



25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM  
2014

## The Influence of UV Varnish on Colorimetric Properties of Spot Colors

Eduard Galic<sup>a,\*</sup>, Ivana Ljevak<sup>b</sup>, Igor Zjakić<sup>c</sup>

<sup>a</sup>*Stega tisak d.o.o., Heinzelova 60/1, 10000 Zagreb, Croatia*

<sup>b</sup>*Badel1862, Vlačka 116, 10000 Zagreb, Croatia*

<sup>c</sup>*University of Zagreb, Faculty of Graphic Arts, Getaldićeva 2, 10000 Zagreb, Croatia*

---

### Abstract

Understanding the influence of UV varnishing on diversified tonality spot colors is significant in offset printing process. Versatility of various spot colors implies repeatability and correct reproduction. UV varnishing methods, besides enhancing the visual impact on the product, have a protective role, but due to the effect on different wavelengths spot colors can cause negative colorimetric changes. The research examined the impact of UV varnishing methods on printed spot colors on diverse printing substrates. The degree of change on prints caused by UV varnish was determined using spectrophotometric and densitometric methods. Research results are clearly showing the modality and the extent UV varnishing method causes on spot colors. This paper presents objective conclusions that help predict possible variations in spot colors, as well as limit values of colorimetric deviations that may affect the quality of the reproduction process.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of DAAAM International Vienna

*Keywords:* UV varnish; spot color; color tolerance; color measurement

---

---

\* Corresponding author. Tel.: +385 98 974 1851; fax: +385 1 6197 430.  
E-mail address: [galic.eduard@gmail.com](mailto:galic.eduard@gmail.com)

## 1. Introduction

Using spot inks has a very important role in the printing industry. In addition to providing the possibility to increase the gamut reproduction, spot inks also provide a very important element: the repeatability of printing process and reproduction chain. These inks with increased pigment concentration attain high tint density during the printing process. These inks are often called mixed colors, and are classified in color scales due to their extremely large number and due to the number of different manufacturers [1]. Pantone color system is certainly one of the most widely used color systems. One of the reasons for the global acceptance of Pantone color system, especially in the printing industry, is its extremely wide array of spot colors. Some of the Pantone system (Pantone Matching System - PMS) colors can be produced using prescribed ratios of CMYK system standard process colors. It is possible to print all PMS system colors in a real-printing process using optimal inking in a combination with a certain ratio of process colors with the addition of PMS system special colors [2]. Coated and uncoated printing substrates require different PMS printing colors. Particular issues in printing PMS system colors, especially in large circulations, are possible variations in color, and the fact that, despite the improvement of printing machines automation and print quality control methods, subjective assessment is still an important factor and a subject of numerous studies [3-7]. In addition to print mechanical protection and shortening the time required to start the finishing processes, varnishing processes are often used for visual enhancement, especially in combinations of various spot varnishing. UV varnishes have different composition than oil-based varnishes. Surface is cured by UV radiation, and achieved gloss surpasses the gloss in prints with oil-based varnish, as well as the gloss in prints with water-dispersible varnishes. For the desirable resulting effects gloss UV varnishing process is often used in combination with matt thermal laminating procedures. UV varnished prints also have great smoothness that cannot be achieved with oil-based and water-dispersible varnishing. The application can be carried out using special printing units within the offset printing machine, using screen printing technique and flexographic printing technique. Components of UV varnish are acrylic oligomers, acrylic prepolymers, and photoinitiators [8]. UV varnishing technology used in the offset printing technique has many advantages, such as high gloss, needs very little or no powdering, instant curing, the ability to print on non-absorbent substrates, excellent product mechanical protection, option of applying different scents, option of different visual effects, and simple spot varnishing. Environmental sustainability of offset printing, as well as the potential impact of UV varnish components on the environment certainly need to be considered in the area of UV varnishing technology and the process of printing PMS colors in an offset printing technique [9]. Color changes influenced by different varnishing methods have been studied over the last ten years. However, previous studies were mainly focused on changes occurring in printing system process colors, and were rarely focused on colorimetric changes occurring in spot colors. This is the subject of this study as spot colors are becoming indispensable when printing a variety of printed products, especially packaging. Therefore, it is necessary to explore and understand the mechanism and change mode of spot colors colorimetric properties when applying a UV varnish in order to avoid significant impact on the observer. In one of the earlier studies Hoffstadt pointed out the issue of color change  $\Delta E$  due to gloss and matt varnishing processes in offset printing [10]. The effect of UV varnishing on surface properties of the most commonly used uncoated, gloss and matt coated printing substrates in CMYK environment was studied in the area of digital printing technology. The study indicated colorimetric differences  $\Delta E$  in samples and differences in gloss  $\Delta GU$ . Increased application of UV varnish caused a proportional increase in gloss and at the same time a decline in roughness on coated printing substrates [11]. The study of interdependence of UV coated and printed printing substrate surface topography and achieved gloss in offset printing technique indicated decreased roughness when using UV gloss varnishing, and increased roughness when using UV matt varnishing [12]. Interdependence of roughness, coating amount and printing substrate gloss was confirmed by other studies [13-16].

