographic index was evaluated by using EPSON V700 flatbed scanner and Verity IA Print Target image analysis software.
- The DOE was analyzed based on main effect plot, interaction plot, and analysis of variance (ANOVA) in order to identify the best combination of variables for texture effect, i.e. to draw the actual effect of all varying parameters on the response.

The identified best combination of variables were re-run to verify the analyzed results from the DOE and further checked for its consistency.

2.1 Measurements and testing

Figure 1: Reference image for texture effect on substrate surface

Figure 1 illustrates the textured finish of the trials being conducted. Tiny dots over the surface are of gloss varnish which is being transferred from anilox roller by coating plate over the matte varnish surface. This combination gives rise to the texture. The topography of the surface understood as the local deviations of the surface from the flat plane. The topography is also known as surface texture. The overall variations in topography are expressed as a topographic index. The printed-substrate topography was measured using the Verity IA Image Analysis software, which uses modified flatbed scanner to acquire an image of the substrate surface. EPSON V700 flatbed scanner was used for this purpose. Verity IA (2017) developed the proprietary Stochastic Frequency Distribution Analysis (SFDA) to describe visible surface features over relatively large surface areas. These variables yield undesirable qualities in paper, board, coating and other surfaces, particularly when additional operations, such as printing, coating or painting, were performed on these surfaces. The human eye can not detect small variations and large blotchy variations at the same time. The SFDA algorithm replicates the analysis and expresses the overall variations as an index number.

The analysis provided detailed information on the roughness of the samples. The roughness of the tested sheets was studied by taking microscopic images of samples at approximately 60× magnification. The data to be gathered was both variables and attributes. The samples were unwound and cut with caution; finger marks were avoided by use of gloves. The cut sheets were placed on scanner bed for scanning through Verity IA Print Target v3 software. The sheets were scanned at 1200 pixels per inch (ppi) and analyzed through the topographic index measurement routine. An Area of Interest (AOI) of size 70 mm × 55 mm was selected from the scanned images and then analyzed through the SFDA algorithm employing suitable settings and profile. The results from software applications were compared and correlations between the results were found.

3. Results and discussion

The data collected from the initial production runs on MET-PET (Table 2) showed mean topographic index of 570 for 100 % dot area, hence it was considered as reference. The target was set to maximize texture effect and verify its consistency.

Table 2: Baseline data for topographic index

Sample no.	Topographic index
1	495
2	590
3	560
4	520
5	715
6	679
7	553
8	552
9	505
10	533
11	576
12	498
13	576
14	590
15	610
Average	570

3.1 Topographic index analysis

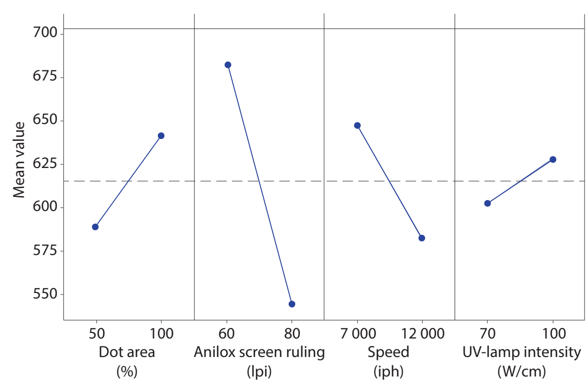

Figure 2: Effects of process variables on topographic index

Figure 2 indicates that topographic index was maximized at higher levels of dot area and UV-lamp intensity, and at lower levels of anilox screen ruling and press speed.The plot also indicates that all the factors are significant as represented by their slope. Lower printing speed corresponds to higher dwell time in nip where the spreading of varnish is high due to prolonged contact period which results in higher topographic index. The higher speed develops more shear rate and concurrently high shear stress induced in the varnish making it resistant to spreading after transfer onto the substrate.

Thus, increase in speed shows lower topographic index. The higher the dot area, the higher amount of matte varnish is released. Therefore, higher dot area results in higher topographic index. Similarly, lower anilox ruling releases more gloss varnish as the cell opening and cell volume is higher on anilox. Therefore, the lower the anilox screen ruling, the higher the topographic index.

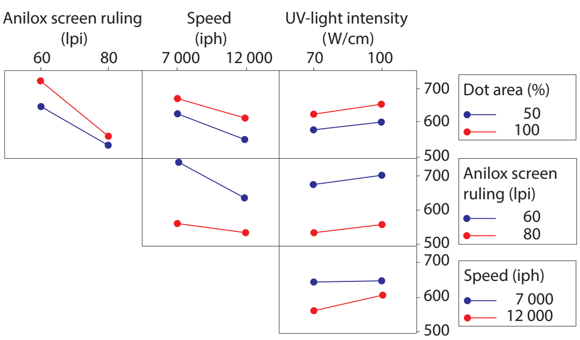

Figure 3: Interaction plot of process parameters for topographic index

Figure 3 indicates that the highest topographic index is obtained at 7 000 iph speed, 60 lpi anilox screen ruling, 100 W/cm lamp intensity and 100 % dot area. The interaction of dot area and speed showed almost parallel, only slightly diverging lines, which indicates the slight degree of interaction. Also, the interaction of dot area with UV-lamp intensity and anilox screen ruling with UV-lamp intensity showed only a bit diverging lines. The interaction of dot area with anilox screen ruling, anilox screen ruling with speed, and speed with UV-lamp intensity shows non parallel state which indicates the significant interaction between them.

3.2 Statistical analysis for topographic index

Table 3 for the topographic index on MET-PET substrate indicates that all the main factors are significant as the *P*-values are below *α* value of 0.05. The *F*-statistic provides an indication of the calculated values by dividing the factor mean square (MS) by the error MS. The larger *F*-statistics with $P < 0.05$ from the ANOVA table confirms the significance of all the main values and interaction between the anilox screen ruling, press speed, UV-lamp intensity and dot area at 95 % confidence interval. The coefficient of determination (*R-Sq*) indicates how well the model fits the data and is calculated by dividing regression sum of squares by total sum of squares. The higher percentage of *R-Sq* indicates 99.55 % of the variability being explained by the model. The *R-Sq*(adj) is a useful tool for comparing the explanatory power of models with different numbers of predictors. The value increases only if the adding of existing factors improves the model to expected change. The *R-Sq*(adj) of 99.20 % indicates the significant improvement of the model by using four factors. It is evident that slight difference between *R-Sq* and *R-Sq*(adj) indicates significant regression of the model by using four factors. The *R-Sq*(pred) indicates how well the model predicts responses for new observations and is calculated from predicted error for sum of squares (PRESS) statistics. The highest *R-Sq*(pred) of 99.42 % indicates that the model predicts new observations nearly as well as it fits the existing data. The lack-of-fit with $\alpha > 0.05$ indicates that the data fits well in the model. The lack-of-fit value of 0.066 represents the accuracy of the model and indicates good predictive ability of regression model. Anilox screen ruling and speed are highly significant while dot area and UV-lamp intensity are important factors in increasing the topographic index.

