J. Print Media Technol. Res. 7(2018)1
March 2018

1-2018

ISSN 2414-6250 (Online)
CODEN JPMTBI
UDC 665

Journal of Print and Media Technology Research

Scientific contributions

ISSN 2414-6250

Editor-in-Chief
Gorazd Golob (Ljubljana)

Published by iarigai
www.iarigai.org

The International Association of Research Organizations for the Information, Media and Graphic Arts Industries

J. Print Media Technol. Res. 7(2018)1
March 2018
ISSN 2414-6250 (Online)
A print version is available on-demand
ISSN 2223-8905 (Print)

Journal of Print and Media Technology Research

A PEER-REVIEWED QUARTERLY

PUBLISHED BY

The International Association of Research Organizations
for the Information, Media and Graphic Arts Industries
Magdalenenstrasse 2, D-64288 Darmstadt, Germany
http://www.iarigai.org
journal@iarigai.org

A mission statement

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.

The journal is fostering multidisciplinary research and scholarly discussion on scientific and technical issues in the field of graphic arts and media communication, thereby advancing scientific research, knowledge creation, and industry development. Its aim is to be the leading international scientific journal in the field, offering publishing opportunities and serving as a forum for knowledge exchange between all those interested in contributing to or learning from research in this field.

By regularly publishing peer-reviewed, high quality research articles, position papers, surveys, and case studies as well as review articles and topical communications, the journal is promoting original research, international collaboration, and the exchange of ideas and know-how. It also provides a multidisciplinary discussion on research issues within the field and on the effects of new scientific and technical developments on society, industry, and the individual. Thus, it intends to serve the entire research community as well as the global graphic arts and media industry.

The journal is covering fundamental and applied aspects of at least, but not limited to, the following topics:

Printing technology and related processes

- Conventional and special printing
- Packaging
- Fuel cells and other printed functionality
- Printing on biomaterials
- Textile and fabric printing
- Printed decorations
- Materials science
- Process control

Premedia technology and processes

- Colour reproduction and colour management
- Image and reproduction quality
- Image carriers (physical and virtual)
- Workflow and management

Emerging media and future trends

- Media industry developments
- Developing media communications value systems
- Online and mobile media development
- Cross-media publishing

Social impact

- Media in a sustainable society
- Environmental issues and sustainability
- Consumer perception and media use
- Social trends and their impact on media

Submissions to the Journal

Submissions are invited at any time and, if meeting the criteria for publication, will be rapidly submitted to peer-review and carefully evaluated, selected and edited. Once accepted and edited, the papers will be published as soon as possible.

✉ Contact the Editorial office: journal@iarigai.org

Journal of Print and Media Technology Research

1-2018

March 2018

J. Print Media Technol. Res. 7(2018)1, 1–50

Journal of Print and Media Technology Research is listed in:

Emerging Sources Citation Index

Scopus

Index Copernicus International

PiraBase (by Smithers Pira)

Paperbase (by Innventia and Centre Technique du Papier)

NSD – Norwegian Register for Scientific Journals, Series and Publishers

ARRS – Slovenian Research Agency, List of Scientific Journals
(not included in the foreign bibliographic databases)

Printed in Slovenia by Collegium Graphicum, d. o. o. Ljubljana

Contents

A letter from the Editor

Gorazd Golob
Editor-in-Chief
E-mail: gorazd.golob@jpmtr.org
journal@iarigai.org

The first three months of this year, among other things, were marked by the new iarigai website <http://iarigai.com/publications/journals/> where all the published issues of the Journal are available, including the last one you are reading now. The new website is also adapted to modern mobile devices, and it was designed in accordance with the requirements and expectations of the Board of iarigai. As with any such operation, of course, some technical issues also occur, but we are continually removing them. The publishing policy and rules for accessing the password protected pdf files of the Journal remain unchanged, the archival copies are available to everyone free of charge, and the last two issues are accessible only for iarigai members and subscribers. According to the first responses and established trends, additional options will be offered, especially separate access to individual papers, of course under the conditions mentioned above. It is too early to talk about other changes, but it is our common interest that the Journal is a well-seen and accessible communication channel for publishing scientific and research papers in the field of graphic arts and media technology.

The first of the three papers in this issue deals with the impact of the uneven absorption of the printing ink in flexography on the print quality. Extensive and in-depth research includes mainly the analysis of the influence of roughness, porosity, and absorbency on the formation of mottling as one of the key quality parameters in the printing on coated cardboard. The extensive set of methods used to characterize the properties of materials and final imprints, and above all their comprehensive evaluation, gives added value to this publication.

The second paper is the research report of the study on the possibility of introducing a new biopolymeric material based on glucomannan. Various possibilities of preparing samples and some basic properties of the potential barrier material for food packaging are presented, in particular, the vapor transmission rate, moisture properties, surface properties, and solubility.

In the third paper, the authors discuss the case of the influence of various factors in the process of lamination of plastic films, which are used primarily as printed packaging materials. The Fuzzy Logic method is briefly presented and some examples of its application are given for individual factors that influence the quality of the laminating process.

In the current Topicalities section, edited by Associate Editor Markéta Držková (marketa.drzkova@jpmtr.org), an excerpt of interesting patents awarded to well-known printing presses manufacturers is presented, together with market reports from Smithers Pira and new printing solutions presented by Saralon. Interesting is the review of new books in a wide range from mathematics to

typography, including manuals for the production of a conference poster and for the writing and publication of a scientific paper. The latter can be used as extensive Guidelines for authors for future contributions to the Journal.

The three Theses presented are substantively as well as geographically quite different. The doctoral degree in the field of researching new business models for digital news publishing was successfully defended by K. Lindskow at the Copenhagen Business School; at the University of São Paulo, I. Ribeiro Aragão received a doctoral degree for her study of Brazilian typographic history; while S. Holúbková completed doctoral thesis on the paper deacidification process evaluation at the Institute of Natural and Synthetic Polymers in Bratislava.

The large number of announced conferences, fairs, workshops and other events, and in particular their scope and the expected number of participants, shows that the scientific research, as well as the business activity covered by the Journal is in good shape and, of course, very interesting for all researchers and experts. For those of them who deal with classical printing business of books and periodicals and the media, the most interesting topics are covered by the London Book Fair and WAN-IFRA events. For the others, there is an overview of events from the areas of printed electronics, industrial and functional printing, packaging, photonics, colors and light, etc.

From all above-mentioned areas, we received several papers for publication in the following issues of the Journal. An additional incentive for the authors and all other participants in the publishing process is also the confirmation that from this year the Journal is indexed by Scopus, however, it will appear on the indexed journal list at the next update. This is good news for all authors and other colleagues from academic and research institutions, where the quality and quantity of published papers are an important measure of their impact and weight. The Journal of Print and Media Technology Research, published by iarigai, is now listed among serious periodical publications and will gain the real impact and status by regularly publishing and quotes in comparable reputable journals. For now, we are on the right track, and again we would like to invite authors to send us quality papers for publication.

Ljubljana, March 2018

JPMTR 104 | 1804
DOI 10.14622/JPMTR-1804
UDC 655.1:777+532.56-035.67

Original scientific paper
Received: 2018-02-07
Accepted: 2018-03-30

The impact of non-uniform ink absorption on flexographic print mottle

Sofia Thorman[1,2], Li Yang[1], Anni Hagberg[1] and Göran Ström[1]

[1] RISE Bioeconomy, Box 5604, 114 86 Stockholm, Sweden
[2] Karlstad University, Department of Engineering and Chemical Sciences, 651 88 Karlstad, Sweden

sofia.thorman@ri.se
li.yang@ri.se
anni.hagberg@ri.se
goran.strom@hotmail.com

Abstract

Absorption non-uniformity and surface roughness of coated packaging boards are believed to have an impact on flexographic print mottle. Yet, their respective contributions are not well recognised due to their co-existence. Therefore, we propose a method that can solely study the effects of absorption non-uniformity on print mottle. This is achieved by artificially introducing uneven absorption, through well-controlled barrier patterns. The barrier patterns were added onto board surfaces using flexographic printing. By applying barrier patterns of several area coverages on board substrates of different intrinsic surface roughness it is possible to create a property-matrix, absorption non-uniformity versus for example surface roughness. With this matrix, the impact on print mottle from either of the properties can be studied independently. The results showed that surface roughness had a dominant effect on the print mottle, but mainly when comparing samples that spanned a broad roughness range. On the other hand, within a limited range of surface roughness, uneven ink absorption governed print mottle instead. This may explain why printing problems are sometimes encountered despite smooth board surfaces. Although the impact of absorption non-uniformity on print mottle differed from one board to another, the results indicated that a change towards more uneven absorption will have a negative impact on the print quality for most of the coated boards. The results give a better understanding of flexographic print quality and thereby can enable more reliable print mottle predictions.

Keywords: liquid packaging board, coated board, surface free energy, surface roughness, image analysis

1. Introduction and background

Liquid absorption and surface roughness are both possible sources of flexographic print mottle. However, their respective contribution and importance appear ambiguous in the literature. It can be difficult to separate their impact, using ordinary printed samples, since the two factors coexist and simultaneously may cause printing problems. Furthermore, there are several aspects of liquid absorption and all might not have the same relevance, and some are even difficult to characterise. Most of the measurement techniques capture only spontaneous (capillary driven) absorption on an average level while others capture forced absorption where an external pressure is applied and only a few techniques measure lateral uniformity. A significant number of scientific works show correlations between flexographic print quality and surface roughness of coated boards (Barros, Fahlcrantz and Johansson, 2005; Barros and Johansson, 2006; Jensen, 1989) and uncoated materials (Aspler, 2004; Lagerstedt and Kolseth, 1995; Wågberg and Wennerblom, 1992). The results are more diversified when it comes to liquid absorbency, and it has been suggested that absorbency has an impact on the print quality only under certain conditions. Sheng, Shen and Parker (2000) suggested that wettability (surface free energy) can have a dominating effect on ink transfer, but only when comparing samples of similar roughness. Aspler (2004), who did not find a correlation between print quality and liquid absorption, instead proposed that liquid absorption might cause problems when being extremely high or low, but has little effect when it lies within the "commercial norm". Lagerstedt and Kolseth (1995) suggested that one unfavourable property alone may not be that harmful, but a combination of two or more factors, e.g. a rough surface with unfavourable surface free energy, is more likely to cause problems.

As liquid absorbency can be linked to pore structure and surface free energy (Bosanquet, 1923; Lucas, 1918; Washburn, 1921), their impact on print quality have also been studied. For example, Lagerstedt and Kolseth (1995) saw a greater ink spreading and deeper ink penetration on coated samples of a more hydrophilic nature, Olsson, et al. (2006) reported that the polarity of coated samples has positive impact on solid tone print density, and Bassemir and Krishnan (1991) suggested that a high polarity can improve the print uniformity. There are reports of deeper ink penetration on more porous coatings, whereas more closed structures improved ink holdout and increased ink spreading (Bohlin, 2013; Preston, et al., 2008). It has also been suggested that ink solids are retained on the coating surface when having a high adsorptive surface area in combination with a low permeability, meaning that the wetting front spends longer time on the surface (Ridgway and Gane, 2002).

Nevertheless, we occasionally come across samples where a print quality issue cannot be explained by either surface roughness or by the average absorption rate. In these cases, absorption non-uniformity may be a possible source of the problem. To our knowledge, little has been published regarding the impact of non-uniform absorption on flexographic print quality. But, as pointed out by Preston, et al. (2008), a uniform ink spreading can be of crucial importance to avoid flexographic print mottle.

The relative importance of uneven absorption, when compared to surface roughness, has seldom been studied systematically. There are two major reasons, (a) it is difficult to obtain samples, between which only their absorption uniformity differs and (b) there has been a lack of relevant measuring techniques when it comes to the evenness of short-time absorption of aqueous liquids (inks). The objective of this study was to gain a better understanding of how board properties impact flexographic print mottle and specifically to decuple the impact of uneven ink absorption from that of surface roughness. We focus on non-uniform capillary driven absorption and propose a method to separately study its effect on flexographic print mottle.

2. Methods and materials

This section describes how absorption non-uniformity can be modified by adding a barrier in form of halftone patterns onto coated board surfaces. When the dot percentages of the halftone barrier patterns vary, various levels of absorption non-uniformity can be created without impacting on other properties of the samples. By doing this on a set of coated board samples, the impact from uneven ink absorption can be studied on boards of e.g. different surface roughness. The patterns were examined in several ways to ensure that only the absorbency and surface chemistry were modified, without the surface roughness being considerably affected. The impact on print mottle by the patterns was then studied. Creation of barrier patterns, printing and testing of contact angle and absorption non-uniformity were made in a laboratory with well-controlled climate conditions: temperature 23 °C ± 1 °C and relative humidity (RH) 50 % ± 2 %.

2.1 Board materials

Seven paper boards were used in this study: four pilot-coated boards (denominated P1, P2, P3, and P4) and three commercially produced boards (denominated CA, CB, and CC). Together, they covered a broad range of surface roughness and surface chemistry, see Table 1.

The pilot-coated boards featured the same 200 g/m^2 duplex base board (Klabin S.A., Brazil) and the same pre-coating (100 pph Hydrocarb® 60 and 13 pph latex type A) but had different top coating formulations, see Table 2. Combinations of four ground calcium carbonate (GCC) pigments (Omya International AG, Oftringen, Switzerland), two types of lattices, thickener (FinnFix 10, Noviant Oy, Finland) and caustic soda (NaOH) were used in the pre-coating (11.8–12.5 g/m^2) and top-coating (11.3–12.0 g/m^2) formulations. A vinyl acetate acrylate latex (CHP 2635EP, CH Polymers Oy, Raisio, Finland) with T_g = 15 °C is referred to as latex type A and a styrene butyl acrylate (Acronal S722, BASF, Ludwigshafen, Germany) with T_g = 23 °C is referred to as latex type B. Increasing the latex content (type A) in the top coating created a more closed structure, while the second latex (type B) created a more hydrophobic coating. The Hydrocarb® 90 (90 % of its particles < 2 μm) and Setacarb® HG (98 % < 2 μm) carbonates have a broad particle size distribution (PSD), whereas Covercarb® 75 (75 % < 1 μm and 95 % < 2 μm) has a narrow PSD. The coating pigment with a narrow PSD gave a greater pore volume and pore size than the broad PSD pigment and the more latex in the coating colour the lower the porosity. Hence, sample P4 had the highest porosity, samples P2 and P3 had the lowest porosity and sample P1 was in-between. The pilot coating was made at 600 m/min with a Jagenberg bent ceramic blade (angle approx. 18°).

Two of the commercial products were coated liquid boards for flexographic printing, referred to as CA and CB (supplied by BillerudKorsnäs, Sweden, and Tetra Pak, Sweden, in no particular order). As a reference, a cast-coated offset grade Chromolux 700 (Zanders GmbH, Germany), of high smoothness, was included and is referred to as CC. Elemental identification using scanning electron microscopy (SEM), SU3500 (Hitachi High-Technologies Europe GmbH, Krefeld, Germany),

Table 1: Surface roughness (standard deviation of height about the mean, lateral wavelength interval of 0.06–1 mm) and contact angle with water (after 0.1 s); ± 95 % confidence interval

Paper board properties	15 Latex A P1	20 Latex A P2	20 Latex B P3	N75 GCC P4	Com. A CA	Com. B CB	Com. C CC
Roughness [µm]	0.86 ± 0.03	0.75 ± 0.02	0.76 ± 0.01	0.86 ± 0.01	1.13 ± 0.04	0.82 ± 0.04	0.28 ± 0.01
Contact angle [°]	78.3 ± 1.1	77.3 ± 0.5	85.8 ± 0.6	75.4 ± 0.5	83.1 ± 0.6	82.6 ± 1.1	86.4 ± 1.2

Table 2: Coating formulations of the four pilot-coated boards (all with the same pre-coating); 0.5 pph thickener and 0.08 pph caustic soda were used in all compositions

Sample code	Latex [pph]		GCC pigment [pph]		
	Type A	Type B	Hydrocarb 90	Setacarb HG	Covercarb 75
P1	15		60	40	
P2	20		60	40	
P3		20	60	40	
P4	15				100

with energy dispersive x-ray analysis indicated that all three commercial boards contained clay and calcium carbonate in the top-coating layer. Clay content was higher than calcium carbonate content and the composition was similar for all three samples.

2.2 Creation of absorption non-uniformity with barrier patterns

Absorption non-uniformity was introduced to the board surfaces by adding a barrier in a halftone pattern. Barrier dots may fill the pore structure and/or modify the surface chemistry, both of which alter the ink absorption locally. Nine barrier tones were included (ranging from 2 % to 14 %) and the board itself (0 %), and the higher the tone value, the more uneven the absorption became. Impact on print mottle was a function of the actual absorption pattern that had been created, and not a direct function of the nominal-tone value.

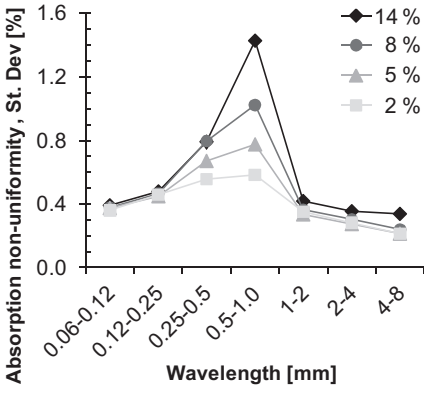


Figure 1: Example of barrier patterns, on sample P1, causing non-uniform absorption with a peak around lateral wavelengths of 0.5–1 mm; the non-uniformity increased with the nominal tone

A coarse screen ruling was used, 31 lpi, which means that the barrier patterns primarily created non-uniformity in the lateral wavelength interval of 0.25–8 mm, peaking at 0.5–1 mm. The absorption non-uniformity for some barrier tones is shown in Figure 1. The procedure to characterise the absorption non-uniformity is explained in the section 2.5 Characterisation of spontaneous absorption non-uniformity.

The patterns were created through flexographic printing with a F1 Printability tester (IGT Testing Systems, Amsterdam, Netherlands) and using the vehicle of a flexographic ink (including binder, additives and solvent, but excluding colorant). The ink was a Siegwerk ink designed for printing at Tetra Pak, Lund, Sweden. Following press-settings were used: anilox with volume of 2.7 cm^3/m^2 (IGT Testing Systems, Amsterdam, Netherlands), UVR 1.7 mm printing plate (MacDermid Printing Solutions Europe, France, with 70 Shore A durometer hardness), speed of 0.5 m/s and the pressure set to 25 N in both the printing and anilox nip. The printing plate was inked once and then directly brought into contact with the board substrate. The barrier printed samples were left to dry for at least three days in a climate-controlled room at 23 °C and an RH at 50 %, nominally.

2.3 Characterisation of surface porosity

The barrier patterns are expected to change the pore structure locally and to reduce the surface porosity by blocking the surface pores either fully or partly. This was verified by examining the two extreme samples, namely commercial sample CC that had a very low surface porosity and, the pilot-coated sample P4 that had quite open surface pore structure. The SEM images were taken after the sputtering of a conductive mono-

layer with a gold/palladium (Au/Pd) alloy. The secondary electron emission from the surface of the samples was detected in a Jeol 6 700 field emission SEM (JEOL Ltd., Tokyo, Japan), using a primary electron beam of 5.0 kV to bombard the samples.

In addition to the SEM imaging technique, maps of surface porosities were acquired using measurements of local refractive indices over an area of 50 mm × 50 mm, using a Surfoptic Imaging Reflectometry System (Data Systems Ltd., Bristol, United Kingdom). This measurement detects refractive index (RI) in the top surface, at less than 1 µm depth (Hiorns, Kent and Parsons, 2005). The porosity map is displayed as a greyscale colour map, where a greater RI is represented by brighter pixels.

Coating pigments, the binder, as well as the ink vehicle, were expected to have rather similar refractive indices (around 1.5–1.6), whereas air (1.0) differed significantly. This means that the larger the porosity (air-content) in the surface layer, the lower the RI and the darker the grey-scale image areas will be.

2.4 Characterisation of contact angle and surface free energy

The total surface free energy, polar and apolar parameters were calculated from contact angle measurements, using the Owens and Wendt method (Owens and Wendt, 1969). This was made for the original board surfaces without any barrier and for solid tones of the barrier on each of the boards.

The contact angles were measured with a dynamic contact angle tester (DAT from FIBRO system AB, Hägersten, Sweden). The contact angle readings were taken at 0.1 s for deionised water (treated by reverse osmosis and deionisation at RISE Bioeconomy, Stockholm, Sweden) and at 0.8 s for diiodomethane (for synthesis, Merck KGaA, Schuchardt, Germany). The drops had stabilised, and the liquid volumes were quite steady around these times. The average contact angle of eight drops is given, within the ± 95 % confidence interval.

2.5 Characterisation of spontaneous absorption non-uniformity

Absorption non-uniformity was characterised with a staining technique, using an aqueous liquid consisting of deionised water, 0.025 % of methylene blue dye (C.I. 52015, Merck KGaA, Darmstadt, Germany) and 0.07 % mass fraction of Surfynol 2502 (acquired from Air Products Chemicals Europe BV, now marketed by Evonik Industries AG, Essen, Germany). The latter is a surfactant that reduces the surface tension of the coloured liquid and is normally used in flexographic inks. The coloured liquid was first applied on the sample and, after tenths of a second, the excess liquid was removed with blotting paper. A modified F1 Printability tester (IGT Testing Systems, Amsterdam, Netherlands) was used to transport the sample from the specially made liquid applicator (a container that is open at the bottom and placed on the sample) to the nip where a blotting paper removes the excess liquid and leaves a stain on the sample (Thorman, et al., 2012). A laterally uneven stain is related to absorption non-uniformity and white-top mottle. Their respective contributions are separated in the analysis using the red (R) and blue (B) image channels, as described by Thorman, Yang and Hagberg (2013).

