WMU 2010
TAGA Book
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Presidents Message

As the printing industry moves towards the future it is important that we remember our past. With that said, I am proud to present the WMU TAGA Student Journal—“EVOLUTION-The History Of Print”. With advancements in printing at the forefront of the industry, we are taking a step away from the present and a step into the past. From Papyrus to Pre press, Duplicators to Digital, we look at who and what helped to make printing the third largest industries in the world.

We feel this book has a special meaning, because most of us are moving from the academic world into the professional world, thus we have decided to take a moment to learn and reflect on where our industry originated. Our concept for this journal came from simple saying that most of the students in our program have come across “You are the printers of tomorrow.” So we asked ourselves “Why not look at the past?”

Although the TAGA Members have put their heart into this journal, this project would not have been possible without the help from our advisors and sponsors. We have certainly been blessed with a group of people who have given their undoubted support through the production of this journal. I would like to thank our faculty advisors Dr. Pekarovicova and Dr. Fleming for their support, encouragement and suggestions throughout the production of this book. I would also to take this opportunity to thank Chair Said AbuBakr and Dean Anthony Vizzini who, through their generous funding, made this journal and trip possible. All of us extend our deepest gratitude to Mark Cummins for being there every step of the way while printing this journal. Xpedx, Thompson Shore, and Malloy Inc. contributed their generous donations of materials, funds, and time that made this journal a success.

The WMU TAGA Chapter invites you to take a step out of the present and a step into the past to learn about our “EVOLUTION – The History of Print” We hope you will enjoy!

Sincerely,

Tim Pietrack
WMU TAGA Student Chapter President
Faculty & Students
In 1982, Dr. AbuBakr received his doctorate in Chemical Engineering from Michigan State University. From 1982-1985, Dr. Abubakr was assistant professor at Yarmouk University—Jordan, where he developed a new Chemical Engineering department. From 1985-1993, he moved to Stevens Point, WI, where he accepted a position as an assistant professor. He was promoted to associate professor and then full professor. In 1993 he joined the USDA Forest Service, Forest Products Laboratory. Dr. AbuBakr was the research project leader/supervisory chemical engineer until accepting the position of chair of the Department of Paper Engineering, Chemical Engineering, and Imaging.

Dr. AbuBakr specializes in paper recycling research. This includes such areas as fiber fractionation, contaminants removal, ultrafiltration, enzymatic deinking, fiber loading and pulping. Dr. AbuBakr is the author of over 130 papers. Some of the more recent articles are “Lightweight, High-Opacity Paper by Fiber Loading: Filler Evaluation,” “United States Postal Service Efforts to Develop an Environmentally Benign Pressure-Sensitive Adhesive for Postal Stamp Applications,” and “Packaging Grade Kraft Pulp from Small Diameter Trees.” Dr. AbuBakr is an author of a book and coauthor of three others. He is a well-known presenter at TAPPI and other prestigious conferences. Dr. AbuBakr has received several meritorious recognitions from all his professional and academic peers. He was the winner of the USDA Secretary’s Group Honor Award, which was won four consecutive years. Other honors include the Forest Service Chief’s Technology Transfer Award, the University of Wisconsin Teaching Excellence Award, and inclusion in Who’s Who in America, Who’s Who in Science and Engineering, and Who’s Who in the World. Dr. AbuBakr is a longtime member of the TAPPI Environmental and Pulping Division Councils and Technical Program Committees. He also served as a panel member for TAPPI’s Forest For Our Future display at Disney’s Epcot Center in Orlando, FL.
Dr. Alexandra Pekarovicova

Dr. Alexandra “Sasha” Pekarovicova is an Associate Professor of the Department of Paper Engineering, Chemical Engineering, and Imaging at Western Michigan University, Kalamazoo, MI where she has worked since 1996. Before that, she was working at North Carolina State University and Slovak Technical University, Bratislava, Slovakia. She received her M.S. and Ph.D. degrees in Chemical Engineering of Wood, Pulp and Paper from Slovak Technical University. Her research interests are mainly in ink and paper interactions, printability analysis, ink chemistry and printed electronics. She received several prestigious grants and awards from UNESCO and NATO and has coauthored 5 patents, more than 50 papers in peer-reviewed journals, and 80 conference articles at various national and international conferences. Dr. Pekarovicova has been the WMU TAGA student advisor from beginning of the WMU TAGA chapter history.
Dr. Paul D. Fleming

Dr. Fleming, Professor, joined the Department of Paper Engineering, Chemical Engineering, and Imaging in 1996. Dan teaches courses in the Imaging, Paper and Chemical Engineering Programs.

Dr. Fleming brings to Western over 22 years of industrial experience and 15 years of academic experience. Prior to joining the faculty at WMU, Dr. Fleming was Group Leader in engineering design and analysis at the GenCorp Technology Center in Akron, Ohio. Previously, he held the position of Senior Research Specialist at Phillips Petroleum Research Center in Bartlesville, Oklahoma. He has held Post-doctoral Research Associate positions in Chemistry at Brown University and Columbia University. Dr. Fleming has over 200 publications and presentations to his credit and one U.S. patent.

Dr. Fleming has been involved with configuring and managing multi platform computer networks. He has managed groups of industrial researchers and advised undergraduate and graduate students in academia. He has been involved in multidisciplinary research and consulting in industry and academia. He is currently the director of the Digital Printing and Imaging Laboratory and the Center for Ink and Printability.

Western Michigan University, Department of Paper Engineering, Chemical Engineering and Imaging, in conjunction with Michigan State University’s School of Packaging, has received a National Science Foundation planning grant to determine corporate interest in establishing a center for research and development in barrier coatings.
Tim Pietrack

Tim is a junior studying Imaging (Graphics and Print Science) at Western Michigan University. Tim began his career in printing at Ann Arbor Huron High School his sophomore year. With two AB Dick Duplicators, A 1970 Heidelberg Kora, and a Heidelberg Speed master readily available, he had the opportunity to print various projects for his school.

After spending a brief time in Leadville, Colorado studying Outdoor Recreational Leadership at Colorado Mountain College he obtained his certification in Wilderness Medicine and Rescue and transferred to Western Michigan University to begin his studies in Imaging (Graphic and Printing Science). During the summer months Tim has been employed at Malloy Inc. a book publisher in Ann Arbor and at W B Doner, the world’s largest independent advertising agency. While at Malloy Inc. Tim worked as a press assistant for a large portion of the summer until he was asked to research a green energy project for Malloy. Tim spent his time at Doner working with the Retouching Studio coordinating projects for Doner Advertising’s headquarters along with creating protocols for Doner’s outside offices in Cleveland, OH and Newport Beach, CA. Along with working in the retouching studio, Tim also assisted with the Print Production department working with clients such as; Mazda, The UPS Store, Minute Maid, Polartec, Del Taco, Sherwin-Williams, and a number of other clients.

During his stint at Western Michigan University Tim has devoted his time working with the TAGA chapter starting in 2008 designing the “Identify” journal, and in 2009 was nominated to be the secretary of the chapter. This year Tim assumed the role of President for the WMU TAGA chapter and began working on this year’s journal titled “Evolution”. Tim also works at Western Michigan University’s Printing Pilot Plant, working with different companies research and development departments. Tim works on a three color Comco Commander Flexographic Press along with a four color Cerutti Rotogravure Press.

Tim will graduate in 2011 with his B.S. in Graphic and Printing Science and minor in General Business. Upon graduation Tim is planning on seeking a career in sales. During his spare time Tim enjoys skiing, rock climbing, and running. Tim would like to extend his deepest gratitude to all that have helped him during his college career.
Jeff Bergkamp

Jeff Bergkamp is a senior studying Imaging (Graphics and Print Science) at Western Michigan University. Throughout his four years at WMU, Jeff has been very active and has been taken part in many extracurricular activities. Jeff along with a fellow Imaging student was chosen to coordinate WMU’s 24th annual Gravure Day; the event was a staggering success. Just recently Jeff was chosen to represent his school along with five others at the Flexographic Technical Association’s Phoenix Challenge in Las Vegas, NV. The team will be solving various problems and will design and print four different items to enter in the competition. Jeff is Vice President in TAGA this year and is looking forward to the competition in San Diego. On top of his participation in these groups Jeff works as a laboratory assistant in the introductory course in print science. He also serves as an office assistant in the Paper Engineering, Chemical Engineering, and Imaging Department at Western.

In the summer of 2009 Jeff traveled to Germany to work as an intern for Schattdecor AG, a world leader in printed décor. He spent three months touring all aspects of their production and soon after arriving back in the States he was offered a full time position at Schattdecor’s soon to be opened production facility in St. Louis, Missouri after he graduates in the summer of 2010. Jeff is very excited for his future in the printing industry and appreciates all the help and support he gets from the faculty at WMU as well as his classmates and family.
Chelsea Wilson is a senior at Western Michigan University in the Imaging (Graphic and Print Science) program. Chelsea was accepted into the Lee Honors College her sophomore year and maintains a Dean’s List worthy GPA every year. During her four years at WMU she has been a part of the Graphic Arts Society, with the title of Production Manager her senior year. She has also been a member of TAGA, the Technical Association for the Graphic Arts and was secretary her senior year. Last year Chelsea was a student participant in the Phoenix Challenge during the 2009 Flexographic Technical Association Conference. She was part of WMU’s first team to participate in this esteemed competition.

Chelsea holds multiple scholarships from printing organizations including the FTA, FPA, Michigan Printing Week Association, Print and Graphic Scholarship, and also won the grand prize scholarship from the AICC and attended their conference in 2009 in Las Vegas, NV. Along with these honors she has many other scholarships from WMU and other private organizations. During the summer of 2009 she had her internship at CL&D Graphics of Oconomowoc, WI. After her graduation in April 2010, Chelsea plans on working in the packaging field preferably with a flexographic company.
Robert Grotans

Robert is currently a senior at Western Michigan University majoring in Imaging (Graphics and Print Science) and minoring in Communication. The printing and graphic communications field has forever appealed to him because he has always been interested in design and page layout. He originally was thinking about joining the graphic design program at WMU before deciding that the printing program was the right fit for him. Robert now works for the Department of Paper Engineering, Chemical Engineering, and Imaging at WMU as a lab and office assistant. Primary job functions include design work for newsletters and flyers, as well as operating the Canon imagePRESS C1+.

Robert has also been awarded many scholarships while pursuing his course of study at WMU from organizations including the Print and Graphics Scholarship Foundation, Michigan Printing Week Association, Ann Arbor Graphic Arts Memorial Foundation, and the printing department itself. He has also made the Dean’s list several times and currently maintains a GPA of 3.64.

Upon graduating Robert would like to work in the area of prepress or digital printing. At the moment he is looking for an internship in both of these fields. He is not afraid to get his hands dirty and is looking forward to exploring all aspects of the printing industry.
Sustainable Green Inks for Flexography: Development and Printability Study

By Vyankat D. Sindphale
Sustainable Green Inks for Flexography: Development and Printability Study

By Vyankat D. Sindphale

Department of Paper Engineering, Chemical Engineering, and Imaging, Western Michigan University,
Kalamazoo, MI 49008

Articles, conferences, buyers and consumers are all talking about being green and sustainable. Interest in sustainability within the print and packaging industries has peaked, due to increased demands from customers, environmental groups, investment firms, government agencies and consumers. Is environmentally friendly printing just hype? Perhaps, but it is today’s necessity. Wal-Mart is leading this green movement while supporting industries such as packaging, printing and its suppliers follow suit.

Due to its low overall content in packaging, ink is not included in Wal-Mart’s sustainability scorecard. However, printers continue to ask their ink suppliers about sustainable/green inks. Water-based inks represent an exciting trend in the flexo packaging industry because of their environmentally benign nature and there has been significant growth in their usage as a result. Still, water-based inks contain petrochemical-based raw materials that are poorly biodegradable and will become more expensive and less available in the future.

The focus of this research was to investigate, whether water-based inks made from renewable and/or biodegradable materials such as a resin could be comparable to, and thus substitute for, conventional flexographic inks printed on paper packaging substrates such as coated news back (CNB) board and solid bleached sulfate (SBS) board. A trial was performed on the Comco Commander flexographic press at the Western Michigan University Printing Pilot Plant. Print performance was analyzed and interpreted. Comparisons were made among:

1. A regular water-based ink made from acrylic resin.
2. A Half Luron® ink made from a blend of bio-based Luron binder and acrylic resin.
3. A Full Luron ink made from a bio-based luron binder only.

The Luron binder is made from a renewable source; albuminous protein, which the supplier claims is readily biodegradable. A printability study in terms of optical density, specular gloss, and CIE L*a*b* color coordinate measurements was performed. Mottle was studied by Verity IA software, and dot detail was measured by image analysis using ImageXpert. Finally a standard Sutherland rub resistance was also investigated for these inks.

It was observed that the blend of acrylic and bio-based resin (Luron) has comparable printability with acrylic resins in terms of optical density, gloss and rub resistance.

Introduction

Green printing refers to the environmental aspects of the printed products, more specifically, environment-friendly printing. “The demand by print customers for printed products that have a minimal environmental impact is growing at an extremely rapid pace,” said Michael Makin, president and CEO of PIA/GATF1. A company’s environmental friendliness is very important these days because of the growing number of inquiries from
customers. “Ninety percent of printers believe their customers will require green printing in the future,” claimed a recent survey conducted by PIA/GATF.

The Sustainable Green Printing (SGP) Partnership was founded in June 2007. The SGP Partnership was established by three founding organizations—PIA/GATF, SGIA, and FTA. The mission of the Sustainable Green Printing Partnership is “to encourage and promote participation in the worldwide movement to reduce environmental impact and increase social responsibility of the print and graphic communications industry through sustainable green printing practices.” The SGP would like to see maximum use of environmentally friendly materials from the print and graphic communications industry.

For this reason, it is important to try to replace ink resins made of fossil raw materials with environmentally friendly ones produced from renewable resources. One of the promising new raw materials is corn. Annual production of corn is 560 million metric tons, with half of that amount produced in the U.S. alone. The main polymer present in corn is starch. Starch decomposition and derivatization leads to many useful materials used in fluid ink formulations. Dry grinding of corn leads to ethanol production, which may be used as an ink solvent or co-solvent. Corn starch can be hydrolyzed to dextrose. Fermentation of dextrose to lactic acid opens possibilities of making chemicals based on lactic acid. PLA (polylactic acid) is a thermoplastic biodegradable polymer which has been successfully used to make biodegradable films for packaging, plastic trays, and bottles. Currently, PLA costs more than petroleum derived commodity plastics, but because of its mass production and the possibility to be derived from agricultural residues, it is possible that its price will drop. It is expected that its demand will grow annually by 25 percent.

The drawback of PLA is that it is marginally soluble in solvents used in the ink industry. It needs to be further developed in order to find application for printing inks. Another application for starch in inks is that it can be plasticized with glycerol and copolymerized with e-caprolactone to form biodegradable water-based polyurethanes. A sodium alginate mixture with coconut oil along with naturally occurring plant colorants (henna, safflower, turmeric, and goldenrod) as pigments have been used to make a screen-printing ink.

Polyhydroxyalkanoates (PHAs), along with PLA, polyglycolic acid (PGA), and apolylactic-co-glycolic acid have been recently used for formulating water-based flexo inks in their natural form or formulated with a triblock compound, to improve the stability of flexo inks. Sakata Ink in Japan claimed successful production of water-based flexo inks based on similar chemistry. Ink was made of polylactic acid (PLA) and other biodegradable polymers, such as polylactic co-glycolic acid, polyglycolic acid, polyvinyl alcohol, and polybutylene succinate which can be used individually or in combinations. Self-dispersible biodegradable polyesters creating emulsion polymer particles were patented. They may be useful in biodegradable inks formulations with water and ethanol as solvents.

Currently, there are few biodegradable polymers available that can be used in the ink industry, mostly due to cost. Biodegradable polymers must be either enzymatically degraded, or serve as a carbon source for microorganisms. Polyhydroxylactanoate and its copolymers may be used as resins for water-based flexo inks. Poly (3-hydroxybutyrate) (PHB) and copolymer poly (3-hydroxybutyrate-co-3-hydroxyvalerate) (PHBV) are other suitable polymers, which can be obtained by bacterial fermentation under modified fermentation conditions. Metabolix fermented glucose to polyhydroxybutyrate valerate (commercial name Biopol) in a commercial fermentation plant.

The biodegradable packaging market is growing rapidly in advanced countries, especially in the U.S. It
will experience an annual growth rate of 22 percent according to one study. Biodegradable packaging is aiming to use films made of biodegradable polymers, but it only makes sense to print on them with biodegradable inks. This packaging is printed most often in the U.S. using flexo because of its simple working principle (Figure 1). Flexography is more efficient, more cost effective and more versatile than other printing processes. The prospect of biodegradable packaging using water-based inks offers flexographic printers an opportunity to develop a new package printing market and can provide environmentally friendly products for consumers. But still water-based inks, which most people consider to be more environmentally benign, contain raw materials that are petrochemical-based.

![Figure 1: Principle of the flexographic printing process. (Source FTA).](image)

### Experimental Materials

SBS and CNB substrates were used as substrates for printing. Water-based ink includes materials listed in Table 1 with their purpose.

**Table 1:** Water-based ink ingredients and their purpose in formulation.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigment Dispersion</td>
<td>Colorant</td>
</tr>
<tr>
<td>JONCRYL 77</td>
<td>Hard film forming emulsion for water and rub resistance</td>
</tr>
<tr>
<td>Luron Binder</td>
<td>Readily bio-degradable resin</td>
</tr>
<tr>
<td>JONCRYL 2153</td>
<td>Hard jetdown emulsion for drying speed and ink stability</td>
</tr>
<tr>
<td>JONCRYL 60</td>
<td>Transfer, gloss and resolubility</td>
</tr>
<tr>
<td>JONCRYL WAX 26</td>
<td>Rub and scratch resistance</td>
</tr>
<tr>
<td>Surfactant (DF-75)</td>
<td>Improve wetting and ink leveling</td>
</tr>
<tr>
<td>Antifoam</td>
<td>Foam control</td>
</tr>
<tr>
<td>Water</td>
<td>Diluent</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>

3500 BC – Egyptians use Papyrus Fibers as a Means for Writing

Paper evolved from the ancient Egyptian writing material known as papyrus. Papyrus was developed as a writing material by cutting the inner pith of the papyrus plant into long strips, which were then woven together. After soaking in water long enough for the decomposition process to begin the strips were beaten with a hammer mashing the mesh into a single sheet. This sheet is then dried under pressure. These sheets were then united in order to form papyrus scrolls.
Figure 2: K-Printing Proofer with Flexo head at PCI lab of Western Michigan University.

Ink formulation

Ink was blended in 500mL batches in a laboratory electric ink mixer (high speed disperser) with the spindle speed of 1500rpm for approximately 10 minutes. The starting formulation was taken from the BASF formulating guide\textsuperscript{15} for water-based packaging inks (Table 2). Luron binder (15.42 percent solids) replaced JONCRYL\textsuperscript{®} 77 (45.9 percent solids) resin according to the ratios given in Table 2. The Luron binder is the aqueous colloidal solution of an albuminous condensation product from BASF Corporation. According to BASF this resin is readily biodegradable\textsuperscript{16}. Luron binder was of much lower solids content than acrylic Joncryl resin; therefore it was not possible to adjust all of the inks to the same value, if higher solids were needed (see Table 3).