Table 3: ANOVA table for topographic index (DF – degrees of freedom, SS – sum of squares within groups, MS – mean square witin groups, F-value – ratio of two sample variations, P-value – criterion for level of significance)

Source	***DF***	**Adj *SS***	**Adj *MS***	***F*-Value**	***P*-Value**
Model	7	259 238	37 034	759.47	0
Linear	4	251 890	62 972	1 291.39	0
Dot area (%)	1	27 848	27 848	571.09	0
Anilox screen ruling (lpi)	1	160 140	160 140	3 284.04	0
Speed (iph)	1	58 084	58 084	1 191.14	0
UV-lamp intensity (W/cm)	1	5 818	5 818	119.30	0
2-Way interactions	3	7 348	2 449	50.23	0
Dot area (%) × Anilox screen ruling (lpi)	1	4 848	4 848	99.42	0
Dot area (%) × Speed (iph)	1	820	820	16.82	0
Anilox screen ruling (lpi) × Speed (iph)	1	1 680	1 680	34.45	0
Error	24	1 170	49		
Lack-of-fit	8	636	80	2.38	0.066
Pure error	16	534	33		
Total	31	260 408			

Summary of model: *S* = 6.98306 *R-Sq* = 99.55 % *R-Sq*(pred) = 99.42 % *R-Sq*(adj) = 99.20 %

The interactions of anilox screen ruling and speed play a significant role in enhancing topographic index.

3.3 Confirmation and consistency for topographic index

The best settings 7 000 iph press speed, 60 lpi anilox screen ruling, 100 W/cm UV-lamp intensity and 100 % dot area as obtained from the interaction plot were confirmed by conducting a press run and then checked for its consistency by re-running for a few days.

Table 4: Production, verification and consistency run for topographic index

Trial	Topographic index	Std. dev.
Production run	570	62.67
Confirmation run	802	17.38
Consistency run	799	21.34

From Table 4, a significant improvement is evident from production run to consistency run in topographic index for MET-PET substrate. The comparison between production run and consistency run shows that topographic index is maximized by 40 %.

4. Conclusion

The research work was focused on investigation of offset process parameters, namely the anilox screen ruling, press speed, UV-lamp intensity and dot area, on texture effect. The texture effect was analyzed by the measurement of topographic index. The higher the topographic index, the higher is the textured finish. The production runs were conducted at 80 lpi anilox screen ruling, 10 000 iph press speed, 85 W/cm UV-lamp intensity and 100 % dot area to identify the reference for texture. The target was set to maximize the topographic index from the reference. The data was analyzed by main effect plot, interaction plot and ANOVA to identify the best set of process parameters maximizing the topographic index. The highest topographic index was identified at lower anilox screen ruling and press speed (60 lpi and 7 000 iph) and higher UV-lamp intensity of 100 W/cm and dot area of 100 %.

The results revealed an improvement of 40 % at the identified settings from the reference. The findings of this study shall reduce the complexities of defect occurrence by implementing the optimized press settings. It shall also help the printers to maintain consistency in reproduction; thereby increasing the productivity and profitability.

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TOPICALITIES

Edited by Markéta Držková

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News & more

Almost a quarter of the way to drupa 2020

Based on the technology showcased at drupa 2016 and complemented by the information gained through interviews, as well as by other available data and trade statistics, Smithers Pira forecasted the changes expected to reshape print and packaging supply chains over the next 10 years.

Considering the technical performance and commercial outlook, the list of key transformative and disruptive technologies from drupa 2016 consists of (i) autonomous printing thanks to offset presses with high level of automation, (ii) digital packaging printing, (iii) tactile print effects, (iv) high-throughput inkjet, (v) no-touch workflows, and (vi) commercial 3D printers. On the other hand, there are some topics seen as the challenges that still need to be solved in the upcoming years. These include the integration of multi-channel marketing strategies and traditional print products, maximising returns and customer service benefits from the web-to-print solutions, using functional features for track-and-trace and direct connection of brands to their customers, transitioning inkjet technology to corrugated, folding carton and flexible plastic packaging, and printing electronics to connect smart packaging to the Internet of Things.

Fourth drupa Global Trends report

With the expert panel refreshed from amongst the visitors of drupa 2016, the global survey conducted in October 2016 had nearly 1200 participants, namely 839 printers and 331 suppliers. In both groups, about two thirds of participants represented Europe and the rest the other regions. The survey confirmed the findings of the previous ones. Overall, improvements in revenues are reported. For suppliers, a positive outlook is supported also by improving margins. On the other hand, based on the data gathered during the four years since the series started in 2013, it can be concluded that solutions believed to reverse or at least to stop the decline in some markets do not fulfil the expectations.

When analysing the markets, Functional and Packaging print continue to grow. Among printing technologies, inkjet dominates for most applications in Functional segment and it will further increase according the investment plans (with 63 %). In Packaging, the importance of digital print raises especially for labels; however, flexography and sheetfed offset still represent over 60 % of planned investment. In spite of adding new services, Commercial printing is still suffering from competition with digital communications. Digital colour cutsheet technologies make almost 50 % in the investment plans of this segment. In Publishing, where an increasing number of titles report reduction in circulation following the introduction of online editions, it is about 10 % less. Comparing the actual performance of printers in 2016 with the forecast based on the 3rd drupa Global Trends report, a substantially worse situation is reported in Africa; however, the expectations of companies' economic situation for the next 12 months are even more optimistic than a year ago. The real economic situation was less positive also in case of Middle East and Asia, while North America is still on top among all regions.

Recent market reports from Smithers Pira

In March 2017, three reports have been released, forecasting the future to 2022. The first one is aimed on printing in the Middle East and North Africa region. According its data, a market valued at almost $27 billion in 2017 will see annual cross-segment growth of 8.4 %, while consumption of printed materials will rise from almost 16 million tonnes in 2017 to more than 22 million tonnes in 2022. Thus, in spite of difficult social and political situation in a number of countries, this market is considered lucrative and expanding, which is supported by rising literacy rates and growth in regional publishing as well as packaging demand.