2.6 Image capturing and analysis

The absorption stains and flexographic prints were scanned in RGB with a flatbed scanner, Epson Perfection V750 Pro (Seiko Epson Corp., Japan), using a gamma value of 1.2 and a resolution of 1200 dpi. These images were analysed with STFI Mottling software (RISE Bioeconomy, Stockholm, Sweden). A calibration set was included in each scan, enabling calibration of each image channel to reflectance. The images of the printed samples were converted to grey-scale before assessing the variations, whereas the absorption non-uniformity was assessed, based on the re-constructed R-channel image:

$$R_{\text{absorption}} = \frac{R_{\text{red}}}{R_{\text{blue}}} \times \bar{R}_{\text{blue}} \qquad [1]$$

where R_{red} and R_{blue} are the reflectance values of the individual pixels in the R and B channels respectively, and $\bar{R}_{\text{blue}}$ the average reflectance in the B-channel image (Thorman, Yang and Hagberg, 2013).

Absorption non-uniformity or print mottle was calculated as the standard deviation of the reflectance values for the pixels within a 21 mm × 21 mm area. Through a Fast Fourier Transform (FFT), the absorption or the print heterogeneity of each image area was divided into spatial wavelength intervals. Standard deviation in the wavelength interval of 0.5 mm to 8 mm is reported. Two areas per sample and barrier tone were analysed, each being 21 mm × 21 mm.

2.7 Characterisation of surface roughness and topography of barrier patterns

The surface roughness of the boards (without barrier) was characterised as height variations about the mean (standard deviation) in the spatial wavelength interval of 0.25 mm to 1 mm. Eight areas of 13 mm × 13 mm were analysed per sample, with a lateral resolution of 12.7 µm. The measurements were made using the photometric stereo technique on an OptiTopo instrument (RISE Bioeconomy, Stockholm, Sweden).

To characterise the topography of the transparent barriers accurately, replicas of the surfaces were cast with a fast-curing two-part silicon rubber compound (RepliSet-GF1 from Struers A/S, Ballerup, Denmark) and measured with the OptiTopo instrument (image area of 15.6 mm × 15.6 mm, resolution of 16.0 µm). One replica (measurement) was made from the coating layer and one with a 10 % barrier tone on each board. Consequently, the roughness was not expected to be exactly the same, due to variations within the sample.

2.8 Printing and print quality evaluation

A solid cyan was printed on the patterned surfaces to evaluate the impact resulting from non-uniform absorption. The laboratory flexographic press, anilox, plate type and speed were the same as when applying the barrier patterns, whereas the pressure was set to 100 N in the printing nip and 75 N in the anilox nip. The complete Siegwerk ink was used, including colorant, which had a surface tension and viscosity of 38.6 mN/m ± 0.1 mN/m (at 300 s with Wilhelmy plate method) and 19 s efflux time (DIN cup 4 mm, temperature 23 °C ± 1 °C), respectively.

To compensate for an uneven inking along the printing direction in the F1 Printability tester, the printing plate was inked for two revolutions before being brought into contact with the patterned board surfaces and two strips were printed in opposite directions. That is, one strip goes from 0 % to 14 % of the barrier patterns and another one in the reversed direction by turning the patterned surface by 180 degrees. The mottle of the solid cyan print is the average of these two stripes. For a couple of strips, a few of the tone values had to be left out, because of defects in the inking. Print mottle was used as a measure of the heterogeneity of the solid cyan prints and was calculated as the standard deviation of reflectance values within full-tone printed areas (each pixel having an individual reflectance value). The printed samples were scanned and print mottle analysed as set out in section 2.6 Image capturing and analysis.

2.9 Linear regression analysis

Statistical analysis of relation between the dependent variable (print mottle, y) and independent variable (absorption non-uniformity, x) was made in the opensource software R (R Foundation for Statistical Computing, Vienna, Austria). The y was regressed onto x to create a model for each sample (James, et al., 2013):

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x \quad [2]$$

where the coefficient $\hat{\beta}_0$ represents an estimate of the intercept of the model with y-axis and $\hat{\beta}_1$ represents an estimate of the slope of the model. The $\hat{y}$ indicates a prediction of print mottle based on absorption non-uniformity measurement. Estimates of the coefficients were produced so that the linear model fitted available data and the residual sum of squared errors (*RSS*) was minimised,

$$RSS = \sum_{i=1}^{n} \left(y_i - \hat{\beta}_0 - \hat{\beta}_1 x_i\right)^2 = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \quad [3]$$

and to minimise *RSS,* following equations were used:

$$\hat{\beta}_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \quad [4]$$

$$\hat{\beta}_0 = \bar{y} - \hat{\beta}_1 \bar{x} \quad [5]$$

where n is the number of data points, y_i and x_i the measurement data of print mottle and absorption non-uniformity related to the i-th data point, respectively, $\hat{y}_i$ the predicted print mottle value from the model, and the averages of the measured x- and y-values are represented by $\bar{x}$ and $\bar{y}$, respectively.

The accuracy of the models and their coefficients was assessed by R^2 statistics that quantify how well each model fits the data. The accuracy of the coefficient estimation was assessed by their standard error and p-value. The p-value indicates the probability of observing this relation between x and y due to random chance. Detailed description of how the R^2 statistics, p-values and standard errors are calculated can be found elsewhere, e.g. James, et al. (2013).

3. Results

In this section, we first present the results of print quality and how this has been affected by surface roughness and uneven absorbency. This is followed by characterisations of the barrier patterns.

3.1 Print mottle on the untreated board samples

A linear correlation (R^2 = 0.69) was observed between the print mottle and the surface roughness, for the boards without barrier patterns (Figure 2a). However, this is largely due to the commercial samples which considerably extended the roughness range. However, the correlation become less obvious for the pilot-coated boards, which were in the mid-roughness range (0.6–0.7 µm). On the contrary, no general correlation between the non-uniform absorption and the print mottle was found (Figure 2b) when considering both the commercial and the pilot-coated boards. Nevertheless, within the group of the four pilot-coated boards, the correlation was very high (R^2 = 0.98). These two graphs reveal that a correlation between

print mottle and surface roughness does not rule out that the print may simultaneously be affected by uneven ink absorption, but possibly to a lesser extent.

3.2 Property matrix

We introduced well-controlled barrier patterns to manipulate the absorption non-uniformity of the coating surfaces. By applying these barrier patterns of several area coverages on board substrates having different intrinsic surface roughness, we received a property matrix, as illustrated in Figure 3. Since the board samples may differ in more aspects than surface roughness, the *x*-axis may also include some other property than surface roughness, or the combined effect of several properties of the boards.

The matrix can be utilised to isolate the impact of absorption non-uniformity from that of surface roughness, or vice versa. This can be done by comparing samples having the same property value in one axis but having different values in the other axis, as illustrated by the dashed rectangles. Within the horizontal rectangle, the samples are compared at the same level of absorption non-uniformity, meaning that print mottle is interpolated/extrapolated to a given absorption level and then compared with e.g. surface roughness. Within the vertical rectangle, the comparison is made between print quality that was obtained with the different barrier patterns (i.e. absorption non-uniformities) on one board. By using the property matrix, it was possible to study if uneven absorption had an impact on print mottle only on pilot-coated boards in the mid-roughness range or if it also would affect the print on the rougher and smoother commercial boards.

3.2.1 The importance of absorption non-uniformity at constant roughness

The impact on print mottle from changes in absorption uniformity was studied with the barrier patterns on the individual board samples. As the tone-value of the barrier pattern increased, the absorption became more uneven and, in turn, this had a negative impact on the print quality. The cyan print on the barrier dots was brighter than on the untreated coating layers, an example from sample P4 is shown in Figure 4. In most of the cases, there was a strong linear correlation between the print mottle and the absorption non-uniformity (see Figure 5). This was also true for the commercial

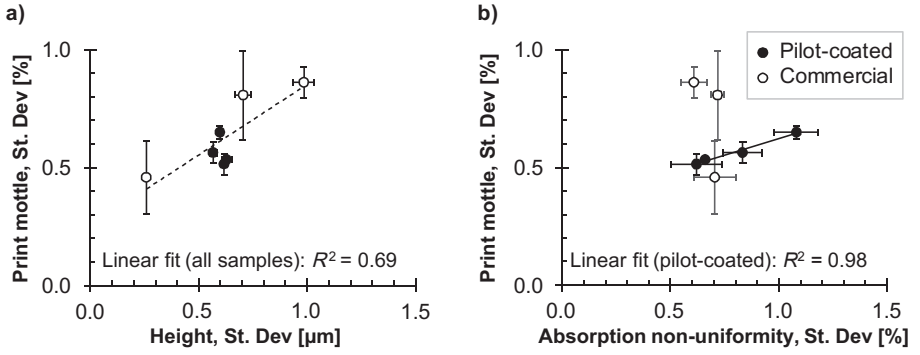


Figure 2: Print mottle plotted versus: a) surface roughness and b) absorption non-uniformity; where regression line in graph a) has been calculated from pilot-coated and commercial boards as one series; the error bars indicate a 95 % confidence interval

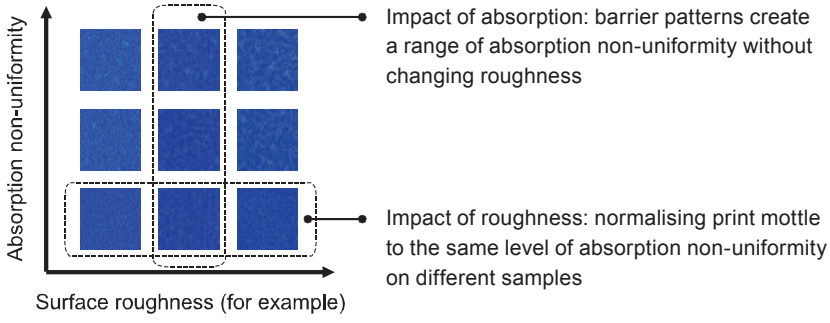


Figure 3: Illustration of property matrix and how it can be utilised when separating the impacts on print mottle resulting from absorption non-uniformity and from, for example, surface roughness

boards, even though Figure 2a indicated that print mottle ranking among these boards was pre-dominantly controlled by surface roughness.

When uneven absorption was introduced, the impact on print mottle was significant on certain samples but modest on others. The steeper the gradient of the regression line, the more sensitive print mottle was to uneven absorption. For example, there was a linear 1:1 correlation between the print mottle and the absorption non-uniformity for sample P4, whereas the gradient was not as steep for samples P1 and P2 (Figure 5a and Table 3). The effect on print mottle was modest when absorption became uneven on sample CB but possibly the impact increased at higher level of absorption non-uniformity (Figure 5b). Table 3 shows that absorption non-uniformity testing was able to explain a large part of the variability in print mottle on each of the five samples. The high R^2-values, ranging from 0.74 to 0.98, indicated that the linear models fitted the data well. The p-values for the absorption non-uniformity coefficients were small (in four cases < 0.001 and in one case < 0.01), which indicated that it is unlikely to observe such substantial association between predictor and response due to random chance. Hence, we conclude that a real association between absorption non-uniformity and print mottle exists.

The barrier patterns successfully altered the absorption non-uniformity on five of the samples without creating a topographical pattern with raised (elevated) dots and on these samples the capillary driven absorption test detected the patterns as expected. Results from these boards are shown in Figure 5. Two samples, commercial sample CC and pilot-coated sample P3, were omitted due to a topographical effect and/or the absorption test not being able to correctly detect the absorption non-uniformity, see results in section 3.3 Characteristics of the barrier patterns.

3.2.2 The importance of surface roughness at constant absorption non-uniformity

The regression analyses of individual boards (Table 3) were utilised to make predictions (interpolations/extrapolations) of print mottle values corresponding to two separate levels of absorption non-uniformity. In Figure 6, the print mottle values have been estima-

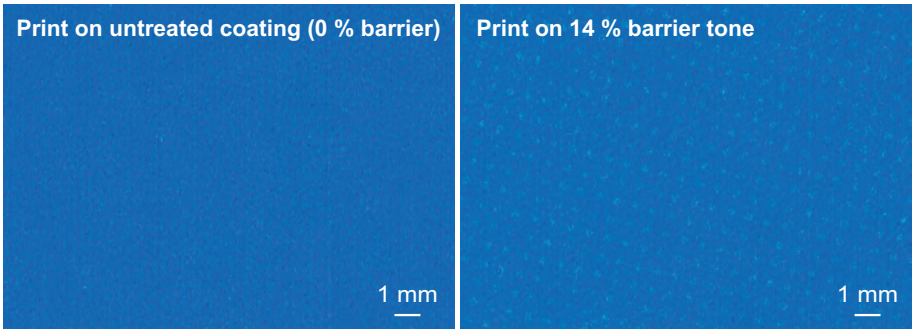


Figure 4: Solid cyan printed on the untreated (left) and absorption modified (right) board surfaces of sample P4; the brightness of the images has been enhanced for better visualisation

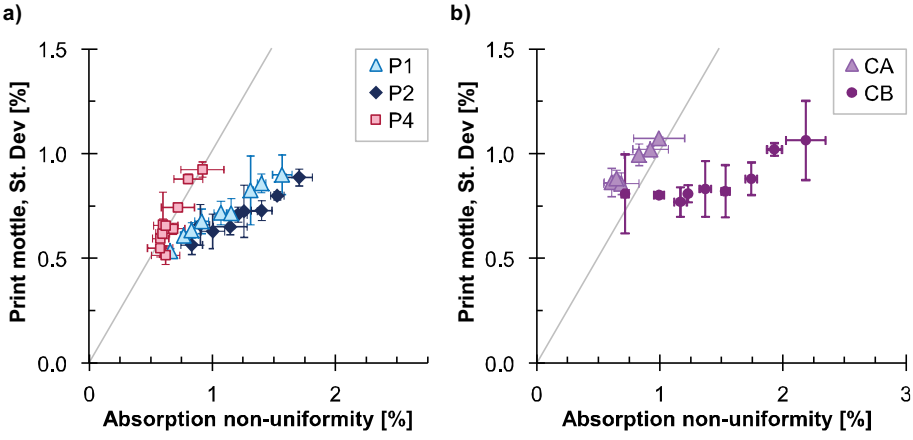


Figure 5: Print mottle versus absorption non-uniformity of the paper boards with barrier tones ranging from 0 % to 14 %; the error bars indicate a 95 % confidence interval

Table 3: Linear regression analyses of print mottle regressed onto absorption non-uniformity (data from Figure 5), where coefficients for intercept ($\hat{\beta}_0$) and gradient ($\hat{\beta}_1$) and their respective standard errors are given; the p-values are indicated by stars, the R^2 quantifies accuracy of the models

	P1	P2	P4	CA	CB
$\hat{\beta}_1$ (absorption non-uniformity)	0.39 ***	0.32 ***	1.09 ***	0.57 ***	0.19 **
Standard error ($\hat{\beta}_1$)	0.02	0.04	0.16	0.06	0.04
$\hat{\beta}_0$ (intercept)	0.30 ***	0.32 ***	−0.05	0.50 ***	0.59 ***
Standard error ($\hat{\beta}_0$)	0.03	0.05	0.11	0.05	0.06
n	8	8	9	5	8
R^2	0.98	0.91	0.85	0.95	0.74

*** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05

ted for absorption non-uniformity of 0.5 % and 1.0 %, respectively. It is evident that surface roughness had greater impact on print mottle when absorption non-uniformity was lower and on a constant level. We do not consider it applicable to extrapolate down to a perfectly uniform absorption state, since the barrier patterns only have added rather than diminished the unevenness. Therefore, we suggest only making forecasts of print mottle at absorption non-uniformity levels that are equal or higher than 0.5 %.

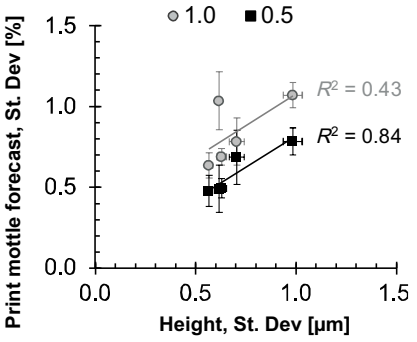


Figure 6: Predictions of print mottle at two absorption non-uniformity levels (1.0 % and 0.5 %) versus surface roughness; the error bars indicate 95 % confidence interval (prediction interval for y-axis)

3.3 Characteristics of the barrier patterns

3.3.1 Topography of the barrier patterns

Any topographical pattern resulting from the barrier dots, was expected to be seen in the height spectra, as surface roughness and as surface peaks. The surface roughness measurements of the replicas indicated that the barrier dots may have created topographical modifications on three samples, i.e. P3, CB and CC, see Figure 7a. This observation is probably true for commercial sample CC, but it is unlikely to apply to the other two samples. Sample CC had a very smooth coating surface, where 93 % of the barrier dots were higher than the rest of the sample, but only by 0.1 µm. More precisely, the barrier dots were about 0.7 µm above the average height (the zero level), and the board in-between the barrier dots was often as high as 0.6 µm and never raised above the barrier dots. The height spectra of this sample also indicated a periodic pattern, which likely was connected to the barrier dots, see Figure 7b.

On the contrary, the original surfaces of the other two boards were much rougher, and only a few of the barrier dots raised above the rest of the board surface. Hence, the evidence that the barrier patterns altered their topography was not strong for sample P3 or CB. As a matter of fact, only 9 % to 10 % of the dots were raised above the other surface areas while as much as 83 % and 72 % of the surface peaks, respectively, were not connected to barrier dots. Our conclusion is that the barrier patterns did not change the topography on six of the seven samples.

3.4 Surface porosity

Figures 8 and 9 show the SEM images of sample P4 and sample CC whose surfaces contained the most open and the most closed coating structures. As shown, the barrier dots have partly filled and/or blocked the surface pores on both surfaces. The images also reveal that the coverage was not uniform within the dots and the porous structures of the coating layers were covered in some parts but remained more open in other parts of the dots. Even when the barrier material covered the porous structure of the coating layer, micro-pores appeared to be present in the barrier material.

Surface porosity measurements, based on RI, gave similar indications as the SEM images. In Figure 10, a periodic pattern is clearly visible in the porosity map for sample P4. More porous areas possess more air and have lower RI (around 1.0). The coating pigment, binders and ink vehicle were not expected to be easily distinguished from one another, due to their similar refractive indices (around 1.5–1.6). Hence, sample P4 displayed a sharp contrast between the porous coating and closed barrier dots. On the contrary, the pattern

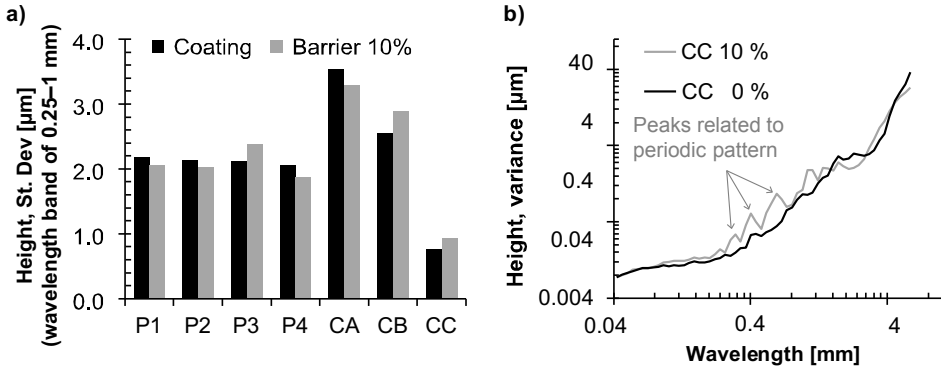


Figure 7: Surface roughness measured on one replica of each coating layer and 10 % barrier pattern on each sample (a); height spectra of board CC (b) before and after adding a barrier pattern

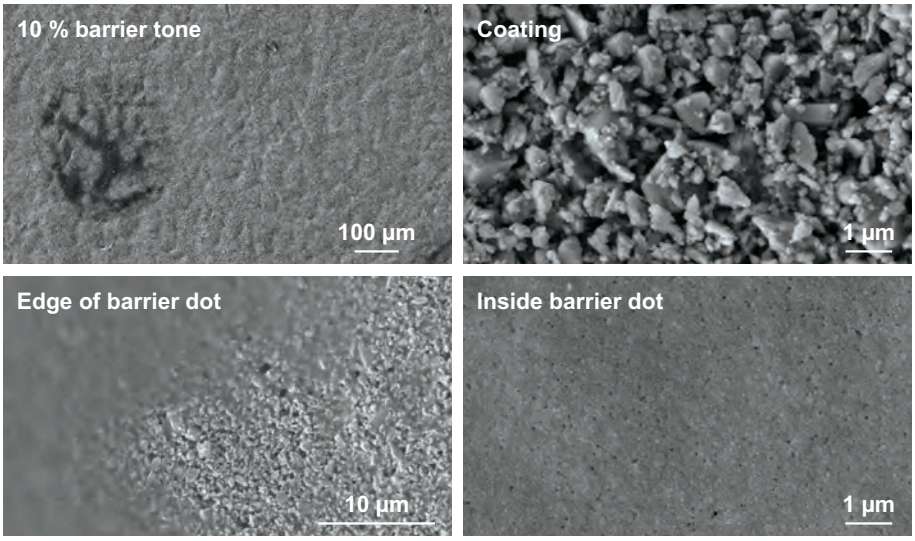


Figure 8: The SEM images of the coating and barrier dots on pilot-coated sample P4; this coating has a very open structure due to broad particle-size distribution of the calcium carbonate pigments

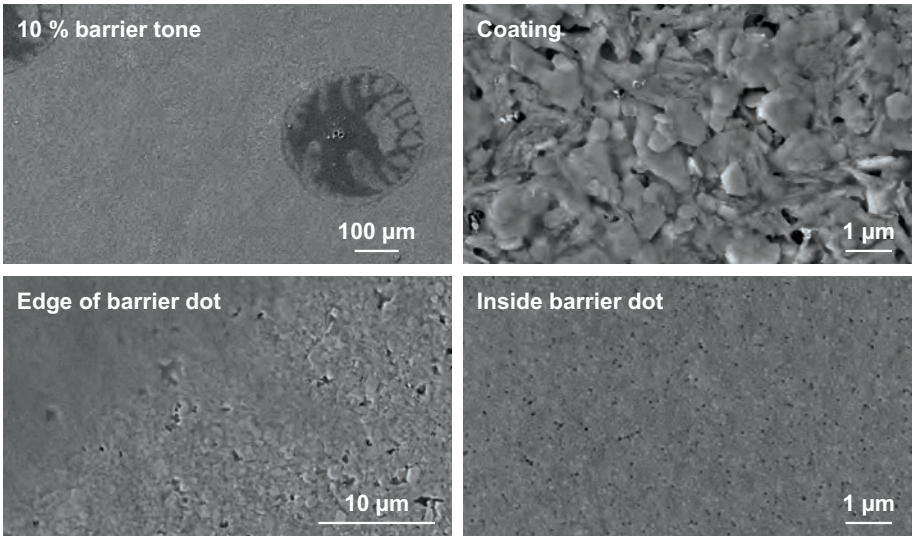


Figure 9: The SEM images of the coating and barrier dots on commercial sample CC; this coating has a very closed structure

was hardly visible in the surface porosity map of sample CC due to a much more closed coating structure.