Table 2: Packaging flexo (Magenta) ink starting formulation (The Chemidex, Cybrary\textsuperscript{14}).

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Reg. Water-based Flexo Formulation (%)</th>
<th>Half Luron Formulation (%)</th>
<th>Full Luron Formulation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigment Dispersion</td>
<td>50.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>JONCRYL 77</td>
<td>23.0</td>
<td>11.5</td>
<td>-</td>
</tr>
<tr>
<td>Luron Binder</td>
<td>-</td>
<td>11.5</td>
<td>23.0</td>
</tr>
<tr>
<td>JONCRYL 2153</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>JONCRYL 60</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>JONCRYL WAX 26</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Surfactant (DF-75)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Antifoam</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Water</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

3500 BC – Egyptians use Papyrus Fibers as a Means for Writing

256 BC – Earliest Evidence of Ink Found

105 AD - Ts’ai Lun Invents Paper
Table 3: Solid contents of Regular, Half Luron and Full Luron inks.

<table>
<thead>
<tr>
<th>Ink Formulations</th>
<th>Solid Contents (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular water-based Flexo Ink</td>
<td>42.66</td>
</tr>
<tr>
<td>Half Luron water-based Ink</td>
<td>34.42</td>
</tr>
<tr>
<td>Full Luron water-based Ink</td>
<td>29.59</td>
</tr>
</tbody>
</table>

**Flexo proofing/printing**

Ink formulations were screened on a laboratory K-proofer (Figure 2) in flexo mode, and several of the best formulations were selected to be printed on a narrow web flexo press. A Comco Commander narrow web flexo press (Figure 3), equipped with chambered doctor blade inking system, 150 LPI photopolymer plate and medium (3M’s SA 2300 MS) tape were employed. A banded ceramic anilox roll with three different screen rulings, 600lpi, 700lpi and 800lpi with 2.80, 2.5, and 2.01bcm respectively was used. A 150lpi photopolymer plate with tone steps, solids text and reverse text was used. Press speed was 100fpm.

![Figure 3: Comco Commander Flexo press at Western Michigan University’s Printing Pilot Plant.](image)

**256 BC – Earliest Evidence of Ink Found**

Evidence for the earliest Chinese inks, similar to modern inksticks, is around 256 BC in the end of the Warring States Period and produced using manual labor from soot and animal glue.
Analytical

Ink viscosity was measured as efflux time on a No. 2 Zahn cup. The printability study in terms of optical density and CIE L*a*b* color coordinate measurements was executed, using an X-Rite 530 Spectrodensitometer. Specular gloss was measured using Nova Gloss Meter with 60° geometry on solid colors, and calculated as an average of five measurements. Print mottle was studied by Verity IA software, and dot detail was measured by image analysis using ImageXpert (KDY Inc.). An end use ink property, rub resistance was also investigated. The testing was done only for solids printed with 600lpi anilox on both CNB and SBS board substrates. 100 strokes on a Sutherland rub tester were made on each sample using a 4lb weight. The optical density was measured before and after rubbing. Rub resistance was calculated as:

\[ \text{Rub resistance} = \left( \frac{\text{Optical density after rub}}{\text{Optical density before rub}} \right) \times 100 \]

Results and Discussion

Initially, research began with the formulation of water-based inks from several bio-based materials such as vegetable protein products (VPP), zein protein, and potato starch. None of these materials gave feasible ink properties such as film formation, resolubility, and adhesion to the substrate, which are easily achievable by acrylic resins found in conventional water-based ink chemistry and are essential for flexo printing performance. In the second phase, we focused on readily dissolved resin (Luron binder, BASF). Inks were formulated with Luron as a sole ink polymer and also in combination with acrylic resins such as Joncryl 77, Joncryl 2153 and Joncryl 60. Inks were first proofed on a laboratory K-proofer (Figure 2) in flexo mode, where ink is transferred from the printing plate to a plain stereo roller and then onto the substrate. Eight initial bio-based formulations were tested, and narrowed down to the three best ones, to be tested on Comco Commander narrow web flexo press (Figure 3) at Western Michigan University’s printing pilot plant.
105 AD - Ts’ai Lun Invents Paper

During the second century in China, Ts’ai Lun is credited with creating one of the Four Great Inventions of Ancient China – paper. This invention spread to the Islamic world and eventually made its way to Europe by the 12th century. The invention of paper plays a significant role in the history of printing for obvious reasons, it was in abundant supply and it gave way for a physical medium to transfer information – suddenly everything from letters to proclamations to newspapers to books were being produced, ushering in a new era of information for the masses.

Figure 4 (a): Optical density of Regular, Half Luron® and Full Luron® magenta ink with different anilox line counts on CNB board substrate.

Figure 4 (b): Optical density of Regular, Half Luron® and Full Luron® magenta ink with different anilox line counts on SBS board substrate.

Figure 5 (a): Delta gloss (@60°) of Regular, Half Luron® and Full Luron® magenta ink with different anilox line counts on CNB board substrate.
Figure 5 (b): Delta gloss (@60°) of Regular, Half Luron® and Full Luron® magenta ink with different anilox line counts on SBS board substrate.

Figure 6 (a): CIE L*a*b* color difference comparison of Half Luron® and Full Luron® magenta ink with regular acrylic water-based magenta ink for different anilox line counts on CNB board substrate.
The earliest printed fragments found in the world originated in China from the Han Dynasty around the year 220 AD. Flowers in three colors were found, and were printing using the most primitive method of printing, the “woodblock.” This form of printing involves a carved piece of wood where the relief areas make up the image areas. The wood is inked up and pressed onto fabric, much like a stamp. This method was developed again in the Arabic world in the 9th and 10th century where it was known as “tarsh,” and eventually this method migrated to Europe early in the 14th century.

**Figure 6 (b):** CIE L*a*b* color difference comparison of Half Luron® and Full Luron® magenta ink with regular magenta ink for different anilox line counts on SBS board substrate.

**Figure 7 (a):** Rub resistance of Regular, Half Luron® and Full Luron® magenta ink with 600 LPI anilox on CNB board substrate.
Selected inks were not adjusted to the same viscosity when printing on the Comco Commander flexo press, and therefore it was not easy to compare them. For fair comparison, further investigation would be necessary to optimize performance of each individual ink. The print results for the three different water-based flexo inks on CNB board and SBS board substrates are shown in Figures 4(a) through 6(b). *FIRST 4.0 (Flexographic Image Reproduction Standard Tolerance)* specified solid densities are shown in Table 3. Obviously, lower anilox line count (600 lpi) deposits more ink than 800 lpi one because of larger, deeper cells. Regular water-based inks made from acrylic resin shows higher optical density, as per Figure 4 (a) and (b), on both CNB and SBS substrates than bio-based water-based inks made from Luron, most likely because of the higher percent solids in acrylic ink (Table 2). But ink made from a blend of acrylic and Luron (Half Luron ink) shows comparable print results with regular water-based inks (made from fully acrylic resin).

The unique thing about this bio-based resin is its ability to exhibit excellent delta gloss (substrate gloss minus print gloss). Both bio-based formulations (Half Luron and Full Luron) show favorable gloss, as illustrated in Figure 5(a) and (b), verses the regular water-based ink formulation on both substrates with all anilox line counts (600, 700 and 800 lpi). Bio-based resin couldn’t offer as high a color density and color strength as regular acrylic resin. However, the inks were not optimized for their best press performance, rheology or solids content, so it is rather difficult to compare them with regular acrylic formulation. Nonetheless, there was a slightly higher color difference between acrylic and Luron-based ink, but the blend showed comparable results, as depicted in Figure 6 (a) and (b).
Evidence of early silk screen printing methods have been found in China that date back to 960 BC during the Song Dynasty. These primitive techniques soon made their way to Japan and other Asian countries where the craft was advanced by using it in conjunction with woodblock printing and paints.
Pilot Plant for providing materials and technical support for this project. The author would like to express gratitude to Dr. Margaret Joyce, and Dr. Erika Hrehorova from the Department of Paper Engineering, Chemical Engineering, and Imaging at Western Michigan University and Joe Kubasiak from Wikoff Color Corp. for their helpful advice and assistance with the work. Finally, author would also like to acknowledge colleagues at Color Resolution International, John D’Amore and James Ford, for offering helpful suggestions in proofreading drafts of this paper.

References
15. BASF, Luron Binder, MSDS, EVP 000303 e, June 2004.
For the next several centuries, very little advancement had been made in the way of print-making. But in the year 1040, Bi Sheng, a Chinese man, was credited in creating “moveable type.” This method is a natural evolution of the woodblock method, whereas in this form each character was a single piece of type and they were added together to form words and sentences. Though Bi Sheng’s method was abandoned for a few reasons, one was due to technical restraints, and also because of the enormous Chinese character set this method never really took off in this region.
Digital Proofing of Spot Color for Speciality Jobs

By Sangameshwar L. Sangmule

1040 - Bi Sheng Developed Moveable Type

1100’s - Paper Makes Its Way to Europe

1200 - Wang Zhen reinvented moveable wooden type.
Digital Proofing Of Spot Color For Speciality Jobs

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Keywords: Digital proofing, Rotogravure, spot color matching, SmartColour™ iVue

Abstract
Spot colors have wide range of application in packaging, as well commercially printing. These are often used in gravure printing in order to achieve more aesthetic and colorful look for the design. Reproduction of spot colors on press and maintaining color consistency and accuracy of is very important. This research was aimed to focus on matching of spot colors for specialty jobs, such as decorative paper laminates printed by rotogravure. For proofing of spot colors, SmartColour™ iVue software was used. The spot color library is accessed via the iVue software and gives the way of choosing and implementing various ink systems on different substrates printed at various press conditions. Two different ink jet printers were compared and evaluated for their ability to reproduce the spot colors. The extra inks that are being incorporated in one of the digital printer used have enabled for better color control and larger coverage of color space. The results showed that SmartColour™ iVue was able to match gravure printed job very closely with the digitally proofed job on diverse substrates.

Introduction
Spot colors or the specialty colors are most commonly used in different printing processes such as gravure, flexo, offset lithography, etc. in order to obtain larger color coverage of color space, when the standard process ink set cannot satisfy customers needs (Hrehorova, 2005; Wilson, 2005). Spot colors are also used in many specialty job applications, such as decorative laminates and wall papers. All the specialty jobs, such as wall paper, decorative furniture laminates and laminated flooring printed with gravure, not only need to provide the accurate spot color to the customer with designs that should match the spot colors, but also the there is shortening of lead times by the client or customer (Geerinckx, 2003). The cost of conventional proofing for gravure printing can be reduced to half by incorporating a digital printer for proofing. Furthermore, with elimination of gravure proofing presses goes also dramatic reduction of ink and paper consumption. According to Chiyoda, Belgian decorative laminates manufacturer, the consumption of paper can be reduced approximately ten times compared to traditional technology (Geerinckx, 2003). Due to some of the unique properties, ink jet proofing and printing provides significant time and cost savings compared to conventional procedures (preparing image carriers and printing proof samples) for potential product verification, matching, and short run production (Suchy, 2005; Wu, 2006; Wu, 2008).

With the combination of the right software, inks and media, an inkjet printer can be treated as a digital proofer for spot color printing, providing significant time and cost savings compared to conventional procedures for job approval of printing technologies, with or without master image carriers. In addition, short run jobs can be

1100’s - Paper Makes Its Way to Europe
Paper was introduced in Spain by the Moors, a nomadic people originally from modern-day Mauritania who spread cultural influences in Europe.
printed digitally instead of using an analog press. The advantage is that a costly process of image carrier preparation could be eliminated for certain extremely short run jobs.

The success and possibility of implementing digital printers for proofing colors is closely related to the developments in color management workflows (Sharma, 2004). For gravure spot color proofing, reproducing the spot colors with a different printing process, different inks, substrates, and possibly with devices at different locations is quite a complex problem. The success and accuracy of digital printing depends on how accurately the digital color numbers are altered and manipulated in comparison with the specific printing process. By using a properly color managed workflow, where correlations between different printing devices are established via device profiles, and characteristics of materials used are taken into account, the flexibility of digital data processing allows digital proofs to simulate printing presses with an ink jet printer (Stewart, 2007; Suchy et al, 2005; Lo, 2006).

Due to the need of extended color gamuts, the main ink jet printer/proofer manufacturers introduced new inking system for the proofing devices that employ extra ink cartridges with specialty inks added to the regular CMYK set of colors. These can include Red, Green, Blue and Orange inks in addition to the standard set of colors and their lighter options. This addition of three more inks to regular process color set is to improve the ability of proofing device to cover a larger color space in order to correctly simulate the spot color from the presses.

This project is aimed to match spot colors for gravure printing of decorative paper laminates, or match existing gravure print digitally, in order to create new samples for customers, or create the same design on different substrate, with the least possible color shift. For proofing of spot colors, SmartColour™ iVue software was used (SmartColour, 2009). SmartColour iVue is an innovative color management system, which allows viewing predicted spot color at every stage of the process of design workflow.

**Color Management requirements for proofing**

The following are the requirement of color management for digital proofing:

- Consistency of reproduced color: All the proofs reproduced from the same image, or data, must look the same in image quality as well as in color reproduction.
- Color gamut: At least the color gamut of all the printing presses (litho, gravure, and flexo) must be covered by the digital proofing machine.
- Color fastness: The output generated by the proofing machine must not change or fade its color for at least 3 months.
Experimental

Press Run

Four spot colors, yellow, brown, orange, and charcoal were gravure printed for a specialty job of wood grain design (Figure 1). Solvent based proprietary inks were employed. They had surface tension in the range of 22-23 mN/m, about 20mN/m lower than the surface energy of the substrate, thus good wetting properties were ensured. Particle size of inks was measured using Submicron Particle Sizer 370 NICOMP based on dynamic light scattering. Inks particle size was as follows: 98±19.5 nm for yellow, 116±23.6 nm for orange, 131±22nm for brown and 305±58nm for charcoal ink. Running viscosity on the press was measured as efflux time on Shell #2 cup which was 18-22sec.

The final print job, including tone step gradations for all four spot colors, and wood grain pattern (Figure 1), was done on a Cerutti (Cerutti Model 118, Italy) four color web fed gravure press using Light Basis Weight (LBW) paper. Cylinders were electromecanically engraved with 120-150 lpi resolution, creating cells with 40-60 deg compression angles. Press speed was 700 ft/min, electrostatic assist was on at all four stations. The order of colors was yellow-orange-brown-charcoal at all times.

Analytical

An EMVECO stylus profilometer was used to determine roughness of the paper substrates. An Autopore IV 9500 mercury porosimeter, measuring the incremental increase of volume of mercury penetrated into the substrate porous network with increasing mercury pressure, was employed for the porosity-related characteristics, such as pore size, and total pore volume of substrate. A first Ten Angstrom FTA200 contact angle instrument was used to measure contact angle of substrate with water and hexadecane. Results from FTA200 were averaged from ten values of surface tension or contact angle for individual drops. The interactions between liquid and paper surfaces were demonstrated in terms of the dispersive and polar energy contributions according to the Owens and Wendt equation (Owens and Wendt, 1969; Barber et al, 2004; Pietak et al, 2007). Total surface energy of low basis weight paper used for gravure press run was 42.2 mJ/m. Some of physical and optical properties of both print substrates for press run and digital proofing are given in the Table 1.
Table 1: Paper properties of selected substrates.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Low Basis Weight Paper (LBW)</th>
<th>Semi-matte Inkjet Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emveco Roughness [μm]</td>
<td>1.88</td>
<td>1.06</td>
</tr>
<tr>
<td>Average pore diameter [nm]</td>
<td>396.9</td>
<td>47.4</td>
</tr>
<tr>
<td>Porosity [%]</td>
<td>36.7</td>
<td>28.9</td>
</tr>
<tr>
<td>Opacity [%]</td>
<td>55.6</td>
<td>96.7</td>
</tr>
<tr>
<td>Specular gloss at 75deg [%]</td>
<td>22.5</td>
<td>47.5</td>
</tr>
</tbody>
</table>

Results and Discussion

Digital proofing strategy
Two different Epson ink jet proofers were evaluated in terms of gamut size and the ability to reproduce different spot colors. The printers differ in number of colors employed i.e. the ink system, Epson Stylus Pro 9800 uses UltraChrome ink technology which has C,c,M,m,Y,YK,LK, and Llk (Cyan, light Cyan, Magenta, light Magenta, Yellow, Black, light Black, and Light light black) inks, whereas the Epson Stylus Pro 7900 uses the same set plus of inks with addition of G and O (Green and Orange). The gamut projections in 3D and 2D were obtained in CHROMiX ColorThink Pro 3 from the calculated ICC profiles. The profiles were created for both printers on semi-matte ink jet substrate, characterized in Table 1. Figure 2 shows the comparison of the two printers as a 3D and 2D projection of color space. Gamut volumes were calculated in the same application, the values are shown in Table 2.

Figure 2: 3D and 2D projection of color space of two different Epson printers.

Adobe® Photoshop has an option for a SmartColour iVue plug-in. The software is equipped with the SmartColour Color Picker (Figure 3), which enables using specific ink on a discrete substrate and predicts color appearance of an actual print. The color picker allows individual selection of colors for any spot element either from brand-specific libraries or general libraries. All libraries contain colors from common substrates and print parameters, allowing selection among those colors that can be achieved on press.

1398 - Gutenberg Was Born

Gutenberg was born in the German city of Mainz, the youngest son of an upper-class merchant. Much of Gutenberg’s early life is unknown, but it is estimated that he was most likely born around 1398.
Fifty different spot colors shown in Figure 4 were chosen from a specific gravure library to create a target for testing the digital proofer ability to match the colors on an ink jet printed proof. These colors were selected to cover the largest portion of color space and differ in lightness and hue. Some of the colors are intentionally out of the printer’s color gamuts to evaluate the matching process. The color accuracy of both printers was evaluated in terms of color differences between the stored CIELAB data of the target and measured CIELAB data on the digital proofs.

A spectrophotometer (i1-iO from X-Rite with 45°/0° degree geometry) was used with no filter applied; the CIELAB data were calculated for D50/2° illuminant/observer combination. Color differences were expressed in $\Delta E_{ab}$ and $\Delta E_{cmc(2:1)}$, which were specified by customer request.

<table>
<thead>
<tr>
<th>Gamut Volume and color accuracy of digital printers Epson Stylus.</th>
<th>Gamut Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta E_{ab}$</td>
<td>$\Delta E_{ab}$</td>
</tr>
<tr>
<td>Mean</td>
<td>Max</td>
</tr>
<tr>
<td>Pro 9800</td>
<td>3.83</td>
</tr>
<tr>
<td>Pro 7900</td>
<td>2.91</td>
</tr>
</tbody>
</table>
SmartColour iVue Proofing

SmartColour iVue software was used to match four spot colors necessary to print wood grain pattern on a newly selected simulated SBS substrate (Figure 5), semi-matte inkjet and LBW paper. The wood grain design included solid and tone patches in order to provide color control tools. The CIELAB measurements were taken for the solid four spot colors on LBW paper and the closest matches were found in the SmartColour Gravure SBS library (Figure 6). Color differences between the expected press on SBS board (data not shown) and current press print and digital proof on semi-matte prints fell in the ΔE 2-4 unit range as predicted.