The next two reports monitoring the use of digital and analogue printing technologies and evolution of flexible packaging segment are based on global data. Digital printing is predicted to continue to grow in most print sectors, with full-colour inkjet taking the place of monochrome electrophotography and the introduction of B2 and B1 digital presses delivering higher performance. In value terms, digital print is forecasted to grow by 2.7 % up to 19.1 % during the upcoming five years, however, still corresponding only to 4.3 % of volume (3.9 % in 2017). In case of flexible packaging, cutting-edge technology developments are seen e.g. in pouch packing machinery, sustainable coatings, or high barrier packaging films. The total market for consumer and industrial flexible packaging is reported to be almost $230 billion in 2017 and expected to grow at an annual rate of 4.3 %, with the volume of consumer flexible packaging increasing from over 27 to almost 34 million tonnes between this year and 2022.

The evolution of G7 method

The G7 set of specifications is developed by Idealliance (International Digital Enterprise Alliance), a global visual communications industry association. It is intended as a guide for achieving grey balance and thus a visually similar appearance across all print processes, substrates, and inks. The method is based on ISO printing standards implementation and additional metrics. In recent months, the XCMYK Extended Gamut process datasets and profiles were introduced, resulting from extensive testing.

A number of leading industry systems enabling to calibrate a printing device are certified to meet the G7 greyscale definition. In February 2017, the whitepapers presenting the value of G7 to brand owners and to print service providers were published. Besides the principles and summary of business benefits, several case studies are included.

Retrofitting trend

In recent years, many companies have restricted their investments into new machinery as a consequence of the crisis and uncertainty in long-term development of print markets. Therefore, the importance of various upgrades and retrofits has greatly increased, which is reflected not only in solutions offered by suppliers of conventional printing presses, but also in portfolios of companies providing automation solutions, either general or specialised.

For example, even a 40-year-old six-colour gravure printing press was retrofitted by BST eltromat International in cooperation with Siemens. The main shaft was replaced with individual drives for each of the printing units and also with controlled drives for their doctor blades; in addition, the new register control was implemented. Similarly, numerous modular press control retrofits in companies across the world were reported by ABB, Beckhoff and many more.

Recent patents granted in the field of printing

A Braille signage UV LED inkjet printer

Direct Color received in November 2016 the U.S. patent 9,498,977 B2 – ADA-compliant Braille signage printer and method of printing UV LED curable ink using a flat bed ink jet printer. The solution should enable faster production of Braille or other signage compliant to the requirements of ADA (Americans with Disabilities Act) thanks to fewer passes needed, which also increases the accuracy of dot placement.

A new anti-counterfeiting feature

The solution presented in the U.S. patent 9,553,582 B1– Physical unclonable functions having magnetic and non-magnetic particles, granted to Lexmark International in June 2017, is based on measuring both magnetic field and image view so that the difficulty of replicating is maximised, making the functions difficult to counterfeit. Patented physical unclonable functions may be incorporated into a user-replaceable printer component; this way, the printer equipped with an appropriate reader can authenticate e.g. the new toner cartridge, fuser, or imaging unit.

Inspection of labels with important information

In February 2017, the U.S. patent 9,569,837 B2 – Label inspection system and method was granted to Crest Solutions. The system is designed to provide the accuracy of any type of label or even multiple-page prints such as booklets shipped e.g. with pharmaceutical products. The label inspection system comprises a label scanner and a processor adapted to analyse scanned images and determine a quality control output through identifying regions of interest in a scanned label and performing inspection associated with each region, where stored training images and criteria for individual regions are employed. The inspection can be done inline or offline.

A feature facilitating a creation of correctly formatted documents

The U.S. patent 9,392,127 B1 – Document production system having automatic adjustment of content to fit the printable area of a pre-printed media that was granted to Xerox Corporation in July 2016 relates mainly to the field of multi-function devices, however, a combination of a printer and a scanner or the use of soft copy template is possible as well. A copy of the pre-printed media, e.g. letterhead paper or form, is analysed and the content of the document to be printed is adjusted to fit the printable areas by either scaling, or cropping and dividing into multiple pages (if the reduction in size would render the content illegible).

Optimising a printed image quality through separate processing of line and area details

In March 2017, the U.S. patent 9,591,185 B2 – Processing an image into sub-images mapped into multi-layer print mask data was granted to the Hewlett-Packard Development Company. To provide the best possible image quality both in lines and area fills at the same time, the processing unit of the printer separates the image into a sub-image containing edge and line details, and a sub-image containing area details, which are then reproduced by two different printing mode processing pipelines, accordingly optimised for either line and text sharpness, or for smooth colour transitions.

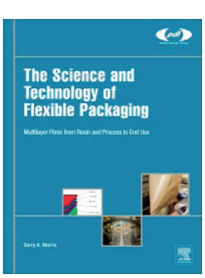
Bookshelf

The Science and Technology of Flexible Packaging: Multilayer Films from Resin and Process to End Use

This reference work has been published with the aim to cover the scientific principles, properties, processes and end-use considerations of multilayer films in flexible packaging and thus aid in material selection and processing, shortening development times, reducing cost, and overall product design improvement. The practical information on material properties essential for or affected by a particular application are given, along with best practice techniques. Environmental sustainability is also considered.

The content is organised in seven parts. The introductory one presents the history and benefits of packaging, consumption patterns, packaging value chain and its needs, benefits of multiple layers in package assembly and related packaging trends. The next two parts overview the basics of processes and materials. Among converting processes, extrusion, film converting, coating and lamination, orientation, and printing are included, together with brief description of packaging equipment and unit operations. For commonly used resins and substrates in flexible packaging, the function, material specifications and regulatory considerations are discussed. One chapter explains the rheology of polymer melts, covering the measurements, influencing factors, relaxation, creep and constitutive equations. Another one focuses on polymer blending for packaging applications, describing the processes and physics of blending, morphology development in blown film, dispersion of rigid particles and nanocomposites and rheology of polymer blends. Part IV summarises film properties – heat seal and barrier behaviour, strength, stiffness, abuse resistance and adhesion, as well as thermoforming, orientation, shrink, frictional and optical properties. The last mentioned can be influenced by the interfacial and surface properties, in addition to the properties of the individual constituent layers. The importance of film properties, suitable measurement methods and typical values are given.

The last three parts are dedicated to practical considerations important for overcoming the challenges of various packaging applications. The book explains how the converting process affects the quality in terms of thermal stability, unwanted material accumulation on the die, moisture-related issues, flow maldistribution, instability issues and curl if the polymers are not well matched, as well as the properties of the blown film related to its stress–strain history, quench rate (air- or water-quenching) and development of elongated morphology in polymer blends. The effect of processing on adhesion to substrates in extrusion coating and interlayer adhesion in co-extrusion is also discussed. Further, a number of end-use factors that should be considered during the design of flexible packaging are covered, such as environmental effects on package performance, interactions between packaging and product, aging, or cost. Finally, the analytical and modelling tools for structure design and process optimisation are presented.