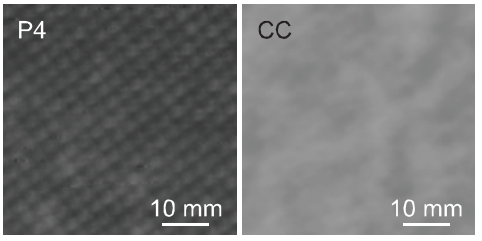


Figure 10: Surface porosity maps of 10 % barrier tones on the open coating of P4 and the closed coating of sample C; darker pixels correspond to lower refractive index, i.e. surface pores are dark

3.5 Absorbency and surface chemistry

The barrier patterns caused an uneven absorption due to closed surface pores and/or a modified surface chemistry. The patterns were most often observed as brighter dots in the stains made by the coloured water, see Figure 11. All the barrier dots received a certain amount of the stain, but the absorbency of the board itself made a stronger impact and created a contrast between low absorbing barrier dots and "high" absorbing board. Samples CC and P3 displayed rather low absorption levels due to low porosity and/or low hydrophilicity, which caused those coatings to be either equally stained or even brighter stained than the barrier dots.

In general, the absorption non-uniformity increased with the barrier tone value, as is shown in Figure 12, even though the impact from the barrier patterns differed among the samples.

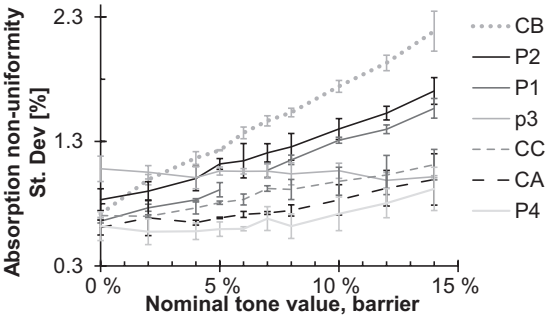


Figure 12: Absorption non-uniformity was created by the barrier patterns on the board samples; the error bars indicate the 95 % confidence interval

As already seen, the barrier material partly filled in (or closed) the surface pores (see Figures 8 and 9), but it also changed the surface chemistry. In most cases, water wetted the barrier material more easily than the board surfaces, due to a higher surface energy and a more polar nature of the barrier material, see Figure 13.

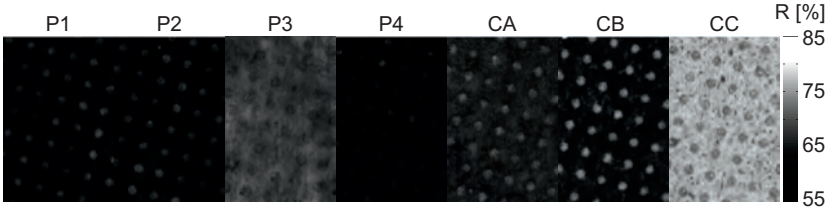


Figure 11: Absorption patterns (14 % nominal tone) in the stains from the coloured water; images show the reconstructed R-channel images (Equation 1), each area is 3.6 mm × 5.4 mm

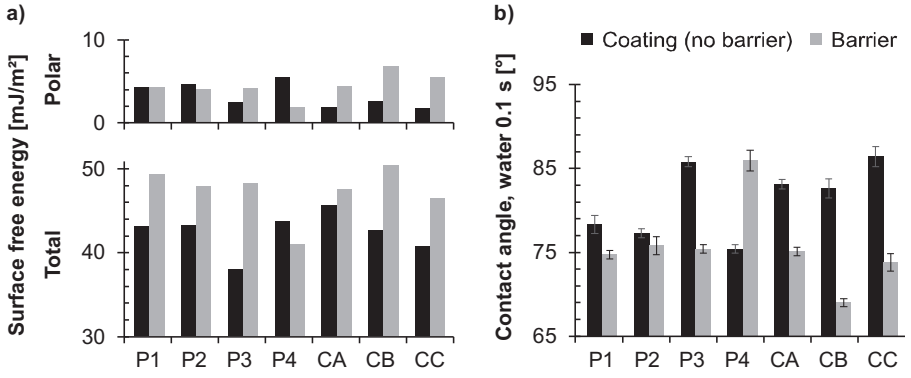


Figure 13: Characterisation of the coating layers and their counterparts covered by a solid barrier tone; a) the total surface free energy (bottom) and the polar component of the surface free energy (top), and b) contact angle of water droplets, a 95 % confidence interval is indicated in b)

With a surface tension of 38.6 mN/m, the printing ink can be expected to wet all the board and barrier surfaces.

4. Discussion

For five of the samples, the untreated board surfaces absorbed more coloured water and acquired a stain that was darker than on the barrier dots. This is attributed to the fact that the barrier material had closed many of the surface pores and, thereby, hindered absorption (Figures 8 to 10). Nevertheless, the barrier dots still acquired a slight bluish shade from the stain. This may be a consequence of the barriers having a favourable surface chemistry with higher surface energy (Figure 13), thus causing them to be wetted easily and, thereby, making it possible for adsorption/deposition of the cationic methylene blue dye to occur.

There were two exceptions where the coatings did not become darker than the barrier dots in the absorption stains (Figure 11). On sample P3, the stain appeared as equally bright on the coating layer as on the barrier dots. This could be explained as a combined effect of low absorbency of the untreated board surface, due to its hydrophobicity that originates from the latex (type B) used in the coating, while the barrier dots were wetted more easily due to higher surface free energy. A similar effect was observed on sample CC, where the stain was even brighter on the board surface than on the barrier dots. Manual tests indicated that also stains on coatings P3 and CC would become darker than on the barrier dots after longer absorption time. This suggests that the colorant in the absorption test was adsorbed on the barrier dots and that the absorption by the coating outside the barrier dots was slow on these particular samples. Since untreated sample CC gave the lowest print mottle, the findings also suggest that strong absorption is not necessary for high print quality as long as it is even.

Unlike the results from the absorption test, all the barrier dots were observed to be brighter on the printed samples, including samples P3 and CC. We suggest that this is primarily due to reduced accessibility to the surface pores rather than modification of the surface chemistry. The effects of the surface chemistry which caused the absorption/wetting to be slow on samples P3 and CC, will be subdued by the nip pressure when printed in the laboratory press. This suggests that the uneven pore structure was most probably responsible for the print mottle that increased with the tone-value of the barrier pattern. When it came to the extreme samples whose original surfaces had very low absorbencies in combination with the easily wetted barrier dots, absorption non-uniformity may not be accurately predicted when using the spontaneous absorption test.

5. Conclusions

Adding a barrier pattern, to control the level of absorption non-uniformity, has proven to be a powerful tool. With this approach, it is possible to study the impact of absorption separately and to compare the impact of surface roughness, for example, when absorption is maintained at a constant level.

With this study, we have gained a better understanding for how and when absorption non-uniformity and surface roughness are of importance. Absorption non-uniformity indeed contributed to print mottle both on rough and smooth boards, but it did not have equally strong impact on all samples. It appears that a change towards a more uniform absorption will have a larger impact on certain boards. The reason for this needs to be investigated further. Secondly, surface roughness accounted for a large part of the print mottle and when comparing two boards of large roughness difference the smoother surface is likely to have less print mottle.

Absorption non-uniformity may result from non-uniformity either in pore structure or surface chemistry, where the pore structure appeared to have a greater impact on print mottle. Finally, for surfaces with a slow absorbency/wetting, spontaneous absorption non-uniformity tests need to be accompanied by characterisations of forced absorption.

Acknowledgements

The authors wish to thank the industrial partners, BillerudKorsnäs, Stora Enso, Tetra Pak, ITC, Klabin, Metsä Board, Metsä Fibre, and WestRock for financing and supporting this research. This study was performed within the Industrial Graduate School VIPP (Values Created in Fiber Based Processes and Products) with financial support from the Knowledge Foundation, Sweden. The study was partly funded with strategic competence funds from RISE, Sweden. Last but not least, we would gratefully like to thank Mr Martin Taylor and Miss Eli Gaskin at Imerys for characterising surface porosity and making SEM images.

References

Aspler, J., 2004. Print quality test methods for linerboard. In: *2004 TAGA Proceedings: 56th Annual Technical Conference*. San Antonio, USA, 18–21 April 2004. Sewickley: Technical Association of the Graphic Arts, pp. 428–452.

Barros, G.G., Fahlcrantz, C.M. and Johansson, P.Å., 2005. Topographic distribution of uncovered areas (UCA) in full tone flexographic prints. *TAGA Journal*, 2(1), pp. 43–57.

Barros, G.G. and Johansson, P.Å., 2006. Prediction of uncovered area occurrence in flexography based on topography: a feasibility study. *Nordic Pulp & Paper Research Journal*, 21(2), pp. 172–179.

Bassemir, R.W. and Krishnan, R., 1991. Surface and colloidal aspects of dynamic ink/paper interactions during printing. In: *Proceedings of CPPA/TAPPI Symposium on Papercoating Fundamentals*, Montreal, Canada, 17–18 May 1991. Montreal: Canadian Pulp and Paper Association, pp. 69–75.

Bohlin, E., 2013. *Surface and Porous Structure of Pigment Coatings: Interactions with Flexographic Ink and Effects on Print Quality.* PhD Thesis. Karlstad University.

Bosanquet, C.H., 1923. On the flow of liquids into capillary tubes. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science: Series 6*, 45(267), pp. 525–531.

Hiorns, A.G., Kent, D. and Parsons, J., 2005. Enhanced performance through multilayer coating. In: *Proceedings of TAPPI Coating conference and exhibit 2005*, Toronto, Canada, 17–20 April 2005. Atlanta: TAPPI Press.

James, G., Witten, D., Hastie, T. and Tibshirani, R., 2013. *An Introduction to Statistical Learning – with Applications in R*. [ebook] New York: Springer-Verlag.

Jensen, K.W., 1989. Flexo printability of coated white-top liner with consideration of convertability. *Graphic Arts in Finland*, 18(1), pp. 14–20.

Lagerstedt, P. and Kolseth, P., 1995. Influence of surface energetics on ink transfer in flexo printing. In: *Advances in Printing Science and Technology: Proceedings of the 23th International Research Conference of iarigai*. Paris, France, 17–20 September 1995. Chichester, UK: John Wiley & Sons, pp. 269–299.

Lucas, R., 1918. Ueber das Zeitgesetz des kapillaren Aufstiegs von Flüssigkeiten. *Kolloid-Zeitschrift*, 23(1), pp. 15–22.

Olsson, R., Yang, L., Van Stam, J. and Lestelius, M., 2006. Effects on ink setting in flexographic printing: coating polarity and dot gain. *Nordic Pulp & Paper Research Journal*, 21(5), pp. 569–574.

Owens, D.K. and Wendt, R.C., 1969. Estimation of the surface free energy of polymers. *Journal of Applied Polymer Science*, 13(8), pp. 1741–1747.

Preston, J., Hiorns, A., Parsons, D.J. and Heard, P., 2008. Design of coating structure for flexographic printing. *Paper Technology*, 49(3), pp. 27–36.

Ridgway, C.J. and Gane, P.A.C., 2002. Controlling the absorption dynamic of water-based ink into porous pigmented coating structures to enhance print performance. *Nordic Pulp & Paper Research Journal*, 17(2), pp. 119–129.

Sheng, Y.J., Shen, W. and Parker, I.H., 2000. Importance of the substrate surface energetics in water-based flexographic printing. *Appita Journal*, 53(5), pp. 367–370.

Thorman, S., Ström, G., Hagberg, A. and Johansson, P.-Å., 2012. Uniformity of liquid absorption by coatings – technique and impact of coating composition. *Nordic Pulp & Paper Research Journal*, 27(2), pp. 459–465.

Thorman, S., Yang, L. and Hagberg, A., 2013. Simultaneous determination of absorption mottle and white-top mottle in the same area on coated boards. In: N. Enlund and M. Lovreček, eds. *Advances in Printing and Media Technology: Proceedings of the 40th International Research Conference of iarigai*. Chemnitz, Germany, 8–11 September 2013. Darmstadt, Germany: iarigai, pp. 225–232.

Washburn, E.W., 1921. The Dynamics of Capillary Flow. *Physical Review*, 17(3), pp. 273–283.

Wågberg, P. and Wennerblom, A., 1992. A correlation between results achieved with an optical profile tester, conventional paper evaluation and printability. In: *Proceedings of TAPPI International Printing and Graphic Arts Conference*, Pittsburgh, USA, 18–21 October 1992. Atlanta: TAPPI Press, pp. 187–196.

JPMTR 105 | 1802
DOI 10.14622/JPMTR-1802
UDC 577.1|62-4-547.4|66.96

Research paper
Received: 2018-01-25
Accepted: 2018-03-30

Biopolymer films from glucomannan: the effects of citric acid crosslinking on barrier properties

Ruoxi Ma, Alexandra Pekarovicova and Paul D. Fleming

Department of Chemical and Paper Engineering, Western Michigan University, a.pekarovicova@wmich.edu
4601 Campus Drive, Parkview, Kalamazoo, MI 49008-5462, United States of America

Abstract

Glucomannan extracted from konjac root is used to form biodegradable films with gas and grease barrier properties for food packaging application. Nano-fibrillated cellulose (NFC) and plasticizers were used to improve the strength properties of the films. Citric acid and sodium hypophosphite (SHP) were used as crosslinking agent and catalyst, respectively, to improve the barrier property of the films against moisture. The film samples were prepared from glucomannan and NFC using a dispersion-casting method. The moisture barrier properties were characterized by the moisture vapor transmission rates (MVTR) and showed a significant decrease of 49.7 % (with 0.35 g citric acid in formulation, cured; marked as CA35-C). The crosslinked glucomannan films were calibrated with increasing mean tensile strength, modulus and elongation.

Keywords: packaging material, composite film, nano-fibrillated cellulose, air permeability, mechanical property

1. Introduction

Biopolymers are a potential alternative source for production of fuels and packaging materials, because they have the capability to be degraded or broken down through the action of naturally occurring organisms leaving behind organic by-products (Othman, 2014). The most common and suitable biopolymers for food packaging applications are naturally occurring materials, such as cellulose, hemicellulose, starch, chitosan and agar. It was recorded that the global bio-plastic demand was 1.4 million metric tons in 2014; and it is expected to reach about 6 million metric tons in 2019 (Chen, 2014). According to studies by Helmut Kaiser Consultancy (2013), bio-plastics are expected to cover approximately 25–30 % of the total plastic market by 2020.

The hydrophilic nature of polysaccharide films offers them good oxygen barrier properties, but their water vapor barrier properties and moisture resistance are relatively poor in comparison with the petroleum-based plastic films (Giancone, et al., 2011), which limits their potential application in packaging materials (Janjarasskul and Krochta, 2010). A high water solubility obviously affects the functionality of hemicellulose-based films as packaging materials. The hydrophilicity of the polysaccharides results in water swelling and impairing their mechanical and barrier properties (Sebti, Delves-Broughton and Coma, 2003). Many studies on hemicellulose-based films report that the water resistance of the films can be improved by chemical or physical crosslinking, during which the polymer chains are crosslinked by covalent bonds (chemical bonds) or weaker physical bonds. The crosslinking reagents could be dicarboxylic or polycarboxylic acids such as citric acid (CA). The crosslinked hemicellulose form three dimensional networks that reduce the mobility of the structure, usually enhancing their water resistance (Figure 1), reducing both water solubility and swelling by water, and boosting their mechanical and barrier properties (Balaguer, et al., 2011).

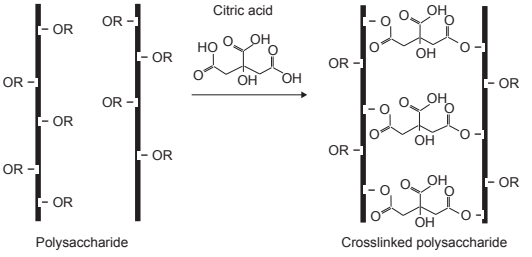


Figure 1: Mechanism for covalent crosslinking between citric acid and a polysaccharide; adapted from Hashem, et al. (2013)

Hemicellulose and nano-fibrillated cellulose are highly promising biopolymers for the production of packaging materials, since they offer films with good tensile and gas barrier properties (Ma, et al., 2017). In addition, they are renewable, available at low cost, and fully biodegradable. However, non-plasticized hemicellulose films are brittle and their hydrophilic character results in poor moisture barrier properties and high water sensitivity compared with petroleum-based plastic films such as polyethylene or polypropylene. A common way to improve the film formation and hydrophobic properties is chemical modification, such as crosslinking. Plasticizers such as water, xylitol or sorbitol reduce the glass transition temperature T_g, of the polymer matrix and prevent the formation of cracks and pinholes (Forssell, et al., 2002; Godbillot, et al., 2006; Stading, Rindlav-Westling and Gatenholm, 2001).

Glucomannan has shown good film-forming capacity, which offers good barrier properties towards air and grease. Several research works and patents have indicated that the development of glucomannan-based films and coatings as sustainable printable packaging materials is commercially promising (Gatenholm, et al., 2008). In the year of 2013, another new patent assigned by Xylophane came out dealing with a method for the production of flexible films or coatings for packaging based on hemicelluloses combined with a crosslinking agent or hydrophobizing agent, to be used as an oxygen, aroma, and/or grease barrier with improved moisture resistance (Gröndahl, et al., 2013).

Nano-fibrillated cellulose (NFC) is a biodegradable film-forming material widely studied for its industrially interesting properties and possible applications in food packaging. Various applications of nano-fibrillated cellulose are under investigation, including its addition as paper fillers (Eriksen, Syverud and Gregerson, 2008), reinforcement in polymer composites (Siqueira, Bras and Dufresne, 2010), coatings for paper and board (Aulin, Gallstedt and Lindström, 2010; Lavoine, Bras and Desloges, 2014; Lavoine, Desloges and Bras, 2014; Lavoine, et al., 2014; Ridgway and Gane, 2012; Syverud, et al., 2009) or stand-alone films (Tammelin, Hippi and Salminen, 2013; Vartiainen, et al., 2016).

However, the focus of this work is on the application of NFC as barrier material used in food packaging and printed electronics. High potential of NFC application as oxygen barrier material on the lab scale was already shown in several works (Aulin, et al., 2010; Aulin, et al., 2013; Honorato, et al., 2015; Kumar, et al., 2014; Rodionova, et al., 2011; Syverud, et al., 2009).

There is a widespread desire and urgent need to replace or partially replace petroleum-based materials with renewable, biodegradable, and eco-friendly packaging materials. Furthermore, there are increasing interests focused on the performance of nano-fibrillated cellulose-containing packaging materials in regard to the end-use properties, such as strength and barrier properties. However, the usage or application of hemicelluloses in packaging is currently limited.

The CA is easily accessible, inexpensive and non-toxic food additive. It has been reported to be utilized as a cross-linking agent to improve the performance of starch, cellulose and PVA/starch films (Coma, et al., 2003; Ma, et al., 2009; Olsson, et al., 2013). The barrier and mechanical properties of plasticized and cross-linked nanocellulose coatings for paper packaging applications has been studied by Herrera, Mathew and Oksman (2017). There has not been information reported using CA as a cross-linking agent in glucomannan/nano-cellulose composite films to enhance the moisture barrier and mechanical properties.

The purpose of this study was to formulate hemicellulose-based stand-alone films with improved moisture barrier and mechanical properties achieved by addition of CA as a crosslinking agent.

The main focus is to explore the optimal film formulations in regard to the barrier and mechanical properties, which will prepare the films for future printing and packaging applications.

2. Experimental

2.1 Materials

Glucomannan from NOW Foods, Inc., in powder form was used. It was derived from the root of *Amorphophalluskonjac* (konjac plant or elephant yam). It is a glucose-mannose polysaccharide in which 5–10 % of the sugars are acetylated. The molecule is structurally related to glucomannan from guar gum. Macroscopically, konjac glucomannan is a soluble, fermentable, and highly viscous fiber.

The NFC (contains: water 95–99 %, cellulose pulp 1–5 %; manufactured by the Department of Chemical and Biological Engineering, University of Maine Process Development Center), in a suspension form was employed in this study. The sample was prepared mechanically by using a pilot scale refiner to break down the wood fibers. The wood fibers were bleached softwood Kraft pulp. The suspensions were obtained at around 3.5 % solids.