Spot 1 - Yellow (L* = 80.05, a* = 9.93, b* = 31.31)
Spot 2 - Orange (L* = 70.69, a* = 22.05, b* = 45.24)
Spot 3 - Brown (L* = 59.84, a* = 23.48, b* = 33.23)
Spot 4 - Charcoal (L* = 23.80, a* = 0.94, b* = 1.41)

![SmartColour Gravure Library for SBS board](image)

Figure 5: SmartColour Gravure Library for SBS board

1400’s - Gutenberg Developed Lead Alloy Based Moveable Type

Johannes Gutenberg was a goldsmith living in Mainz Germany during the 15th century. It was here that he used his knowledge of metals from his time as a craftsman to create more sophisticated versions of type, making them out of a lead alloy. Moveable type is quicker than the use of woodblocks for printing, and due to their metal construction they are much more durable. The uniformity between the size and style of the letters, gave birth to the art of typography and fonts.
Figure 6: SmartColour Re-colored Spot Channels and Document Settings

The design was rendered using the SmartColour iVue color management engine and displayed in the SmartColour Preview window on a calibrated monitor with an ICC profile assigned to it. Accurate previewing is a key feature of iVue and helps to prevent mismatches on press due to inaccurate spot color predictions throughout the workflow. In order to send the data to a digital printer, or correctly preview the design on a monitor, the SmartColour iVue engine renders the image on pixel-by-pixel basis and calculates the color CIELAB values for single color or overprints of the spot colors. The simulation of final job previewed on a calibrated monitor is shown in the Figure 7. It shows the difference between the Adobe Photoshop Preview window on the left and SmartColour Preview window on the right displayed on a calibrated Apple Cinema Display. The SmartColour rendered image applies the substrate characteristics and shows more true looking and accurate results. The left an right previews in Figure 7 will only display correctly on a calibrated monitor.
Gutenberg’s main contribution to printing was the development of a punch and mold system which opened the way for the creation of moveable type that could be used to produce a page of text. The letters were put together in a tray where they were locked in and pressed onto a page as a print. This way of setting type allowed for mass production of pages in much less time than it would have taken otherwise, thus creating a breakthrough in the business of book publishing.

Table 2: ΔE values of solid spot color between press sheet and digitally printed on Epson Stylus Pro 9800 on semi-matte inkjet paper without simulation of paper white.

<table>
<thead>
<tr>
<th>Color</th>
<th>ΔE&lt;sub&gt;ab&lt;/sub&gt;</th>
<th>ΔE&lt;sub&gt;cmc(2:1)&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>5.83</td>
<td>3.05</td>
</tr>
<tr>
<td>Orange</td>
<td>2.69</td>
<td>1.47</td>
</tr>
<tr>
<td>Brown</td>
<td>3.38</td>
<td>2.51</td>
</tr>
<tr>
<td>Charcoal</td>
<td>3.72</td>
<td>3.76</td>
</tr>
</tbody>
</table>
Table 3: ΔE values of solid spot color between press sheet and digitally printed on Epson Stylus Pro 9800 on semi-matte inkjet paper with simulated paper white.

<table>
<thead>
<tr>
<th>Color</th>
<th>$\Delta E_{ab}$</th>
<th>$\Delta E_{cmc(2:1)}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>3.71</td>
<td>3.24</td>
</tr>
<tr>
<td>Orange</td>
<td>4.13</td>
<td>2.38</td>
</tr>
<tr>
<td>Brown</td>
<td>6.81</td>
<td>5.07</td>
</tr>
<tr>
<td>Charcoal</td>
<td>2.74</td>
<td>3.41</td>
</tr>
</tbody>
</table>

The next step was to digitally proof on the actual press substrate, LBW paper, which was done only on the Epson Stylus Pro 9800. It was decided that it is not necessary to deal with tone value increase on the yellow printer, because of yellow design, which will print close to 100% coverage on all wood grain area anyway. Multiple tests were conducted to come up with the best match for wood grain pattern. It should be noted that the digital printers are not designed to use press production substrates, as these are not coated with ink jet ink receptive coatings (Wu, 2008). The best visual match of wood grain pattern was found when proofing with no tone value increase for yellow, orange, brown, and 25% TVI for charcoal. The color difference between original press proof and digital proof on LBW was $\Delta E_{cmc(2:1)} = 1.78$ for solid yellow, maximum $\Delta E_{cmc(2:1)}$ was 10.60 for orange; and maximum $\Delta E_{cmc(2:1)}$ 10.95 for brown. The worst match was found for charcoal printer, with $\Delta E_{cmc(2:1)}$ 16.21. Software iVue treats the printer as an RGB device, and there is no control over dealing with the black printer, creating four color black with maximum $a^*$ of -8.22. Figure 8 shows running $\Delta E_{cmc(2:1)}$ values of between the digital proof and the press print on the low basis weight paper printed on Epson Stylus Pro 9800.

The aim of this work was to confirm that depending on a specific substrate and a printing process and a software application that enables selection of proper spot colors from a library of inks, previously matched on
The digital proofs made for the SBS board were then printed in actual size on the digital printer using a semi-matte inkjet substrate and compared to the press print made on the LBW paper. The capability to predict the real colors that will be achieved on the real press is available from iVue, which is able to deliver the real press color data that were precisely measured, stored and maintained within the Global Shade Libraries. It could be seen from this experiment, that the accuracy of proof-press color matching is affected by the printer, software, and substrate involved in the digital proofing processes. There is also a significant dependence of color reproduction on the choice of substrate. This is manifested, when attempting to proof spot colors on the same substrate as employed on the gravure production press. The gravure production substrate has a more open structure (with average pore size of 396.9 nm) than digital semi-matte paper (average pore size of 47.4 nm). It is likely that LBW is trapping the small ink pigment particles along with vehicle, which resulted in the smaller color gamut (111,997cCu on LBW paper compare to 741,513 on semi-matte one), and larger ΔE values of solids compared to digital proofs made on semi-matte paper. The particle size of ink sets for both Epson Stylus Pro 7900 and 9800 were not measured at this point. Based on our past work on an Epsom 2200, these digital inks should have particle size around 100 nm (Chovancova 2004, 2005), which is much smaller than the average pore size of the production LBW substrate, thus sinking of pigment into LBW porous network is inevitable.

Previously, several projects matching spot colors were done, but none of these works involved spot color overprints (Wu et al, 2006; Wu et al, 2008). The software SmartColour™ iVue is tailored for packaging printing. Therefore, in the library of inks and substrates are found substrates and inks for that purpose. If print on decorative substrates with specified physical and optical properties, it is feasible to predict the results that will be achieved on a designated printing press. The software is also able to predict ΔE color tolerances to be expected on the press. The print was achieved from a controlled gravure press run on a substrate that was designed for one type of application. This proof was then set to be a standard for matching the colors and design when printed on a different type of a substrate. The same layout file was then brought to the SmartColour iVue application environment and the solid spot colors were matched to the ones measured for the press print. The specific library within the Global shade library was specified and the closest matches to all spot colors were found for a new substrate. The design was then rendered to the SmartColour iVue Preview window with specific settings set for the substrate, ink system and printing process. The colors and the design of the print job were then checked on the screen, as SmartColour iVue offers the preview with all the possible press settings and overprint model available to the user. When the monitor display system is correctly calibrated and profiled, the iVue preview window shows the soft proof of the design when digitally proofed and printed on a press.

Two different ink jet printers were considered to be the devices for creation of digital hard proofs. The two proofers differed in the amount of the inks/colors used in them. One using the single CMYK set, the other one in addition to CMYK set included Orange and Green inks. The digital proofers were submitted to the test of correctly proofing 50 different spot colors that were designed to cover the majority of the color hues. The colors were intentionally picked to be in and out of the proofers’ achievable color gamut in order to see the rendering capabilities of both printers. Expectedly, the proofer with the extra ink set produced better results in achieving the correct colors on digital media.

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laminates substrate, such as LBW paper, is to be color matched, it was necessary to test several different ink sets in iVue library to achieve the best match. Another issue in proofing of spot color inks is their overprint. The final appearance will definitely depend on particle size of pigments and other ink components, and other issues. Also, the order of spot colors printing, can tremendously affect the final result.

**Conclusion**

With the help of Smart color iVue, it was possible to match a gravure printed job on one substrate digitally to a different substrate, which can be helpful in creation of new applications for the same design. Also, it was possible to digitally print on production substrate with decent visual match. However, it was confirmed that the Epson Stylus Pro 9800 was deficient in printing black or charcoal, especially in areas of 70-100% tone. Of course, ΔE values for the production substrate printed on the digital press were much higher than those for manufacturer recommended digital paper, mainly due to its large porosity. For the best visual proof, it is necessary to match solids of first printer and achieve the best possible mid-tones for the charcoal.

**Literature Cited**


1400’s - The Hierarchy of Print Shops

After an apprentice completed his training, he becomes a journeyman; printer, at this point as journeymen they are free to seek other places of employment. The role of a journeyman in a printing house is to facilitate the spread of the print to all areas of the substrate. Another worker in the printing house is the compositor. A compositor is responsible for setting the type for the print. And finally there is the actual pressman. This person is the one who is really operating the press. This was also the most physically labor intensive position in the facility.
Exploring Overprint Varnish for Direct Food Contact

By Christy Root
Exploring Overprint Varnish For Direct Food Contact

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Abstract

The printing industry is exploring environmentally friendly alternatives that allow food to directly contact print and satisfy Food and Drug Administration (FDA) regulations for the food packaging industry. The goal of this research is to evaluate the use of shellac as an overprint varnish to act as a barrier in direct food contact packaging. Several overprint varnishes will be formulated, tested, and analyzed for barrier, mechanical, and optical properties. The overprint varnishes will be tested on paper and film substrates previously printed with edible and traditional ink.

Introduction

The food packaging industry is looking for environmentally conscious and cost effective innovations to meet the growing “green” requirements, desired by both consumers and manufacturers. By using an overprint varnish instead of trapping or laminating ink between layers of substrates, less materials will be utilized and the biodegradability of the product would increase. An improvement in the company’s environmental impact would only be beneficial if the new technology was cost effective. Reviewing available literature, shellac resin would be an adequate option as the basis for a biodegradable overprint varnish for direct food contact. This shellac overprint varnish would have to create a strong barrier between print and food while withstanding various conditions that typical food packaging endure such as temperature extremes and wear and whether it will affect the odor or taste of the food it protects. However, if the overprint varnish decreases the optical quality of the printed product, the varnish would be deemed unsuitable. In passing physical and optical standards, the next step would be to evaluate the overprint varnish as a barrier for oxygen and moisture, as it relates to preserving the food that it packages.

Literature Review And Analysis

Environmental concerns have brought about a change in the packaging industry. It has been found that consumers tend to purchase food products produced in a more sustainable way and 45% of these consumers continue to buy “green” even with the higher price tag and struggling economic conditions [1]. Furthermore, 62% of U.S. consumers will tend to buy from companies that put forth an effort to reduce waste and minimize pollution [1]. The food packaging industry is considering bio-based materials, which have become the replacement for
products produced from nonrenewable resources. These environmentally friendly materials like shellac may have the ability to function as a barrier layer, extend shelf life, and meet the environmental and safety concerns of the consumer. The shellac resin is a bio-based material that originates from the Lac insect (Laecifer lacca). The shellac resin would be a coated, edible barrier layer and could potentially eliminate the need for laminating in the flexible packaging structure. Currently, extrusion polymers are used 46% and aluminum 18% of the time to create a functional or barrier layer [2]. The main function of a barrier is to keep water, water vapor, grease or oil, or oxygen from penetrating into a package [2]. Barriers are especially important for food packaging; particularly the moisture content needs to be maintained in order to ensure quality and safety standards [3]. By understanding how current barriers and processes such as laminating perform, shellac or other biodegradable and edible coatings can be better evaluated.

Laminating combines different substrates, like film, paper and foil, to create various properties for unique packages. Adhesives, waxes, heat-sealable coatings, and extrusion lamination are all ways to achieve lamination [4]. These structures trap the ink, residual solvents, adhesives, and other bonding materials in the package to prevent contamination of the product. Laminating inks, mainly solvent-based, are reverse printed onto film and then laminated to another structure such as paper, film or foil [4]. When using the laminating process laminating inks need to provide good adhesion to the substrate and high cohesion characteristics for high packaging integrity [4]. A main issue encountered with laminating is residual solvents. If all solvent is not evaporated and some is trapped in the laminated structure, then unwanted odor may surround the package and potentially deteriorate it [4]. However, other issues like abrasion resistance is not a problem for laminating inks since the laminated structure provides these and other properties, like water and heat resistance [5]. The laminated structure would also provide the barrier properties required. Abrasion, water, and heat resistance are key end-use factors in surface printed ink. By eliminating the laminating process, and replacing it with the edible shellac coating substitute, the coating will have to provide those resistance and protective barrier properties for the package.

As a barrier, the edible coating would have to prevent transfer of moisture and oxygen between packaging, environment, and the food it stores. Shellac varnishes would exhibit desirable gloss characteristics as well as a moisture barrier, but possible yellowing of the structure could be seen, therefore it will be necessary to select formulations with adequate transparency to prevent altering the graphic appearance of the packaged product [3]. Shellac is a natural polymer that is brittle by nature, so possibly plasticizer would be needed to improve the handling and to prevent cracking of the resin [3]. According to recent research, however, the addition of plasticizer has a minimal effect on the water vapor permeability of the coated structure [3].

Beyond performance and barrier properties, the shellac coating would need to stand up to FDA regulations for direct food contact. Inks and overprint varnishes have to comply with FDA regulations, and they need to undergo evaluation, which would explore the complete composition, toxicity, chemical identity, and the processing steps for this material will also be evaluated [6]. Approval for shellac coatings would also be based on the environmental impact, the types of food the coating is expected to contact under various temperature and time conditions, and dietary information regarding concentration and consumption amounts consumers can be exposed to [6]. The FDA states that if the ink or printed material is to come into contact with the food, then it is considered a food additive [7]. Food additives are regulated, since they may migrate into the food or be subject to ingestion.
However, if a barrier approved for direct food contact by the FDA is used, then the printing ink and substrate would not be considered an additive and their ingredients would not need regulation [7].

Certain manufacturing steps can be used on food packaging in order to prevent ink migration to the food. These manufacturing operations include using overwrap or an FDA approved coating/varnish to conceal the conventional printing ink or simply using inks made for direct food contact [7]. Overwrapping using food safe plastic is expensive due to additional steps and materials needed; direct food contact ink is becoming more popular, but needs to ensure all ingredients and the substrates used are FDA regulated; in such scenario it looks like overprint varnishes or coatings are the least expensive solution, but need to prove zero risk of pinholing or voids [7]. If the goal is to be more sustainable, then increasing the materials used like in overwrapping, is not an option and it does not solve many direct print issues. Direct food contact inks are more expensive due to the extensive regulations, which call for each ingredient to be a higher quality and therefore more expensive [8]. For example, pigment loads are about ten times greater in direct food contact inks due to regulations and strength of the ink system compared with conventional inks [8]. Instead an overprint vanish could be used along with conventional ink instead of the expensive direct food contact inks.

Concerns for overprint varnishes include variation in runability, performance under inconsistent press conditions, and abrasion resistance when housing abrasive food that could potentially break the overprint seal [7]. Coating thickness and coverage consistency would need to be monitored, if using a coating or vanish, to avoid migration of elements of ink into the food product, which can be a difficult task. By reviewing the information, the shellac overprint varnish under assessment would have to be tested for its ability to cover the substrate constantly, create a barrier, and be resistant against abrasion. Furthermore, it will be necessary to understand the effect the shellac overprint varnish will have on the odor and taste of the food and the visual appearance of the print. Since shellac inks are FDA approved, it is presumed that there should be no negative effect on the package or its contents.

**Problem Statement**

Packaging contributes to the protection, transportation, and presentation of a product, but it mainly protects the food inside the package. Could new overprint varnish technology uphold barrier properties that ensure similar or longer shelf life like laminating processes can achieve? If an overprint varnish can act as a strong barrier, can it be made using biodegradable materials such as shellac resin? Would a shellac overprint varnish protect the product without any effects on visual presentation or the packaging process and would this new packaging be more biodegradable?
Goals And Objectives

The objective of this research is to document the runability and barrier properties, such as water and oxygen penetration through a package that uses a shellac overprint varnish instead a laminating technique. The varnish will be analyzed for blocking, coefficient of friction (COF), moisture vapor transmission rate (MVTR), oxygen transmission rate or permeability (OTR), and adhesion. If all tests have suitable results, visual properties such as transparency and color will have to be assessed along with evaluating if the shellac overprint varnish has an effect on the food’s taste or odor.

Experimental Schematic And Procedures

Seeing that shellac resin would be a suitable candidate for an edible and biodegradable coating it needs to be shown that it can provide proper end-use and barrier properties. Going green would not be effective if the contents of the food packaging became spoiled due to the packaging process. This would create more waste, than just the packaging itself. Testing samples made from simple draw-downs, comprised of various ink systems and varnish formulations, would obtain results while being efficient and cost effective.

Figure 1: Coating Frame Courtesy of Paul N. Gardner Company, Inc (Gardco).

Figure 2: Figure 1: K-Proofer with Flexo Attachment Courtesy of R K Print-Coat Instruments Ltd.
Six shellac overprint varnishes will be formulated with different solids content [Table 1]. Ethyl alcohol based and water based varnishes will be evaluated. FDA approved surfactants and solvents will be used in the formulation to ensure proper wetting to the substrate. These varnishes will be overprinted to a preprinted film substrate for evaluation. Draw-downs of white, edible, FDA approved ink for direct food contact will be completed on clear PET (polyethylene terephthalate) film, provided by AET Films, Co, using a flexo hand proofer or laboratory K-proofer in flexo mode [Figure 1]. The ink used will be donated by Colorcon Co. The ink will be applied to the film under constant conditions and thickness. This printed structure will then be overprinted with the various varnish formulations using a Gardco coating frame [Figure 2]. The coating frame [Figure 3] being used will apply different thicknesses such as two, four, six, and eight microns of wet ink film. Control samples will consist of the PET film and white ink combination as well as the PET film and overprint only combination. A sufficient amount of samples, for example eight sheets per varnish, will be created using the laboratory facilities at the Western Michigan University’s CEAS printing laboratories.