The Science and Technology of Flexible Packaging:
Multilayer Films from Resin and Process to End Use
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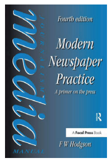
Hardcover
Available also as an eBook

Modern Newspaper Practice: A primer on the press

Author: F. W. Hodgson



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Hardcover
Also as an eBook

This classical book that was first published more than 30 years ago, in 1984, and later updated up to the fourth edition from 1996, is now available as a hardcover. It provides an introduction to all aspects of newspaper journalism from the viewpoint of all who are involved. Given the immense changes of the media landscape through the last two decades, this edition could not have an ambition to provide a comprehensive insight into the present situation, but it still can offer its readers the proven fundamentals of newspaper practice.

Ecommerce Analytics: Analyze and Improve the Impact of Your Digital Strategy

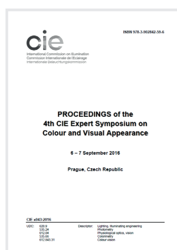
Author: Judah Phillips

Publisher: Pearson Education
1st ed., April 2016
ISBN: 978-0134177281
368 pages, Hardcover
Also as an eBook

The author builds on his experience as a leader of large-scale analytics programs and offers a comprehensive guide for those who want to exploit the potential of e-commerce analytics in business value creation. He advices how to employ visualisation and dashboards to gain in-depth insights, manage data administration while maintaining privacy and security, and build successful analytical teams. The book covers e-commerce analytics value chain, methods, techniques, data model and technology, e-commerce marketing and advertising analytics, customer behaviour understanding, optimisation of conversion rates, loyalty, merchandising and product

CIE x043:2016: Proceedings of the 4th CIE Expert Symposium on Colour and Visual Appearance

The proceedings of the last CIE event, held in Prague in September 2016 as a joint symposium of CIE Division 1 Vision and Colour and CIE Division 2 Physical Measurement of Light and Radiation, offer almost 50 papers dealing with various aspects of the visual assessment of the appearance of objects and materials. The included presentations contribute to the research on visual perception, fundamental metrology of BRDF (Bidirectional Reflectance Distribution Function), measurement of goniochromatism, novel approaches to appearance measurement, as well as models and digital rendering. The studied samples range from special-effect pigment samples through materials of cultural heritage to human skin. Similarly, diverse environment and lighting conditions are covered, including museum lighting, full-field exposure conditions in architectural-scale, LED illuminated roads, spectrum tuneable lighting systems, multichannel hybrid LED luminaires, mesopic conditions, or the stroboscopic effects of pulse-width modulated white LED indoor illumination. Also more specific topics are presented, like the visual fidelity assessment of artworks in virtual reality.

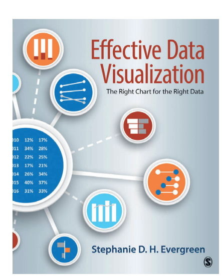


CIE x043:2016: Proceedings of the 4th CIE Expert Symposium on Colour and Visual Appearance
Publisher: Commission Internationale de L'Eclairage
1st ed., September 2016
ISBN: 978-3-902842-59-6
510 pages
Hardcover
Available also as an eBook

Effective Data Visualization: The Right Chart for the Right Data

This guide has good chances to really improve the quality of data visualisation output as indicated by a positive response from readers, reflecting their will to present the data in a clear and visually appealing way. The author explains how to decide which chart or graph is appropriate for particular data and provides the instructions for making it in (widely used) Microsoft Excel, while getting beyond the default options. Readers will learn how to show mean, frequency and measures of variability, visualise comparisons, display relative performance, communicate the survey results, visualise parts of a whole, communicate correlation and regression, visualise qualitative data, and depict trends. The final chapter shares four examples of a positive impact achieved when the new approach in data visualisation enabled to clarify the message and streamline the decision processes.

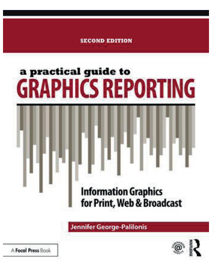
Effective Data Visualization: The Right Chart for the Right Data
Author: Stephanie D. H. Evergreen
Publisher: SAGE Publications
1st ed., May 2016
ISBN: 978-1-5063-0305-5
264 pages
Softcover
Available also as an eBook



A Practical Guide to Graphics Reporting: Information Graphics for Print, Web & Broadcast

This edition reflects the substantial changes in the field of information visualization that happened during the ten years since this book was first published. Due to the expansion of information visualization from traditional news environments to online media and various digital platforms in most sectors of communication and business, a cross-platform, cross-industry approach is necessary. The examples of print, online, and broadcast graphics, as well as tutorials and resource files for exercises, are provided and regularly updated on a companion website.

After the introduction of visual storytelling and its role in the digital age, the guide covers all basic aspects of the topic. It presents visual ethics and standards and explains how to do research, writing, design and data visualisation for information graphics, how to create maps and a diagrammatic representation, and how to add interactivity and produce motion graphics. Each of these chapters is concluded with an expert view and a hands-on exercise. The last chapter includes four case studies.



A Practical Guide to Graphics Reporting:
Information Graphics for Print, Web & Broadcast
Author: Jennifer George-Palilonis
Publisher: Focal Press
2nd ed., September 2016
ISBN: 978-1-138-89131-9
232 pages
Hardcover
Available also as an eBook

Eco Packaging Now

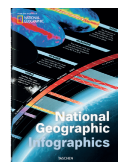
This volume presents several tens of inspiring examples of ecologically conscious packaging from around the world, selected by two renowned branding and packaging designers. The motivation is to show design packaging strategies that fulfil the basic requirement of product protection, but at the same time ensure that the packaging is more sustainable and not harmful for the environment. Taking into account the global trade and growing volume of packaging, this approach is increasingly important. The packaging industry is searching for ways to reduce waste, save energy, enhance the sustainability of the overall product and create green packaging. The book briefly presents the main features of such packaging – the use of natural, handmade and composite materials, green inks, and simplified design. The main part in three detailed sections showcases the results of successful efforts to make the packaging recyclable, biodegradable and reusable through finding the unique ways to manipulate materials, structures and uses.