Sorbitol in powder form with a purity of 99 %, CA and sodium hypophosphite (SHP) in powder form with a purity of 98 %, from Sigma Aldrich were applied.

Table 1: The crosslinking film formulations and treatment

Formulation	NFC (g)	Glucomannan (g)	Xylitol (g)	CA (g)	SHP as catalyst (g)
N-CA	0.4	1	2	0.00	0.000
CA5-C	0.4	1	2	0.05	0.125
CA15-C	0.4	1	2	0.15	0.125
CA25-C	0.4	1	2	0.25	0.125
CA35-C	0.4	1	2	0.35	0.125
CA25-NC	0.4	1	2	0.25	0.125

2.2 Film formation

The composite film formulations are shown in Table 1. The NFC was added to distilled water for 15 min (10 g / 100 ml) with a mass fraction of 0.5 % of glucomannan (on a NFC basis), a mass fraction of 10 % of sorbitol (on a NFC basis), a mass fraction of 5 %, 15 %, 25 %, and 35 % of CA (on a glucomannan basis), and a mass fraction of 50 % of SHP (on a CA basis) by using a VWR Power Max ELITE Dual Speed Mixer at 45 °C and mixing speed of 450 min^{-1}. The solutions were casted to a mold with the dimensions of 200 mm × 100 mm. Films were dried in the Environmental Test Chambers (Caron Model 6010; temperature range: 5 °C to 70 °C; humidity range: 20 % to 98 % relative humidity (RH)) for 24 hours at 60 °C and 35 % RH. Dried hemicellulose-based films were peeled off manually and then subjected to a curing treatment at 105 °C for 10 min using a fan oven (VWR Model 1305 U). Three film series were prepared following the same procedures, namely, N-CA (films without CA), CA#-C (those added with CA and cured) and CA25-NC (added with 25 % CA and not subjected to the curing treatment).

3. Analytical

Water vapor permeability of the films was evaluated by the gravimetric moisture vapor transmission rate (MVTR) test according to the ASTM E96 desiccant method (American Society for Testing and Materials, 1993). The samples were placed on top of a test cup (Thwing-Albert EZ-Cup 2″) containing sufficient amount of desiccant (anhydrous calcium chloride) to maintain 0 % RH, and the films were sealed to the cup (Figure 2). The assembled cups were placed in the testing room at 23 °C and 50 % RH and weighed every 24 h until constant rate of weight gain was attained. The moisture vapor transmissions (*MVT*) were calculated by Equation [1].

$$MVT = \frac{G}{(A \times t)} \qquad [1]$$

Where G is the weight change of the film, in grams; A is the area of the tested film, in cm^2; t is the time during which G occurred.

Figure 2: The Thwing-Albert EZ-Cup 2″ and the procedure of film sealing

The typical MVTR barrier values are shown in the Table 2. The water solubility test was conducted on the same specimens that were cut and used for the MVTR measurements. The specimen was a round piece with diameter of 2.5 inch. The film specimens were dried in the oven (VWR Scientific Model 1305 U) at 105 °C for 15 min and then weighed. Then the samples were immersed in 50 ml of distilled water for 6 h at 25 °C with continuous stirring using a magnetic stirrer (Corning Model PC-420). The remaining film pieces were dried and weighed. The insoluble matter was calculated as a percentage of the remaining weight over the initial weight of the film specimen.

The tensile properties of the film samples were assessed according to TAPPI (2006) Standard T494 at 25 °C and 50 % RH using an INSTRON 430I with a 500 N load cell. The specimens were conditioned under 25 °C and 50 % RH for 24 hours prior to testing. The initial gauge length was 100 mm, and the crosshead speed was 25 mm/min. The width of each specimen was 15 mm. The average value and standard deviation of tensile strength, Young's modulus (E) and elongation at break were evaluated for at least five of the tested specimens.

Table 2: Moisture vapor transmission rate permeability properties of plastic films (Khalifa, 2016)

Film type		MVTR at 30 °C, 90 % RH ($g/100\ in^2$ per day)	(g/m^2 per day)
Biaxially–oriented PP	Good MVTR	0.25–0.40	3.9–6.2
HDPE	↑	0.30–0.50	4.7–7.8
Cast PP	↕	0.60–0.70	9.3–11.0
Biax PET	↕	1.00–1.30	16.0–23.0
LDPE	↕	1.00–1.50	16.0–23.0
EVOH	↕	1.40–8.00	22.0–124.0
OPS	↓	7.00–10.00	109.0–155.0
Biax NYLON–6	Poor MVTR	10.00–13.00	155.0–202.0

The surface free energy of the films (CA25-C, CA25-NC and N-CA) was estimated by the FTA200 (First Ten Angstrom Dynamic Contact Angle) measurement apparatus. The FTA200 is a flexible video system for measuring contact angle, surface and interfacial tensions, wettability, and absorption. For the evaluation of the surface free energy, the contact angle of three liquids, deionized ultra-filtered water (DI), hexadecane, and methylene iodide (MI), was measured against surfaces of the N-CA and CA#-C film series, and the critical surface energy was calculated using the Owens-Wendt method (Owens and Wendt, 1969) as well as by the Good-Girifalco modification (Girifalco and Good, 1957) of Young-Dupre equation (Young, 1805; Chaudhury, 1996). Although these methods only estimate the surface free energy of solid, such values are useful for comparing the wettability of solid surfaces and predicting print adhesion. During each measurement, a droplet of liquid (1 µl) was deposited on the film specimen surface through a needle with 0.7 mm diameter. Series of images were captured and analyzed. A minimum of five readings were taken for each sample.

4. Results and Discussion

4.1 Caliper

The caliper of the film samples was measured by the Technidyne PROFILE/Plus Thickness instrument. The calipers of the film samples are shown in Table 3.

Table 3: The caliper of hemicellulose-based films

Sample	Caliper (mm)
N-CA	0.36 ± 0.01
CA5-C	0.35 ± 0.01
CA15-C	0.38 ± 0.03
CA25-C	0.37 ± 0.02
CA35-C	0.37 ± 0.02
CA25-NC	0.36 ± 0.01

The importance to characterize the caliper of the sample films is to ensure the repeatability of the film formation procedures in respect to caliper as well as to eliminate the impact of varying caliper on the barrier properties of the film samples. Thus, consistent caliper will enable to compare film series with various formulations and verify the crosslinking effectiveness. The film caliper was controlled by utilizing equal mass of glucomannan gel to fill the casting mold with identical dimensions.

4.2 Moisture vapor transmission rate

The MVTR of the films characterizing the volume of water vapor passing through a film per unit area and time under specified conditions was measured at a steady state. The expectation for the CA#-C films is lower MVTR and higher strength. The water vapor transfer rate for a packaging material such as low density polyethylene (LDPE) is 16–23 g/m^2 per day for film with 1 mm thickness (Khalifa, 2016). In this study, the CA#-C film series fulfilled this requirement. The N-CA films also fulfilled this requirement, but hornification occurred and resulted in higher opacity and rougher surface, which could lead to poor printability.

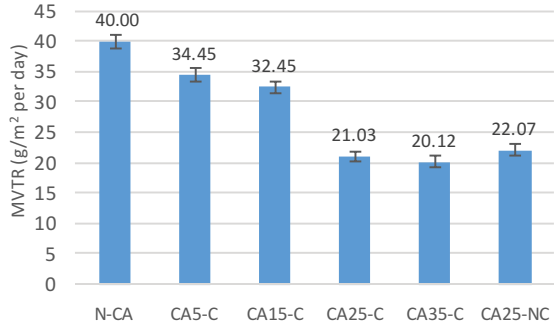


Figure 3: The moisture vapor transmission rate for the hemicellulose-based films

The values (Figure 3) show a reduction of MVTR with addition of CA. The MVTR tended to decrease with the

addition of CA. The fall of MVTR values may be caused by a decreased solubility of water in the amorphous regions of the hemicellulose structure thanks to an increasing fraction of the acetylated hydroxyl groups, or simply more thorough crosslinking.

The relatively low air permeability of the films indicates that there were few connected pores through the cross section of the films. Therefore, it would be of interest to investigate the oxygen transmission rate (OTR) in the future work of this study, since it is a very important property for food packaging materials. The gas permeability depends on the dissolution of oxygen and its rate of diffusion in the material when there are no pores allowing for gas to flow through it.

4.3 Tensile Properties

Tensile properties for the different film series are presented in Table 4. Some studies have reported that CA not only effects moisture barrier properties of polysaccharide films, but also functions as plasticizer to improve their tensile properties (Abdillahi, et al., 2013). Correspondingly, this study presented that these effects apparently coexists. On one hand, CA addition decreased the MVTR and soluble matter of the films by approximately 13 %, indicating the crosslinking reaction between glucomannan and CA. On the other hand, the tensile strength, modulus and elongation at break increased with addition of CA, reflecting a functioning of CA as plasticizer. According to the study of Wang, et al. (2014), the plasticizing effect of CA was attributed to increasing interstitial volume of the film or increasing molecular mobility, making the polymeric structure less dense. However, over crosslinked (CA30-C) hemicellulose is brittle and lack of elasticity.

4.4 Surface free energy

When it comes to printing, it is essential to understand the behavior of ink on the chosen substrate. Surface free energy / surface tension is responsible for the surface behavior (atmosphere–solid contact) and the wetting phenomena (liquid–solid contact).

Estimated surface free energy value of the CA#-C film surface is 40.92 mJ/m^2, while the surface tension of the nano-silver conductive ink is 32–36 mN/m (Table 5). This predicts good wetting with ink and high ink adhesion on the N-CA film surface. Hemicellulose is hydrophilic in nature, hence hemicellulose-based films are generally hygroscopic, which means they will absorb moisture. During the surface free energy estimation test, the water drops spread on the films and totally wet the surface. However, the methylene iodide drops bead up on the film surface. This is because the hemicellulose has abundant free hydroxyl groups distributed along the main and side chains and is affinitive to water.

4.5 Solubility

The solubility and the degree of swelling are very important properties for food packaging. The solubility usually decreases as the degrees of crosslinking are increased (Zou, Qu and Zou, 2007). The solubility val-

Table 4: The tensile properties of the hemicellulose-based films

Sample	N-CA	CA5-C	CA15-C	CA25-C	CA35-C
Tensile strength (N/m^2)	2.49 ± 0.11	2.47 ± 0.22	2.89 ± 0.25	3.47 ± 0.12	2.98 ± 0.11
Modulus (N/m^2)	0.011 ± 0.002	0.013 ± 0.001	0.013 ± 0.001	0.016 ± 0.001	0.013 ± 0.002
Elongation (%)	23.38 ± 1.20	22.12 ± 2.10	23.31 ± 2.30	25.55 ± 1.80	22.50 ± 1.30

Table 5: The surface energy estimation of the selected film surfaces

Sample	Surface free energy (mJ/m^2)	Dispersive part (mJ/m^2)	Polar part (mJ/m^2)
N-CA	64.96	20.18	44.78
CA25-NC	42.65	35.43	7.22
CA25-C	40.92	38.78	2.14

Table 6: The solubility values of the film series

Sample	N-CA	CA5-C	CA15-C	CA25-C	CA35-C	CA-NC
Initial weight (g)	1.02	1.05	1.05	1.04	1.03	1.02
Dry weight (g)	0.36	0.39	0.44	0.51	1.03	0.49
Solubility (%)	64.20	62.85	58.09	51.14	45.63	51.96

ues of the N-CA, CA#-C and CA-NC films are found in the Table 6. The CA-NC film has lower solubility than the N-CA film sample, while there is no significant difference of solubility between the CA-NC and CA#-C film samples. This indicates the crosslinking may happen during the mixing and drying process even without film curing. The CA#-C and CA-NC films result in lower solubility, which corresponds to their lower MVTR values.

5. Conclusions

In summary, the glucomannan/NFC stand-alone films were successfully formulated from the solution through mixing, followed by film casting in the presence of CA. The addition of CA led to a significant enhancement in moisture barrier properties. The CA was shown to be effective as a crosslinker, and it decreased water solubility and water vapor permeability of innovatively formulated glucomannan/NFC composite films. The CA also functions as plasticizer to increase the tensile properties of the hemicellulose-based films, proved by higher tensile strength and elongation. Moreover, the crosslinked glucomannan film resulted in a lower solubility. Due to the biodegradability and biocompatibility, this biopolymer film based on glucomannan nano-fibrillated cellulose with improved moisture barrier properties possess potential in food packaging and offers an alternative to petroleum derived products. This work was done in laboratory scale, and therefore more experiments need to be done to scale up stand-alone films production into industrial settings.

References

Abdillahi, H., Chabrat, E., Rouilly, A. and Rigal, L., 2013. Influence of citric acid on thermoplastic wheat flour/poly(lactic acid) blends. II. Barrier properties and water vapor sorption isotherms. *Industrial Crops and Products*, 50, pp. 104–111.

American Society for Testing and Materials, 1993. *ASTM E96-93 Standard test methods for water-vapor transmission of materials*. Philadelphia: ASTM.

Aulin, C., Gallstedt, M. and Lindström, T., 2010. Oxygen and oil barrier properties of microfibrillated cellulose films and coatings, *Cellulose* 17(3), pp. 559–574.

Aulin, C., Johansson, E., Wågberg, L. and Lindström, T., 2010. Self-organized films from cellulose I nanofibrils using the layer-by-layer technique. *Biomacromolecules* 11(4), pp. 872–882.

Aulin, C., Karabulut, E., Tran, A., Wågberg, L. and Lindström, T., 2013. Transparent nanocellulosic multilayer thin films on polylactic acid with tunable gas barrier properties. *ACS Applied Materials & Interfaces* 5(15), pp. 7352–7359.

Balaguer, M.P., Gomez-Estaca J., Gavara, R. and Hernandez-Munoz, P., 2011. Functional properties of bio-plastics made from wheat gliadins modified with cinnamaldehyde. *Journal of Agricultural and Food Chemistry*, 59(12), pp. 6689–6695.

Chaudhury, M.K., 1996. Interfacial interaction between low-energy surfaces. *Materials Science and Engineering: R: Reports*, 16(3), pp. 97–159.

Chen, J., 2014. *Global markets and technologies for bioplastics*. [online] BCC Research, Code PLS050C. Available at: <http://www.bccresearch.com/market-research/plastics/bioplastics-pls050c.html> [Accessed 24 July 2017].

Coma, V., Sebti, I., Pardon, P., Pichavant, F.H. and Deschamps, A., 2003. Film properties from crosslinking of cellulosic derivatives with a polyfunctional carboxylic acid. *Carbohydrate Polymers*, 51(3), pp. 265–271.

Eriksen, Ø., Syverud, K. and Gregerson, Ø., 2008. The use of microfibrillated cellulose produced from kraft pulp as strength enhancer in TMP paper. *Nordic Pulp & Paper Research Journal,* 23(3), pp. 299–304.

Forssell, P., Lahtinen, R., Lahelin, M. and Myllärinen, P., 2002. Oxygen permeability of amylose and amylopectin films. *Carbohydrate Polymers*, 47(2), pp. 125–129.

Gatenholm, P., Bodin, A., Gröndahl, M., Dammstrom, S. and Eriksson, L., Xylophane AB, 2008. *Polymeric film or coating comprising hemicellulose*. U.S. Pat. 7,427,643.

Giancone, T., Torrieri, E., Di Pierro, P., Cavella, S., Giosafatto, C.V.L. and Masi, P., 2011. Effect of surface density on the engineering properties of high methoxyl pectin-based edible films. *Food and Bioprocess Technology*, 4(7), pp. 1228–1236.

Girifalco, L.A. and Good, R.J., 1957. A theory for the estimation of surface and interfacial energies. I. Derivation and application to interfacial tension. *Journal of Physical Chemistry*, 61(7), pp. 904–909.

Godbillot, L., Dole, P., Joly, C., Rogé, B. and Mathlouthi, M., 2006. Analysis of water binding in starch plasticized films. *Food Chemistry*, 96, pp. 380–386.

Gröndahl, M., Bindgard, L., Gatenholm, P. and Hjertberg, T., Xylophane AB, 2013. *Polymeric film or coating comprising hemicellulose*. U.S. Pat. 8,557,033.

Hashem, M., Sharaf, S., Abd El-Hady, M.M. and Hebeish, A., 2013. Synthesis and characterization of novel carboxymethylcellulose hydrogels and carboxymethylcellulolse-hydrogel-ZnO-nanocomposites. *Carbohydrate Polymers*, 95, pp. 421–427.

Helmut Kaiser Consultancy, 2013. Bioplastics market worldwide 2010/11-2015-2020-2025. [online] Available at: <http://www.hkc22.com/bioplastics.html> [Accessed 24 July 2014].

Herrera, M.A, Mathew, A.P. and Oksman, K., 2017. Barrier and mechanical properties of plasticized and cross-linked nanocellulose coatings for paper packaging applications. *Cellulose,* 24(9), pp. 3969–3980.

Honorato, C., Kumar, V., Liu, J., Koivula, H., Xu, C. L., and Toivakka, M., 2015. Transparent nanocellulose-pigment composite films. *Journal of Material Science,* 50(22), pp. 7343–7352.

Janjarasskul, T. and Krochta, J.M., 2010. Edible packaging materials. *Annual Reviews of Food Science and Technology*, 1, pp. 415–448.

Khalifa, Y.I.M, 2016. Effect of the printing remedies and lamination techniques on barrier properties "WVTR and OTR value" for polypropylene film*. EC Nutrition*, 5(2), pp. 1089–1099

Kumar, V., Bollström, R., Yang, A., Chen, Q., Chen, G., Salminen, P., Bousfield, D., and Toivakka, M., 2014. Comparison of nano- and microfibrillated cellulose films. *Cellulose,* 21(5), pp. 3443–3456.

Lavoine, N., Bras, J. and Desloges, I., 2014. Mechanical and barrier properties of cardboard and 3D packaging coated with microfibrillated cellulose. *Journal of Applied Polymer Science*, 131(8), pp. 40106–40117.

Lavoine, N., Desloges, I. and Bras, J., 2014. Microfibrillated cellulose coatings as new release systems for active packaging. *Carbohydrate Polymers,* 103, pp. 528–537.

Lavoine, N., Desloges, I., Khelifi, B. and Bras, J., 2014. Impact of different coating processes of microfibrillated cellulose on the mechanical and barrier properties of paper. *Journal of Material Science,* 49(7), pp. 2879–2893.

Ma, R., Pekarovicova, A., Fleming, P.D. and Husovska, V., 2017. Preparation and characterization of hemicellulose-based printable films. *Cellulose Chemistry and Technology*, 51(9–10), pp. 939–948.

Ma, X., Chang, P.R., Yu, J. and Stumborg, M., 2009. Properties of biodegradable citric acid-modified granular starch/thermoplastic pea starch composites. *Carbohydrate Polymers*, 75(1), pp. 1–8.

Olsson, E., Menzel, C., Johansson, C., Andersson, R., Koch, K. and Järnström L., 2013. The effect of pH on hydrolysis, cross-linking and barrier properties of starch barriers containing citric acid. *Carbohydrate Polymers*, 98(2), pp. 1505–1513.

Othman, S.H., 2014. Bio-nanocomposite materials for food packaging applications: types of biopolymer and nano-sized filler. *Agriculture and Agricultural Science Procedia,* 2, pp. 296–303.

Owens, D.K. and Wendt, R.C., 1969. Estimation of the surface free energy of polymers. *Journal of Applied Polymer Science,* 13(8), pp. 1741–1747.

Ridgway, C.J. and Gane, P.A.C., 2012. Constructing NFC-pigment composite surface treatment for enhanced paper stiffness and surface properties. *Cellulose,* 19(2), pp. 547–560.

Rodionova, G., Lenes, M., Eriksen, Ø. and Gregersen, Ø.W., 2011. Surface chemical modification of microfibrillated cellulose: improvement of barrier properties for packaging applications. *Cellulose* 18(1), pp. 127–134.

Sebti, I., Delves-Broughton, J. and Coma, V., 2003. Physicochemical properties and bioactivity of nisin-containing cross-linked hydroxypropylmethylcellulose films. *Journal of Agricultural and Food Chemistry*, 51(22), pp. 6468–6474.

Siqueira, G., Bras, J. and Dufresne, A., 2010. Cellulosic bionanocomposites: a review of preparation, properties and applications. *Polymers,* 2(4), pp. 728–765.

Stading, M., Rindlav-Westling, Å. and Gatenholm, P., 2001. Humidity-induced structural transitions in amylose and amylopectin films. *Carbohydrate Polymers*, 45(3), pp. 209–217.

Syverud, K., Gregersen, Ø., Chinga-Carrasco, G. and Eriksen, Ø., 2009. The influence of nano-sized microfibrillated cellulose on paper strength and surface properties. In: *14th Fundamental Research Symposium on Advances in Pulp and Paper Research*. Oxford, UK, 14–18 September 2019, pp. 899–930.

TAPPI, 2006. *Tensile properties of paper and paperboard (using constant rate of elongation apparatus), Test Method TAPPI/ANSI T 494 om-13*. Peachtree Corners, GA: TAPPI.

Tammelin, T., Hippi, U., and Salminen, A., Teknologian Tutkimuskeskus VTT/Aalto University Foundation, 2013. *Method for the Preparation of NFC Films on Supports*. WO2013060934.

Vartiainen, J., Shen, Y., Kaljunen, T., Malm, T., Vähä-Nissi, M., Putkonen, M. and Harlin, A., 2016. Bio-based multilayer barrier films by extrusion, dispersion coating and atomic layer deposition. *Journal of Applied Polymer Science.* 133(2), no. 42260.

Wang, S., Ren, J., Li, W. and Liu, S., 2014. Properties of polyvinyl alcohol/xylan composite films with citric acid. *Carbohydrate Polymers*, 103, pp. 94–99.

Young, T., 1805. An essay on the cohesion of fluids. *Philosophical Transactions*, 95, pp. 65–87.