## 2. Experimental

Due to the extremely large variety of PMS system colors, colors used for the purpose of this research were randomly selected from different parts of the spectrum. In total, four selected colors were printed in an offset printing technique using newer generation printing press. Colors were printed on different printing substrates that are the most commonly used substrates in everyday production. Printing conditions were in accordance with the

international standard ISO 12647-2:2013 which provides optimal conditions for obtaining high-quality prints. Characteristics of printing substrates with accompanying standards and values are shown in the tables below.

Table 1. Technical characteristics of matt coated printing substrate.

Characteristics	Standard	Measure	Value
Basis Weight	ISO 536	g/m <sup>2</sup>	350
Gloss Hunter	ISO 8254-1	%	57
Brightness D65	ISO 2470-2	%	99
CIE Whiteness		%	128
Opacity	ISO 2471	%	99,5
Gloss Lehmann	ISO 8254-2	%	55
Smoothness PPS 10	ISO 8791-4	µm	2

Table 2. Technical characteristics of gloss coated printing substrate.

Characteristics	Standard	Measure	Value
Basis Weight	ISO 536	g/m <sup>2</sup>	350
Gloss Hunter	ISO 8254-1	%	79
Brightness D65	ISO 2470-2	%	96
CIE Whiteness		%	127
Opacity	ISO 2471	%	99,6
Gloss Lehmann	ISO 8254-2	%	77
Smoothness PPS 10	ISO 8791-4	µm	0,95

Table 3. Technical characteristics of uncoated printing substrate

Characteristics	Standard	Measure	Value
Basis Weight	ISO 536	g/m <sup>2</sup>	250
Brightness D65	ISO 2470-2	%	103
CIE Whiteness		%	150
Opacity	ISO 2471	%	98,5
Roughness Bendtsen	ISO 8791-2	µm	230
L* (D65)	ISO 5631-2		92,7
a* (D65)	ISO 5631-2		8,1
b* (D65)	ISO 5631-2		-14,9

Selected PMS system colors: 200C/U, 485C/U, 513C/U and 877C/U are characteristic for several reasons. PMS system color 200C is composed of a dominant Rubine Red component (73.9%), Pantone Yellow component (24.6%) and Pantone Black (1.5%) component. The corresponding wavelength is 399 nm. Rubine red pigment is a non-alkali-resist ink pigment, which can cause color-shift due to pH incompatibilities between the alkaline aqueous coating and certain alkaline sensitive ink pigments. Components of PMS color 485C are Rubine Red (50%) and Yellow (50%), and the average wavelength is 618 nm. PMS 513C contains Rubine Red (75%) and Pantone Green (25%), and the average wavelength is 425 nm. PMS color 877C, compared to other selected PMS system colors, is specific for several reasons. 'Conventional' metallic base colors contain metal flake, which leads to the surface as the ink dries to produce the metallic effect. The extent of this 'leafing characteristic' can vary depending on the length of time it takes for the ink to dry. This can lead to inconsistencies in the appearance of the colors from run to run [17]. The inks were mixed according to PMS 'recipe' and prescribed ratios, and the ingredients were from a reputable printing inks manufacturer – Flint. Inks were mixed in C (coated) and U (uncoated) version, with respect to the printing substrate. A control strip was used for printing quality control during the printing process as printing process was carried out under the standardized conditions according to ISO 12647-2:2013 standard [18]. Control strip, for the purposes of the study and spectrophotometric measurement, consists of 100% RTV measuring fields in each selected PMS system color. In-line spectrophotometric and densitometric control was carried out during the printing process. A visual inspection of printed PMS colors was also carried out – comparison with the 5 month old reference PMS system color scale in C and U version. Upon printing process completion, the samples, as recommended by the color and printing substrate manufacturers, underwent 24 hour drying process - oxypolymerization and adsorption – in climate controlled conditions of T 25°C and RH 55%. UV gloss varnishing in screen printing technique has also been carried out under the standardized conditions and the material used was from a reputable manufacturer. 150 microns density screen printing mesh was used. In order to determine the limit