Eco Packaging Now
Editors: Tony Ibbotson, Peng Chong
Publisher: Images
1st ed., October 2016
ISBN: 978-1-86470-703-8
248 pages
Hardcover

mix, transactions streamlining, and accurate sales attributing. The author also explains what is an e-commerce platform and how the integration of data and analysis can drive e-commerce strategy, concluding with a view on the future of e-commerce analytics methods and capabilities.

National Geographic Infographics

Editor: Julius Wiedemann



Publisher: Taschen
1st ed., December 2016
Multilingual edition:
English/French/German
ISBN: 978-3836545952
480 pages, Hardcover

The collection of the best National Geographic infographics of the past 128 years is now published in a large-format edition, accenting the attention that the magazine has continually paid to every detail since its launch in 1888. The evolution of National Geographic and its functional use of graphics is reviewed in an essay by Nigel Holmes and faithfully reflected by the main content – including four fold-outs mimicking the magazine original pull-outs or inserts. The infographics, which is organised in seven sections, explores the history, the planet, humans, animals, plants, science and technology, and space. The Italian/Portuguese/Spanish multilingual edition is also available.

CP Logo Set

Editor: Leterme Dowling

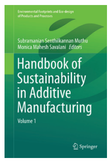
Publisher: Counter-Print
1st ed., 2013–2016
ISBN: 978-09570816|11
|28|42|66|80/
978-0993581205
952 pages, Softcover

A set of six books with animal, monogram, human, alphabet, nature, and abstract logos is now on sale. Each book contains several hundreds of logos from some of the world's leading design companies, categorised in relevant sections.

Handbook of Sustainability in Additive Manufacturing

Editors: Subramanian S. Muthu, Monica M. Savalani

Publisher: Springer
1st ed., March/April 2016
ISBN: 978-9811005473/ 978-9811006043
282 pages, Hardcover
Also as an eBook

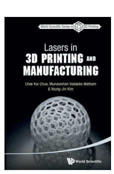


To move additive manufacturing technology towards mainstream production, the sustainability aspects must be solved. This handbook summarises the current knowledge gained from life cycle, embedded carbon and environmental impact assessment studies of this technology, originating from both industry and academic research projects. The first volume discusses the studies of support structures in the production of extrusion-based parts, laser energy consumption model, sociocultural sustainability of 3D printing, sustainable design, functionality integration, part consolidation, and production systems redesign. The second one examines, among others, the energy efficiency of metallic powder bed processes, biomimetic design models, frugal design, and carbon footprint comparison of flat and curved layer-by-layer approaches.

Lasers in 3D Printing and Manufacturing

Authors: Chee K. Chua, Vadakke M. Murukeshan, Young-J. Kim

Publisher: World Scientific Publishing Co.
1st ed., May 2016
ISBN: 978-9814656412
400 pages, Hardcover
Also as an eBook



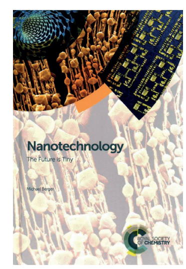
This book focused on the employment of lasers in additive manufacturing covers all important aspects – the basics of lasers, optics and materials, various techniques of laser-assisted manufacturing and 3D printing, including micro- and nanopatterning, as well as laser safety and hazards. It concludes with future prospects.

Nanotechnology: The Future is Tiny

This book presents current nanotechnology advances in a less conventional way; 176 research projects are introduced using interviews and descriptions of the projects in the scientists' own words, thus offering a personal perspective on the trends and development in the field of nanoscience and technology. In seven chapters, the book goes through power generation decentralized down to a personal level, fully flexible and transparent electronics, nanofabrication, two-dimensional nanomaterials, the use in medicine e.g. for cancer diagnostics and therapeutics, more special areas where nanotechnology materials and methods are applied, such as metamaterials, atomically precise manufacturing, developments in DNA-based nanotechnology, or sensing by the so-called smart dust, concluding with environmental impact, discussing both the anticipated benefits and potentially negative effects of engineered nanoparticles.

In respect to printing, for example the inkjet-printed solar cells, foldable capacitive touch pad printed with nanowire ink, nanomaterial printed to assemble microstructures from 0D to 3D, and printing of graphene structures, composite structures containing e.g. quantum dots, or complex capsule arrays are mentioned.

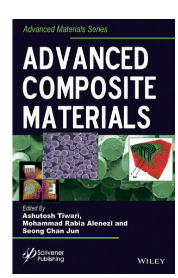
Nanotechnology: The Future is Tiny
Author: Michael Berger
Publisher: Royal Society of Chemistry
1st ed., August 2016
ISBN: 978-1-78262-526-1
373 pages
Hardcover
Available also as an eBook



Advanced Composite Materials

The first chapter of this book reviews composite materials for application in printed electronics – filler materials and conductive polymers, preparation of electronics materials for printing, and overview of application fields. In the following chapters, the study of current-limiting defects in superconductors using low-temperature scanning laser microscopy, innovative high-tech ceramics materials, enzymatic electrochemical sensing based on carbon nanomaterials, nanostructured ceramics and bioceramics for bone cancer treatment, the importance of biomaterials testing in adequate animal models for a development of bone regeneration therapeutic strategies, tuning hydroxyapatite particles' characteristics for solid freeform fabrication of bone scaffolds, and carbon nanotubes-reinforced bioceramic composite as an advanced coating material for orthopedic applications are presented.

Advanced Composite Materials
Editors: Ashutosh Tiwari, Mohammad R. Alenezi, S. Chan Jun
Publisher: Wiley-Scrivener
1st ed., October 2016
ISBN: 978-1-119-24253-6
480 pages
Hardcover
Available also as an eBook



Bookshelf

Academic dissertations

Printed Wearable Electrochemical Sensors for Healthcare Monitoring

Doctoral thesis – Summary

Author:
Amay Jairaj Bandodkar

Speciality field:
NanoEngineering

Supervisor:
Joseph Wang

Defended:
7 June 2016, University of California, Department of NanoEngineering San Diego, California, United States

Contact:
amay.bandodkar@northwestern.edu

Addressing the need for the sensors that allow continuous non-invasive monitoring of vital chemical biomarkers, this thesis aimed to develop body-compliant, skin-worn electrochemical sensors, enabling the detection of physiologically relevant chemicals directly on the human skin. The first chapter briefly introduces wearable electrochemical sensors and their fabrication, including the conditions which must be met if these sensors should be completely printed – with respect to materials, operation, power source, communication, data security and analytics. The following chapters detail the preparation of all-printed stretchable electrochemical devices based on screen printing of appropriately modified conducting inks, subsequently functionalised where needed. The electrochemical performance of devices with intrinsic stretchability was stable at strains of up to 100 %, while the devices combining intrinsic and design-induced stretchability could withstand strains of up to 500 %. The self-healing microcapsules-based printed devices regained the original electrochemical properties within a few seconds even after being completely severed. Among printed wearable sensors for real-life applications, pontentiometric, amperometric and hybrid sensors are presented. The epidermal tattoo-based potentiometric pH and sodium sensors had reversible response to varying concentrations of analyte and survived repeated mechanical deformations; their viability to record transient pH and sodium levels in the human sweat in a non-invasive fashion was demonstrated by on-body tests. Similarly, the tattoo-based amperometric sensors for detection of lactate and glucose were thoroughly tested and their high selectivity and sensitivity was validated by epidermal studies. Finally, the first example of a hybrid wearable sensor patch that integrates a lactate biochemical sensor with an electrocardiogram electrophysiological sensor is given. The need for cross-disciplinary research to realize the full potential of wearable chemical sensors is stressed in conclusion.