Zou, G.-X., Qu, J.-P., and Zou, X.-L., 2007. Optimization of water absorption of starch/PVA composites. *Polymer Composites*, 28(5), pp. 674–679.

JPMTR 106 | 1806
DOI 10.14622/JPMTR-1806
UDC 678.7|62-41-024.25-021.465

Case study
Received: 2018-02-18
Accepted: 2018-03-22

Analysis of the relationship of quality factors in the solventless lamination process

Vyacheslav Repeta, Yurii Kukura and Valentyna Kukura

Faculty of Publishing and Printing Information Technology,
Ukrainian Academy of Printing,
19, Pidholosko St., Lviv, 79020, Ukraine

vreneta@yandex.ua
yurii.lviv@gmail.com

Abstract

The paper presents the necessity of establishing the priority ranking of factors which influence the solventless lamination process. The quality factors in the lamination process have been determined through the questionnaire survey of specialists experienced in the lamination of flexographic prints. To establish the priority of the quality factors in the flexographic prints lamination process, a ranking methodology was used which is based on the fact that the importance of the factor is determined by numerical indicators related to the number of influences and dependencies between the factors and their respective weight coefficients. The interconnections between the factors in the lamination process have been established and the model of the importance of quality factors in the solventless lamination process of flexographic prints was constructed with the help of the ranking method. In accordance with the obtained results, the following factors are of the highest priority: the construction of the section for adhesive supply, the type of adhesive, the complexity of the printed image, the type of material, web width, and the temperature. By the set terms, the fuzzy knowledge base of parameters in the solventless lamination process with the performance of the condition "if–then" has been formed. Based on this knowledge base, fuzzy logic equations for the calculation of the quality factors in the lamination process options have been built and defuzzification by the "center of gravity" method to get the quantitative quality parameters of the lamination technological process and to optimize the process.

Keywords: flexible packaging, factor analysis, process parameters, fuzzy logic

1. Introduction

The growing demands for strength, barrier properties and design of flexible packaging have stimulated the use of combined materials in its production, in particular from different types of polymer films, aluminium foil, paper and cardboard. This, in its turn, has given a new impetus to the development and improvement of laminating technologies – obtaining of complex multilayer materials through their combining (most often – gluing). Today, practically every printing company, specializing in the production of flexible packaging, has a laminator among its equipment. In the conditions of a large assortment of materials for lamination, adhesives and equipment, the requirements of finished laminates quality are also steadily increasing, so a comprehensive analysis of laminating technologies and the importance of criteria affecting the quality of the finished packaging is an urgent task.

2. Literature review

The segment of flexible packaging of the global packaging market demonstrates the highest pace of development. According to the forecasts by Smithers Pira (2015), an international analytical company, the average annual growth rate of the global flexible packaging market will remain at 3.4 % over the next five years, and by 2020 the market capacity will reach $ 248 billion. Such growth rates are supported by the demand for flexible packaging with huge potential for the developers of packaging technologies, polymer recyclers, and packaging manufacturers. Among the main trends in the development of the European market for flexible packaging in recent years, the following directions are clearly distinguished: the increase in the production of retort-packaging, the growth of production of materials with special and high barrier properties, the growth of the production of biodegradable polymers, the growth

of the requirements for the quality of printing and the quality of packaging in general. All of these trends are directly related to the production of various types of laminates (Laminating, 2016).

Despite such a rapid development of packaging laminating technologies, printing experts did not pay sufficient attention to them. In particular, Lv, Xu and Zuo (2010) determined that the change of adhesive viscosity is the main factor of unevenness in coating thickness, in the work of Kyryliuk and Zorenko (2012) the main attention was paid to laminating technologies used in book and magazine production, in the production of postcards, etc. In the research paper of Izdebska, Żołek-Tryznowska and Wirtek (2015) it was found that the thickness of the ink, printed on the inside of the laminated film has a significant influence on the mechanical properties of the laminates. The paper from Havenko, et al. (2008) which describes a mathematical model of lamination strength and curling of laminates, depending on the paper properties, working speed and temperature, can serve as a useful basis for the research in this study.

With the technology of solventless lamination, a single- or two-component adhesive (most often on a polyurethane base) is applied on a material in a heated state. The unit for the adhesive application is a system of rollers, two of them are dosing; the adhesive is poured between them for the dosage. The transfer shaft transfers the adhesive to the working shaft from which it is applied to the web material. Manufacturers of equipment offer various construction solutions of this unit, which significantly influences the uniformity of the adhesive application (Wolf, 2010). It is technologically necessary to apply a minimum, but still sufficient layer of the adhesive in the amount of 1–4 g/m^2. After the adhesive application, two films that are passing through the system of pressing rollers are glued in the laminating unit. A separate unit is used as a mixing station of solventless two-component adhesive. Here both components – the resin and the hardener – are heated to a certain temperature and are fed through separate hoses to the mixing head, from which the ready-to-use adhesive enters the unit for its application. Most laminators are also equipped with an additional device for processing (activation) of films by corona discharge and a cooling cylinder (after the laminating unit).

The peculiarity of the technology of solventless lamination is that after gluing, the roll of the laminate should stand still for one or two days, before proceeding with the next technological operation in order to reach the final polymerization of the adhesive (this time is 3–6 hours with solvent lamination). Adhesives for solventless lamination have insufficient thermal stability, so the resulting laminates have limited resistance to sterilization.

On the other hand, the widespread application of the technology of solventless lamination has provided a number of advantages. In addition to its high performance, the undoubted advantage of this technology is its cost-effectiveness (Caimmi, et al., 2013). First, it is obvious that we save costs as there are no expenses for solvents. Secondly, the absence of drying devices can significantly save energy costs (up to 30 %). In addition, the solventless technology involves the application of very thin layers of adhesive without reducing the laminate quality. This technology is also more environmentally friendly since it does not use organic solvents.

The final quality of the finished packaging depends on the qualitative performance of the lamination process, and the control of the technological process is complicated by the fact that while the defect can be seen immediately during printing, the lamination defects appear with some delay – the material can exfoliate, wrinkle and telescope in a roll. Therefore, the question of controlling the quality of the solventless lamination process is important for all enterprises that use this technology.

3. Methods

3.1 Determining the importance of factors

To determine the factors that are important in the solventless lamination, a survey was conducted among eighteen experts (specialists in this technology). They expressed their opinion about the influence of various factors on the lamination process in the questionnaires. The questionnaires prepared according to the methodology by Gurgal, et al. (2013) were processed and twelve most important factors were identified. The importance of the factors with influence on the lamination process has been analyzed using the ranking method (Senkivsky and Pikh, 2013). The method of ranking is based on the fact that the importance of the factor is determined by numerical indicators concidering the number of influences and dependencies between factors and their respective weight coefficients.

Based on the survey of experts, an oriented graph is designed and the relationships between factors are determined. When analyzing the graph, we calculated the total weight value of direct and indirect influences of factors and their integral dependency on other factors. To do this, the following notation was introduced. Let k_{ij} to be the number of influences ($i = 1$ for direct, $i = 2$ for indirect) or dependencies ($i = 3$ for direct, $i = 4$ for indirect) for the j-th factor ($j = 1, ..., n$) and w_i to be the weight of the i-th type. For the calculations, the following conditional values for the weight coefficients in the conditional units were accepted: $w_1 = 10$, $w_2 = 5$, $w_3 = -10$, $w_4 = -5$.

The weight values of all types of relationships of quality factors were denoted by P_{ij}. To calculate it, the following equations were used:

$$P_{ij} = k_{ij}\, w_i \text{ for } i = 1, 2, 3, 4 \text{ and } j = 1, ..., n, \quad [1]$$

where n – is the number of the factor.

For a designed oriented graph (Figure 1), taking into account Equation [1], we obtained:

$$P_{Fj} = \sum_{i=1}^{4} \sum_{j=1}^{m} k_{ij} w_i \quad [2]$$

where m – is the number of factors determined in the questioning process.

If a factor is missing one of the types of relationships, the corresponding k_{ij} value in the Equation [2] is equal to zero. Thus, the given formula serves as the basis for obtaining weight values of the factor ranking, taking into account the different types of relationships between them. It should be noted that $P_{3j} < 0$ and $P_{4j} < 0$, since according to the given initial conditions $w_3 < 0$ and $w_4 < 0$. Consequently, in order to bring the total weight values of the factors to a positive value and using the property of division by 5, the Equation [2] is transformed into:

$$P_{Fj} = \frac{1}{5}\left(\sum_{i=1}^{4} \sum_{j=1}^{m} k_{ij} w_i + S_j \right), \quad [3]$$

where

$$S_j = \max|P_{3j}| + \max|P_{4j}|. \quad [4]$$

This technique has been successfully tested in the work of Repeta, Senkivsky and Piknevych (2014).

Qualitative parameters of solventless lamination process are the result depending on the characteristics of the used materials, equipment specifications and technological process modes, included in selected factors.

3.2 Factor analysis using fuzzy logic

One of the principles for analyzing and quantification of the factors that influence the quality of the process is the fuzzy logic through which it is possible to interpret ambiguous statements into the language of clear mathematical formulas and operate with fuzzy input data. Such principles are realized in the work of Bellman and Zadeh (1970), who laid the foundations of the direction of fuzzy logic and introduced the concept of some universal set for a certain problem area. The advantages of a systems with fuzzy logic are the ability to operate the fuzzy input data, for example, the values that continuously vary in time. The basics of fuzzy logic are applied to control web tension in roll-to-roll based printing systems (Ponniah, et al., 2012), for the model for calculation of numerical color reproduction quality value (Temponi, Fard, and Corley, 1999), for the method of calculating flexographic prints quality (Repeta and Kukura, 2016), etc.

In general, the evaluation of the laminated prints quality by means of fuzzy logic includes the following:

- the establishment of a universal term-set of values and its corresponding linguistic terms of the isolated quality factors (linguistic variables);
- the construction of matrices of pair wise comparisons for the set of linguistic terms for the corresponding interval of values of a universal set and obtaining the functions of membership for each matrix;
- the development of a fuzzy knowledge base using fuzzy logical statements such as "if–then";
- the construction of fuzzy logic equations based on the matrix of knowledge and the functions of membership, which determine the connection between the functions of membership of input and output data;
- the defuzzification of a fuzzy set, the essence of which is a calculation of the numerical indicator of the predicted quality, for example, by the method of the centre of gravity of a plane figure.

To simulate the influence of process factors on the quality of lamination and its evaluation by means of fuzzy logic, we used the possibilities of the development system of the fuzzy control system – the Fuzzy Logic Toolbox of the MATLAB computing environment. For the defuzzification operation, we used the principle of "the centre of gravity" (Rotshtein, Lariushkin and Mityushkin, 2008).

4. Results and Discussion

4.1 Determining the importance of factors

The following factors, which determine the quality of the solventless lamination process of flexographic prints, have been established in the survey:

k_1 – the viscosity of adhesive (VA);
k_2 – the lamination speed (SP);
k_3 – the type of adhesive (AD);
k_4 – the tension of the material tape (MT);
k_5 – the construction of the adhesive feeding section (CS);
k_6 – the width of the material (WM);
k_7 – the complexity of the printed sample (PP);
k_8 – the pressure in the contact area (PR);
k_9 – the surface properties of materials (SM);

k_{10} – the lamination temperature (LT);
k_{11} – the properties of the printing cylinder (PC);
k_{12} – the type of the material (TM).

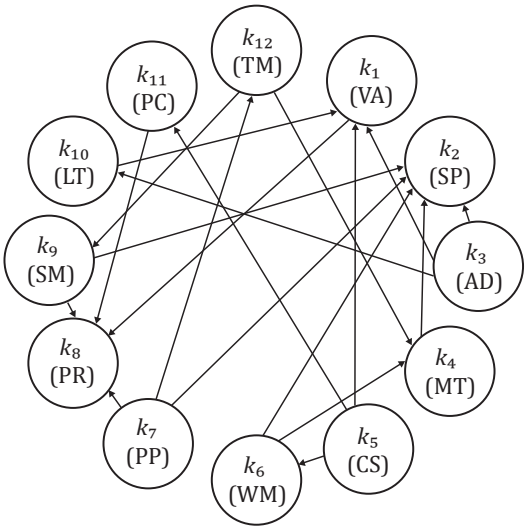


Figure 1: The graph of relationships between the factors

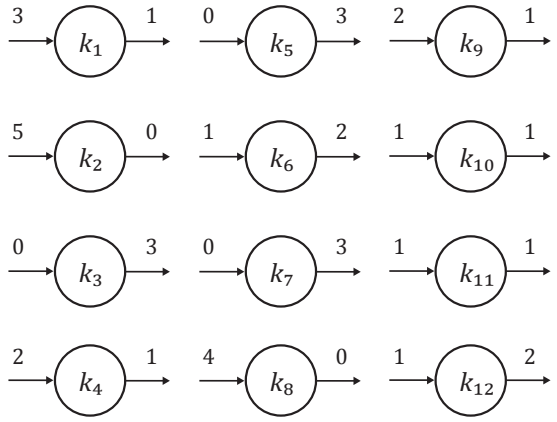


Figure 2: Influences and dependencies for quality factors of the solventless lamination process

The determined factors and possible relationships between them are presented in the form of an oriented graph (Figure 1). It indicates a certain interdependence of the individual factors of the solventless lamination process.

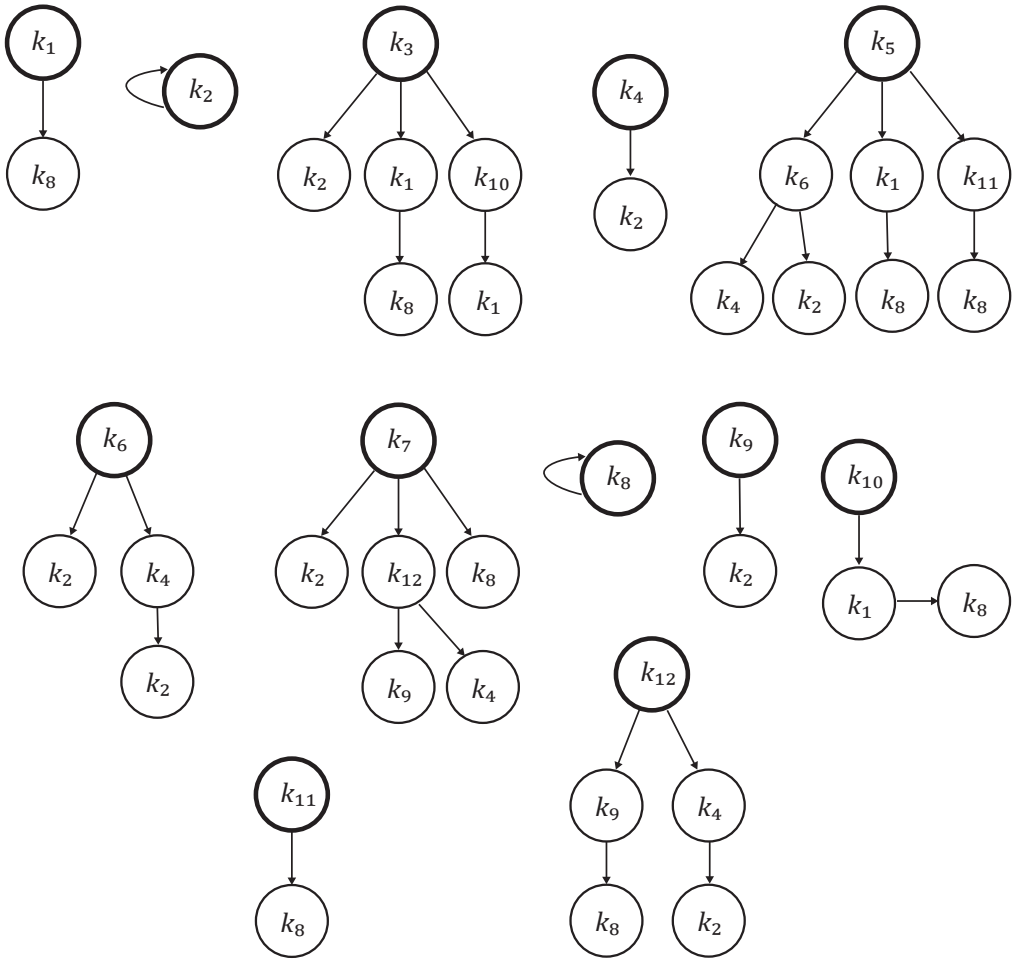


Figure 3: Graphs of multilevel hierarchical influences for quality factors of the solventless lamination process

Table 1: The calculated data of the factor ranking

Factor *j*	k_{1J}	k_{2J}	k_{3J}	k_{4J}	P_{1J}	P_{2J}	P_{3J}	P_{4J}	P_{FJ}	Level of ranking
k_1	1	0	3	1	10	0	−30	−5	9	10
k_2	0	0	5	3	0	0	−50	−15	1	12
k_3	3	2	0	0	30	10	0	0	22	2
k_4	1	0	2	2	10	0	−20	−10	10	9
k_5	3	3	0	0	30	15	0	0	23	1
k_6	2	1	1	0	20	5	−10	0	17	5
k_7	3	1	0	0	30	5	0	0	21	3
k_8	0	0	4	4	0	0	−40	−20	2	11
k_9	1	0	2	1	10	0	−20	−5	11	8
k_{10}	1	1	1	0	10	5	−10	0	15	6
k_{11}	1	0	1	0	10	0	−10	0	14	7
k_{12}	2	2	1	0	20	10	−10	0	18	4

To determine the number of factor influenced by given factor, we determined its direct influences, expressed by the corresponding coefficient k_{1j}. Similarly, coefficients k_{1j} were obtained to reflect the number of factors influencing given factor (Figure 2). The combined consideration of indirect influences or dependencies of the factor (i.e. the influence or dependency through other factors) reflect the coefficients k_{2j} and k_{4j}, respectively.

To do this, by analyzing an oriented graph (Figure 1), we constructed hierarchical trees of their relationships with other factors for each of the factors, taking into account the influences of both types – direct and indirect, which pass through another factor (Figure 3).

Based on the calculations, we formed Table 1 to determine the importance of factors. As we can see from the table, $\max|P_{3j}| = 50$; $\max|P_{4j}| = 20$, which we took into account when calculating in accordance with the above Equation [4]. Accordingly, the specified values were added in each of the rows to the sum of the values in the columns P_{1j}, P_{2j}, P_{3j} and P_{4j} and the result was divided by 5. Finally, we obtained the resulting weight of the factor, which serves as the basis for determining the rank (importance) of the factor r_j, which is equivalent to the priority of its influence on the lamination process. The best rank has the factor with the highest value P_{Fj}.

We designed a scheme of factors' priority based on the results of their importance for the lamination process (Figure 4).

In accordance with the results in Table 1, the most important factors are: k_5, k_3, k_7, k_{12}, k_6, and k_{10}.

The optimal selection and the observance of these factors will allow us to ensure the lamination process with the highest qualitative indicators. In particular, the observance and regulation of the temperature regime of the adhesive will stabilize its viscosity, the use of materials with narrower width will stabilize the tension of the web and enable to increase the speed of the lamination process, and on the other hand the sample with large saturated colour-printed areas can lead to the appearance of spots, due to decrease the surface free energy of the ink layer.

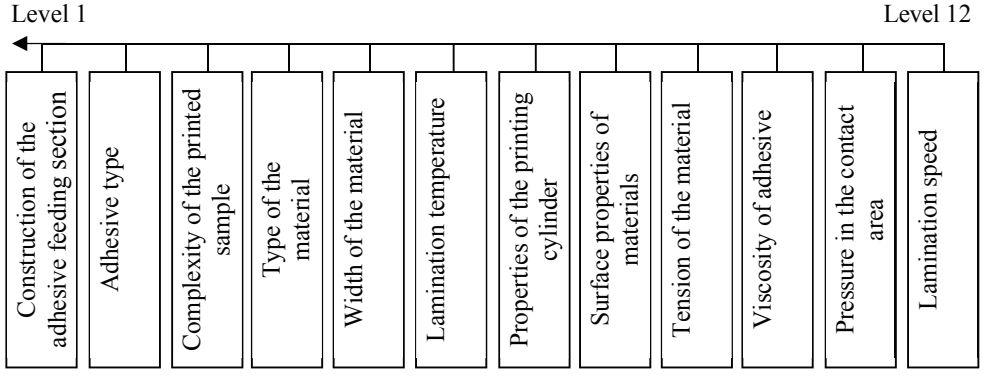


Figure 4: The model of the importance of quality factors of the solventless lamination process, as a result of the analysis of their relationships

4.2 Analysis of the process quality factors by fuzzy logic

The next stage of our work was an analysis of the technological process to determine the influence of the selected factors on the lamination quality. We assumed the following: the temperature regime of the process was stable; the settings of the machine were based on the type of material, which includes also its properties such as the film thickness and its "creep"; and the constructive invariability of the laminating machine was known. Then, for the next analysis, we took the indicators relating to the behavior of materials used in the process. Accordingly, the quality of the lamination process Q depends on the the the viscosity of the adhesive, the surface free energy of the polymer film, width of the film roll, and the speed of the material in the lamination process:

$$Q = f(V, E, W, S) \quad [5]$$

where V is a linguistic variable that characterizes the viscosity of adhesive; E is a linguistic variable that characterizes the value of the surface free energy of the film; W is a linguistic variable that characterizes the width of a laminated film; S is a linguistic variable that characterizes the speed of the lamination process. The evaluation of the values of linguistic variables has been carried out using the system of qualitative concepts. Each of these concepts is a corresponding fuzzy set, that is, some property that is considered as a linguistic term. For linguistic variables that provide the quality of lamination, Table 2 presents the calculated terms.