values representing the impact of UV varnishing on colorimetric changes of selected PMS colors laboratory testing and samples measuring was done by X-Rite eXact spectrophotometer device. The results the device displays when measuring UV varnished surfaces are similar to those displayed when measuring surfaces varnished in different techniques and laminated surfaces [19]. Printing substrate gloss was measured using Elcometer 407 Statistical Glossmeter, which measures gloss at three angles of reflection: 20°, 60°, and 85°.  $\Delta E$  colorimetric differences (as a result of UV varnishing) and  $\Delta GU$  differences in printing substrate gloss were defined by calculating mean value of CIE L\*a\*b\* values on measured samples with respect to different printing substrates and depending on printing substrate gloss parameters.

### 3. Results and discussion

Figure 1 presents CIE L\*a\*b\* values of observed PMS system colors. Measured samples are labelled as: C-coated, G-gloss paper, M-mattepaper, U-uncoated paper, UV-with UV varnish.

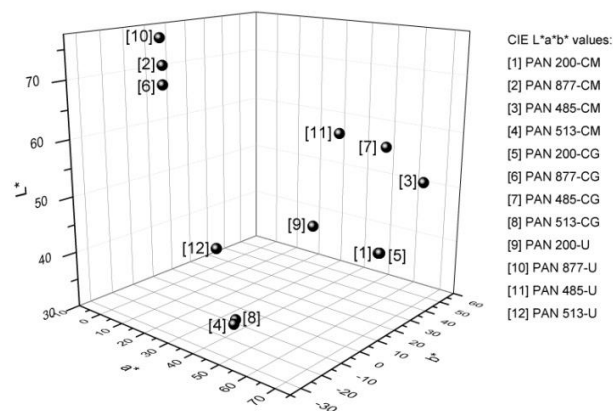


Fig. 1. CIE L\*a\*b\* values of observed samples without UV varnishing.

Figure 2 presents values of measured color samples influenced by UV varnishing:

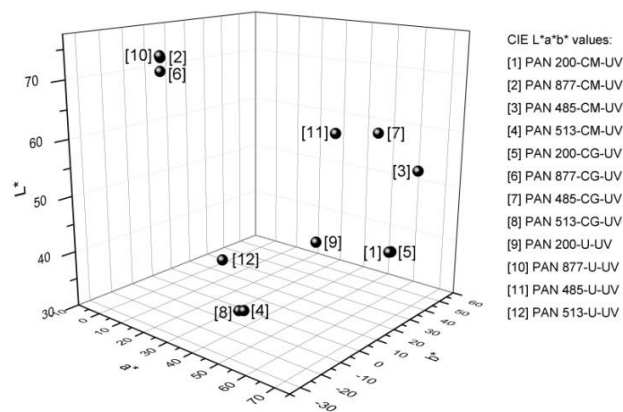


Fig. 2. CIE L\*a\*b\* values of observed samples with UV varnishing.

The measurement of printing substrate gloss with and without UV varnishing resulted in values presented in Figure 3. It can be noted that the process of UV gloss varnishing significantly increases gloss values on matt and gloss coated printing substrates, while it does not have significant effect on uncoated printing substrates.

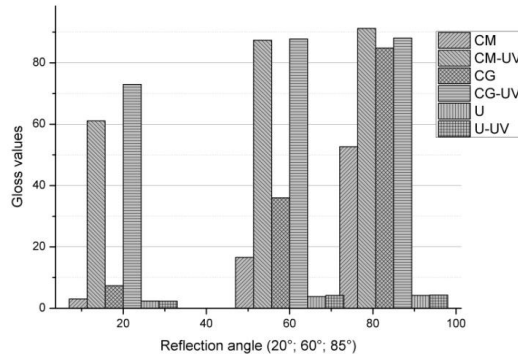


Fig. 3. Printing substrate gloss values at different reflection angles, with and without UV varnish.