### Table 1: Shellac Overprint Varnish Solids Content.

<table>
<thead>
<tr>
<th>Varnish Number</th>
<th>Solids Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>55% Solids Content, with Ethyl Alcohol as a solvent</td>
</tr>
<tr>
<td>2</td>
<td>45% Solids Content, with Ethyl Alcohol as a solvent</td>
</tr>
<tr>
<td>3</td>
<td>35% Solids Content, with Ethyl Alcohol as a solvent</td>
</tr>
<tr>
<td>4</td>
<td>55% Solids Content, Water-Based</td>
</tr>
<tr>
<td>5</td>
<td>45% Solids Content, Water-Based</td>
</tr>
<tr>
<td>6</td>
<td>35% Solids Content, Water-Based</td>
</tr>
</tbody>
</table>

The shellac overprint varnishes will be made with ethyl alcohol as the diluting solvent and as a water-based overprint. Surfactants and solvent will be added to create percent solids as seen in Table 1. A high content of solids will be evaluated first. Each varnish will be applied at three different coating thicknesses 4, 6, and 8 microns. If desired leveling cannot be achieved when applying the varnish to the printed film, then the solution should be diluted to decrease the thickness and even the leveling. By keeping the leveling constant, the gloss will remain satisfactory and constant.

The overprint varnish samples will be tested for several end-use, optical, and barrier properties. Several measurements for color, opacity, gloss, coefficient of friction, water vapor transmission rate, and oxygen transmission rate will be gathered. The samples will also be tested for odor and visually analyzed for pinholes. Most tests will be done using the Western Michigan University’s testing equipment, however, samples will need to be sent out to Michigan State University for oxygen transmission rate (OTR) testing. CIE L*a*b* values will be determined for the control samples (white ink) and then for each overprinted sample. Delta E will be calculated to see the difference in color. Opacity will be used to see the transparency of the varnish. The clear film and varnish only samples will be compared to a sample of the film to determine if there is a change in transparency. Gloss will be tested using a 60 degree angle of reflection. The gloss of the ink and overprint will be tested and compared. Coefficient of friction will need to be tested since it is important in regards to the packaging production lines. For comparison purposes the COF of the film and printed film will be evaluated as well as the overprint varnished film. Moisture vapor transmission rate and oxygen transmission rate will be tested and compared to a laminated

**1454 - Gutenberg Invents the Mechanical Printing Press**

The invention of moveable type and eventually Gutenberg’s mechanical printing press in 1454 rapidly spread across all of Europe and eventually all around the globe, a catalyst to the Renaissance. For the first time high quality, low priced books were available to the masses, literacy rates skyrocketed and the overall intelligence level of the world grew substantially, and because of this Gutenberg’s printing press is widely regarded as the most important invention of the second millennium.
Data Collection And Analysis

Once all the data has been collected, a comparison will be made between the overprint varnished and non-overprint varnished samples. Average values will be calculated and used in the final data analysis. If the data for the barrier properties are seen to be statistically in the same range or surpass the laminating range than the shellac coating will be an effective substitute for laminating. Odor would be analyzed on a pass or fail basis. The thicknesses will also be evaluated to determine the optimal level. Optical properties would be evaluated based on effects on the visual appearance. If the varnish has a negative affect on the printed aesthetics then the shellac varnish would be limited by application. COF would be evaluated, but would be more depended on a customer’s product lines.

Table 2: Sample Optical Properties Data Collection Sheet.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Color</th>
<th>Opacity %</th>
<th>Gloss at 60°</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solvent Varnish 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent Varnish 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent Varnish 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film Only</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Film and Ink Only</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Sample End-Use/Barrier Properties Data Collection Sheet.

<table>
<thead>
<tr>
<th>Sample</th>
<th>COF</th>
<th>WVTR</th>
<th>OTR</th>
<th>Odor</th>
<th>Pinhole Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/m²/day</td>
<td>cc/m²/24 hr</td>
<td>(yes/no)</td>
<td>Comments</td>
<td></td>
</tr>
<tr>
<td>Solvent Varnish 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent Varnish 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solvent Varnish 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water-based Varnish 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Film and Ink Only</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Budget**

For this project the materials will be donated as well as the labor. AET Film will provide the clear PET film, Colorcon will provide the white, FDA approved ink, and the shellac overprint varnish ingredients will be provided by the Paper, Chemical, and Imaging (PCI) Department of Western Michigan University. At about twenty hours a week for about three months and at a rate of $10 an hour for Graduate students in the PCI department, the labor would cost $2,400. The labor however, will be done on a volunteer basis by one elected student. All testing will be done within Western Michigan University’s facility, which will have no cost. One except is the OTR test, which will need to be sent out for testing and will cost about $50 per test at Michigan State University. With six varnishes there will be six to eighteen samples so a cost of $300 to $900. Since labor and materials are donated and testing equipment is available at no cost at Western for faculty and students then the only cost of this project will be the shipping and labor fee for the OTR test.

**Timeline**

It is estimated that three months would be needed to complete this project. Three weeks would be dedicated to creating the shellac overprint varnishes. Three weeks will then be used to create the final samples, first week and a half complete ink draw downs and the rest complete the overprint samples. Another four weeks would be for testing and sending out material and gathering results. In the last two weeks data would be analyzed and the conclusions and recommendations would be presented. The last weeks will also serve as rework time if needed.

1454 - Gutenberg Invents the Mechanical Printing Press

Johannes Gutenberg and his associates are also credited as being the original developers of oil-based inks, specifically suited for use with his mechanical press.
<table>
<thead>
<tr>
<th>January Week</th>
<th>February Week</th>
<th>March Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Formulate and Mix Solvent and Water Based Shellac Overprint Varnishes</td>
<td>4 Create Samples</td>
<td>11 Analyze Data, Create Conclusions, Issue Recommendations</td>
</tr>
<tr>
<td>2 Tiger Shellac Coat to Film</td>
<td>5 K-Proofer Ink to Film</td>
<td>12 Recommendations</td>
</tr>
<tr>
<td>3 K-Proofer Ink to Film</td>
<td>6 Coating Frame Varnish to Ink</td>
<td></td>
</tr>
<tr>
<td>7 Optical Send Out Samples for MVTR</td>
<td>8 Testing Visual Pinholes COF</td>
<td></td>
</tr>
<tr>
<td>8 Testing Visual Pinholes COF</td>
<td>9 ORT Finish</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4: Research Schedule**

**Conclusions**

With the continual rise in demand for environmentally friendly products, the printing and packaging industries will make advancements to find cost effective ways to produce a simpler and more eco-safe products. Research shows that shellac resin has been used as an edible ink previously, and is a naturally produced resin from the Lac insect. The shellac overprint varnish has the potential to eliminate the laminating process in regards to direct food contact packaging. This project will show that using the shellac overprint varnish can produce a more biodegradable package and reduce material cost by eliminating the extra lamination layers and adhesives.

**Recommendations**

As stated previously, if the varnish does not apply smoothly then the solids content should be decreased and the experiment should be reworked. Also, changing the surfactants used in the overprint varnish formulation will be another option to create a more constant leveling effect. If successful in all areas, however, a full-scale test should be run on a trial flexography press. In furthering the research if the shellac overprint varnish can act as a proper barrier, then the barrier tests should be redone for samples using conventional inks instead of the edible ink. Depending on the results of this experiment water-based shellac overprint varnishes should also be investigate further. The water-based varnish would be considered more green, and environmentally sound then the solvent based varnish.
Literature Cited


1475 – The First Book in English is Printed

Disassembling of Composite Images
By Reem Ek Asaleh
Disassembling of Composite Images

Reem El Asaleh

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Kalamazoo, MI 49008

Abstract

A method developed to exclude unwanted noise or marks from printed documents or images, where no original source of those images exists, is presented.

Using the fact that generally all digital images consist of a fixed set of rows and columns of pixels, where each pixel holds color information in terms of Red, Green and Blue colors, a C++ program was developed to disassemble a digital file in order to read and write its contents and reset its pixel colors. The investigated color images were scanned and digital files were obtained. This approach helped to clean an image or document from any unwanted overwritten marks. Finally, the new cleaned image was stored as another digital file.

Introduction

A digital image can be thought as a digital or numerical representation of photographic paper or art, which can be created by scanning or by using a digital camera and stored in a computer for manipulation and enhancement procedures [1].

Generally, a digital image consists of a fixed set of rows and columns of pixels. These pixels (or picture elements) are the smallest construction units in the digital image and usually have a square shape. Each individual pixel holds numeric data that represent the brightness and the color of that image area in terms of red, green and blue [2].

The numbers of pixels in a digital image is referred as the resolution of the image [3]. Its also can be expressed as pixels per inch (ppi) or dots per inch (dpi). However, dpi is more accurately used to represent the resolution of a printer device, such as an inkjet printer [4]. Increasing the resolution will increase the total number of pixels covering the image area and it will also increase its quality and its storage file size. In addition, the overall size of an image is tied to its resolution, as the pixel size will increase if the resolution decreases [4]. The default resolution for a displayed image on a monitor will be 72 ppi, while for a good quality print, the image needs to have about 300 dpi resolution [2].

An image that is represented by a grid of pixels is also known as a raster graphic or a bitmapped graphic. Bitmapped graphics use the bits (binary digit), which are the basic unit of computer processing, to store the color information (i.e. 1 bit means the color could be white or black) [5]. The number of bits that is used to represent a color in a single pixel is called the bit depth (thus 1 bit-depth produce a binary image). For a grayscale image the
8-bits depth will generate an image with 256 shades of gray [6].

For colored digital images, each pixel holds color information in terms of red, green and blue and each color uses 8-bits to represent colors (or 1 byte). The result will be an RGB image with 24-bit depth (also known as true color) and with a total of 16,777,216 mixed colors [4].

The cones in the human eye are sensitive to light with particular wavelengths and, in particular, to the red, green and blue parts of the visible spectrum [7]. Additive and subtractive colors are two ways used to reproduce colors. Additive colors use the red, green and blue as primary colors. Secondary colors (cyan, magenta and yellow) can be produced by mixing any two of the primary colors. Mixing all the primary colors yields white. While the subtractive colors use the secondary colors as primaries. Mixing any two of the secondary colors will produce primary colors [8].

The CIE LAB, or CIE L*a*b*, and CIE LCH are two device independent ways used to describe color. The CIE (Commission Internationale de L’Éclairage) LAB color space is based on the human vision system, where the L* axis represents “Lightness” [L=0(black) – L=100 (white)]. The a* axis is green (represented by -a), and red at the other (+a). And the b* axis has blue at one end (-b), and yellow (+b) at the other [9].

L*C*H* is presented in the form of a cylinder, where The L* axis represents Lightness and the C* axis represents Chroma or “saturation”, C=0 is completely unsaturated (i.e. a neutral grey, black or white) and C=100 maximum Chroma or saturation. The “Hue” is the circular axis (H°), where H=0° (red), H=90° (yellow), H=180° (green) and H=270° (blue). The two are not different color spaces, they are the same space, but one is in Cartesian coordinates (CIE LAB) and the other is in Cylindrical coordinates (CIE LCH) [9].

**Experimental**

The goal of this research was to develop a method that can help cleaning the interrupting noise, or unwanted overwritten handwriting, from printed documents, where no original file exists.

For the purpose of this research and evaluating the quality of our method, one document was printed using two different digital printers (HP DeskJet F380 and HP LaserJet CP 3505).

Assuming that our document has no original digital file, the first step of this investigation was creating a digital version of these documents by scanning them using a high resolution (in this case we used 1200 dpi). The scanned files were then saved as BMP files.

Different scanned document samples were selected to test this method. These samples represent a variety of overwritten situations on text characters that include different pen ink and marker colors.

The main idea behind the cleaning method is to deal with the difference of ink color. Since the tested documents are now converted to digital files, rather than dealing with ink dot color, we are dealing with BMP pixel color.
The tested method depends on the LAB values of each pixel. Recalling the fact that each pixel holds color data in terms of RGB values, each pixel's RGB value needs to be converted to its equivalent LAB value in order to test the cleaning method.

This method actually consists of two different approaches. The first approach is applying a chroma test that uses the absolute a* and b* values in the LAB color model, where any pixels having higher absolute values for a* and b* than a critical constant value (in this case 20) will be considered as colored pixels and will be set to white color (or cleaned). For black color (the text color), the a* and b* values are either equal to 0 or very low.

The second approach uses the L* (brightness) values where pixels that have high L* values indicate either a bright color or white (L*=100). Turning any pixels that have high L* value to white will leave the dark text color. However, instead of comparing each pixel with constant critical value, the mean and the standard deviation of all pixels's L* values were calculated first. Then each pixel's L* value was compared with the difference of the mean and the standard deviation. The mean value represents the average of the L* (brightness) values, while the standard deviation represents how much the brightness values vary. As a result of subtracting the mean from the standard deviation, a critical value will be generated, where all of the pixel's L* values that are higher than this number will be considered a very bright color and need to set to white (in other words cleaned). This approach improves the cleaning of the noise and improves the contrast of the text color as well.

To apply this method to the scanned document, a C++ program code was developed using Visual C++ 2008 software. This code will read the investigated BMP files; set their pixel colors and the new cleaned documents will be stored as other BMP format files.

Results and Discussion

Figure 1 shows a close look at one of BMP files that was generated from the document, printed on the HP DeskJet printer. This shows that each pixel has a different RGB value. The reason for that is when sending a digital image to be printed, its RGB values will be transformed to CMYK values which is equivalent to the printer device color model. Recall the fact that the same RGB value can be reproduced with different combinations of CMYK values. In addition, for the same printed document, the overall look could differ depending on the printing device, where each printing device employs a different printing process and ink. Also, it depends on the paper type that is used to print on.

1796 - Alois Sennefelder Invents Lithography

Alois Sennefelder, a Bavarian author, invented lithography in 1796. Lithography is a method of printing in which chemicals are used to create an image. For example, the inked part of an image would be a hydrophobic chemical, and the non-image area will absorb water. This would then result in the ink adhering to the positive image and the water will clean the negative image. This method of printing was fairly prominent during its time for printing text, but it would later be incorporated into and then replaced by offset lithography.
Figure 1: Close looks of a BMP file showing the image pixel structure.

Figure 2 shows two different BMP files each representing different printing processes (i.e. LaserJet and DeskJet). Despite that each pixel has different RGB values; the overall pixels color appears, for the BMP file that represents LaserJet, darker than what represents the DeskJet. This allows more pixels that do not require any cleaning to maintain their color values after applying the cleaning method as demonstrated in Figure 3.

Figure 2: A close look of two tested BMP files represent two printing process, LaserJet (A) and DeskJet (B). Before cleaning process.
1807 - Friedrich Koenig Invents the First Steam Powered Press

In 1807, German printer Friedrich Koenig, who had moved to London three years prior, secured financial support with his partner Thomas Bensley to fund his project in creating the first non-man powered printing press. In 1810, his device was patented. Friedrich Koenig had designed a printing press that operated with the power of steam, “much like a hand press connected to a steam engine” as he described it. In April of 1811 the first production trial of this press took place, this was a landmark time in the evolution of how printing presses were made, this was one of the earliest inventions that eventually led into the Industrial Revolution later that century.

Figure 3: A close look of two tested BMP files represent two printing process, LaserJet (A) and DeskJet (B). After cleaning process.

Despite that the final cleaned images look different when closely viewed as in Figure 3, this could not be noticeable for the human eye, due to the small size of the pixels that represent a high resolution (in this research the resolutions is 1200 ppi). Overall results on all tested images were close. The text characters were cleaned from any overwritten ink and became recognizable.

In Figure 4 part A, a blue pen color had overwritten some of the document characters. Despite the cleaning of the document characters, some darker spots of the blue ink were not set to white color and therefore are still seen in the cleaned image as shown in part B. This means that these dark color pixels didn’t pass either the brightness or the chroma test.

Figure 4: A scanned document with a blue ink pen (was printed using the HP DeskJet printer) before (A) and after (B) the cleaning process.
Also, each cleaned pixel was set to white color, while the other remaining pixels didn’t change in color. However, in Figure 5 all the untouched pixels were set to black color which gave better contrast for the text characters.

Figure 5: Part B from Figure 4 the BMP pixels were set to black color.

The red ink from Figure 6 part A was totally cleaned and all the colored pixels pass the brightness and the chroma test, therefore there are no signs of noise in the cleaned document. The resulting image is demonstrated in part B.

Figure 6: A scanned document with red ink pen (was printed using the HP DeskJet printer) before (A) and after (B) cleaning process.
Figure 7: A scanned document with a cyan marker (was printed using HP DeskJet printer) before (A) and after (B) cleaning process.

Figure 8: A scanned document with a magenta marker (was printed using HP LaserJet printer) before (A) and after (B) cleaning process.

Figures 7 and 8 part A used two different marker colors (cyan and magenta). Both resulting images (part B) from the software showed cleaned document characters.

All the above BMP samples were taken from a document that was printed using an HP DeskJet printer. A second set of BMP samples were taken from the same document but this time it was printed using the HP LaserJet.

1822 - William Church Invents the First Mechanical Typesetting Device

While living in Boston, William Church patented the Church Typesetting Machine in England, consisting of a keyboard on which each key released a piece of type of the corresponding letter stored in channels in a magazine.
printer. The BMP files were processed through the same C++ software and the overall results were similar to the first set of BMP files (Figure 9). However, the only difference that all the unchanged pixels maintain their color values and did not reset them to black, due to the better quality printing of the LaserJet printer.

![Figure 9: A scanned document with a blue ink pen (was printed using the HP LaserJet printer) before (A) and after (B) cleaning process.](image)

**Areas for Future Research**

Converting RGB values to CIE XYZ is accomplished using a 3x3 transform matrix along with reference white point. This software uses the standard sRGB white point. In case the scanned image has an embedded profile, it should use the profile and its reference white point for more accurate conversion.

A new approach needs to be investigated to save the cleaned image as PSD (Photoshop) format. The advantage is to create separated layers for the background and foreground images and being able to combine these entire layers into a single file.

**Conclusions**

Generally dark colors have low $L^*$, $a^*$ and $b^*$ values, as a results dark color pixels might not pass the brightness test or the chroma test, which may still appear in the document file as unclean pixels or even appear around the text characters as well. These cases might be considered as limitations of the new approaches and more investigations need to be done to separate the dark color ink from the text characters.
References


Author Biographies

Reem El Asaleh received her B.Sc. in Computer Science from UAE University in Al-Ain. She received her MS in Paper and Imaging Science and Engineering and is currently enrolled in the PhD program at Western Michigan University.

1851 – The New York Times Debuts

The New York Times was founded on September 18, 1851, by journalist and politician Henry Jarvis Raymond, the second chairman of the Republican National Committee, and former banker George Jones as the New-York Daily Times. When first distributed The New York Times sold for only a penny.
The Photocatalytic Paper With Coating Formulations of Titanium Dioxide and Natural Zeolite

By Qi Li
The Photocatalytic Paper With Coating Formulations Of Titanium Dioxide And Natural Zeolite

Qi Li

Department of Paper Engineering, Chemical Engineering, and Imaging, Western Michigan University, Kalamazoo, MI 49008

Abstract

The purpose of this paper was to determine the photocatalytic activity of different ratios of zeolite in combination with TiO$_2$. This research has showed zeolite-based TiO$_2$ papers to very effectively decompose gaseous toluene with UV irradiation. The removal efficiency was greater than that of several commercial non-zeolite based photocatalytic papers. The coatings also provided good optical properties and provided an alternate route to photocatalytic paper. The ratio of zeolite and TiO$_2$ was varied along with the type of latex binder used. The optical, as well as the photocatalytic activity, were studied. Rutile increased the brightness more than anatase. Also, at the same ratio of zeolite to TiO$_2$, the samples with rutile can gave higher opacity. This class of papers can be used to purify air and water along with providing optical properties normally expected of TiO$_2$.