Nano-Material Based Flexible Radio Frequency Sensors for Wearable Health and Environment Monitoring: Designs and Prototypes Utilizing 3D/Inkjet Printing Technologies

Doctoral thesis – Summary

Author:
Taoran Le

Speciality field:
Electrical and Computer Engineering

Supervisor:
Manos Tentzeris

Defended:
23 June 2016, Georgia Institute of Technology, School of Electrical and Computer Engineering Atlanta, Georgia, United States

Contact:
tao@72sense.com

The objective of this thesis was the design and fabrication of novel, low-cost, battery-free and flexible wireless sensors with enhanced sensitivity and miniaturized size to enable real-time sensing and monitoring of environmental conditions over large areas, as well as new applications of wearable flexible electronics. In the development of passive wireless sensors for gas or strain detection, suitable nanomaterials were utilised and printed on a 3D or inkjet printer. Involving a multidisciplinary approach, a nanomaterial study, an electromagnetic design, and a fabrication process are discussed for each sensor, along with optimising their performance based on real scenarios. After the introduction and literature survey of the related areas of remote sensing, the dissertation presents three groups of passive wireless sensors. First, the possibility to use carbon nanomaterials to detect extra low concentration of gases has been proved. A novel graphene oxide ink was inkjet printed, cured, and eventually reduced in a hydrogen and argon

atmosphere under elevated temperature to restore the graphene electrical properties. The resulting wireless gas sensors exhibited zero/low-power operation, high sensitivity and good selectivity. Second, two antennas were printed with in-house-developed electrically conductive adhesives and utilised as flexible and stretchable strain sensors – one based on a 2D bow tie antenna and the other one on a 3D antenna. In the latter case, both the antenna and the substrate were printed using the same commercial 3D printer. The silver-filled adhesive material enabled to keep the conductivity above 10^3 S/cm at a strain of 240 %. Finally, the electrically conductive adhesives were applied to pattern cascaded spiral resonators as a hand gesture sensor that combines chipless RFID technology and flexible, stretchable conductors fabricated by a commercial 3D printer, showing a potential to enhance human-computer interaction.

Doctoral thesis – Summary

Author:
Estefanía Costa Rama

Speciality field:
Electroanalysis

Supervisors:
María Teresa Fernández Abedul
Agustín Costa García

Defended:
17 June 2016, University of Oviedo, Department of Physical and Analytical Chemistry
Oviedo, Spain

Language:
Spanish/English

Contact:
ecosta.rama@gmail.com

(Bio)Electroanalytical Devices Based on Carbon Transducers: Screen-Printed Electrodes and Pins

In this thesis, the miniaturised, low-cost commercial screen-printed carbon electrodes and later the mass-produced pins are employed as transducers to develop a number of electrochemical devices for the sensing of several analytes of clinical or food industry interest. After the introduction covering electrochemical detection, biosensors and transducers, flow injection analysis and relevant analytes, and defining the objectives, the dissertation is divided into three parts. The first one deals with amperometric enzymatic sensors for glucose, fructose, and ethanol. The aim was to obtain biosensors as simple as possible but with analytical characteristics suitable for determination in real samples. To accomplish this, the commercial disposable three-electrode electrochemical cells screen-printed on a ceramic substrate were used and the carbon ink of the working electrode was modified with ferrocyanide as a redox mediator. In case of alcohol sensors, also Prussian blue and cobalt phthalocyanine were tested. To immobilise the enzymes, the solution was simply deposited on the electrode surface and let to dry. The analytes in real samples (food, drinks and blood) were detected with high accuracy, good sensitivity, intersensor reproducibility, and high stability.

In the second part, a thorough review of the main biomarkers of cancer and cardiovascular diseases is presented, along with the electrochemical immunosensors for their detection that are based on screen-printed electrodes. Then, the fabrication of an immunosensor for Alzheimer's disease biomarker and a bi-immunosensor for two breast cancer biomarkers is described. The sensors are based on screen-printed carbon electrodes that are nanostructured with gold nanoparticles generated *in situ*. The analytical signal is based on the anodic stripping of enzymatically generated silver by cyclic voltammetry. The sensor consisting of a competitive immunoassay for Alzheimer's disease biomarker showed a low limit of detection and a wide linear range. For the simultaneous detection of two biomarkers, a design with two working electrodes was utilised; the evaluation of the sensor precision and stability and the validation of its performance in clinical settings is in progress. The third part presents the electroanalytical devices utilising stainless-steel pins, with those acting as working electrodes modified with carbon ink. First, an enzymatic glucose sensor was constructed; its analytical characteristics were comparable to those of glucose sensor mentioned above. Second, following the automation trend, the pins were integrated into a flow injection electroanalytical system. As a proof-of-concept, the feasibility of the system to determine glucose was evaluated and the application to real food samples has shown accurate results.

Events

Online Print Symposium 2017

Munich, Germany
6–7 April 2017

This event is organised by Fogra, Zipcon consulting led by Bernd Zipper, the author of the German-written book that summarises the fundamentals, strategies and utilisation of web-to-print (Strategie: Web-to-Print – Grundlagen, Strategien, Anwendungen), and the German printing and media industries federation, bvdm (Bundesverband Druck und Medien). The slogan chosen for the 5th edition is 'Online Challenge – Customer Centricity Focus.' The program highlights include the critical success factors of mass customisation, competition with future potential, creating a brand with print products in the online business, and proper use of collected customer data in both on- and offline marketing, directly based on best practice examples.