Degree of colorimetric differences  $\Delta E$  on observed printing substrates was determined by isolating individual PMS colors.

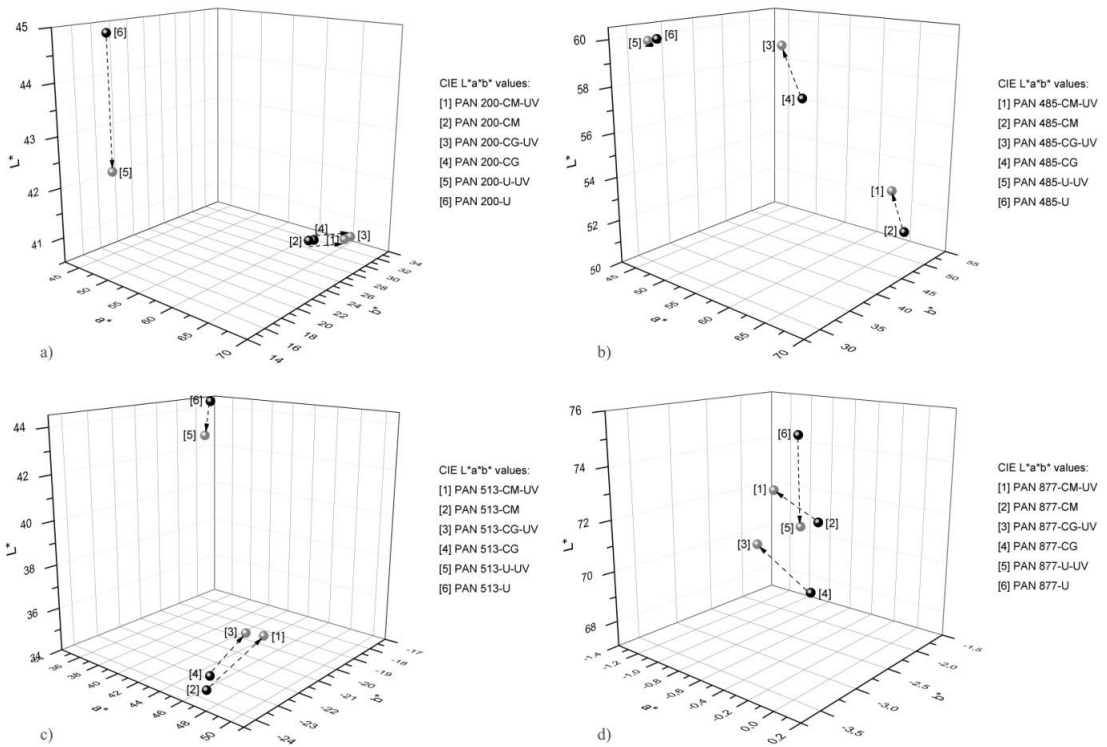


Fig. 4. CIE L\*a\*b\* values of different colors on different printing substrates with and without UV varnish: a) PMS 200; b) PMS 485; c) PMS 513; d) PMS 877.

It can be noted that UV gloss varnishing caused a visible shift in L\* axis of all colors on matt coated and gloss coated printing substrates. UV gloss varnish did not increase gloss on uncoated printing substrate, but on the contrary, color was darkened. For PMS 200 color the smallest colorimetric differences  $\Delta E < 1.5$  were recorded under the influence of UV coating on matt and gloss coated printing substrates;  $\Delta E = 2.66$  for uncoated printing substrate. PMS 485 color influenced by gloss UV coating recorded the biggest change on gloss coated printing substrate:  $\Delta E = 2.24$ ; the lowest  $\Delta E = 0.33$  on uncoated printing substrate. PSM 513 had the highest  $\Delta E = 2.59$  on matt coated printing substrate, and the lowest on gloss coated printing substrate  $\Delta E = 1.24$ . Silver PMS 877 color recorded the highest colorimetric changes on uncoated printing substrate  $\Delta E = 2.32$ , and the lowest on matt coated printing substrate  $\Delta E = 1.11$ . Figure 5 presents all  $\Delta E$  colorimetric differences of selected PMS system colors for a given printing substrate.