Introduction

TiO$_2$ (Titanium Dioxide) has the highest refractive index of all coating pigments. Its main strength is its opacifying power \(^{(1)}\). It is used in coated recycled boxboard and unbleached kraft board. The price of TiO$_2$ is high, because it is made using a very complex production processes. Titanium dioxide (TiO$_2$) has been largely used as an opacifying pigment and photocatalytic agent in paper \(^{(2)}\). TiO$_2$ has been engaged in the applications that require high opacity and brightness, such as coatings, paints, plastics, ink and paper, because of the unique optical properties obtained through its high refractive index and whiteness \(^{(3)}\).

TiO$_2$ is well known to have three main crystalline structures, each of the structures have different optical and physical properties, namely anatase, brookite and rutile \(^{(2)}\). Anatase is superior to the others for photocatalytic oxidation, because its conduction band is favorably located to support sufficient conjugation involving electrons and it also can generate very stable peroxide radicals on the surface during the oxidation reaction \(^{(4)}\).

Photocatalytic activity (PCA) results from the ability of a material to create an electron hole pair as a result

1880 - Rotogravure is Developed

During the end of the 19th century a now prominent printing method was first developed, gravure printing. This process is a variation on intaglio printing. Gravure printing utilizes this idea of engraving the image onto the image carrier; in this case it is a copper cylinder. This technology also utilizes the mechanics of a rotary printing press in which the image carrier is a cylinder that is rolled onto the paper. The cylinder is then rolled over the ink and the excess is removed via a doctor blade. In most cases there are four different printing units on a gravure press, one for each of the process colors (cyan, magenta, yellow and black). Contrary to most other printing techniques, the paper comes in reels rather than sheets, the paper is then webbed between the four printing units and is fed out the delivery end of the press where it is then re-rolled.
of exposure to ultraviolet or visible radiation \(^{(5)}\). The reactions that occur during photocatalytic activity are shown in Figure 1.

Natural zeolite plays an important role between fibers and TiO\(_2\) particles. It can also enhance the photocatalytic activity of the photocatalytic paper. So, the investigation of the integration of natural zeolite and nanosized TiO\(_2\) and the evaluation of the activity of photocatalytic coated paper using natural zeolite-based nano TiO\(_2\) is of great interest. Previous work by Ko \(^{(6)-(8)}\), demonstrated the benefits of a TiO\(_2\) retention system based on natural zeolite in enhancing photocatalytic activity.

![Figure 1: The reaction of the photocatalytic activity of the material \(^{(5)}\).](image)

Zeolite is named after the two Greek words, ‘Zea’ for boils and ‘lithos’ for stones. A zeolite was conceptually defined by Smith \(^{(9)}\) as: “a crystalline aluminosilicate, with a tetrahedral framework structure enclosing cavities occupied by cations and water molecules, both of which have enough freedom of movement to permit cation exchange and reversible dehydration.”

There are various factors influencing the characteristics of zeolite. They depend on the structure of the framework (Figure 2), channel size and shape. It is, therefore, extremely important to recognize the structural properties of zeolites in the perception of phenomena associated with catalytic reactivity and adsorptive features as a diffusion medium, sorbent and molecular sieve.
Experimental

Coatings were prepared using nanosized TiO$_2$ and zeolite in combination with S/B latex (31264.5 NA), Acronal S-728 (styrene acrylic latex) and Polyco3103 (vinyl-acrylic latex). The pigments used were anatase, rutile and zeolite. Assuming 100 parts pigment on a dry basis, the binder level was 10 parts for all the coating formulations. Coatings were applied to a 66 g/m$^2$ wood free paper and a 104 g/m$^2$ photocatalytic paper produced by Nippon by performing rod drawn downs in the laboratory. After coating, the optical and catalytic properties of all papers were measured.

With the different ratios of the pigment used in coating formulations, there were a total of 8 different coating formulations applied. The coatings were applied at 2 different coat weights, resulting in 16 different coating conditions being studied. The conditions studied are summarized in Table 1.
Table 1: Summary of coating conditions.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Anatase (%)</th>
<th>Total TiO₂ (%)</th>
<th>Binder</th>
<th>Solids (%)</th>
<th>pH</th>
<th>Coat Weight (%)</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>80.0</td>
<td>75.0</td>
<td>S/B</td>
<td>41.8</td>
<td>7.1</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>2</td>
<td>80.0</td>
<td>75.0</td>
<td>S/B</td>
<td>41.8</td>
<td>7.1</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>3</td>
<td>83.3</td>
<td>75.0</td>
<td>S/B</td>
<td>46.3</td>
<td>7.3</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>4</td>
<td>83.3</td>
<td>75.0</td>
<td>S/B</td>
<td>46.3</td>
<td>7.3</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>5</td>
<td>80.0</td>
<td>80.0</td>
<td>S/B</td>
<td>44.0</td>
<td>6.9</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>6</td>
<td>80.0</td>
<td>80.0</td>
<td>S/B</td>
<td>44.0</td>
<td>6.9</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>7</td>
<td>83.3</td>
<td>80.0</td>
<td>S/B</td>
<td>41.0</td>
<td>7.4</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>8</td>
<td>83.3</td>
<td>80.0</td>
<td>S/B</td>
<td>41.0</td>
<td>7.4</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>9</td>
<td>100.0</td>
<td>75.0</td>
<td>S/B</td>
<td>44.7</td>
<td>7.0</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>10</td>
<td>100.0</td>
<td>75.0</td>
<td>S/B</td>
<td>43.3</td>
<td>7.1</td>
<td>6 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>11</td>
<td>100.0</td>
<td>80.0</td>
<td>S/B</td>
<td>43.3</td>
<td>7.1</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>12</td>
<td>100.0</td>
<td>80.0</td>
<td>S/B</td>
<td>43.3</td>
<td>7.1</td>
<td>8 g/m²</td>
<td>Wood Free</td>
</tr>
<tr>
<td>13</td>
<td>69.7</td>
<td>83.3</td>
<td>Polyco</td>
<td>45.0</td>
<td>7.0</td>
<td>6 g/m²</td>
<td>Nippon</td>
</tr>
<tr>
<td>14</td>
<td>69.7</td>
<td>83.3</td>
<td>Polyco</td>
<td>45.0</td>
<td>7.0</td>
<td>8 g/m²</td>
<td>Nippon</td>
</tr>
<tr>
<td>15</td>
<td>69.7</td>
<td>83.3</td>
<td>Acronal</td>
<td>45.0</td>
<td>7.0</td>
<td>6 g/m²</td>
<td>Nippon</td>
</tr>
<tr>
<td>16</td>
<td>69.7</td>
<td>83.3</td>
<td>Acronal</td>
<td>45.0</td>
<td>7.0</td>
<td>8 g/m²</td>
<td>Nippon</td>
</tr>
</tbody>
</table>

Table 2: Example of the coating formulations listed as No.1 above.

<table>
<thead>
<tr>
<th>Parts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anatase</td>
<td>60</td>
</tr>
<tr>
<td>Rutile</td>
<td>15</td>
</tr>
<tr>
<td>Zeolite</td>
<td>25</td>
</tr>
<tr>
<td>S/B latex</td>
<td>10</td>
</tr>
</tbody>
</table>

The nanosized TiO₂ colloidal nanoparticles, rutile (Vantage RPS) was obtained from DuPont and the anatase (AT-1) was obtained from MILLENIUM. Natural zeolite was obtained from BEAR RIVER ZEOLITE mines. The three TiO₂/zeolite ratios tested were: 5 TiO₂/1 natural zeolite, 4 TiO₂/1 natural zeolite and 3 TiO₂/1 natural zeolite. The reason for testing the 3:1 is that zeolite is significantly less expensive and if the coatings perform well both optically and catalytically at this ratio, there will be a significant cost advantage over the higher TiO₂ levels.

The optical properties were tested with a glossmeter (Novo-gloss Glossmeter, Paul N. Gardner Corp.), an opacimeter (BNL-2 Opacimeter, Diano Corp.), and Brightness meter (Brightimeter Micro S-5, Technidyne Corp.) All measurements were performed 10 times for each sample, for which the average values are reported. All tests were performed according to TAPPI standards.

In order to determine the effect of the photocatalytic papers on the decomposition of toluene, (0.5μL) of liquid toluene was injected into a glass cell with a UV lamp. After 30 mins, 50μL of gas was withdrawn from the cell and injected into a Gas Chromatograph. An SRI Instruments Gas Chromatograph, equipped with a Flame Ionization Detector (FID), was used to measure the toluene content of the injected sample, using PeakSimple soft-
ware. After running about 10 mins, the result of the area under the toluene peak was obtained. This defined the initial value for the toluene in the cell. Initial data evaluation took about 3 measurements. The UV was switched on and the decomposition of the gas with time was recorded every 10 minutes over 4 hours.

Results And Discussion

Opacity was measured using an Opacimeter BNL-2 (Opacimeter, Diano Corp.). Opacity is the characteristic of a single sheet to hide printed material on the reverse side of the sheet. Figure 3 shows the opacities of the 6g/m² coated samples. With the same zeolite ratio, the samples with rutile tended to give higher opacity than without rutile. S/B lattices are water resistant or hydrophobic because they are comprised of non-polar components.

![Opacity 6gsm](image)

Figure 3: Opacity of the same coat weight 6 g/m².

From Figure 3 above and Figure 4 below, lower zeolite ratios give more opacity than the higher zeolite ratio. Sample 8, with 83% anatase and 80% total TiO₂, had higher opacity than the other S/B samples. The opacities of the high coat weight Nippon papers are higher than the other coated wood free papers, probably due to their higher basis weight. The 8 g/m² Nippon paper with the Acronal S-728 as binder had the highest opacity of all the samples.

1890 - Bibby Baron and Sons Patent the First Flexographic Press

The first patented flexographic press was built in England by Bibby, Baron and Sons in 1890. The science behind flexography and how it works is that it utilizes a flexible relief plate, much like a more advanced version of a letterpress. This type of printing can be used on almost any type of substrate including but not limited to paper, cellophane, plastic, metallic films, fabrics, as well as corrugated board stock.
Brightness was measured using a Brightness meter (Brightimeter Micro S-5, Technidyne Corp.). Brightness, \( R_\infty \), is defined as the percent reflectance of blue light, as measured at a wavelength at or about 457 nm off an infinite stack of paper sheets.

The Brightness (Figure 5) of sample 9 has the lowest brightness of the low coat weight samples. This is due to the high percentage of zeolite (which has impurities, see below) used in this formulation and absence of rutile \( \text{TiO}_2 \).
A flexographic print is achieved by making a mirror of the master image as a three dimensional relief on a rubber or polymer material. The anilox roll then dispenses a measured amount of ink onto the raised surface of the plate. When this plate comes in contact with the material to be printed the ink is transferred and the print is made.

1890 - Bibby Baron and Sons Patent the First Flexographic Press
Sample 16 with Acronal S-728 binder and Nippon base paper at the highest coat weight gave the highest gloss (Figure 8) of all samples tested. Again, the reason is not clear. Samples 9-12, with 100% anatase, had the lowest gloss values.

Gas Chromatography:

Including the base sheet, there were a total of 16 samples measured. The experiment was carried out at room temperature. The volume of the glass reactor is 1L and a UV lamp (EIKO blacklight lamp, 4W, λ = 365nm) was used. The initial concentration of toluene was 73.1 ppm (v/v). The software used was Peak-Simple. The gas samples were withdrawn from a sampling port attached to the reactor and injected into the GC (SRI 8610C) (6) (7). Some of the results are given in Figures 9-15.

The total percentage toluene removal for this case is calculated as:

100% - [(Initial toluene - Ave residual toluene (240 mins))/Initial toluene]% = 100% - 69.4% = 30.6%.
1890 - Bibby Baron and Sons Patent the First Flexographic Press

Due to lower quality expectation for packaging coupled with the significantly lower cost compared to rival printing methods, flexography has become the dominate method of package printing within the last few decades. This printing technique has always controlled a significant share in the food packaging market as well, and with many of the advancements made within the last few decades it continues to tighten its grasp on this particular market.

**Figure 10:** The Gas Chromatography of the removal toluene with the TiO2: Zeolite 4:1, anatase: Rutile 4:1 ratio, S/B Latex.

**Total percentage toluene removal is:**

\[
100\% - \left( \frac{\text{Initial toluene - Ave residual toluene (240 mins)}}{\text{Initial toluene}} \right)\% = 100\% - 57.8\% = 42.2\%.
\]

**Figure 11:** The Gas Chromatography of the removal toluene with the TiO2: Zeolite 3:1, anatase: Rutile 4:1 ratio, S/B Latex.

**Total percentage toluene removal is:**

\[
100\% - \left( \frac{\text{Initial toluene - Ave residual toluene (240 mins)}}{\text{Initial toluene}} \right)\% = 100\% - 43.1\% = 56.9\%.
\]
1880 - Rotogravure is Developed

1890 - Bibby Baron and Sons Patent the First Flexographic Press

1903 - Ira Rubel Invents Offset Printing

Figure 12: The Gas Chromatography of the removal toluene with the TiO2: Zeolite 3:1, 100% anatase ratio, S/B Latex.

\[
\text{Total percentage of toluene removal is:} \quad 100\% - \left( \frac{\text{Initial toluene} - \text{Ave residual toluene (240 mins)}}{\text{Initial toluene}} \right) \% = 100\% - 57.2\% = 42.8\%.
\]

Figure 13: The Gas Chromatography of the removal toluene with the TiO2: Zeolite 4:1, 100% anatase ratio, S/B Latex

\[
\text{Total percentage of toluene removal is:} \quad 100\% - \left( \frac{\text{Initial toluene} - \text{Ave residual toluene (240 mins)}}{\text{Initial toluene}} \right) \% = 100\% - 16.1\% = 83.9\%.
\]
The area that has seen the most advancement made is in photo polymer print plates. These advancements include improvements to the material which the plate is made from. Photographic exposure followed by chemical etch is how the plates are most often created, but a new emerging trend is the use of direct laser engraving.

\[ \text{Total percentage of toluene removal is:} \]
\[ 100 \%-\frac{\text{[Initial toluene-Ave residual toluene (240 mins)]}}{\text{Initial toluene}}\% = 100\%-73.4 \%= 26.6\%. \]

In the legends for Figure 15, the first two numbers stand for the ratio of TiO\textsubscript{2} to Zeolite. The latter two numbers stand for the ratio of Anatase to Rutile. From Figure 15, we can see that the 100\% anatase and 80\% TiO\textsubscript{2} was the most efficient in decomposing toluene. The samples with S/B Latex, with 83.3 \% anatase and less zeolite,
decomposed toluene faster. Also, the samples with 100% anatase and less zeolite decompose toluene faster. For 83.3% anatase, the samples that have more zeolite tend to decompose the toluene faster. The three samples of Nippon paper tended to give similar values.

Conclusions

We present here the results for the studies of the optical properties and photocatalytic activity of anatase, rutile and zeolite pigments that allow a coating to be designed using TiO$_2$ nano pigments with unique principal crystal structures of anatase and rutile. Eight different kinds of coating formulations were made, each of them have two different coat weights.

The opacity of 83.3% anatase and 80% TiO$_2$ is higher than that achieved by the other S/B samples. Brightness for 83.3% anatase and 75% TiO$_2$ was better than that achieved by the others. Coated Nippon papers have the highest gloss and opacity. The 80% anatase and 75% TiO$_2$ had significantly higher gloss than the other S/B samples.

For photocatalytic activity 100% anatase with 80% TiO$_2$ had the highest efficiency. These results agree with previous research about photocatalytic activity of titanium dioxide and zeolite reported previously (4) (6) (7) (8) (10) (12) (13). The optimal coating formulations for optical properties and photocatalytic activities were not the same. Compromises can be made, but different coating formulations would need to be made to separately optimize for optical and photocatalytic activity. A summary of the observations is given in Table 3.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Samples with higher properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss</td>
<td>80% anatase and 75% TiO$_2$</td>
</tr>
<tr>
<td>Opacity</td>
<td>83.3% anatase and 80% TiO$_2$</td>
</tr>
<tr>
<td>Brightness</td>
<td>83.3% anatase and 75% TiO$_2$</td>
</tr>
<tr>
<td>Photocatalytic activity</td>
<td>100% anatase and 80% TiO$_2$</td>
</tr>
</tbody>
</table>

Acknowledgement

We would like to thank Matt Stoops for his valuable time and efforts in carrying out the coating and helping with the use of the gas chromatograph.

References

In 1903, Ira Washington Rubel, an American printer, invented the first offset printing press. Offset printing involves an inked image being transferred from a planographic plate to a rubber blanket; the image is then transferred from the blanket to the printing surface. The main idea behind the lithographic process is the fact that oil and water do not mix. In offset lithography there is a flat, planographic image carrier where the image area accepts ink from the ink rollers. During this process the non-image area accepts fountain solution (a water-based film), thus keeping the non-image areas free of ink.

Effects of Coat Weight and Pigment Selection on Flexographic Printability of Coated Test Liners

By Sinan Sonmez
Effects of Coat Weight and Pigment Selection on Flexographic Printability of Coated Test Liners

Sinan Sonmez
Department of Paper Engineering, Chemical Engineering, and Imaging, Western Michigan University, Kalamazoo, MI 49008

Abstract

Coated linerboard continues to be a growing value-added market of interest to containerboard and corrugated markets. Development of coatings to improve the surface properties of kraft and test liners continues to be important, as manufacturers try to further improve the visual appearance of a printed box. In this study, the surface and print properties of a 100 g/m² commercial test liner coated with different coat weights using different pigments and binders are compared. Coating, coat weight, PPS porosity, caliper, roughness, gloss, CIE whiteness and brightness are compared before and after calendaring. The uncalendered and calendered samples were then printed with water based Performa Reflex Blue flexographic ink, using a laboratory K-proofer press. Ink density, print contrast, dot gain, dot roundness, delta gloss, and print mottle were then measured and compared. Results from the optical and print properties are related to the measured wetting and pigment packing properties of the coating. This study reveals that while coating and calendaring positively affect print quality, coating weight did significantly affect print quality. Many of the print properties were influence by pigment type. Higher levels of kaolin addition resulted in an increase chroma and print density, and a decrease in print mottle. The use of CaCO₃ increased print lightness, print delta gloss and print contrast, but lowered coating gloss.

Introduction

In the paperboard industry, linerboard is the largest segment. Linerboard has relatively few grades compared with other paper and paperboard products. The majority of linerboard is unbleached kraft, which is mainly produced from kraft and recycled fibers [1]. Linerboards that include 80 to 100% kraft pulps are called kraft liners [2], while those comprised of 100% recycled fibers are called recycle linerboard or test liners [3]. In comparison to kraft liner, the fiber strength of test liner is less, limiting its use to applications where strength is not a major requirement [4]. The primary use of linerboard is in the manufacture of corrugated containers for packaging products. Other uses of linerboard include laminated roll wrap for protecting rolls of paper during shipping, barrier coated liner for vapor barriers for the construction industry, and in applications where a cushion or barrier is needed to protect a product.