SPIE Optics & Optoelectronics 2017

Prague, Czech Republic
24–27 April 2017

This European conference dedicated to the advances in laser technology covers 17 conference topics and offers over 700 presentations, with a few ones showing applications of printing techniques – for example the trace nitroaromatics discrimination using aerosol jet printed fluorescent sensor arrays or preparation of Mach-Zehnder interferometric photonic biosensors by inkjet printing technology. Plenary presentations will discuss the prospects and challenges of next-generation lasers generating peak power of 100 petawatts and beyond, advanced optical manipulation using materials science, optical systems implemented with multimode fibers, new opportunities enabled by x-ray laser radiation provided by European x-ray free electron laser (XFEL), and high average power, diode pumped petawatt laser systems for precision science and commercial applications.

Two weeks later, SPIE Microtechnologies 2017 held in Barcelona, Spain (8–10 May 2017) includes presentations of various inkjet printed sensors, namely the sensors for detection of dissolved oxygen and pH value, capacitive sensor for position tracking of a mirror in a Michelson interferometer setup based on micro-opto-electro-mechanical (MOEMS) systems, and selective microfluidic biosensor using functionalised carbon nanotubes. At the end of June, two events are co-located in Munich, Germany – SPIE Optical Metrology 2017 focused e.g. on optical measurement systems for industrial inspection and automated visual inspection, and a new conference, SPIE Digital Optical Technologies (25–29 June 2017). The latter one is reserved for optics designed, fabricated, enhanced or altered by digital means, and related developments in 3D sensors, immersive multimedia, novel displays, light sources and imaging systems. Registered attendees of both events will have a chance to try out four advanced virtual reality, augmented reality and mixed reality headsets available today.

Graphics Canada 2017

Toronto, Canada
6–8 April 2017

The largest fair for the graphic communications and printing industries in Canada features also several panel discussions, educational conferences, seminars, training sessions and more, including the half-day Idealliance G7 Summit (more details on G7 can be found in News & more section).

Smithers Pira Events

A number of events (co-)organised by Smithers Pira have been scheduled for the spring months worldwide. First, the 9th edition of Specialty Papers Europe held with TAPPI in Cologne, Germany (3–5 April 2017), and this year's SustPack in Scottsdale, Arizona, USA (24–26 April 2017), again organized jointly with SPC, the Sustainable Packaging Coalition.

Three weeks later, the list continues with the Global Food Contact in Rome, Italy (15–17 May 2017), offering also the workshop on product stewardship for food contact materials, discussing best practices and special issues related to the EU and US legislation.

In June, three consecutive US events follow in Atlanta, Georgia; namely the 3D Printing for Industrial Applications (5 June 2017), Digital Print for Packaging (6–7 June 2017), and, finally, Digital Textile Printing (8–9 June 2017).

Inkjet Summit

Ponte Vedra Beach, Florida, USA
24–26 April 2017

This summit reflects the expected growing importance of inkjet printing technology in the graphic arts industry. It connects senior managers and business executives, who consider or already started implementing inkjet solutions, with the industry experts and market leaders, thus providing the opportunity to develop strategies and partnerships important for major investment decisions.

WAN-IFRA Events

The present and upcoming months offer also a great number of various events for all who are interested in media and news publishing. Besides 2017 editions of Publish Asia in Kuala Lumpur, Malaysia (18–20 April 2017), Digital Media Europe in Copenhagen, Denmark (24–26 April 2017), and Zeitung Digital in Berlin, Germany (22–23 June 2017), the series of WAN-IFRA Academy trainings can be attended. For example, several 'Editorial Leaders' modules are scheduled for May and June in India, showing how to create engaging stories, utilise online video and data journalism, write for the web, harness social media, and lead the newsroom.

World News Media Congress 2017

Durban, South Africa
7–9 June 2017

All the five topics of the 69th edition, traditionally co-located with the World Editors Forum in its 24th year, stress the need for deep reflection in 2017 in order to rebuild trust and distinguish quality news, while at the same time developing a sustainable business. As usually, the program full of networking is complemented by workshops and exhibition.

Forum & INFO*FLEX 2017

Phoenix, Arizona, USA
30 April to 3 May 2017

The annual Forum of Flexographic Technical Association in 2017 has offered new technical sessions, spanning four days. The pre-conference session is reserved for the information prepared by the Flexo Quality Consortium, this year starting with a brief update on the new and changing standards, continuing with three reports of projects dealing with flexographic printing plate and mounting tape optimisation, high resolution printing and press characterisation based on CxF (Colour Exchange Format), and concluding with two presentations on expanded gamut printing, intended to detail the effects of ink sequence on colour gamut.

The main program then comprises ten sessions, traditionally covering wide range of topics. On the first day, the size and scope of the flexography market together with the expected impact of an announced redesign to the Nutrition Facts Label and changes to Food Contact Compliance are in focus, as well as the current status of the employment situation showing a shortage of skilled labour, with recommended measures in respect to recruiting and training. Various new technologies that substantially change the landscape in flexography and package printing are presented on the second day. Improving the overall efficiency through effective prepress workflow, colour management system, automation and proper pressroom metrics, along with the ways to succeed in the corrugated market, are the topics of the third day. The final sessions are dedicated to the right choice of consumables and practical press optimisation trial.

The Excellence in Flexography Awards winning solutions, announced on Sunday evening, are on display for the duration of INFO*FLEX on Monday and Tuesday.

CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing to CIE S 025

Bern-Wabern, Switzerland
8–11 May 2017

This tutorial and practical workshop is organised by CIE Division 2 to facilitate the implementation of the CIE S 025 standard, which defines the test method for LED lamps, LED luminaires and LED modules, in industrial test laboratories and national metrology institutes. This standard published in 2015 lists the requirements that must be met to perform reproducible and traceable photometric and colorimetric measurements (see News & more section in previous issue, 5(2016)4).

After the introduction and theoretical background presented on Monday afternoon, there are two days filled with practical work in the optics laboratories of METAS, the National Metrology Institute of Switzerland, making use of its state-of-the-art measurement equipment that includes goniophotometers, integrating spheres, spectroradiometers and tuneable lasers. The fourth day gives a chance to recap, discuss and make conclusions. In the afternoon, the workshop on MESaIL and PhotoLED could be attended, presenting the results of the two respective European research projects related to photometry and radiometry.

Printed Electronics Europe 2017

Berlin, Germany
10–11 May 2017

In 2017, the European IDTechEx event joins nine conferences. The agenda runs in eight tracks, starting with numerous keynotes on printed electronics in general, sensors, wearables, Internet of Things applications, 3D printing (followed by graphene keynotes), energy harvesting, energy storage innovations, and electric vehicles.