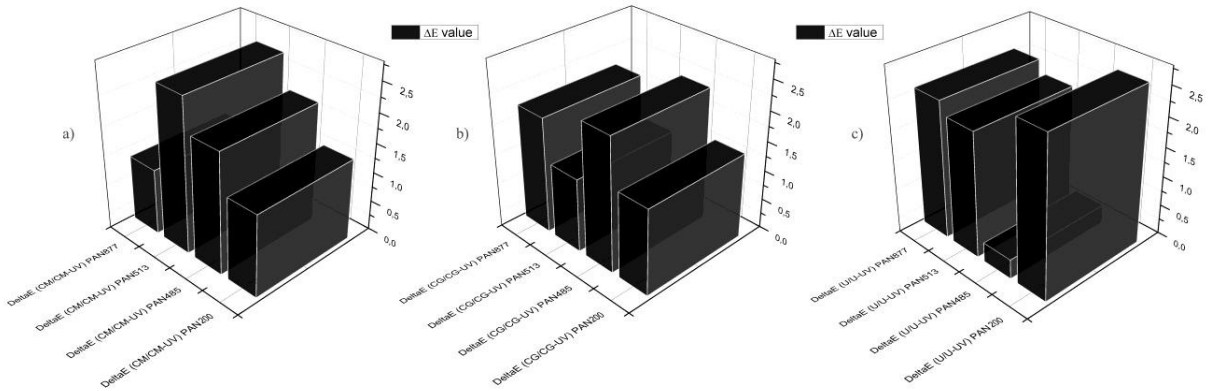


Fig. 5.  $\Delta E$  values of selected PMS system colors for: a) matt coated printing substrate; b) gloss coated printing substrate; c) uncoated printing substrate.

Colorimetric differences of  $\Delta E = 1-2$  represent very small difference, while  $\Delta E = 2-3.5$  represents moderate difference that is visible to the human eye. Figure 6 shows which of the samples are in the  $\Delta E = 2-3.5$  category. It can be noticed that moderate colorimetric changes under the influence of UV varnishing occur in all observed PMS system colors, regardless of the printing substrate type.

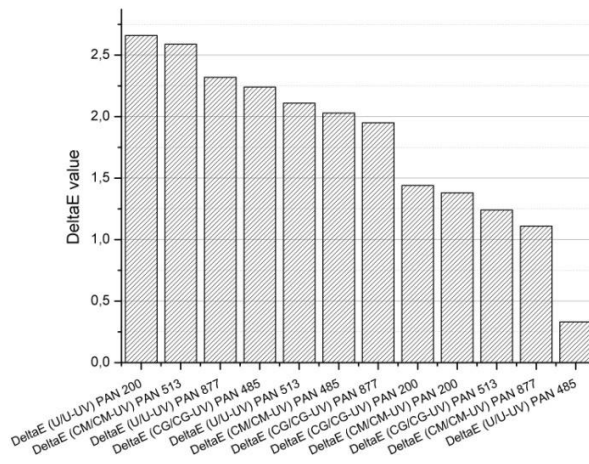


Fig. 6. Overview of colorimetric  $\Delta E$  differences of observed samples with and without UV varnish, with regard to PMS system colors and different printing substrates.

## Conclusion

The research on the influence of UV gloss varnishing process on colorimetric changes of the PMS system colors printed on the most commonly used printing substrates resulted in several conclusions. Gloss of the observed printing substrate, before and after UV varnishing process, is directly related to colorimetric changes in spot PMS colors. Although UV varnishing process contributes to final printed product visual appearance enhancement and improves the print's mechanical protection, it also affects colorimetric changes. Colorimetric properties of PMS system spot colors have changed under the influence of UV gloss varnish on all observed printing substrates. More significant changes where CIE2000  $\Delta E > 2$  were measured in all observed colors: Pantone 200 on uncoated printing substrate, Pantone 513 on matt coated and uncoated printing substrate, Pantone 877 on uncoated printing substrate, Pantone 485 on gloss and matt coated printing substrate. Given the presented results, this study has proven that colorimetric changes occur when printing spot colors undergoing UV varnishing process and that these colorimetric changes should be taken into account; otherwise, qualitative deviations and the inability to achieve printing process traceability and repeatability can occur, as well as a deviation from the original concept during the printing of graphic products. Printing substrate and change in gloss are not the only factors causing colorimetric changes; the physical and chemical properties of both PMS system spot colors and UV varnish should also be taken into account. This is an important fact that certainly improves the reproduction process traceability and standardization. Following on from this study it is possible to use its results to generate the appropriate correlation parameters regarding specific spot color in question and UV varnish, in the preparatory phase of graphic production, as well as in the proof production. Further research on the colorimetric changes in spot colors is also needed in the area of other print varnishing types and methods, and especially so in the area of water-dispersible varnishing.