We continued from a fuzzy knowledge base for evaluating the parameter Quality of lamination using a set of fuzzy rules "if–then":

- If (Viscosity is 'Optimal') and (Surface free energy is 'High') and (Width is 'Narrow') and (Speed is 'High') then (Quality is 'High').
- If (Viscosity is 'Average') and (Surface free energy is 'High') and (Width is 'Wide') and (Speed is 'High') then (Quality is 'Low').
- If (Viscosity is 'Optimal') and (Surface free energy is 'High') and (Width is 'Wide') and (Speed is 'Medium') then (Quality is 'Medium').
- If (Viscosity is 'Optimal') and (Surface free energy is 'Low') and (Width is 'Wide') and (Speed is 'High') then (Quality is 'Low').
- If (Viscosity is 'High') and (Surface free energy is 'Satisfactory') and (Width is 'Narrow') and (Speed is 'High') then (Quality is 'Low').
- If (Viscosity is 'Optimal') and (Surface free energy is 'High') and (Width is 'Medium') and (Speed is 'Medium') then (Quality is 'High').
- If (Viscosity is 'Optimal') and (Surface free energy is 'High') and (Width is 'Narrow') and (Speed is 'Low') then (Quality is 'High').

We constructed the functions of membership for variable "Viscosity". The value of the indicator is defined on the universal set:
u_1 = 2 500 mPa·s; u_2 = 3 000 mPa·s; u_3 = 3 500 mPa·s;
u_4 = 4 000 mPa·s; u_5 = 4 500 mPa·s; u_6 = 5 000 mPa·s;
u_7 =5 500 mPa·s; u_8 = 6 000 mPa·s; u_9 = 7 000 mPa·s.
For a linguistic evaluation of this indicator, we used a set of fuzzy terms: T(V) = <Optimal, Average, High> (Figure 5a).

Similarly, we constructed the functions of membership for the variable "Surface free energy". The value of the indicator is defined on the universal set:
u_1 = 32 mJ/m^2; u_2 = 33 mJ/m^2; u_3 = 34 mJ/m^2;
u_4 = 35 mJ/m^2; u_5 = 36 mJ/m^2; u_6 = 37 mJ/m^2;
u_7 = 38 mJ/m^2; u_8 = 39 mJ/m^2; u_9 = 40 mJ/m^2.
For a linguistic evaluation of this indicator, we used a set of fuzzy terms: T(E) = <Low, Satisfactory, High>. Accordingly, we obtained the functions of membership of the linguistic variable "Surface free energy" (Figure 5b).

Table 2: The quality factors of the solventless lamination process

Variable name	Universal set	Level of ranking
Viscosity	2 500 to 7 000 mPa·s	Optimal Average High
Properties of materials (Surface free energy of polymer film)	32–40 mJ/m^2	Low Satisfactory High
Width of the material	30–100 cm	Narrow Medium Wide
Speed	100–180 m/min	Low Medium High

We obtained the functions of membership of the linguistic variable "Width" with fuzzy terms: T(*W*) = <Narrow, Medium, Wide>. The constructed functions of membership with corresponding terms for variables are shown in Figure 5c.

Accordingly, we defined the value for the indicator "Speed" on a universal set:
u_1 = 100 m/min; u_2 = 120 m/min; u_3 = 140 m/min;
u_4 = 160 m/min; u_5 = 180 m/min.
For a linguistic evaluation of this indicator, we used a set of fuzzy terms: T(*S*) = <Low, Medium, High>. And, similarly, we obtained the functions of membership of the linguistic variable "Speed" (Figure 5d).

The gradation of the linguistic variable "Quality of lamination" was determined in the following values: High – 10 conditional units; Low – 1 conditional unit.

The dependency of the initial parameter "Quality of lamination" on the values of the adhesive viscosity, the surface free energy, the width of the roll and the printing speed has been calculated on the basis of Mamdani and Assilian (1975) algorithm. The result of processing the introduced fuzzy rule, based on fuzzy inference system (FIS) editor, is shown in Figure 6.

The resulting model is based on the application of empirical knowledge obtained from the working expe-

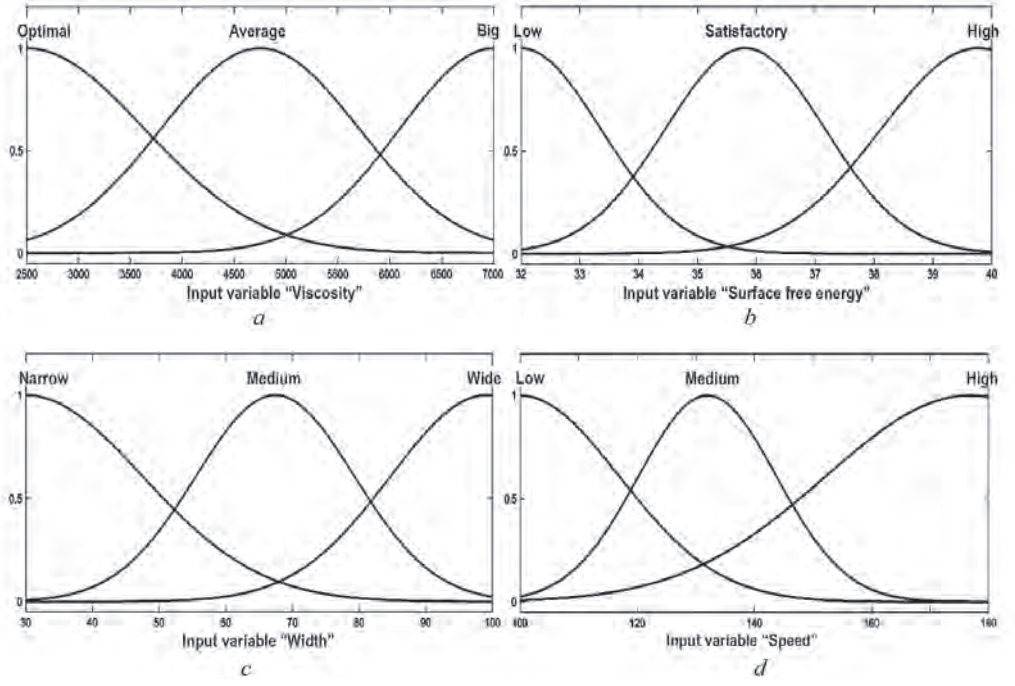


Figure 5: Functions of membership of the factors of solventless lamination: a – viscosity; b – surface free energy; c – width of the roll; d – speed

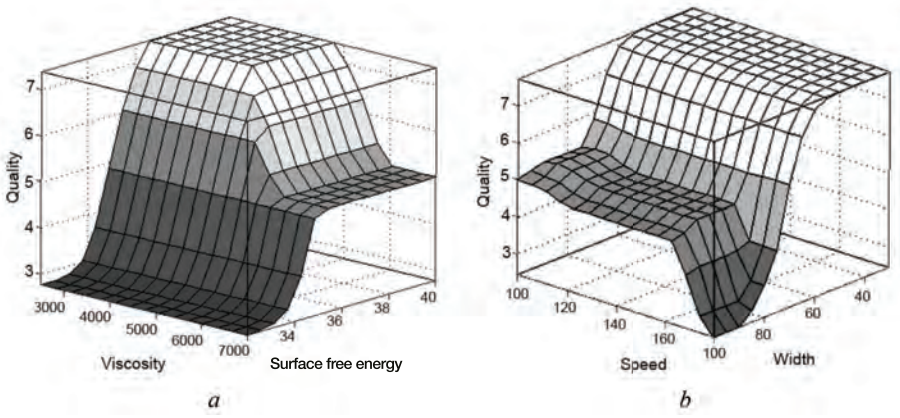


Figure 6: The model of the combined influence of factors on the quality of lamination process: a – the viscosity and the surface free energy; b – the speed and the width of the roll

rience and the observations of the technological process, and shows the influence of the selected factors on the quality of solventless lamination.

5. Conclusions

Thus, as a result of the analysis and the survey among experts, the factors of the quality of the lamination process have been determined, and due to the application of the ranking method, their importance in the solventless lamination process of flexographic prints has been calculated. The oriented graph and the synthesized model of the priority of the influence of factors have shown the dependency of some factors in relation to others. The analysis with the use of expert-linguistic information and the "if–then" rules has allowed us to obtain the functions of membership of such linguistic variables as the adhesive viscosity, the surface free energy of the films, the width of the roll and the speed of lamination, and to calculate their influence on the quality of the solventless lamination process. The suggested analysis of the process can be used to develop training systems, forecasting and control of the laminated prints quality of the solventless lamination process taking into account the remaining factors.

References

Bellman, R.E. and Zadeh, L.A., 1970. Decision-making in fuzzy environment. *Management Science*, 17(4), pp. 141–164.

Caimmi, G., Smith, N., Pedersen, S. and Potts, K., 2013. Print protection: The world of lamination & its benefits – from dry to wet, hot-wax & solventless application. *Flexo*, 38(10), pp. 37–48.

Izdebska, J., Żołek-Tryznowska, Z. and Wirtek, M., 2015. Study of the effects of the ink layer on selected properties of multilayer packaging films. *Journal of Print and Media Technology Research*, 4(1), pp. 27–32.

Gurgal, N., Repeta, V., Senkivsky, V. and Shybanov, V., 2013. Definition of quality criteria of the technological process of narrow web UV-printing. *Journal of Graphic Engineering and Design*, vol. 4(2), pp. 7–11.

Havenko, S., Bogorosh, A., Martynyuk, M., Kibirkštis, E. and Vaitasius, K., 2008. Influence of technological factors on physical and mechanical properties of laminated prints. *Strojniški vestnik – Journal of Mechanical Engineering*, 54(3), pp. 225–231.

Kyryliuk, A.V. and Zorenko, O.V., 2011. Doslidzhennya laminuvannya lystivok. *Tekhnolohiya ta tekhnika druku*, No.4(34), pp. 46–56. (In English: Research of laminating of postals).

Laminating, 2016. Laminirovaniye materialov dlya gibkoy upakovki: sostoyaniye rynka, perspektivy razvitiya i innovatsii. *Flexo Plus*, No.6(114), pp. 26–28. (In English: Laminating materials for flexible packaging: market condition, development perspectives and innovations).

Lv, L., Xu, W. and Zuo, G., 2010. Characteristics research about coating system of solventless laminator. In: *Proceedings of the 17th IAPRI World Conference on Packaging*. Tianjin, China, 10–15 October 2010. Wuhan, China: Scientific Research Publishing, pp. 63–67.

Mamdani, E.H. and Assilian, S., 1975. An experiment in linguistic synthesis with a fuzzy logic controller. *International Journal of Man-Machine Studies*, 7(1), pp. 1–13.

Ponniah, G., Zubair, M., Doh, Y.-H. and Choi, K.-H., 2012. Fuzzy logic based control design for active dancer closed loop web tension control. *International Journal of Engineering Research and Applications,* 2(3), pp. 438–443.

Repeta, V., Senkivsky, V. and Piknevych, S., 2014. Calculation of the importance of quality factors in Braille application process on labels by screen UV-varnishes. *Journal of Graphic Engineering and Design*, 5(2), pp. 5–8.

Repeta, V. and Kukura, Y., 2016. Quantitative evaluation of quality of flexographic imprints by means of fuzzy logic. *Acta Graphica*, 27(1), pp. 39–46.

Rotshtein, O.P., Lariushkin, E.P. and Mityushkin, Y.I., 2008. *Soft computing v biotekhnolohi: bahatofaktornyy analiz i diahnostyka*. Vinnytsia, Ukraine: Universum-Vinnytsia, pp. 42–70. (In English: *Soft Computing in biotechnology: multifactorial analysis and diagnostic*).

Senkivsky, V. and Pikh, I., 2013. Matematychne modelyuvannya protsesu ranzhuvannya faktoriv. *Modelyuvannya ta informatsiyni tekhnolohiyi*, No.69, pp. 142–146. (In English: Mathematical modeling of the process of ranking of factors).

Smithers Pira, 2015. *Market insight: four key trends driving flexible packaging. [online] Available at:* <https://www.smitherspira.com/resources/2015/september/insight-four-key-trends-driving-flexible-packaging> [Accessed 23 January 2018].

Temponi, C., Fard, F.D. and Corley, H.W., 1999. A fuzzy decision model for color reproduction. *International Journal of Production Economics*, 58(1), pp. 31–37.

Wolf, R., 2010. *A technology decision – adhesive lamination or extrusion coating/lamination?* In: 2010 Tappi PLACE Conference. Albuquerque, New Mexico, USA, 18–21 April 2010. Red Hook, NY: Curran.

TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

A brief review of patents granted in 2017 to leading printing press manufacturers

Koenig & Bauer

The most of more than 70 patents granted to Koenig & Bauer during the last year, when the company celebrated 200 years, relate to conventional offset printing, such as five German patents dealing with registering in printing press, including the solution for blanket tension adjustment after the change of print substrate, or two U.S. patents describing the method for changing printing forms using a vertically movable storage device in web-fed printing machines and a method for conveying the forms during the changeover.

Among the others, the U.S. patent 9,533,486 B2 – Printing press for security printing and method for changing a printing forme and printing press start-up concerns with an effective and safe run and operation of a press having an Orlof offset printing unit, despite its complex design. The printing unit with improved ink metering, usable for simultaneous multicolour printing, is described in the U.S. patent 9,604,446 B2 – Inking unit of a printing unit, printing unit and method for operating a printing unit. Further, the U.S. patent 9,643,399 B2 – Ink feed device comprising an ink blade, provides a method for renewing a metering edge of an ink blade dosing the ink; the device may be a part of an inking unit that cooperates with a selective inking cylinder of an Orlof gravure printing unit.

Another example is the U.S. patent 9,776,423 B2 – Web-fed inkjet printing press and method for printing a printing material, describing a solution for achieving high quality even when printing on a non-inkjet-optimised paper by employing the polymer-containing water-based printing ink, where polymer prevents the colour pigments from penetrating into the printing material together with the aqueous phase. Among the Koenig & Bauer patents on inkjet, two of the European patents deal with personalised printing. The system comprising the stationary inkjet printing mechanism and a positioning of the print substrate relative to this mechanism is presented in EP 3 010 718 B1 – Printing machine having a plurality of printing units, which jointly print on a printing material. The solution for reprinting an individualised print copy that is missing in the set, based on the inline detection of the set's completeness, is provided in EP 3 003 721 B1 – Method for reprinting at least one individualised print copy.

Heidelberg

In 2017, over 110 patents were granted to Heidelberger Druckmaschinen worldwide, including the Japanese patents. Besides the improvements of conventional printing presses, a number of solutions in other areas are covered. Several patents deal with inkjet printing; for example, the method for preventing damage to the highly sensitive printing nozzles of an inkjet head by turned-up corners, edges or creases of defective sheets without stopping the machine is provided in the U.S. patent 9,815,307 B2 – Method for avoiding collisions, for adapting a spacing and for actuator-based lifting movement in an inkjet printing machine.

Smithers Pira market reports

The forecasts to 2023 have been published at the beginning of 2018 for three printing sectors.

According to the first market report for dye-sublimation printing, an overall annual growth rate of 10.2 % is expected for the worldwide market, corresponding to the change from €7.63 billion in 2018 to €12.4 billion in 2023. Even higher growth rate by volume of print media is forecasted and attributed to the increase in machine productivity, simplification of workflows, improvements in colour gamut, UV resistance, etc. End-use applications in garments, technical textiles, household, visual communications and rigid substrates are considered. The appendices summarise developments for key equipment manufacturers and integrators, as well as selected recent patents in a dye-sublimation segment.

In case of thermal printing, the compound annual growth rate of 5.0 % is forecasted, from $35.5 billion to $45.4 billion over the next five years. The analysis considers the influences of thermal print market saturation due to competing digital technologies, both print and online, vertical integration trend within thermal printing supplies. and more.

For flexographic printing, an annual increase of 2.6 % is expected, with a global market value increase from $35.8 billion to $40.1 billion between 2018 and 2023. The report takes into account market influences, such as the persistent pressure from digital technologies, declining run lengths and changes in end-use applications from packaging over newspapers to kitchenware, as well as flexographic technology developments, including the integration of digital printing in hybrid flexographic presses.

Printed Electronics Solutions for Packaging

A spin-off from the Institute of Print and Media Technology at the University of Technology Chemnitz (pmTUC), German company Saralon, offers several patented solutions for functional packaging based on Saral Inks©, enabling to print various disposable electronic applications on conventional printing machines.

Light-emitting package features are marketed as SaralLight© and SarallIlu©. The first one utilises the light-emitting diodes using surface-mount technology, which are fixed directly on the cardboard, powered by a thin printed battery and activated by printed sensors. The second one is based on electroluminescent inks printed on paper, plastic or glass and activated by an integrated or external power supply. These solutions can be implemented also as a part of promotional marketing items, such as designs on sheets, cards, posters, glass or acrylic glass items, cardboard carriers, trolleys, etc. In addition, SaralPromo© series offers printed illuminated point-of-sale shelves and displays powered by a standard power supply and controlled by an inverter, with the light switched on by detecting motion.

SaralSecurity© solutions in the form of different labels provide the anti-counterfeiting protection for cardboard and blister packages, pharmaceutical bottles, unpacked items, and, in case of electronically secure plastic sleeves, also the product differentiation features. They consist of a printed electrochromic display, powered by a battery and connected to push sensor for switching the display on. The opening of the package or the cap of the bottle breaks the connector and the display either does not work anymore or indicates a status update (e.g. unlocked or open). Another option is the NFC label with a printed electrochromic display, diode and antenna. The display is switched on when the package is brought near to a near-field communication device.

Inkjet printing process is employed also in a group of Heidelberg patents that are focused on printing on 3D objects, including those with curved surfaces. As an example, the U.S. patent 9,744,776 B2 – Device for printing on multi-dimensional objects describes the solution comprising a tool carrier with stationary processing tools and an object carrier for holding and moving an object to be printed, with three axes of movement and rotation. Another solution, intended to effectively reduce or avoid the problems with drying – especially with UV curing – of the imprint on the 3D surface, which can be attributed to scattered radiation, is described in the U.S. patent 9,636,928 B2 – Apparatus for the printing and radiation treatment of a curved surface of an object.

Among the other applications, the U.S. patent 9,573,359 B2 – Method and device for producing and transferring diffractive microstructures to a printing material and printing press having the device deals with e.g. holograms or other fine structures on paper, board or film. Prepress is represented for example by the U.S. patent 9,609,175 B2 – Method for generating PDF trapping objects without knowing the description of the contours.

Manroland

Regarding Manroland printing presses, almost 50 patents were granted during 2017. Among the European and German patents of Manroland Sheetfed, several ones deal with embossing and cold foil stamping or with an integration of other functional modules to a sheet-fed printing machine. Another group of patents is related to machine operation and quality control. Sheet inspection system is described in the patent DE 10 2010 030 789 B4, for example. In the patent EP 2 953 793 B1 – System for printing press operation, the utilisation of a gesture control in connection with a large-screen monitor is presented, employing a 3D sensor for the detection of hand and finger gestures as a receiving device. This is the one representing the newer inventions, while the most of the Manroland Sheetfed patents granted recently were filed more than ten years ago. The newest one is described in the patent EP 2 982 510 B1 – Modular inkjet unit in a hybrid printing press.

The Manroland Web Systems patents granted in 2017 are mostly related to improvements in printing and folding processes in reel-fed printing presses, such as the method for checking the position of printing plates on the respectively associated plate cylinders, applicable also to presses where several printing plates are attached on one cylinder (EP 3 053 742 B1 – Printing press and method for operating a printing press). Further, digital printing is utilised, covered by the U.S. patent 9,701,106 B2 – Digital printing device for the dynamic printing of a statically printed substrate web and reel-fed printing press, and the U.S. patent 9,754,196 B2 – Method and device for the markless control or regulation of a digital printing process.

Komori

Last year, 20 European and U.S. patents were granted to Komori Corporation, presenting a variety of print-related solutions. Taking printing machines as an example, the patents include US 9,579,880 B2 – Screen printing apparatus and combination printing press including the screen printing apparatus, US 9,579,881 B2 – Rotary screen printing press, US 9,770,895 B2 – Intaglio printing press, US 9,844,931 B2 – Combination printer, with the Orlof and offset printing sections, and EP 2 910 374 B1 – Combination printer, presenting the printing press capable of performing number printing and double-sided coating in one pass, intended mainly for securities.

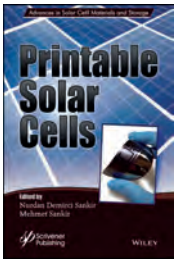
Bookshelf

Printable Solar Cells

This book is the first volume of the new series dedicated to materials, manufacturing techniques and storage applications for solar cells. The book brings an overview of advances in solution processing and thin film deposition techniques for solar cell applications, along with the related new materials. With the authors active in different fields, including physics, chemistry, materials science, optoelectronic information, electrical, mechanical and manufacturing engineering, as well as engineering focused on biochemistry, photovoltaics and renewable energy, the aim is to provide a multidisciplinary view and cover various aspects of materials science and manufacturing technologies for printable solar cells. The four parts of the book deal with the utilisation of hybrid materials, organic materials, perovskites and inorganic materials, respectively, together with the corresponding technologies for their processing.

The first part presents various organic and inorganic hybrid solar cells, solution processing and thin film formation of hybrid semiconductors for energy applications, organic-inorganic hybrid solar cells based on quantum dots, hole transporting layers in printable solar cells and a brief summary of working principles, deposition techniques and characterisation methods used for printable solar cells. The section with printing techniques reviews screen printing, gravure printing, flexography and inkjet printing. It explains the basic principles of each technique and discusses their advantages and limitations with respect to solar cells manufacturing, together with example practical applications. The second part introduces spray-coated organic solar cells, discusses the importance of interface engineering for potential commercialization of printable organic photovoltaic cells and summarizes the structural, optical, electrical and electronic properties of poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS) thin films and their applications in solar cells.