Namely, Track 1 in Hall Europa includes keynotes discussing the status, forecast, innovation and opportunities of printed, hybrid and flexible electronics, the challenges faced by printable electronics in automotive, packaging digitalization opportunities and issues from a brand owner perspective, as well as end user insight panel. The program there then continues with sessions dedicated to structural electronics, hybrid electronics, display innovations, printed electronics devices and solutions, printed and flexible electronics manufacturing, and finally the closing keynotes. These uncover a new printing technology for printing of nano- and micro-electronics and sensors on flexible or rigid substrates, a different approach to volume manufacturing of printed electronics, advancements in future display technologies with free form displays, and digital fabrication of integrated electronic systems.

The list of presentations in all the other tracks is also rich, covering virtually any research topic or identified business opportunity in this field. The main two days of Printed Electronics Europe 2017 conference and exhibition are as usually framed by the days offering masterclasses and tours. The schedule consists of 25 masterclasses organised into 5 blocks with 5 topics each.

CPES2017 – Canada's Printable Wearable Flexible Electronics Symposium

Toronto, Canada
24–26 May 2017

The sessions of the first day go from smart packaging and retail, through intelligent homes and buildings – with the keynote speech of Ron Zimmer reviewing the key developments and opportunities for flexible electronics in this market, to wearables and smart textiles, complemented by live demonstrations of advances in wearables and bio-sensing garments. The second day is focused on printable, flexible, and wearable electronics manufacturing. In keynotes scheduled that day, Michel Popovic presents France's printable electronics sector, Russell J. Schwartz plans to address some of the main trends in functional printing for the new electronics era, and Stan Farnsworth discusses the market challenges from wearables to Internet of Things and automotive. The noon time is reserved for Innovation awards.

On the third day, CPES participants can for the first time attend either financing and mentoring panel for early and growth stage companies, followed by the Startup of the Year Award presentation, or choose a masterclass; either the one targeted on evolving printable electronics standards or the other one dealing with inks and pastes for printable, flexible and wearable technologies. Throughout all days, the exhibition and academic poster presentations are at hand.

49th Conference of the International Circle of Educational Institutes for Graphic Arts Technology and Management

Beijing, China
14–16 May 2017

In 2017, the IC event is hosted by the Beijing Institute of Graphic Communication and China Academy of Printing Technology. It is organised jointly with the 8th China Academic Conference on Printing and Packaging. The keynotes span a wide range of topics that include e.g. the study of white appearance by M. Ronnier Luo, latest research achievements in smart packaging by Pierre Pienaar, professional standards for Russian printing industry by Alexander Tsyganenko, print media and the cloud custom business by Hsieh Yung-Cheng, or business models, innovation and strategy finding for printing industry by Alexander W. Roos.

Archiving 2017

Riga, Latvia
15–18 May 2017

As the other events organised by the Society for Imaging Science and Technology, this conference offers an intensive program with presentations, short courses and more. In the 2017 keynotes, Raivo Ruusalepp deals with the born-digital heritage and Chris Edwards with the 3D imaging of the Berlin Philharmonie.

Graphitec 2017

Paris, France
30 May to 1 June 2017

The 16th edition of the leading graphics industry event in France offers exhibition, conferences, workshops, round tables and more, covering web-to-print, cross media, production management, prepress, offset and digital, packaging, labels, and finishing, among others.

Dscoop EMEA 6

Lyon, France
7–9 June 2017

The program of the three-day event consists of several keynotes, numerous presentations, discussion panels, and solutions showcase. The educational sessions are organised in four tracks: business models, sales and marketing, innovation and future trends, and production management, which cover publishing, commercial print, photo, and labels and packaging.

Digital Publishing Innovation Summit

London, UK
12–13 June 2017

On both days of the event, the schedule is composed of presentations and panel discussions featuring over 30 industry speakers. The topics range from high-impact advertisement through expanding digital subscription revenue, successful strategy development and various publishing models up to creation and testing of digital content, including the development of editorial content at CERN, the European Organization for Nuclear Research.

2017 PPFIC Conference 63rd Annual Pulp, Paper and Forest Industry Technical Conference

Tacoma, Washington, USA
18–23 June 2017

Besides attending the conference technical program, developed over the course of a two year period, the participants can register for tutorials organised at last two days and aimed on paper machine drives, electrical safe work practices for the forest product industry, and significant industrial changes to the 2017 edition of the US standard NFPA 70 – National Electrical Code (NEC), developed by the National Fire Protection Association.

2017FLEX

Monterey, California, USA
19–22 June 2017

Sticking to the established format, the program of this event that is aimed primarily on flexible hybrid electronics offers one day of short courses and three days of technical conference, complemented by the exhibition on 20 and 21 June. Three short courses options are listed in the morning; the attendees can learn about flexible hybrid electronics printing, placement and packaging, deal with flexible sensor systems integration, or get introduced to the seven primary techniques used in commercial 3D printing and additive manufacturing. In the afternoon, one course is about the harvesting of energy, its efficient storage and use for powering the Internet of Things devices, and another one will discuss the reliability assessment protocols for flexible hybrid electronics, both the already developed ones and the ones being currently developed, including their comparison against the techniques in practice for conventional electronics.

The technical conference starts with two plenary sessions exploring relevant markets and road maps. The following sessions are splitted into three tracks and cover the substrates, nanoparticle inks, technologies, methods and facilities for flexible printed and hybrid electronics manufacturing, including printing technology, 3D printing, direct write technology, encapsulation and coating, further the flexible printed and hybrid electronics applications, namely the conductors, flexible displays, power technology, sensors, biosensors, radio frequency technology, military and security applications, as well as inline inspection, related standards and reliability testing, and also various emerging capabilities.

In addition, Applied Materials Tour is organised on 23 June, explaining the roadmap for flexible displays from rigid through bendable and rollable up to foldable ones, giving updates on chemical vapour deposition and SmartWeb roll-to-roll sputter system, and finished by a lab tour.

ICC Graphic Arts Experts' Day Prague

Prague, Czech Republic
29 June 2017

The International Color Consortium is holding this event focused on current issues in colour management within its Prague meeting scheduled for 27–29 June. The program is aimed on the printing, packaging and publishing industries in the Eastern Europe region. The speakers will discuss working with PDF/X files, using standard printing conditions and characterization data, working with the Perceptual Reference Medium gamut, doing soft proofing, colorimetric and spectral matching, communication of spectral data from prepress to press, using the new measurement conditions (M0–M3) defined in ISO 13655 Graphic technology – Spectral measurement and colorimetric computation for graphic arts images, the ICC Profile Registry, problems that can be solved with iccMAX, multi-colour (CMYK++) printing and proofing, matching offset and pure digital printing, consistent colour appearance, and various aspects of multi-angle measurement. The event is free to attend, but places are limited.

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