## References

- [1] H. Kipphan, Handbook of Print Media, Springer, Berlin, 2001.
- [2] I. Zjakić, Upravljanje kvalitetom ofsetnog tiska, Managing the Quality of Offset Printing, Hrvatska sveučilišna naklada, Croatian University Press, Zagreb, 2007.
- [3] J. Lundström, A. Verikas, E. Tullander, B. Larsson, Assessing, exploring, and monitoring quality of offset colour prints, Measurement, (46), Issue 4, 2013, pp. 1427-1441.
- [4] A. Verikas, J. Lundström, M. Bacauskiene, A. Gelzinis, Advances in computational intelligence-based print quality assessment and control in offset colour printing, Expert Systems with Applications, Vol. 38, Issue 10, 2011, pp. 13441–13447.
- [5] M. Gong, M. Pedersen, Spatial pooling for measuring color printing quality attributes, Journal of Visual Communication and Image Representation, Vol. 23, Issue 5, 2012, pp. 685–696.
- [6] L.C. Cui, Do experts and naive observers judge printing quality differently?, Image Quality and System Performance, San Jose, California; January, 2004; pp. 132-145.
- [7] I. Zjakić, Dj. Parac-Osterman, I. Bates, New approach to metameric measurement on halftone color images, Measurement, Volume 44, Issue 8, 2011, pp. 1441-1447.
- [8] A.R. Marrion, The Chemistry and Physics of Coatings, Second Edition, The Royal Society of Chemistry, Cambridge, 2004.
- [9] I. Bolanca Mirkovic, I. Majnaric, S. Bolanca, Ecological Sustainability of the Sheetfed Offset Printing, Annals of DAAAM for 2012 & Proceedings of the 23rd International DAAAM Symposium, ISBN 978-3-901509-91-9, ISSN 2304-1382, pp 0947 - 0952, Editor B[ranko] Katalinic, Published by DAAAM International, Vienna, Austria, 2012.
- [10] J. Hoffstadt, Simulating color changes due to a coating of offset prints, CGIV 2004 Second European Conference on Colour in Graphics, Imaging and Vision, Aachen, Germany, 2004, pp. 489-493.
- [11] I. Majnarić, I. Bolanča Mirković, K. Golubović, Influence of UV curing varnish coating on surface properties of paper, Technical Gazette 19, 1, 2012, pp. 51-56.
- [12] I. Karlović, D. Novaković, Effect of different coating amounts on the surface roughness and print gloss of screen coated offset prints, The Journal of Imaging Science and Technology, March/April 2011, pp. 1-10.
- [13] J.S. Arney, L. Ye, S. Banach, Interpretation of Gloss Meter Measurements, Journal of Imaging Science and Technology, 50 (6), 2006, pp. 567-571.
- [14] R. Berns, R.E. de la Rie, The relative importance of surface roughness and refractive index in the effects of varnishes on the appearance of paintings, ICOM-CC Triennial Meeting Preprints, Rio de Janeiro, 2002, pp. 211-216.
- [15] J. Jarnstrom, P. Ihalainen, K. Backfolk, J. Peltonen, Roughness of pigment coatings and its influence on gloss, Applied Surface Science, 254 (18), 2008, pp. 5741-5749.
- [16] J.S. Preston, L.F. Gate, The influence of colour and surface topography on the measurement of effective refractive index of offset printed coated papers, Colloids and Surfaces A: Physicochemical and Engineering Aspects, Volume 252, Issues 2–3, 2005, pp. 99–104.
- [17] P. Wißling, Metallic Effect Pigments, Hannover, Vincentz Network, 2006.
- [18] ISO 12647-2:2013 Graphic technology: Process control for the production of half-tone colour separations, proof and production prints - Part 2: Offset lithographic processes, ISO Geneva, www.iso.org.
- [19] G. Radencic, E. Neumann, M. Bohan, Spectrophotometer Inter-Instrument Agreement on Standard Reference Materials and Printed Samples, Printed Industries of America/Graphic Arts Technical Foundation, 2008.