An advantage of test liner over kraft liner is cost, due to the high recycled fiber content. Although the recycled fibers are weaker, cost effective dry-strength agents can be added to increase product strength [5].

1903 - Ira Rubel Invents Offset Printing

The inspiration for this technology was actually an accident by Rubel. While he was operating his lithographic press Rubel noticed that if he did not insert the paper into the press the image would be transferred onto the rubber impression cylinder from the plate. Rubel was amazed to discover that when the image was transferred from the rubber impression cylinder to the paper the image looked much clearer and it gave the image a much sharper look. Ira Rubel then took this idea and replicated it and the idea would soon be known as offset lithographic printing.
focus of most research on the use of recycled old corrugated containers (OCC) has sought to determine ways of improving the quality of test liners for use in packaging [6]. While, traditionally, uncoated test liners have been used in the packaging sector, in recent years, due to point of purchase sales, the demand for high print quality coated test liner has increased [7]. To meet these demands, manufactures have sought to develop coated grades capable of providing the print surfaces desired for good readability and image quality.

For most corrugated box manufacturers, flexographic printing is the preferred print method. Advancements in flexo press and material technologies, such as anilox rolls and plate technology, have enabled good quality print to be achieved on test liners [8].

Advancements in surface coating and paperboard technology have also occurred. These advancements have resulted in improvements in the appearance and printability of test liner surfaces, and have proved to be one of the most important factors contributing to better print quality [9]. Most applications of test liners require a coating to produce acceptable print quality and/or barrier properties. White top-coated test liners provide smooth external surfaces with high printability. A coating improves and controls smoothness, ink receptivity and surface structure [9], which some believe are the most important determinants for print quality. The coating process is the most important determinant for achieving gloss, smoothness, brightness and print detail.

Y. H. Zang and J. S. Aspler [10] found that linerboards could be printed by water-based flexography, either before or after being combined with the corrugated medium. Surface roughness, porosity, and water absorbency are important factors. The image quality of post-printed combined boards depends on the surface properties of the liner, the structure of the fluted medium, and the effects of wash boarding.

The demand for high quality graphics on linerboard continues to rise. Coating quality significantly influences test liner printability [11]. Therefore, coating improvements continue to be sought. The objective of this study was to determine the influence of pigment type on the surface appearance and flexographic print properties of a test liner.

Methodology

This study is divided into three phases: (1) application of select coatings to a commercial test liner, (2) calendering of coated test liners and (3) measurement of coated test liner’s optical, surface and print properties.

Materials

A 100 g/m² commercial test liner was used as the base substrate for coating. The test liner properties are summarized in Table I. The properties of the coating materials are given as reported by the supplier in Table II and III. The (%) solids of the mineral pigments and binders used in the coating formulations are given in Table IV.
Table 1: Properties of the base test liner.

<table>
<thead>
<tr>
<th>Testing</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basis Weight (g/m²)</td>
<td>100</td>
</tr>
<tr>
<td>Caliper (mm)</td>
<td>0.17</td>
</tr>
<tr>
<td>Cobb₆₀ (g/m²)</td>
<td>127</td>
</tr>
<tr>
<td>Bulk (cm³/g)</td>
<td>1.70</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>6.9</td>
</tr>
<tr>
<td>Brightness (R457) (%)</td>
<td>24.66</td>
</tr>
<tr>
<td>CIE Whiteness</td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>-57.30</td>
</tr>
<tr>
<td>T</td>
<td>-16.74</td>
</tr>
</tbody>
</table>

Table 2: Mineral pigment properties.

<table>
<thead>
<tr>
<th>Pigments and binders</th>
<th>Solid (%)</th>
<th>Particle size</th>
<th>Brightness (%)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaolin (BASF, Nuclay)</td>
<td>68</td>
<td>78-82 %</td>
<td>88</td>
<td>7.5</td>
</tr>
<tr>
<td>CaCO₃ (Omya, Hydrocarb 90)</td>
<td>76</td>
<td>90 %</td>
<td>93</td>
<td>9.5</td>
</tr>
<tr>
<td>TiO₂ (Tronox, R-KB-2)</td>
<td>94</td>
<td>0.3 µm</td>
<td>95</td>
<td>7.5</td>
</tr>
</tbody>
</table>

Table 3: Binder Properties.

<table>
<thead>
<tr>
<th>Binders</th>
<th>Dry matter (%)</th>
<th>Viscosity (mPa.s)</th>
<th>Density (g/cm³)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latex (BASF, Acronal S 360 D)</td>
<td>50 ± 1</td>
<td>370</td>
<td>1.02</td>
<td>8 ± 0.50</td>
</tr>
<tr>
<td>CMC (CPKelco, Finnfix 5)</td>
<td>98</td>
<td>20 - 50</td>
<td>1.6</td>
<td>5.5 - 8</td>
</tr>
</tbody>
</table>

1903 - Ira Rubel Invents Offset Printing

During the last 100 years offset printing has become the most dominant form of high-volume commercial printing in the world. This is for a variety of reasons: first of all it has an advantage in quality compared to the flexographic process, and it is also cost effective for high volume production. A large portion of the cost goes into set-up and preparation of the press, once this is complete, paper is fed through the press until completion. Each page costs less than the last, making for a very efficient means of printing.
Table 4: (%) Solids of the mineral pigments and binders in coating formulations.

<table>
<thead>
<tr>
<th>Pigments and binders</th>
<th>Solid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaolin (Nuclay)</td>
<td>70</td>
</tr>
<tr>
<td>CaCO₃ (Hydrocarb 90)</td>
<td>70</td>
</tr>
<tr>
<td>TiO₂ (Tronox R-KB-2)</td>
<td>65</td>
</tr>
<tr>
<td>CMC (Finnfix)</td>
<td>4</td>
</tr>
</tbody>
</table>

Coating Formulations and Application Methods

For this study, six different coatings were prepared. The formulations of the coatings applied are given in Table V. All coatings were prepared at 60% solids. The pH of the coatings were not adjusted and ranged from pH 8-9. After mixing for 30 minutes, the pH, percent coating solids, and viscosity were measured. The viscosities of the coatings were measured with a Brookfield viscometer (spindle No. 2; at 100 rpm). Coatings were applied using a K-Control laboratory rod coater. The coatings were applied to an unsized commercially produced test liner. Because the test liner was unsized, the coat weights required to get good coverage were very high. Two different coat weights (36±3 and 57±2 gsm) were applied. The lower coat weight is within a commercially acceptable range. The higher coat weight was chosen to assure complete coverage was accomplished. After coating, the samples were air dried overnight under TAPPI conditions. The coated samples were then calendered at 150 PLI, 2-nips against a polished metal roll.

Table 5: Coating formulations.

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>N1</th>
<th>N2</th>
<th>N3</th>
<th>N4</th>
<th>N5</th>
<th>N6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td>Dry Parts Added</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaolin</td>
<td>100</td>
<td>50</td>
<td>80</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CaCO₃</td>
<td>100</td>
<td>50</td>
<td>20</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TiO₂</td>
<td>30</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latex (Acronal)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Co-binder (CMC)</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

All samples were conditioned for 24 h at 50% RH and 23 °C (73.4 °F) before testing. The calendered and uncalendered test liner samples were tested for PPS porosity, air permeability, caliper, roughness, gloss, CIE whiteness and brightness. The Parker Print porosity was measured using a Parker Print Surf (PPS) tester at 1000 kPa with a soft backing. The thickness of the coated test liner samples were measured using a TMI Micrometer.
Paper roughness was measured using a PPS ME-90 (1000 kPa, soft backing) based on TAPPI T555-OM-99. Air permeability was calculated from the PPS porosity results [12]. The brightness of coated samples was measured with a Brightimeter Micro S-5 based on TAPPI Standard T452-OM-98 (457 nm light). Paper gloss was measured at 75° using a Novo-Gloss™ Glossmeter based on TAPPI standard T480-OM-99. A First Ten Angstroms dynamic contact angle-measuring device, FTÅ200, was used to measure the change in contact angle of deionized water with time.

Printed calendered and uncalendered test liners were prepared using a K Motorized Printing Proofer in flexographic mode. The effected screen frequency was 100 lpi and effect anilox roller screen frequency was 163 lpi, with cell volume of 10 bcm. The ink used was a Performa Reflex Blue XGL305696 flexographic ink described elsewhere [13]. After the printing, density, print contrast, dot gain, gloss, and CIE L*a*b* values were measured with an X-Rite EyeOne IO Spectrophotometer. Print mottle [14] was measured using a Verity IA Print Target analysis program. ImageXpert software was used to measure dot quality [15].

Results and Discussions

The optical and print properties were measured for 10 samples of each coating formulation were and the averages reported. From the tables below it is noticed that increasing the coat weight from 36±3 to 57±2 gsm had little effect on the brightness. The brightness of the N1 coating decreased slightly after calendering, due to a loss in air voids. PPS Porosity and permeability also decreased. Samples were calendered to a target PPS roughness of 2.00-2.50 microns [8]. The PPS porosities of the substrates are a specific property of prime importance for the determination of the printability. Low PPS porosity (low permeability) often is associated with high ink holdout. In Table 4-7, porosity of the lower coat weights is obviously higher. The least PPS porosity was obtained with the higher coat weight clay formulations. The PPS porosity of TiO$_2$ is higher than Kaolin and CaCO$_3$. The least Hunter Gloss 75º value was measured for the 100 parts CaCO$_3$ coating, N2. For the other formulas’, the Hunter Gloss 75º values were generally similar. The thickness affects air permeability (reflected by PPS porosity). After calendering, the thickness values of all samples were all similar (Table VI-IX).

Table 6: Optical and physical properties of uncalendered-coated test liners for low coat weight.

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>Brightness (%) Ave. Std.</th>
<th>PPS Roughness (micron) Ave. Std.</th>
<th>PPS Porosity (ml/min) Ave. Std.</th>
<th>Permeability (nm²) Ave. Std.</th>
<th>Hunter Gloss 75º (%) Ave. Std.</th>
<th>CIE Whiteness (%) Ave. Std.</th>
<th>Thickness (mil) Ave. Std.</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>73.4 0.66 6.9 0.11</td>
<td>11.0 0.41</td>
<td>109.0 0.00</td>
<td>31.5 1.05</td>
<td>72.0 0.57 8.0 0.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>73.0 0.51 7.9 0.11</td>
<td>37.7 1.76</td>
<td>398.0 1.00</td>
<td>8.7 0.31</td>
<td>72.3 0.68 8.5 0.29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N3</td>
<td>76.4 0.45 7.4 0.11</td>
<td>18.9 0.95</td>
<td>195.0 0.00</td>
<td>16.6 0.66</td>
<td>74.2 0.33 8.3 0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N4</td>
<td>76.4 0.44 6.9 0.11</td>
<td>11.7 0.39</td>
<td>119.0 0.00</td>
<td>25.9 1.03</td>
<td>73.8 0.39 8.2 0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N5</td>
<td>85.5 0.29 7.1 0.16</td>
<td>20.3 1.82</td>
<td>212.0 1.00</td>
<td>23.9 0.79</td>
<td>81.1 0.31 8.4 0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N6</td>
<td>90.6 0.58 7.1 0.15</td>
<td>55.4 1.44</td>
<td>612.0 0.00</td>
<td>28.1 0.72</td>
<td>88.0 0.50 8.9 0.25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1903 - Ira Rubel Invents Offset Printing

Offset printing has many other advantages beyond its efficiency. Producing plates for printing is very easy and can be achieved quickly. These plates last much longer than direct lithography because there is no direct contact between the substrate and the plate. All of these advantages come together to make offset printing the least expensive method of printing high quality commercial-length runs.
### Table 7: Optical and physical properties of calendered-coated test liners for low coat weight.

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>Brightness (%)</th>
<th>PPS Roughness (micron)</th>
<th>PPS Porosity (ml/min)</th>
<th>Permeability (nm²)</th>
<th>Hunter Gloss 75º (%)</th>
<th>CIE Whiteness (%)</th>
<th>Thickness (mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>71.3</td>
<td>0.72</td>
<td>2.3</td>
<td>0.48</td>
<td>4.9</td>
<td>0.68</td>
<td>34.0</td>
</tr>
<tr>
<td>N2</td>
<td>71.4</td>
<td>0.69</td>
<td>3.0</td>
<td>0.50</td>
<td>15.1</td>
<td>2.52</td>
<td>109.0</td>
</tr>
<tr>
<td>N3</td>
<td>74.5</td>
<td>0.71</td>
<td>2.3</td>
<td>0.26</td>
<td>7.5</td>
<td>0.62</td>
<td>55.0</td>
</tr>
<tr>
<td>N4</td>
<td>74.3</td>
<td>0.66</td>
<td>2.6</td>
<td>0.60</td>
<td>5.7</td>
<td>0.98</td>
<td>42.0</td>
</tr>
<tr>
<td>N5</td>
<td>84.7</td>
<td>0.36</td>
<td>2.1</td>
<td>0.19</td>
<td>7.5</td>
<td>0.33</td>
<td>57.0</td>
</tr>
<tr>
<td>N6</td>
<td>90.4</td>
<td>0.75</td>
<td>2.5</td>
<td>0.15</td>
<td>18.2</td>
<td>0.82</td>
<td>135.0</td>
</tr>
</tbody>
</table>

### Table 8: Optical and physical properties of uncalendered-coated test liners for high coat weight.

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>Brightness (%)</th>
<th>PPS Roughness (micron)</th>
<th>PPS Porosity (ml/min)</th>
<th>Permeability (nm²)</th>
<th>Hunter Gloss 75º (%)</th>
<th>CIE Whiteness (%)</th>
<th>Thickness (mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>77.3</td>
<td>0.36</td>
<td>6.3</td>
<td>0.12</td>
<td>7.3</td>
<td>0.24</td>
<td>76.0</td>
</tr>
<tr>
<td>N2</td>
<td>79.0</td>
<td>0.18</td>
<td>8.1</td>
<td>0.11</td>
<td>28.4</td>
<td>1.14</td>
<td>314.0</td>
</tr>
<tr>
<td>N3</td>
<td>79.7</td>
<td>1.19</td>
<td>7.2</td>
<td>0.09</td>
<td>14.1</td>
<td>0.57</td>
<td>152.0</td>
</tr>
<tr>
<td>N4</td>
<td>80.0</td>
<td>0.28</td>
<td>6.8</td>
<td>0.19</td>
<td>8.4</td>
<td>0.19</td>
<td>91.0</td>
</tr>
<tr>
<td>N5</td>
<td>87.4</td>
<td>0.20</td>
<td>6.9</td>
<td>0.23</td>
<td>15.1</td>
<td>0.22</td>
<td>165.0</td>
</tr>
<tr>
<td>N6</td>
<td>91.9</td>
<td>0.39</td>
<td>7.3</td>
<td>0.20</td>
<td>45.9</td>
<td>1.51</td>
<td>558.0</td>
</tr>
</tbody>
</table>
1903 - Ira Rubel Invents Offset Printing

There are a few disadvantages with this method that are starting to lead towards the decline of this powerhouse printing method. First of all the image quality is not as high as its competition, gravure. Also since plates must be made before printing it is very difficult to print variable data, such as addresses or names. Over the last decade digital printing has improved by leaps and bounds and is now approaching offsets level of cost/benefit for high quality printing, though it has yet to match its efficiency at commercial-length print runs.

Table 9: Optical and physical properties of calendered-coated test liners for high coat weight.

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>Brightness (%)</th>
<th>PPS Roughness (micron)</th>
<th>PPS Porosity (ml/min)</th>
<th>Permeability (nm²)</th>
<th>Hunter Gloss 75º (%)</th>
<th>CIE Whiteness (%)</th>
<th>Thickness (mil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>76.0</td>
<td>0.31</td>
<td>2.0</td>
<td>0.46</td>
<td>3.8</td>
<td>0.94</td>
<td>28.0</td>
</tr>
<tr>
<td>N2</td>
<td>78.0</td>
<td>0.51</td>
<td>3.2</td>
<td>0.37</td>
<td>11.5</td>
<td>2.21</td>
<td>90.0</td>
</tr>
<tr>
<td>N3</td>
<td>78.7</td>
<td>0.51</td>
<td>2.2</td>
<td>0.51</td>
<td>5.9</td>
<td>0.87</td>
<td>45.0</td>
</tr>
<tr>
<td>N4</td>
<td>77.7</td>
<td>0.45</td>
<td>2.3</td>
<td>0.46</td>
<td>3.8</td>
<td>0.40</td>
<td>29.0</td>
</tr>
<tr>
<td>N5</td>
<td>86.9</td>
<td>0.26</td>
<td>2.2</td>
<td>0.21</td>
<td>6.5</td>
<td>0.15</td>
<td>51.0</td>
</tr>
<tr>
<td>N6</td>
<td>91.7</td>
<td>0.23</td>
<td>2.6</td>
<td>0.14</td>
<td>16.5</td>
<td>0.57</td>
<td>123.0</td>
</tr>
</tbody>
</table>

Print Density

Print density is important in determining the contrast between print and substrates. It determines dot gain and print contrast. Print density is affected by a paper’s physical properties, the kind of coating pigment and ink properties. Also, in flexographic printing, the printing condition has an important effect on print density [16]. Both paper permeability and ink absorption were affected by pigment type. This is because the pigment used impacted the permeability of the coating layer. When ink composition is the same, a paper with high permeability will exhibit high ink absorption, and likewise, a paper with low permeability will exhibit less absorption. Due to the platy structure of kaolin, coatings containing a high percentage of kaolin typically will have low ink absorption, thereby increasing print density. The same was found in this study. In Tables 4-7, the paper samples containing a higher percentage of kaolin, N1 and N4, were less permeable and had higher print densities (Figure I), although not much in some cases as indicated by the error bars. In other words, the ink absorption of the coated test liners was reduced due to a decrease in permeability resulting from an increase in the amount of kaolin in the coating formulation. Also, calendering increased print density for each formulation by the same mechanism. The print densities of the coated test liners were much better than the base test liners by reason of the reduction of the porosity by coating. However; increasing the coating weight did not show a significant effect on print density, most likely due to the high coat weights applied.
Print Contrast

Print contrast is an important indicator of printing press quality. A well adjusted printing press produces low dot gain and high print contrast. Print contrast takes into account the solid ink density and the dot area. Print contrast is calculated by measuring the ink density of a solid area and the ink density in a 75% tint. The percentage of print contrast is calculated as: [17]

\[
\text{Percentage of Print contrast: } \left( \frac{D_{\text{solid}} - D_{75\%}}{D_{\text{solid}}} \right) \times 100
\]

In general, the print contrast of the base test liner has a very low value, while values significantly increase after coating for each formulation. Especially, coating formulation N2 with 100 parts CaCO$_3$ had the highest print contrast after calendering, thereby giving good tone values for flexographic printing. Coating formulations N5 and N6, which contain TiO$_2$, exhibited a decrease in print contrast. Print contrast increased after calendering. So, a quality print with better shadow detail can be obtained by calendering. Kaolin did not significantly affect print contrast values. Figure II shows that coating weight had no effect on Print contrast (Figure II).
**Delta Gloss**

The substrate surface affects both the print gloss and the gloss of unprinted paper. As the surface physical properties, smoothness and porosity, affect the gloss of print, the amount and kind the ink ingredients, especially the binder, has an important effect on obtaining a glossy print. However, it cannot be said that a glossy paper will guarantee a glossy print [18].