The third part starts with the overview of optoelectronic properties of organometal trihalide perovskite absorbers and their applications for solar cells. The following chapter describes the organic-inorganic hybrid perovskite solar cells with scalable and roll-to-roll compatible coating and printing processes. The section with the latter includes the same printing methods that are listed in Part I, however, building mostly on different references. The inkjet printable processes for dye-sensitised and perovskite solar cells and modules based on advanced nanocomposite materials are then further elaborated in the last chapter here. Namely, it covers the utilisation of inkjet printing for pattern deposition of transition metal oxides, dyes on semiconducting oxides, ionic liquid-based electrolytes, as well as perovskite materials. Finally, the fourth part details solution-processed kesterite solar cells, inorganic hole contacts for perovskite solar cells, electrode materials for printable solar cells and photonic crystals for photon management in solar cells.



Editors: Nurdan D. Sankir, Mehmet Sankir

Publisher: Wiley-Scrivener
1st ed., May 2017
ISBN: 978-1-119-28371-3
576 pages
Hardcover
Available also as an eBook

Computer Vision, Imaging and Computer Graphics Theory and Applications

Editors: José Braz, Nadia Magnenat-Thalmann, Paul Richard, Lars Linsen, Alexandru Telea, Sebastiano Battiato, Francisco Imai

Publisher: Springer
1st ed., September 2017
ISBN: 978-3319648699
608 pages, 319 images
Softcover
Also as an eBook

This volume presents the edited and extended versions of selected papers presented at VISIGRAPP 2016, the 11th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (see the Events section in 4(2015)4). From in total 338 paper submissions, less than a quarter was accepted and published as full papers, 28 of which are included in this selection in a revised form. The intention was to represent and highlight the research from different areas covered by the conference.

Math for Scientists: Refreshing the Essentials

Authors: Natasha Maurits, Branislava Ćurčić-Blake

Publisher: Springer
1st ed., August 2017
ISBN: 978-3319573533
233 pages, 125 images
Softcover
Also as an eBook

Intended for non-mathematics students and scientists, this book briefly reviews the math topics that are essential for understanding the math and formulae most common in the scientific literature and useful for everyday research tasks. The authors first present numbers and mathematical symbols, then explain equation solving, trigonometry, vectors and matrices, and finally, they clarify limits, derivatives and integrals. In each chapter, the theory is complemented by practical exercises and examples.

XJDF: Exchange Job Definition Format

Written by the chairman of XJDF Workgroup operating within CIP4, the International Cooperation for the Integration of Processes in Prepress, Press, and Postpress Organization, this book brings an introduction to XJDF with the emphasis on its technical implementation. The XJDF is developed in order to provide the general information interchange interface in print workflows and represents an alternative to JDF for integration of devices and applications in the graphic arts (see also the Events section in 4(2015)1). The XJDF Specification and Schema were released together with the version 1.6 of JDF Specification at the beginning of March 2018.

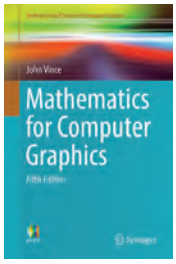
The book intends to provide the readers with a fundamental understanding of XJDF and the core concepts behind it. From a practical point of view, it explains how to work with the XJDF Specification, which requires the background both in programming and printing. The goal of the book is to help overcome this challenge by discussing all essential aspects of XJDF and presenting how to describe products and processes. One chapter deals with XJMF, i.e. the Exchange Job Messaging Format for control and status communication between the interacting systems. The book also clarifies the CIP4 authoring process that was redesigned to ensure transparency and consistency in the development of standards. The community is encouraged to take an active part; this book shows how to begin, follow, or track discussions on extensions, modifications, and improvements of the XJDF Specification.

Author: Stefan Meissner

Publisher: Ricebean.net Software
1st ed., June 2017
ISBN: 978-3-00-055604-3
229 pages
Hardcover

Mathematics for Computer Graphics

Since its first concise edition in 2001, this book is gradually expanded and covers the computer graphics mathematics from the very basics to more advanced topics. Considered to be the most comprehensive single source, it presents all important formulae and processes while still offering sufficient depth to get introduced to the field. The fifth edition offers over a hundred worked examples. The chapters go through numbers, algebra, trigonometry, coordinate systems, determinants, vectors, matrix algebra, geometric transforms, interpolation, curves and patches, analytic geometry, barycentric coordinates, geometric algebra, up to differential and integral calculus.



Author: John Vince

Publisher: Springer
5th ed., August 2017
ISBN: 978-1-4471-7334-2
505 pages, 292 images
Softcover
Available also as an eBook

Academic & Scientific Poster Presentation: A Modern Comprehensive Guide

As its title suggests, this book can help in deciding whether poster presentation is appropriate for the message that should be communicated and if yes, then it can serve as a guide to poster design, examining the visual and textual elements of posters and discussing the ways of presenting the information comprising images, facts, and data. The role of themes, colour, tone and aesthetics is also mentioned, as well as the possibilities to provide supplementary information such as extended text, podcasts and video available online through the incorporation of QR codes or direct links if a poster is presented electronically. In addition, hard-copy materials can be distributed to visitors during the poster presentation. All these poster features and their impact are considered also from the viewer perspective. Further, the recommendations for those who fund and host poster sessions are presented.

Besides advice in practical aspects, the substantial part of the text discusses the value of poster presentation as a means of scientific communication. In spite of an exponential increase in the numbers of posters, the approach to poster presentation, in fact, has not changed since the 1960s and the efficacy is therefore questionable. The author offers evidence-based suggestions for improvement in this area and also in the overall conference experience.

Author: Nicholas Rowe

Publisher: Springer
1st ed., September 2017
ISBN: 978-3-319-61278-2
170 pages, 27 images
Softcover
Available also as an eBook

Typographic Design: Form and Communication

The seventh edition of this successful book, first published 25 years ago, adds the coverage of contemporary typography processes and more detailed discussion of on-screen typographic design concepts, including new examples from branding, print, web and motion, as well as updated case studies and extended supplemental materials available online at the Wiley website. The main chapters start with the evolution of typography and its anatomy, then discuss the legibility, the typographic grid, syntax and message. The book continues with the evolution of typographic technology and the use of type in time-based media. Finally, the education and process of typographic design are explored.

Authors: Rob Carter, Sandra Maxa, Mark Sanders, Philip B. Meggs, Ben Day

Publisher: Wiley
7th ed., February 2018
ISBN: 978-1-119-31256-7
360 pages
Softcover
Available also as an eBook

Writing and Publishing a Scientific Research Paper

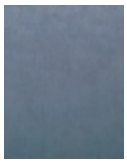
Editors: Subhash C. Parija, Vikram Kate

Publisher: Springer
1st ed., July 2017
ISBN: 978-9811047190
195 pages, 51 images
Hardcover
Also as an eBook

This book was published to provide an accessible, comprehensive and essential resource helping to share the findings gained in research so they reach their audience. The part on writing a scientific research paper first discusses the reasons to do so and then describes the structure of a manuscript, explaining the purpose and features of individual components, i.e. the title, abstract, keywords, introduction, methods, results, discussion and conclusion, references, figures, tables, and supporting material. The second part tracks the process of publishing a paper, from choosing a journal and methods of paper submission to revision and dealing with the rejected manuscript. Further, it clarifies author- and contributorship, types of manuscripts, reviewer role, open access models, and also plagiarism, permissions, and other ethical aspects of scientific publication.

Manuale Calligraphicum: Examples of Calligraphy by Students of Hermann Zapf in the Manner of "Pen and Graver," as a Tribute to Their Teacher

Design: Jerry Kelly



Publisher: RIT Cary Graphic Arts Collection
1st ed., October 2016
ISBN: 978-1939125552
60 pages
Hardcover

This limited edition was contributed by Larry Brady, Marsha Brady, Annie Cicale, Rick Cusick, Claude Dieterich A., Reggie Ezell, Peter Fraterdeus, Kris Holmes, Jerry Kelly, Peter Noth, Marcy Robinson, Ina Saltz, Steven Skaggs, John Stevens, and Julian Waters.

Novel Wearable Antennas for Communication and Medical Systems

Author: Albert Sabban

Publisher: CRC Press
1st ed., October 2017
ISBN: 978-1138047907
420 pages, 458 images
Hardcover
Also as an eBook

Written by the author with expertise in the field, this book is one of a few comprehensive books presenting the design and utilisation of compact, efficient and wearable antennas. The content is framed by the theoretical chapters that provide necessary background with respect to antennas, wearable communication systems, including the medical ones and wireless body area networks, as well as suitable measurement setups for their characterisation. Among the description of suitable types of antennas and antenna arrays, several sections cover different types of wearable printed antennas, from basic to tunable and fractal ones, and their applications. The book also presents the optimisation of antenna design and compares the computed performance with the results measured near the human body.

Multilayer Flexible Packaging: Technology and Applications for the Food, Personal Care, and Over-the-Counter Pharmaceutical Industries

Editor: John R. Wagner, Jr.

Publisher:
William Andrew
2nd ed., April 2016
ISBN: 978-0323371001
410 pages, Hardcover
Also as an eBook

This book reviews the polymers and technologies for their processing into multilayer films, as well as main characteristics of multilayer films and regulatory aspects of food packaging. Print quality is considered e.g. in case of oriented films or web processing. Printing is also mentioned as a new process for pattern metallisation.

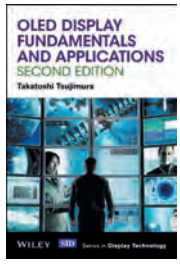
OLED Display Fundamentals and Applications

For the second edition, the content of this book was updated and extended to reflect the recent advances in the design and manufacture of displays based on organic light-emitting diodes (OLED). These include the approaches to improved power efficiency and colour gamut for OLED television, materials and manufacturing methods for flexible OLED displays, roll-to-roll manufacturing of OLED lighting and structures of transparent OLED panels. There is also wider coverage of the underlying scientific principles.

Individual chapters describe OLED devices, manufacturing process, display modules, technologies for colour patterning, thin-film transistor technologies for active-matrix driving, applications of OLED technology in television devices, new OLED applications, namely flexible, transparent and tiled displays, and finally the utilisation of OLED in lighting applications. With respect to printing, solution processing is identified as one of the two most promising approaches proposed to reduce production costs caused by low material utilisation and low throughput of manufacturing equipment used for colour patterning, with inkjet printing discussed as the most used one among the available printing technologies. In addition, screen printing is utilised for perimeter sealing in case of bottom-emission structures.

Author: Takatoshi Tsujimura

Publisher: Wiley
2nd ed., April 2017
ISBN: 978-1-119-18731-8
312 pages
Hardcover
Available also as an eBook

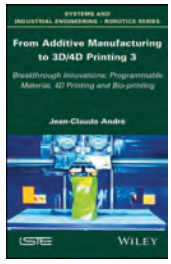


From Additive Manufacturing to 3D/4D Printing 3: Breakthrough Innovations: Programmable Material, 4D Printing and Bio-printing

The technologies described in the third volume of this publication (see Bookshelf section in 6(2017)4) are characterised by their interdisciplinarity, because the development in these areas strongly depends on advances in other fields, especially in nanotechnology, biology, medicine, chemistry, energy storage, and digital sphere. The first part introduces programmable matter, called smart or intelligent, stimulated organisation, a transition to 4D printing with swimming robots, and several 4D printing applications. The second part deals with live 'smart' matter, reviewing bioprinting technologies and examples of 3D bioprinted tissues. The author also discusses related ethical issues and questions of epistemology and modelling.

Author: Jean-Claude André

Publisher: Wiley
1st ed., January 2018
ISBN: 978-1-786-30232-8
468 pages
Hardcover
Available also as an eBook



Bookshelf

Academic dissertations

Exploring Digital News Publishing Business Models: A Production Network Approach

Doctoral thesis – Summary

Author:
Kasper Lindskow

Speciality field:
Organisation and Management

Supervisors:
Anker Brink Lund
Jonas Hedman
Stig Kirk Ørskov

Defended:
5 April 2016, Copenhagen Business School, Department of Business and Politics
Frederiksberg, Denmark

Contact:
kasper.lindskow@eb.dk

The core of this dissertation lied in the study of new business models derived from the changing modes of consumption, competition and production of news publishers' offerings due to the emergence of the networked information society. Because the original objectives turned out to exceed the scope of one thesis, the main focus has been reset on the elaboration of a theoretical model for the analysis of the strategic design of business models and on the development of a new set of automated tools to enable mapping the resource exchanges between news publishers and their business partners based on very large amounts of data. The theoretical framework used for the examination of the digital news publishing production networks associated with HTML-based news offerings on the open Web, presented in Part I, combines network-based strategy theory with Emerson's power-dependence theory and a network-centred business model construct. Part II details the developed method for systematic mapping and data interpretation. In Part III, the resource flows between a total of 1 356 business partners and news publishers and their activities were identified and visualised within the analysis of the large data collected for 41 leading American news publishers. The structure is characterised by co-production, highly asymmetric distribution of power dependencies and co-existence of collaboration and competition. A shared fundamental architecture and a typology of nine different production network types are described, with eight of them represented in the studied sample. Based on the comprehensive analyses and discussions, the dissertation concludes that digital news publishers balance different competitive and collaborative strategies in order to manage their dependencies on a large number of partners including the global, dominating ones, which produce resources with superior value.

Movable Metal Types from Funtimod: Contributions to the Brazilian Typographic History

Doctoral thesis – Summary

Author:
Isabella Ribeiro Aragão

Speciality field:
Design and Architecture

Supervisor:
Priscila Lena Farias

Defended:
6 May 2016, University of São Paulo, Architecture and Urbanism College
São Paulo, Brazil

Language:
Portuguese

Contact:
isabella.aragao@gmail.com

This thesis studied the largest Brazilian type foundry, which operated during almost the entire 20th century – Funtimod, with the aim to elucidate its place in the typographic history of Brazil. While the focus of the investigation was on the metal movable types cast by the company, the case study also explored its historical development and the Funtimod factory. The data were gathered from a number of sources – specimens, documents, interviews, non-participant observations and physical artefacts. The study was complemented by the analysis of type alloys.

After a brief overview of the type casting history and specification of the methods, two chapters describe the Funtimod story and the factory organisation. The history of the type foundries in Brazil started rather late, at the beginning of the 1800s, and spanned the transformation from manual methods to automation and industrialisation. Funtimod was founded in São Paulo in 1932. With subsidiaries in Belo Horizonte, Curitiba, Porto Alegre, Recife and Rio de Janeiro since the 1950s, Funtimod supplied the graphic industry across the country. The work divides the Funtimod history into

four phases and examines the contribution of Karl H. Klingspor, Theodor Hofmann and Peter Papenburg to the company development. Further, the production equipment and procedures are discussed, including the use of electrotyping in part for the production of matrices based on the imported and unlicensed types as templates, besides the use in a standard production. Another interesting point is that some of the interviewees mentioned the superiority of the alloy of the Funtimod types as opposed to those of Manig and Monotype but, based on the X-ray fluorescence analysis, the metallic components of Manig and Funtimod had similar percentages of lead (85 %), antimony (10 %), tin (4 %) and other metals (1 %). The next two chapters then deal with Funtimod types, their origins and characteristics, as well as the variations revealed in nine specimens of Funtimod's type catalogues. Overall, the collection of Funtimod types is a reflection of the German typographic scene of the early 20th century, especially from Stempel and Klingspor type foundries, with only minor changes throughout the whole Funtimod history. Not all of the typefaces have been identified in other foundries; however, the evidence of any original typeface design released in Brazil by Funtimod was not found. On the other hand, the comparative analysis revealed several specifics, e.g. with respect to the shading of some face styles. Certain characters, especially the ones joined with the tilde and cedilla diacritics, presented variations in shape, position, weight and size. The dissertation concludes that although the role of Funtimod was important, the lack of original type designs and the strong dependence on German type foundries is somewhat disappointing and, therefore, the real Brazilian typographic history started later with the first original typefaces.

Doctoral thesis – Summary

Author:
Silvia Holúbková

Speciality field:
Technology of Macromolecular Materials

Supervisors:
Svetozár Katuščák

Defended:
17 August 2016, STU, FCHPT, Institute of Natural and Synthetic Polymers, Department of Wood, Pulp and Paper Bratislava, Slovakia

Language:
Slovak

Contact:
silvia.holubkova@gmail.com

Multicriterial System of Deacidification Processes Evaluation

Dealing with the topic important for the preservation of printed cultural heritage, the aim of this thesis was to propose and use a multicriterial system of objective testing and evaluation of mass deacidification processes in order to gain deeper insight into their overall influence on acid paper characteristics. The work included the experimental study of all relevant deacidification processes available, which proved their capability to increase the pH of acid paper and to add an alkaline reserve, but in some cases, the processes were evaluated as unacceptable due to insufficient mechanical permanence, damage of documents, or safety risks. Based on the measured kinetics of monitored changes, higher efficacy was achieved with the processes that provide more homogeneous distribution of the alkaline reserve. The lack of international standardisation and large variability of criteria, approaches, methods and experimental conditions used was considered to be a key problem of the existing evaluation studies for specific, narrow-focused, as well as multi-purpose conservation methods. To solve the problem of the meta-analysis, the data from the most important comparative studies available worldwide and from the study done within this work were transformed to a comparable form through estimating sequences. This method enabled to compare various aspects of quality and efficacy of two or more deacidification treatments. The proposed multicriterial system allows selecting the best available technology for books and archive documents with respect to their mechanical, optical and chemical properties, stability and paper longevity. As the priority is to extend the lifetime, the major concern is the testing of mechanical permanence. Based on this approach, the work advises the use of magnesium titanium ethoxide in hexamethyldisiloxane (Papersave) for mass deacidification of books, while the method using the aqueous solution of magnesium bicarbonate and methylcellulose (Bückeburg) is suggested for archive documents.

Events

Printed Electronics Europe 2018

Berlin, Germany
11–12 April 2018

A proven format of this event comprises a two-day conference programme accompanied by an exhibition, with blocks of 30 masterclasses in total offered the day before and the day after. The European agenda in 2018 again joins nine conferences dedicated to printed electronics, 3D printing, wearables, off-grid energy independence, energy storage innovations, graphene, sensors, Internet-of-Things applications, and electric vehicles. The schedule includes more than two hundred speakers representing the world leading companies and research institutes as well as the new specialised businesses, with sessions mostly running in eight tracks and starting with a block of keynotes. After the opening ones by IDTechEx, summarising the progress and outlook in individual sectors, the following keynotes are focused on various sensors and sensor systems, Body Area Network, data-enabled building, 3D printing cost analysis considerations, energy solutions, and more. The regular sessions then explore the current developments in a number of areas, for example, in digital healthcare, smart cities, new microgrids, technology for water, desalination and thermoelectric power, self-powered wireless sensors, and RFID solutions for Industry 4.0. Similarly, the topics covered by the masterclasses span from the introductory ones over those dealing with different materials and applications up to the sessions presenting advances in related areas, such as fibre laser technologies, synthetic biology and new robotics.

To further support the networking, a new match-making service is offered through a dedicated app. Within the exhibition, visitors to the Demonstration Street can examine various working prototypes and commercial products, while the Manufacturing Street is a place for interactive demonstrations of a number of printing and process steps.

SPIE Photonics Europe 2018

Strasbourg, France
22–26 April 2018

This European cross-disciplinary optics and photonics event covers in 2018 several new topics, including the conference on 3D printed optics and additive photonic manufacturing, and another one on fundamentals and devices in organic electronics and photonics.

One week earlier, the 2018 edition of SPIE Commercial & Scientific Sensing and Imaging is held in the United States (15–19 April 2018, Orlando, Florida), co-located with the conferences on Defense & Security. Here, for example, the invited talk entitled 'Computed axial lithography: volumetric 3D printing of arbitrary geometries' is scheduled, demonstrating the support-less, layer-less and very fast printing of complex geometries. The technique enables to print 10^8–10^9 voxels in 2–4 minutes.

The London Book Fair 2018

London, UK
10–12 April 2018

Three days of this large annual event organised during London Book & Screen Week (9–15 April) again offer a rich programme for many thousands of publishing professionals and business visitors. Besides the other networking events, nearly two hundred seminars are scheduled, including those on current enabling technologies, skills development and scholarly topics, such as the transition to Open Access, global copyright legislation, innovations connected to digital transformation and content management, and how the evolving needs of authors can be met. In addition, the 2018 editions of The Quantum Conference, What Works? Education Conference, Research & Scholarly Publishing Forum, and Introduction to Rights half-day workshop are held.

Archiving 2018

Washington, DC, USA
17–20 April 2018

As all events sponsored by the Society for Imaging Science and Technology, Archiving 2018 offers invited focal papers, keynote talks, and technical programme with peer-reviewed oral and poster presentations. The focus of Archiving for this year is set on digitization, preservation and access. The first day, Tuesday, is reserved for a short courses programme with two revised and several new courses. The new topics deal with practical aspects and efficient use of colour measurement, metadata, multispectral and advanced image data management, and digital audiovisual file formats.

PIA Events

The schedule of the events sponsored by Printing Industries of America in the second quarter of this year starts with the biggest one – the 2018 Continuous Improvement Conference focused on the concepts of lean manufacturing and other management and quality systems (8–11 April). The aim of the one-day Automation Ready! conference (10 May) is to show the opportunities for cost savings and efficiency gains through the automation of digital printing workflows. The Print & Packaging Legislative Summit (19–20 June) is an industry-wide meeting and networking event hosting legislators, printing and graphic communications professionals, and policy experts. The topics of workshops and webinars cover various practical issues, including how to manage legalised marijuana in the workplace.

InPrint Industrial Inkjet Conference

Chicago, Illinois, USA
1–2 May 2018

This event is dedicated to the advancements in industrial inkjet technology across functional, decorative and package printing applications. The technical presentations cover for example the UV LED technology along with supporting infrastructure, new plasma pretreatment for digital UV printing, drying and curing of water-based inkjet inks, recirculation inkjet technology, and specific requirements on inkjet printhead design, as well as on raster image processing for industrial inkjet. On the other hand, the agenda offers market forecasts and review of development potential across relevant market segments, together with their comparison with the state of the market drawing upon observation, qualitative research and surveys, roundtable discussions, case study presentation, and lessons learned from different digital industrial

CIE 2018 Smart Lighting Conference and Colour Vision and Healthful Lighting Tutorials

Taipei, Chinese Taipei
24–28 April 2018

This conference is the first one of the new Topical Conference series organised by CIE (International Commission on Illumination), with focus topics intended to reflect a strong interest and need in the region as well as general international needs for education, research and discussion in general lighting or other topics related to CIE Divisions. Smart Lighting represents an area that is expected to bring significant energy savings and many other benefits. The supply chain in Taipei region remains a world leader in the light-emitting diode industry, with local manufacturers maintaining the second largest share of global LED chips production. Scientific and technical inputs shared during the conference should aid future progress with confidence in regards to lighting quality, comfort, and safety.

The two-day conference starts on 26 April with keynote presentations and panel discussion on Standards Needs for Smart Lighting. The sessions are then split into three tracks with oral lectures, invited papers and brief poster presentations, followed by a poster session. The topics include adaptive, intelligent and dynamic lighting in the interior as well as the exterior environment, integrative lighting and health, displays and imaging devices with lighting applications, solid-state lighting technologies, colour and vision, and colour quality. The contributions deal e.g. with comprehensive modelling of colour quality for LED lighting, impact of ageing changes in human visual system on discomfort glare sensation and printed text readability, colour depth as a key for understanding the relationship among colour systems, colour tones, and colour emotions, and visual evaluation of colour differences between 3D objects. The associated tutorials are scheduled during the first two days of the event, presenting spectrum-tunable lighting systems for visual and non-visual research and applications, lighting effects connected to health and well-being, including harmful effects of optical radiation, and roadway lighting practices. The last day of the event is reserved for CIE Divisions and Technical Committees meetings.

Forum & INFO*FLEX 2018

Indianapolis, Indiana, USA
6–9 May 2018

Forum, the biggest annual event of the Flexographic Technical Association, keeps the proven format consisting of regular sessions spanning all four days, complemented by the INFO*FLEX exhibition, social events and a free pre-conference session, this year with advice on future purchases of printing and converting equipment. The main programme in 2018 offers nine sessions. Forum officially starts with five contributions of Flexo Quality Consortium session reporting on various research activities and new standards relevant for the package printing workflow. The following sessions explore alignment between strategic goals and company's culture, new technologies for flexographic printers in general as well as for the corrugated market, expanded gamut printing and press approval, combined with a live demonstration of predictable printing for wide-web flexible packaging enabled by FIRST (Flexographic Image Reproduction Specifications & Tolerances) and two panel discussions – on packaging design and problem troubleshooting.

RadTech 2018

Chicago, Illinois, USA
7–9 May 2018

Organised by RadTech, The Association for Ultraviolet and Electron Beam Technologies, the programme of this large event offers three days of conference sessions. Technical contributions dealing with the latest development in UV and EB (ultraviolet and electron-beam) curing are organised in three tracks, accompanied by the exhibition and panel discussions. On the first day, two sessions are dedicated to advances in materials for 3D printing, while panel discussions start with trends in UV inkjet and digital printing. The panel on 3D printing is scheduled on the second day, as well as two sessions focused directly on printing and packaging. The latter include talks aimed on developing new raw material chemistry in accordance with the Guidance Note on Packaging Inks within the Nestlé Packaging Safety and Compliance Program, reviews of resins and oligomers for inks and overprint varnishes without Bisphenol A together with a discussion of their performance, a risk assessment approach to manufacturing and detection limits of residual building block chemicals in raw materials and finished printing inks, and presentation of various advances in UV LED technology in graphic arts applications, such as novel UV LED solutions overcoming low surface cure, UV LED flexographic printing, UV LED low-migration laminating adhesives for flexible packaging, and water-based UV LED curable compositions for graphics applications including food packaging and inkjet inks.

The conference is preceded by one day of short courses on inkjet surface decoration, polymer chemistry for UV/EB curing professionals, advanced photopolymerisation topics and the so-called click chemistry in radiation curing. In addition, the two-part course showing how to employ Design of Experiments for improvement and optimisation of UV/EB curing processes and formulations is scheduled during the main conference days.

CPES2018

Toronto, Canada
23–24 May 2018

The 2018 edition of this event presenting the broad spectrum of flexible and hybrid electronics puts emphasis on the value chain required to bring innovative products and applications to market. The agenda delivers more time to network, more industry panels and a greater focus on helping startups and early-stage companies. The announced keynotes include the discussion of consumer products journey from trial to large-scale implementation of flexible and hybrid electronics technologies by Christine Di Fabio, presentation of the flexible and hybrid electronics technology roadmap by Melissa Grupen-Shemansky, introduction of the Advanced Manufacturing Supercluster initiative in Canada by Jayson Myers, elucidation of the approach to textile innovation adopted by the Sweden's Smart Textiles Institute by Susanne Nejderås, and discussion of the gender gap by Geneviève Tanguay, pointing out that women remain under-represented among Canadian graduates in the areas of Science, Technology, Engineering and Mathematics (STEM). The day before the symposium, on 22 May, the masterclasses dealing with relevant standards, smart textiles, human-centred design principles, and intellectual property management and protection are available.

print applications from packaging over consumer goods to textiles. In addition, the creative applications track further details industrial print opportunities in interior and 3D surface décor, direct object printing for beverage can market, and more.

International Day of Light

16 May 2018

Starting with this year, the International Day of Light will be held on 16 May every year, the anniversary of the first successful operation of a laser in 1960. The goal is to highlight the importance of light and optical technologies for the development not only in many scientific fields but also in art, culture and society in general. Besides the United Nations Educational, Scientific and Cultural Organization, the Steering Committee includes representatives from over twenty institutes, associations, and companies active in related areas. Currently, various activities in more than fifty countries and several worldwide events are announced.

Smithers Pira Events

The first of the 2018 spring events, Specialty Papers Europe, is held with TAPPI again in Cologne, Germany (23–25 April), with e.g. performance of engineered polysaccharides, water-based barrier coatings and foam coating technology for applying thin functional layers among the topics.

The series of the US events starts with Global Food Contact USA in Bethesda, Maryland (9–11 May).

The Digital Print Week is organised a month later in Chicago, Illinois, with US editions of Digital Print for Packaging (4–6 June) and Digital Textile Printing (7–8 June).

INMA World Congress of News Media

Washington, DC, USA
31 May to 5 June 2018

The first two days of this event organised by the International News Media Association (INMA) are reserved for the study tour that begins at the National Press Club and Washington Post, continues in U.S. News & World Report, Vox Media and Atlantic Media, the next day then in Gannett/USA Today Network, Politico, and CQ Roll Call, concluding with a visit to the National Geographic Museum. On the next day, the INMA Board of Directors Meeting is scheduled. The seminar programme on 3 June explores various international case studies, fake news challenges, collaboration, smart data, print innovations, and more. The Media Conference is held on the last two days, with the Global Media Awards Ceremonies on 4 June. The agenda offers several panel discussions e.g. on business model transformation, alternative revenue models, freemium, metered and hybrid digital subscription models, consumer engagement, video strategies, and the rise of marketing services, a keynote of Bob Woodward entitled 'Have We Forgotten the Lessons of Watergate?', insight into Google News Lab, and much more.

WAN-IFRA Events

Traditionally, a great number of media and news publishing events in the second quarter of this year are organised also by the World Association of Newspapers and News Publishers. The main ones comprise the 2018 editions of Digital Media Europe in Copenhagen, Denmark (10–11 April), combined with the European Digital Media Awards and followed by the study tour visiting the revenue innovators in Scandinavia (12–13 April), Publish Asia in Bali, Indonesia (24–26 April), and the 70th World News Media Congress with the 25th World Editors Forum held in Estoril, Portugal (6–8 June).

Hybrid and Organic Photovoltaics 2018

Benidorm, Spain
28–31 May 2018

For its 10th anniversary, this conference returns to the venue where it was first held, with the main topics dealing with perovskite solar cells, organic photovoltaics, photoelectrochemical water splitting and quantum dots. The intensive programme of the three main conference days starts on 29 May and consists of the morning plenary sessions with invited speakers, followed by four parallel sessions with oral scientific contributions running in the afternoons, and also a Tuesday poster session.

Each day is opened by a keynote. The first one by Harald W. Ade is on the importance of molecular interaction and vitrification of non-fullerene organic solar cells, and the second one by Antoni Llobet deals with hybrid molecular photoanodes for water splitting. Last, but definitely not least, the recent emergence of molecular photovoltaics and perovskite solar cells as a new generation of photovoltaics is in the focus of the third keynote presented by Michael Grätzel. The topics of the other invited lectures range from recapitulation of the past ten years in the field of hybrid and organic photovoltaics, accompanied by a significant change in scientific communication in general, over metal-oxide-based perovskite solar cells, growth of layered perovskites, molecular-based photocathodes for H_2 evolution, and material design for fullerene-free polymer solar cells, up to near and short-wave infrared colloidal quantum dot solar cells and the research on singlet exciton fission that could improve the efficiency of photovoltaic devices.

The contributions utilising printing technology mainly deal with perovskite solar cells. Their topics include inkjet-printed perovskite photovoltaics, design and development of all printable perovskite solar modules with active area of nearly 200 cm^2, the influence of 5-ammonium valeric acid iodide content on the stability of this type of solar cells and modules, improved performance of printable perovskite solar cells with bifunctional conjugated organic molecule, efficient and stable ambient-processed printable mesoscopic perovskite solar cells, design and optimisation of fully printable perovskite solar modules by scribing method, certified printed perovskite photovoltaics by a molten salt approach, and printable carbon-based perovskite solar cells employing functionalized oxide interlayers. Also, the study of alternative printable interlayers for polymer solar cells is listed among the presented papers.

8th Conference on Information and Graphic Arts Technology

Ljubljana, Slovenia
7–8 June 2018

The 8th edition of this international event organised by the University of Ljubljana, Faculty of Natural Sciences and Engineering (formerly Symposium of Information and Graphic Arts Technology) is held under the auspices of the International Circle of Educational Institutes for Graphic Arts Technology and Management. The conference covers the wide range of topics related to the field of graphic arts, print and media technology, including the areas of graphic materials, printing technology, quality control, innovative packaging, printed electronics, advances in printed communication, graphic and media design, typographic design, interactive media, and marketing.

Journal of Print and Media Technology Research
A PEER-REVIEWED QUARTERLY

ISSN 2414-6250 (Online)
ISSN 2223-8905 (Print)
CODEN JPMTBI
UDC 665

Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

JPMTR is listed in Emerging Sources Citation Index, Scopus, Index Copernicus International, PiraBase (by Smithers Pira), Paperbase (by Innventia and Centre Technique du Papier), NSD – Norwegian Register for Scientific Journals, Series and Publishers, and ARRS – Slovenian Research Agency, List of Scientific Journals.

Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

The journal will consider for publication papers on fundamental and applied aspects of at least, but not limited to, the following topics:

- **Printing technology and related processes**
  Conventional and special printing; Packaging; Fuel cells, batteries, sensors and other printed functionality; Printing on biomaterials; Textile and fabric printing; Printed decorations; 3D printing; Material science; Process control
- **Premedia technology and processes**
  Colour reproduction and colour management; Image and reproduction quality; Image carriers (physical and virtual); Workflow and management
- **Emerging media and future trends**
  Media industry developments; Developing media communications value systems; Online and mobile media development; Cross-media publishing
- **Social impact**
  Environmental issues and sustainability; Consumer perception and media use; Social trends and their impact on media

Submissions for the journal are accepted at any time. If meeting the general criteria and ethic standards of scientific publishing, they will be rapidly forwarded to peer-review by experts of relevant scientific competence, carefully evaluated, selected and edited. Once accepted and edited, the papers will be published as soon as possible.

There is no entry or publishing fee for authors. Authors of accepted contributions will be asked to sign a copyright transfer agreement.

Authors are asked to strictly follow the guidelines for preparation of a paper (see the abbreviated version on inside back cover of the journal).

Complete guidelines can be downloaded from: <http://www.iarigai.org/publications/journals/>
Papers not complying with the guidelines will be returned to authors for revision.

Submissions and queries should be directed to: journal@iarigai.org

Journal of Print and Media Technology Research
A PEER-REVIEWED QUARTERLY

Vol. 7, 2018
Prices and subscriptions

Since 2016, the journal is published in digital form.
A print version is available on-demand and at additional price.

Please, find below the prices charged for the Journal, as well as for a single paper.
Use the opportunity to benefit from the Subscriber's discount price.

By ordering a publication, or by subscription, a password will be provided to you for downloading.
The password protection of every issue is active during a period of six months.
After this period the publications will be available free of charge.

iarigai members will be given the download password for free.

Regular prices

Four issues, digital JPMTR (password protected)	300 EUR
Single issue, digital JPMTR (password protected)	100 EUR
Single paper from JPMTR (PDF file)	20 EUR
Four issues, print JPMTR (on-demand)	400 EUR
Single issue, print JPMTR (on-demand)	100 EUR

Subscription prices

Annual subscription, four issues, digital JPMTR (password protected)	240 EUR
Annual subscription, four issues, print JPMTR (on-demand)	400 EUR

Prices for iarigai members

Four issues, digital JPMTR (password protected)	Free of charge
Single paper from JPMTR (PDF file)	Free of charge
Four issues, print JPMTR (on-demand)	400 EUR
Single issue, print JPMTR (on-demand)	100 EUR

Place your order online at: <http://www.iarigai.org/publications/subscriptions-orders/>
Or send an e-mail order to: office@iarigai.org

Guidelines for authors

Authors are encouraged to submit complete, original and previously unpublished scientific or technical research works, which are not under reviews in any other journals and/or conferences. Significantly expanded and updated versions of conference presentations may also be considered for publication. In addition, the Journal will publish reviews as well as opinions and reflections in a special section.

Submissions for the journal are accepted at any time. If meeting the general criteria and ethical standards of the scientific publication, they will be rapidly forwarded to peer-review by experts of high scientific competence, carefully evaluated, and considered for selection. Once accepted by the Editorial Board, the papers will be edited and published as soon as possible.

When preparing a manuscript for JPMTR, please strictly comply with the journal guidelines. The Editorial Board retains the right to reject without comment or explanation manuscripts that are not prepared in accordance with these guidelines and/or if the appropriate level required for scientific publishing cannot be attained.

A – General

The text should be cohesive, logically organized, and thus easy to follow by someone with common knowledge in the field. Do not include information that is not relevant to your research question(s) stated in the introduction.

Only contributions submitted in English will be considered for publication. If English is not your native language, please arrange for the text to be reviewed by a technical editor with skills in English and scientific communications. Maintain a consistent style with regard to spelling (either UK or US English, but never both), punctuation, nomenclature, symbols etc. Make sure that you are using proper English scientific terms. Literal translations are often wrong. Terms that do not have a commonly known English translation should be explicitly defined in the manuscript. Acronyms and abbreviations used must also be explicitly defined. Generally, sentences should not be very long and their structure should be relatively simple, with the subject located close to its verb. Do not overuse passive constructions.

Do not copy substantial parts of your previous publications and do not submit the same manuscript to more than one journal at a time. Clearly distinguish your original results and ideas from those of other authors and from your earlier publications – provide citations whenever relevant.

For more details on ethics in scientific publication consult Guidelines, published by the Committee on Publication Ethics (COPE):
<https://publicationethics.org/resources/guidelines>

If it is necessary to use an illustration, diagram, etc. from an earlier publication, it is the author's responsibility to ensure that permission to reproduce such an illustration, diagram, etc. is obtained from the copyright holder. If a figure is copied, adapted or redrawn, the original source must be acknowledged.

Submitting the contribution to JPMTR, the author(s) confirm that it has not been published previously, that it is not under consideration for publication elsewhere and – once accepted and published – it will not be published under the same title and in the same form, in English or in any other language. The published paper may, however, be republished as part of an academic thesis to be defended by the author. The publisher retains the right to publish the printed paper online in the electronic form and to distribute and market the Journal containing the respective paper without any limitations.

B – Structure of the manuscript

Preliminary

Title: Should be concise and unambiguous, and must reflect the contents of the article. Information given in the title does not need to be repeated in the abstract (as they are always published jointly), although some overlap is unavoidable.

List of authors: I.e. all persons who contributed substantially to study planning, experimental work, data collection or interpretation of results and wrote or critically revised the manuscript and approved its final version. Enter full names (first and last), followed by the present address, as well as the E-mail addresses. Separately enter complete details of the corresponding author – full mailing address, telephone number, and E-mail. Editors will communicate only with the corresponding author.

Abstract: Should not exceed 500 words. Briefly explain why you conducted the research (background), what question(s) you answer (objectives), how you performed the research (methods), what you found (results: major data, relationships), and your interpretation and main consequences of your findings (discussion, conclusions). The abstract must reflect the content of the article, including all keywords, as for most readers it will be the major source of information about your research. Make sure that all the information given in the abstract also appears in the main body of the article.

Keywords: Include three to five relevant scientific terms that are not mentioned in the title. Keep the keywords specific. Avoid more general and/or descriptive terms, unless your research has strong interdisciplinary significance.

Scientific content

Introduction and background: Explain why it was necessary to carry out the research and the specific research question(s) you will answer. Start from more general issues and gradually focus on your research question(s). Describe relevant earlier research in the area and how your work is related to this.

Methods: Describe in detail how the research was carried out (e.g. study area, data collection, criteria, origin of analyzed material, sample size, number of measurements, equipment, data analysis, statistical methods and software used). All factors that could have affected the results need to be considered. Make sure that you comply with the ethical standards, with respect to the environmental protection, other authors and their published works, etc.

Results: Present the new results of your research (previously published data should not be included in this section). All tables and figures must be mentioned in the main body of the article, in the order in which they appear. Make sure that the statistical analysis is appropriate. Do not fabricate or distort any data, and do not exclude any important data; similarly, do not manipulate images to make a false impression on readers.

Discussion: Answer your research questions (stated at the end of the introduction) and compare your new results with published data, as objectively as possible. Discuss their limitations and highlight your main findings. At the end of Discussion or in a separate section, emphasize your major conclusions, pointing out scientific contribution and the practical significance of your study.

Conclusions: The main conclusions emerging from the study should be briefly presented or listed in this section, with the reference to the aims of the research and/or questions mentioned in the Introduction and elaborated in the Discussion.

Note: Some papers might require different structure of the scientific content. In such cases, however, it is necessary to clearly name and mark the appropriate sections, or to consult the editors. Sections from Introduction until the end of Conclusions must be numbered. Number the section titles consecutively as 1., 2., 3., ... while subsections should be hierarchically numbered as 2.1, 2.3, 3.4 etc. Only Arabic numerals will be accepted.

Acknowledgments: Place any acknowledgements at the end of your manuscript, after conclusions and before the list of literature references.

References: The list of sources referred to in the text should be collected in alphabetical order on at the end of the paper. Make sure that you have provided sources for all important information extracted from other publications. References should be given only to documents which any reader can reasonably be expected to be able to find in the open literature or on the web, and the reference should be complete, so that it is possible for the reader to locate the source without difficulty. The number of cited works should not be excessive - do not give many similar examples.

Responsibility for the accuracy of bibliographic citations lies entirely with the authors. Please use exclusively the Harvard Referencing System. For more information consult the Guide to Harvard style of Referencing, 6th edition, 2016, used with consent of Anglia Ruskin University, available at:
<https://libweb.anglia.ac.uk/referencing/files/Harvard_referencing_201718.pdf>

C – Technical requirements for text processing

For technical requirement related to your submission, i.e. page layout, formatting of the text, as well of graphic objects (images, charts, tables etc.) please see detailed instructions at:
<http://www.iarigai.org/publications/journals/>

D – Submission of the paper and further procedure

Before sending your paper, check once again that it corresponds to the requirements explicated above, with special regard to the ethical issues, structure of the paper as well as formatting.

Once completed, send your paper as an attachment to:
journal@iarigai.org

If necessary, compress the file before sending it. You will be acknowledged on the receipt within 48 hours, along with the code under which your submission will be processed.

The editors will check the manuscript and inform you whether it has to be updated regarding the structure and formatting. The corrected manuscript is expected within 15 days.

Your paper will be forwarded for anonymous evaluation by two experts of international reputation in your specific field. Their comments and remarks will be in due time disclosed to the author(s), with the request for changes, explanations or corrections (if any) as demanded by the referees.

After the updated version is approved by the reviewers, the Editorial Board will decide on the publishing of the paper. However, the Board retains the right to ask for a third independent opinion, or to definitely reject the contribution.

Printing and publishing of papers, once accepted by the Editorial Board, will be carried out at the earliest possible convenience.

1-2018

Journal of Print and Media Technology Research

A PEER-REVIEWED QUARTERLY

The journal is publishing contributions in the following fields of research

- Printing technology and related processes
- Premedia technology and processes
- Emerging media and future trends
- Social impacts

For details see the Mission statement inside

JPMTR is listed in

- Emerging Sources Citation Index
- Scopus
- Index Copernicus International
- PiraBase (by Smithers Pira)
- Paperbase (by Innventia and Centre Technique du Papier)
- NSD – Norwegian Register for Scientific Journals, Series and Publishers
- ARRS – Slovenian Research Agency, List of Scientific Journals

Submissions and inquiries

journal@iarigai.org

Subscriptions

office@iarigai.org

More information at

www.iarigai.org/publications/journal

Publisher

The International Association of Research Organizations
for the Information, Media and Graphic Arts Industries
Magdalenenstrasse 2
D-64288 Darmstadt
Germany