The gloss was measured before and after printing. Delta gloss was calculated as:

\[
\text{Delta Gloss} = \text{Gloss after printing} - \text{Gloss before printing},
\]

all at the same angle. For these measurements, both gloss values were measured using Hunter Gloss 75°.

Figure III shows that the application of the coating increased delta gloss for each formulation. However; no noticeable change in delta gloss was associated with coat weight. Even the N2 coating formulation coating containing 100 parts CaCO$_3$, which had the lowest unprinted gloss, had high delta gloss values. By contrast, the N1, and N6 coatings containing 100 parts TiO$_2$, had the highest unprinted gloss; however, after printing, the delta gloss values decreased (Figure III). Therefore; we conclude that pigment properties have an important effect on unprinted gloss, but after the printing process is completed and the ink is bound to the coating the delta gloss values may increase or decrease, depending on which pigments and which ink ingredients, are present.

---

**1907 - Modern Methods of Screen Printing is Developed**

Although the art of screen printing had been around for centuries, it was never a viable method until proper materials were readily available for printers. In the early 20th century, silk meshes were more readily available and were then able to be implemented in the art of screen printing. Screen printing is essentially a method of printing where ink is adhered to the substrate as it is pushed through a mesh screen. The image areas are definite by blocking them off with a non-permeable material which forms a stencil. The open spaces on a screen is where the ink will flow through and will become the image on the item.
Print Lightness

Print density and the density range in dot areas are affected by lightness values. Generally, the higher the lightness, the lower the density. Non-uniform ink coverage due to roughness could reduce print density, increase the print lightness value and thus reduce the color saturation of the print [18] and increase mottle. So, print lightness is significant for print quality due to its adverse effect on print density [19].

Figure IV shows that the print lightness of N2 before calendering is significantly higher than the other formulas. The print lightness values of the calendered samples are less than the uncalendered samples due to the reduction of the porosity and the improvement in surface smoothness of test liners as a result of the calendering process.

The base test liners had the highest print lightness. This means that the base test liners had lower print density and color saturation than the coated test liners. In other words, coating improves the surface smoothness. As a result of this, the print lightness of coated test liners decreased, while print density and color saturations increased. The print lightness values are similar for the low and high coat weights samples. So, we conclude that coat weight does not significantly affect the print lightness (Figure IV).
1938 - Chester Carlson Develops Xerography
On October 22nd, 1938 Chester Carlson invented electrophotography, later to be renamed xerography. In this process the image is formed by the action of a light on a specially coated charged plate. The latent image is developed with power that would only adhere to the charged areas. The first copy printed were the written words “10.-22.-38 ASTORIA.” The image was transferred to a sheet of wax paper, which was then heated causing the wax to melt off producing the first duplicate page ever produced.
Print Mottle

Mottle is an important characteristic to quantify printability. The variations in surface roughness influence the ink transfer and are responsible for a form of mottle. Print mottle is affected by the ingredients in the coating, as well as the base paper properties [21]. The mottle values for the 100 % solid areas were measured. From the results shown in Figure 6, it is obvious that the mottle values of the uncalendered test liners are higher than the calendered test liners. It can also be seen that although the ratio of kaolin in the coating formulations increased mottle before calendering, the N1 coating containing the most kaolin was least mottled after calendering [22]. This is most likely due to platelets being misaligned at the surface prior to calendering. After calendering the platelets are flattened, forming a smooth surface suitable for uniform printing. For N3 and N4, the CaCO$_3$ fills in the voids in the surface and produces a smoother surface before calendering (Figure VI).

![Figure 6: Print mottle.](image)

Dot gain

Dot gain is known to increase the size of the half-tone dots over the period between the pre-press and printing processes. A low dot gain demonstrates high print quality. Generally, dot gain is affected by both the anilox roller and the plate for flexographic printing [16]. In this experiment both the plate and the effective anilox roller screen frequency were low.

After calendering, dot gain decreased. However, the differences before and after calendering are not significant. The lowest dot gain was obtained from the N6 coating. Also, dot gain is not significantly dependant on coating weight (Figure VII, VIII).
In 1949, Cerutti produced their first rotogravure press which was shipped to Prasa of Warsaw, Poland. This press was dedicated to PVC printing. This was the first press entirely designed, engineered, and manufactured by Cerutti.

**Dot Roundness**

The measure of dot roundness is a method to characterize dot quality. This measurement, together with dot gain, gives a very good characterization of the dots. An ideal circular dot has a 1.00 dot roundness, the maximum value for a closed figure [23]. Table X shows the dot roundness values for each coating. The values, being close to one, are all within acceptable tolerance limits.

Coating provides a much whiter and smoother surface than the base test liners, which have a surface color. It decreased the color contrast between print and coated test liners. Therefore, the readability of printed texts increased. Also, the surface smoothness affected the uniformity of the dot shape and size. Low dot gain and rounder dot shape are important properties to obtain a good print. Table X demonstrates that coating increases dot roundness. However, the change in coating weight does not show significant effect on dot roundness values.

---

**Figure 7:** Dot gain (%) values of coated test liners for low coat weight.

**Figure 8:** Dot gain (%) values of coated test liners for high coat weight.
Contact Angle

Papers with low surface energy will have a high contact angle, which indicates poor ink wettability. Figures IX and X illustrate the contact angle curves from 10 second dynamic contact angle experiments. A steep decline curve reflects fast ink spreading on the paper surface. The N2 and N6 coatings have higher initial contact angles than the others. This indicates that the N2 and N6 coatings have a lower surface energy. During the 10-second test, the contact angles of these coating formulations decline slowly. This indicates less ink spreading, or ink immobilization. This could also provide improved image resolution and sharpness, provided the actual water-base ink wets the paper surface sufficiently and that it does not rub off easily.

The N1 coating is more hydrophilic than the others. Coat weight did affect contact angle. Test liner coatings with the high coat weight have a higher contact angle than test liners with low coat weight. However, with calendering, the contact angles of both coat weights drop. (Figure IX, X).

**Table 10: Dot roundness values.**

<table>
<thead>
<tr>
<th>Coating formulations</th>
<th>base test liner</th>
<th>uncalendered test liners (low coat weight)</th>
<th>calendered test liners (low coat weight)</th>
<th>uncalendered test liners (high coat weight)</th>
<th>calendered test liners (high coat weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>0.78</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>N2</td>
<td>0.78</td>
<td>0.96</td>
<td>0.97</td>
<td>0.97</td>
<td>0.97</td>
</tr>
<tr>
<td>N3</td>
<td>0.78</td>
<td>0.97</td>
<td>0.99</td>
<td>0.97</td>
<td>0.98</td>
</tr>
<tr>
<td>N4</td>
<td>0.78</td>
<td>0.97</td>
<td>0.98</td>
<td>0.98</td>
<td>0.99</td>
</tr>
<tr>
<td>N5</td>
<td>0.78</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>N6</td>
<td>0.78</td>
<td>0.97</td>
<td>0.99</td>
<td>0.98</td>
<td>0.99</td>
</tr>
</tbody>
</table>

**Figure 9:** Surface contact angle values of coated test liners for low coat weight.
Figure 10: Surface contact angle values of coated test liners for high coat weight.

Conclusion

This study examined the printability properties of flexographic printed calendered coated test liners. The mineral pigments used affected the optical properties of the calendered coated test liners. The air permeability of test liners decreased after calendering. The higher air permeability of uncalendered test liners resulted in a lower print density. Coating formulations with kaolin had lower PPS porosity and permeability of the coated test liners relative to the CaCO₃ and TiO₂ pigmented coatings.

In flexographic printing, the print conditions have an important effect on print quality. The screen frequencies of flexo plate and anilox roll are especially important to print quality. Also, pigment type influences on print quality in flexography. This study showed the influence of pigment type on print quality. CaCO₃ coatings had higher delta gloss values after printing. However, these showed lower chroma values than the others. The use of Kaolin in the coating formulations increased Chroma, which enabled a higher color gamut to be obtained. A higher color gamut provides better color reproduction in flexography. However, the use of CaCO₃ in the coating formulations increased print lightness. Therefore, these formulations had the least print density. Decreasing print density can show reduced color saturation. Also, the use CaCO₃ increased print contrast after calendering.

The coated and calendered values show a significant contribution to the quality of the printed result. As expected, the coated test liners showed improved smoothness values after calendering. This is especially important for good printability.

Controlling ink spreading is the most important property in flexography, due to the tendency of dots to grow because of flattening of the raised dots on the plate. In this study, coating formulations with CaCO₃ and TiO₂ demonstrated hydrophobic surfaces. In contrast, kaolin showed a hydrophilic surface for the coated test liners.

Coating weight had little effect on optical and physical properties and the resulting print quality, due to the high weights applied. In particular, there is little or no effect of coating weight on dot gain and dot roundness as well as the pigment type in coating, and calendering. However, print mottle was affected by pigment type in the

1949 - Xerox Introduces the First Office Photocopyer

In 1949, Xerox Corporation introduced the first xerographic copier called the Model A. Xerox became so successful that, in North America, photocopying came to be popularly known as “xeroxing.” Xerox has actively fought to prevent “Xerox” from becoming a generalized trademark. Even still the word “Xerox” has appeared in some dictionaries as a synonym for photocopying.
coating and with calendering. After calendering, Kaolin decreased print mottle much more than CaCO$_3$ and TiO$_2$.

Acknowledgements

Matthew Stoops from the department of Paper Engineering, Chemical Engineering, and Imaging at Western Michigan University is thanked for performing the laboratory calendering; Michael Kirmeier from Prüfbau, Dr.-Ing. H. Dürner GmbH is thanked for helpful advice with the Verity IA Print Target analysis program. The author, Sinan Sonmez, would like to thank the department of Printing Education, Faculty of Technical Education at Marmara University where these coatings were prepared and applied and the department of Paper Engineering, Chemical Engineering, and Imaging at Western Michigan University for helping to get these samples calendered and in supporting the testing and printing portion of this study.

References


1962 - Heidelberg Makes the Leap From Letterpress to Offset Printing

Hubert H. A. Sternberg, Chairman of the Management Board for Heidelberg, had resisted this move for decades, until some technicians were finally able to convince him of this new technology’s advantages. Today Heidelberg is the world’s largest producer of
Application of Polyoletin Dispersions in Paper Coatings
By Roland Gong
Application of Polyolefin Dispersions in Paper Coatings

Roland Gong
Department of Paper Engineering, Chemical Engineering, and Imaging, Western Michigan University,
Kalamazoo, MI 49008

Abstract
The quality of inkjet printed color is significantly influenced by the substrate coating structure, which strongly affects ink-setting performance. Small amounts of coating additives are necessary and play an essential function, which in turn affects the substrates final surface structure, optical properties and printed color. The main objective of this study was to evaluate the performance of various polyolefin dispersions in paper coatings for inkjet papers and their effects on paper properties, inkjet printability and color. The polyolefin dispersions were added to a typical silica based coating formulation, and then compared to a control coating without a polyolefin additive. The coatings were applied to base sheets by a cylindrical laboratory coater. Coated papers were then calendered. To ascertain the mechanism underlying the effects of tested additives coating rheology, surface properties, optical properties, and print quality were measured. Based on the results, these additives provide increased paper brightness due to enhanced OBA efficiency, better lightfastness, and the potential for improved coating application.

Introduction
Among digital printing technologies, inkjet offers a high quality of color reproduction, resolution, and speed. This makes inkjet a leading digital printing method to challenge conventional printing for photo reproduction and high quality graphics. Generally, inkjet inks are aqueous, dye or pigment based, which are composed of 65-90% water [1]. Due to the drying mechanism, it is critical that an inkjet substrate absorbs ink instantly. Consequentially, substrate quality significantly influences inkjet printing quality. For inkjet paper, the coating structure and quality determine commercial inkjet paper grades and functions [2]. Many efforts have been made by manufacturers and researchers to approach high print performance; such as wide color gamut, optical density, sharpness or resolution, and archival properties.

During this experiment, four anionic and one nonionic polyolefin dispersions from Baker Hughes were tested. To prescreen these additives, drawdown coating tests were performed prior to application by a cylindrical laboratory coater (CLC). Due to the significant impact on coating rheology, the nonionic additive was removed after the prescreening. This paper reviews test results from the four anionic additives.

Methodology
Amorphous silica based coating formulations are widely applied on premium inkjet papers, due to their highly absorbent nature and brightness characteristics [3]. For this study, a typical silica based inkjet coating formulation was applied with and without polyolefin additives. The coating formulation is given in Table 1. Siac dispersion was Pyrogenic (Fumed) Amorphous Silica from Cabot (CAB-O-SPERSE PG 001, particle size: 188

1969 - Gary Starkweather of Xerox Invents the Laser Printer
In 1969 Xerox modified one of their own xerographic copiers to produce what they dubbed, the laser printer; Gary Starkweather, an American engineer and inventor, was one of the principal engineers behind this advancement which would eventually become a multibillion-dollar business for Xerox.
nm, pH: 9.9-10.9). Polyvinyl alcohol (PVOH) was partially hydrolyzed from Celanese (Celvol 203 S). To maintain dispersion stability, PVOH pH value was modified with NH₄OH to be close to that of silica [4]. Starch was modified hydrophobic surface starch (Filmkote 54, National Starch). Optical brightening agent (OBA) was cationic, Leucophor FTS from Clariant. Additives tested included polyolefin dispersions A, B, C, and D (see Table 2). A control without additive was also tested. These names were also used to designate the coated paper samples. A total of five coating formulations were prepared. The final coating solid content was 26.5%-27.5%.

The base sheet used in the coating experiments was a sized paper. The physical properties measured for the base sheet were: basis weight of 62 g/m², Parker Print Surf roughness of 4.05 μm (1000 Pa, soft backing), TAPPI brightness of 86.8%, and paper gloss (at 75°, MD) of 14.3%.

Table 1: Typical Commercial Coating Formulations.

<table>
<thead>
<tr>
<th>Coating</th>
<th>Control</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingredients</td>
<td>Dry Parts Added</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silica</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>PVOH</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Starch</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>OBA</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td></td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Four Anionic Polyolefin Dispersions.

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Viscosity (cps)</th>
<th>Solids (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Functional Polyethylene</td>
<td>10.0-15.0</td>
</tr>
<tr>
<td>B</td>
<td>Functional Polymer</td>
<td>10.0-20.0</td>
</tr>
<tr>
<td>C</td>
<td>Functional Polyalphaolefin</td>
<td>400.00</td>
</tr>
<tr>
<td>D</td>
<td>Functional Polymer</td>
<td>20-30</td>
</tr>
</tbody>
</table>

To identify the influence of tested additives on coatings, an AR 2000 Dynamic Stress Rheometer (TA Instruments) was used to study rheological properties at low shear rates. In addition, a Hercules Rheometer was used to determine rheological behavior at high shear rates (E Bob, 6600 max RPM and Spring Set at 200 kilo dynes-cm, 20.4 Sec).
In 1970 the dot matrix or impact matrix printer debuted, offering an alternative form of a personal printer. This technology uses a print head that runs back and forth across the page, printing by impact. The impact is the striking of an ink-soaked cloth ribbon against the paper, here is where the printing occurs. Unlike a typewriter the letters are drawn out of a dot matrix, which opens the device up for the ability to print more than one type of font and even images, because the print is based on thousands of tiny little dots forming together to create the image.

The coatings were applied by a blade type, cylindrical laboratory coater (CLC) at 3000 ft (762 m) per minute. The target coating weight was 14 g/m². All the samples were calendared with the soft-hot nip calender through 2 nips, at 500 pli (1000 psi on gauge) and 71.1°C (160°F).

Paper roughness was measured by PPS ME-90 (1000 Pa, soft backing) based on TAPPI T555-OM-99. Air permeability, from PPS porosity was also measured under the same conditions. Brightness of coated samples was measured with a BrightMeter Micro S-5 based on TAPPI Standard T452-OM-98 (457 nm light). Paper gloss was measured at 75° using a Novo-Gloss™ Glossmeter based on TAPPI standard T480-OM-99, in both machine direction and cross-machine direction. CIE L*a*b* value of paper samples were measured by X-Rite EyeOne IO SpectroDensitometer. To study the water absorption on coated papers, an ultrasonic water penetration test was performed using an EMCO DPM30. Dynamic contact angle tests, which were related to paper surface energy, were also performed by using FTA 200; and water drops spreading (simulating aqueous ink spreading) were observed too.

Samples were printed with an Epson Stylus Photo 2200 printer using an Ultrachrome 4-picoliter pigment ink. ORIS Color Tuner 5.5.1, one printer RIP software from CGS Publishing, was applied to achieve accurate CMYK tint color [5]. 100% and 20% CMYK tints were printed on each sample. Optical density was measured with an X-Rite 530 SpectroDensitometer on the 100% tint. Print gloss was measured on the 100% magenta tint using a Novo-Gloss™ Glossmeter (at 75°). A TC3.5 CMYK test chart was printed on each sample (at 720 dpi) to determine each samples color reproduction performance. These charts were measured with an X-Rite EyeOne IO Spectrophotometer. ICC profiles were then generated using Profile Maker 5.08 software. The color gamut volumes achieved from the coated papers were derived from CHROMiX ColorThink 3.0 Pro software. All samples were then exposed to over 48 hours to a xenon exposure system, Suntest CPS+, Atlas (@ 765 W/m²) to determine fade resistance. The intensity of light exposure used is equal to 4.5 months of daylight (June) in Florida [6, 7]. The charts were then measured again to calculate their color gamut volumes [8].

An Epson premium photo glossy paper was selected as a reference for some tests. It is a typical resin coated photographic paper of five layer construction. The paper base weight was 250 g/m² and caliper was 10 mils.

Results and Discussion

Brightness and CIE L*a*b*

The largest observed benefit of the polyolefin additives were higher brightness and improved L*a*b*. Paper brightness is related to print contrast and color reproduction, and is one of the key factors for print appeal. Fluorescence optical brightening agents (OBAs) are widely used in inkjet paper. OBAs increase brightness by absorbing light in the UV spectrum (340-370 nm) and re-emitting blue white visible light (420-470 nm) [9]. As shown in Figure 1, all of the tested polyolefin additives significantly increased the brightness of the paper samples. Additive D increased it the most.

In addition, samples containing polyolefin additives showed significantly lower b* values compared to the control. The lower b* values relate to a bluer undertone that contributes to perceived brightness. Additive B and
D have the lowest value, as shown in Table 3. The precise mechanism is not yet clear. One potential mechanism is that these additives might carry or fix the OBA near the coating surface. Another could be that these additives enhance the cationic brightener efficiency. From their performance, it could be interpreted that these polyolefin additives function as efficient OBA carriers [9].

![Figure 1: Paper Brightness.](image)

**Table 3: CIE L*a*b***

<table>
<thead>
<tr>
<th></th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>95.92 ± .08</td>
<td>-.30 ± .08</td>
<td>-1.24 ± .28</td>
</tr>
<tr>
<td>A</td>
<td>96.08 ± .07</td>
<td>-.09 ± .06</td>
<td>-.59 ± .21</td>
</tr>
<tr>
<td>B</td>
<td>96.08 ± .08</td>
<td>.12 ± .11</td>
<td>-.95 ± .33</td>
</tr>
<tr>
<td>C</td>
<td>95.98 ± .08</td>
<td>-.31 ± .06</td>
<td>-1.64 ± .18</td>
</tr>
<tr>
<td>D</td>
<td>96.09 ± .04</td>
<td>.08 ± .04</td>
<td>-3.02 ± .20</td>
</tr>
</tbody>
</table>

**Lightfastness**

Initially marketed inkjet photo paper had a poor lightfastness, or fade resistance. As the uses of digital cameras have grown, consumers want the digital output, from generally inkjet printers, to last as long as possible [10]. Many other documents also require the print to have better archival ability. According to Epson Corporation, a photo paper typically has a polymer layer that protects against fading caused by light and air pollution [11].
In the lightfastness test performed in this experiment, polyolefin additives showed slightly lower color gamut loss when compared with the control, except for sample B. Furthermore, the performance is all very comparable to Epson photo paper. Compared to the commercially manufactured photo paper, with a protective layer and well-controlled quality, the effects of the three tested polyolefin additives were definitely positive. This further confirms the hypothesis based on the brightness test results: these additives function as efficient OBA carriers [9]. The results are shown in Figure 2.

**Color Gamut & Optical Density**

Except for color fidelity and optical density, print quality can be evaluated by the color gamut volumes [8]. A wider color gamut volume results in better color reproduction [6-8]. From Figure 3, tested samples showed color gamut volumes similar to those of the control, except for sample A, which is slightly lower. Additionally, all samples with polyolefin additives have better color reproduction in highlight areas (see Fig.4 top left region) and blue regions in 3D color space, compared to the control. The difference between sample A (lowest color gamut volume) and sample D (lowest b* value) with the control are shown in Figure 4. The lower color gamut volumes of the Epson paper is due to the higher absorbance of ink. In the optical density test, there were no significant differences in optical density between the control and the samples with additives. However, they also had better values than the commercial Epson ink jet paper. For instance, 100% black tint density on sample D (2.07) is 25% higher than the value on Epson (1.49).
Rheology

Rheology significantly affects coating performance and process run ability [12]. Table 4 lists the coating rheology properties, which were derived from the rheological measurements. Three measurements, Oscillation Stress Sweep, Oscillation Frequency Sweep and Steady State Flow were performed; all are commonly used to analyze coating viscoelasticity and flow properties. Onset Point is a critical point where the elastic modulus (G') starts to decrease and the coating dispersion starts to flow.
Table 4: Coating Rheology Properties.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset Point: Pa</td>
<td>2.4</td>
<td>2.9</td>
<td>3.2</td>
<td>3.7</td>
<td>2.2</td>
</tr>
<tr>
<td>G': Pa</td>
<td>169</td>
<td>162</td>
<td>340</td>
<td>187</td>
<td>108</td>
</tr>
<tr>
<td>Z. R. V*: KPa·s</td>
<td>11.2</td>
<td>19</td>
<td>41.8</td>
<td>29.7</td>
<td>4.3</td>
</tr>
<tr>
<td>I. R. V**: Pa·s</td>
<td>.09</td>
<td>.08</td>
<td>.08</td>
<td>.08</td>
<td>.05</td>
</tr>
</tbody>
</table>

* Zero-Rate Viscosity; ** Infinite-Rate Viscosity

Figure 5 shows coating viscosity versus shear rate. Separate testing was done at both low and high shear rates and fitted onto one chart. Compared to the control, three of the additives slightly increased the coating viscosity at low shear rates. Additive D presented the lowest viscosity in the low shear rate range, which could allow an increase in coating solids content. Due to economic considerations, manufacturers prefer to apply coatings at the highest solids possible [13].

In addition, the control presented a slight dilatant behavior in the high shear range. This could contribute to poor run ability, especially using blade type coaters [14]. This dilatant behavior was not observed for the tested polyolefin additives.

![Figure 5: Coating high and low shear rate vs. viscosity (Cross model).](image)

Roughness, PPS Porosity & Water Penetration

Although there is not a uniform interpretation for the ultrasonic water penetration test, some previous research has shown a correlation of these values to paper roughness, air permeability and wetting time [15]. In Table 5, two important parameters are shown. $t_b$ is the time with maximum transmission, which is the elapsed wetting time; $t_s$ is the time with most negative gradient, which refers to peak absorbency time.

1981 - Adobe is Founded

Adobe’s first product was PostScript, a simpler language which went on the market in 1984. At about this time they were visited by Steve Jobs, who urged them to adapt PostScript to be used as the language for driving laser printers. After the success of PostScript they led the industry in the creation of digital fonts.
Samples B and D had moderately shorter initial wetting times. It was observed that all of the tested additives required more time to reach their peak absorbent time, compared with the control. From the long period absorption curves in Figure 6, all of the additives prolonged the water penetration time (or saturated time); with Additive C doing so the most. However, both paper roughness and air porosity were similar for all the samples. Therefore, these additives increase the samples hydrophobic properties, rather than decrease the air permeability. The net effect is that the additives reduce the ink penetration rate into the base paper.

![Figure 6: Ultrasonic Water Penetration in 20 seconds, Y axis is energy transmission rate (r %).](image)

**Table 5: Ultrasonic Water Penetration & Paper Surface.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Con*</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E*</th>
</tr>
</thead>
<tbody>
<tr>
<td>t_w: ms</td>
<td>308</td>
<td>307</td>
<td>107</td>
<td>323</td>
<td>87</td>
<td>37</td>
</tr>
<tr>
<td>t_s: s</td>
<td>3.6</td>
<td>4.6</td>
<td>5.4</td>
<td>7.3</td>
<td>6.3</td>
<td>0.28</td>
</tr>
<tr>
<td>R**: microns</td>
<td>1.17</td>
<td>1.23</td>
<td>1.11</td>
<td>1.17</td>
<td>1.25</td>
<td>2.08</td>
</tr>
<tr>
<td>P**: ml/min</td>
<td>24.9</td>
<td>23.1</td>
<td>23.5</td>
<td>23.4</td>
<td>23.1</td>
<td>161</td>
</tr>
</tbody>
</table>

* Con: Control, E: Epson; ** Roughness, error ±15%; *** PPS Porosity, error ±10%.

![Figure 7: Typical Photo Paper Polyethylene Coating Construction.](image)
Premium inkjet paper, such as Epson photo paper, normally adopts two imaging layers to provide sufficient ink capacity. The first imaging layer is set to fix ink droplets in place; the second layer absorbs additional ink (Figure 7). It also has two extruded polyethylene layers to eliminate ink penetration into the core paper layer and maintain dimensional stability; which also improves smoothness, gloss and anti-curling (back layer) properties [11, 16]. Hypothetically, choosing suitable additives for the second imaging layer might eliminate the need for the top polyethylene layer. If so, inline coating would become possible. However, this is beyond the scope of this paper.

Contact Angle

Figure 8 shows the change of water contact angle on the paper samples in 10 seconds. The angle change represents water spreading. The initial contact angles of the samples with additives are comparable to the control. The Epson paper has a higher initial contact angle because it has a low surface energy protective polymer layer. During the 10-second test, the contact angle of samples A, C and D showed a slower decline than the control, which indicates less ink spreading or ink immobilization. This could provide improved image resolution and sharpness, providing further support that polyolefin additives enhance the performance of the first imaging layer of the photo paper.

The change of droplet volume was also recorded and it is shown in Figure 9. These data were normalized to their initial readings. Combining this data with the above contact angle results indicate that samples A, C and D have less ink spreading than the control. Compared to Epson paper, the contact angle of samples C and D declined slower, while the remaining drop volumes dropped faster than the Epson paper. This indicated that the ink droplet would be well fixed on the spot with less spreading.

1984 - HP Develops the Thermal Ink-Jet Printer

Another personal printer technology that gained and still retains considerable market control soon after its release is ink jet printing. This technology operates by propelling variably-sized droplets of ink onto a page. Hewlett-Packard, Canon, Epson, and Lexmark all share the credit in the development of this printing technology and they remain the four market leaders in sales of ink jet printers for personal use. Because of its low cost and high quality print outs in a wide range of colors, these have become the most popular type of personal computer printers available.
**Conclusion**

Overall, the four anionic polyolefin additives provided improved performance of the paper coatings. Additive D provided the best total performance with positives related to optical properties, print properties and run ability. Additives A, B, and C provided a mixture of positive and neutral test results.

All of the additives significantly increased paper brightness. We theorize that this is related to improved OBA efficiency. Additive D provided good lightfastness. It also provided the ability to control ink spreading, which would improve the image resolution. While all additives eliminated the dilatant behavior observed with the blank control coating, Additive D also reduced the viscosity at low shear rates, which might enable an increase of coating solids content.

**References**


1987 - QuarkXPress Debuts

The first version of QuarkXPress was released in 1987 for the Macintosh. A Microsoft Windows version followed in 1992. In the 1990s, QuarkXPress quickly became widely used by professional page designers, the typesetting industry and printers. In particular, the Mac version of 3.3 (released in 1996) was seen as stable and trouble-free, working seamlessly with Adobe’s Postscript fonts as well as with Apple’s TrueType fonts.
Customized ICC Display Profile
Construction and Concerns
By Reem El Alaleh
Customized ICC Display Profile Construction and Concerns

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Keywords
LCD Monitor, ICC Profile, Matrix-based, Lookup Table

Abstract
With the advent of the modern digital technology, users can capture an image and reproduce it between different media, such as display it on LCD or CRT monitor, print it on desktop printer or send it to a printing press. The challenge is then to maintain the accuracy of image colors during this reproduction. This has led to the development of Color Management Systems. Using these systems, the color reproduction across-media is accomplished using device ICC profiles that describe each device’s color characterization data in a standardized format in terms of a device independent color space (Profile Connection Space or PCS).

ICC display profiles use a matrix transformation or a multidimensional Lookup Table (LUT) to map the PCS to the device colorant space. The matrix transform may be obtained by linear regression. The LUT, however, is usually constructed based on an estimated characterization device model (using nonlinear regression for interpolation functions fit to a set of measurement data) to speed the transformation performance.

Due to the significant role that monitors play in Color Management Systems, their characterization method needs to be accurate and reproducible. This paper evaluates existing display characterization methods for LCD monitors and uses the evaluation results to develop a new enhanced display characterization method that smoothes the display device gamut and reduces measurement noise. A C++ program code is constructed to build a new well-behaved (continuous, differentiable, with continuous derivatives, and invertible) display profile, using the resulting values from the new characterization method. The ΔE error will be computed to evaluate the accuracy of the characterization.

Introduction
In the imaging system world, where different digital devices exist (e.g. scanners, digital cameras, monitors and printers), each with its unique color characterization and color space, it is required to have reliable color reproduction among these devices. Color Management comes into place to assure consistence color transformation and appearance across assorted color devices or media (Adams, and Weisberg, 2002).

Controlling and achieving reliable color reproduction across different devices is the main goal of color management systems (CMS). Two main procedures need to be employed as part of CMS manipulation to achieve accuracy. These procedures involve Calibrating and Characterizing each device that is involved in the transformation.
The device needs to be optimized prior to calibration, to achieve consistency in its behavior. Device calibration involves adjustment of device response in order to match an established condition (Wallner, 2002). Characterizing the device involves using instruments, such as a colorimeter and spectrophotometer, to measure the device response for color signals (from color test charts) that are sent to it. As a result of this procedure, the gamut of the device will be calculated and the characterization data are used to create a special computer file called an “ICC Profile”, which is an important part of the CMS (Bala, 2003).

The first version of the ICC (International Color Consortium) profile was developed in 1993, as a result of establishing the ICC (Reinhard, Khan, Akyuz, and Johnson, 2008). The main reason to create such files is to ease mapping color across different imaging devices (scanners, monitors, printers, etc.) by using each device’s color characterizations data that are stored in special tags to remap the device color space to a standard color space (PCS or Profile Connection Space) to establish a communication across different devices.

The data inside ICC profile are divided into three main parts: a fixed size profile header, which includes homogeneous information that can be found in all profiles, a variable size tag table and the tagged element data (Wallner, 2002).

For accurate color space conversion to and from the PCS, two algorithm models are used: the Matrix/TRC model and the LUT (Lookup table) model. Therefore ICC profiles are divided into two models (Matrix-base and LUT-base profiles), based on the calculation algorithm that is used to convert between color spaces (Reinhard, Khan, Akyuz, and Johnson, 2008). The type of the profile model can be determined by the user of the profiling software.

For implementing these models, each model is required to have a special set of data, which are stored in a special tag type (Reinhard, Khan, Akyuz, and Johnson, 2008). Therefore, the Color Management Model (CMM) will use these data in performing the conversion between different color spaces through the standard PCS color space.

The Matrix/TRC Model
This model structure involves:

3X3 matrix → one dimensional LUT → PCS (CIE XYZ)

The 3 one dimensional LUTs are represented by the Tone Reproduction curves (TRC) (Sharma, 2004). To transfer color between input and output tables, a linear interpolation calculation is performed (Rao, Rosen, Berns, and Carlson, 2005). In this model the PCS will only use the CIE XYZ standard color space (ICC, 2004). The Matrix/TRC model is generally valid for CRT displays, but it can be useful for any device for which the transformation to the PCS is nearly linear.

For displays, the TRC curves also determine the gamma value of the display. Therefore, matrix-based profiles are generally used in monitors, or RGB devices, and they are simple and produce small size profiles (Sharma, 2004).
LUT Model

In contrast with the matrix-base profiles, the LUT-base profiles are complex and large size profiles. The following is the LUT model structure (Sharma, 2004):

\[
\text{PCS} \rightarrow 3\times3 \text{ matrix} \rightarrow 1\text{D input LUT} \rightarrow \text{multi-DLUT} \rightarrow 1\text{D output LUT}
\]

The LUT-based profile can be used for all kinds of device profiles (input, display and especially output) (Wallner, 2002).

To achieve a consistent color appearance for an image across media, each digital device needs to be accurately calibrated and characterized. The characterization methods for input, display and output devices are different depending on the device physical properties. Understanding the fundamentals of each device characterization methods is essential for achieving consistent results in a color reproduction system. The aim of this research is to develop a new accurate approach for characterizing display devices that smooths the device gamut by minimizing any measurements errors or noise.

Experimental Design

CRT (Cathode Ray Tube) and LCD (Liquid Crystal Display) are two widespread types of display technologies. E-papers (Electronic Papers), LED (Light-Emitting Diode display) and OLED (Organic Light-Emitting Diode display) are some new developments of display technologies. LCDs have more advantages than CRT in terms of stability, brightness and sharpness, besides their high resolution, which make them more acceptable as a display device (Bala, 2003).

A dual quad tower Mac Pro with two LCD monitors were used to assist this experiment with the following specifications:

<table>
<thead>
<tr>
<th>Monitors</th>
<th>24” Apple Cinema Display, 1920x1200, LED backlight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20” Acer, 1680x1050, Fluorescent backlight</td>
</tr>
<tr>
<td>Video Card</td>
<td>ATI Radeon HD 4870</td>
</tr>
<tr>
<td>Operating systems</td>
<td>MacOS and Windows</td>
</tr>
</tbody>
</table>

Recalling the fact that the matrix-based profiles are a special case of LUT-based profiles as their structures are less complex, it is easier to control the transformation matrix in the matrix-based profiles to avoid any noise or error that could affect the transformation procedure. Therefore, the focus of this study was finding the appropriate way to control the native matrix-based profile of different displays.

This study is divided into three phases: (1) evaluating the physical behavior of the monitors, (2) determining the system gamma value and construct ICC Matrix-based profiles based on it and (3) evaluating the local transformation matrix of the newly constructed profiles. GretagMacbeth ProfileMaker Pro 5.0.8 and X-Rite

1988 - QMS ships ColorScript 100, the First Color Post-Script Printer

In 1988, QMS distributed the ColorScript 100; this was the first color postscript printer ever produced. The ColorScript offered designers, pre-press, and graphics professionals continuous tone color output, extensive paper size options, and support for an array of color management and color calibration tools.
Monaco PROFILER 4.8.3 software were used to construct all the profiles in this study with the assistance of an Eye-One Pro spectrophotometer as a measuring instrument.

For the first phase a set of native whitepoint ICC profiles were constructed for each display using the two profiling software. The constructed profiles represent the two ICC profiles models i.e. matrix and LUT-based profiles. All the profiles had the same gamma setting (a 1.8 gamma value). The profiles were then selected as the system monitor profile for each display. The main goal of using native profiles is to evaluate the real behavior of the display without any color corrections.

Each evaluated display has a different backlight (LED and Fluorescent backlights) and therefore a warm-up and a brightness tests were applied to evaluate both displays. For the warm-up test a uniform square white (255,255,255) and gray (100,100,100) patches were constructed in Adobe Photoshop CS4 software and displayed alternatively every two minutes. The patches tristimulus values were measured by the Eye-On Pro Spectrophotometer in the intermediate of each period starting form a cold powered up to a total of 2 hour. For the brightness test the same white patch was displayed on each monitor. Both displays were set to different brightness levels and the tristimulus value of the white patch was measured at each brightness level.

Phase two starts with controlling the video card gamma of the two displays through the Video Card Gamma Tag (vcgt) which is part of the monitor ICC profile structure. The actual task that is performed by this tag is to adjust the contrast (or the gamma) of the display by adjusting the contents of the video card look-up table (Apple Computer, 1998).

New native white point profiles were constructed, but with a gamma value of 1. The vcgt tag data were read from all the newly constructed profiles by a customized C++ code (designed using Microsoft Visual Studio 2008 VC++ 9.0). The contents of the vcgt tag were constructed as RGB channels. Linear regression in Minitab 15 was then used to find the slope between each range and the respective vcgt channel value. The inverse value of the graph slope will represent the actual displayed gamma for each RGB channel. The average gamma value of the RGB channel will be considered as the native gamma of that certain display. Therefore, new native white point matrix-based profiles were constructed again for each display using the new calculated gamma value as a native gamma. Knowing the primaries value from the last set of the constructed ICC profiles, local transformation matrices would be obtained and evaluated as the last phase of this study.

**Results and Discussions**

Figures (1) illustrate the tristimulus values of the displayed white patch under different brightness levels for both tested display (Acer and Apple cinema). As expected the XYZ values of the white patch that was displayed on the Apple cinema display decrease with the decreasing of the display’s brightness levels. The fluorescence backlight has a different behavior where the XYZ values of the white patch remain stable and then start decreasing when the brightness level reach 60%. In addition, despite that the brightness level was 0% the measured XYZ value of the white patch at that level was higher than those in Apple cinema display and wasn’t even close to 0.
In 1987, University of Michigan student Thomas Knoll and his brother John Knoll developed an image editing program called ImagePro. Later that year, Thomas renamed his program Photoshop. After the development was complete, John traveled to Silicon Valley to give a demonstration of the program to engineers at Apple and Russell Brown, art director at Adobe. Both showings were successful, and Adobe decided to purchase the license to distribute in September 1988.

Overall, the measured XYZ for both gray and white patches on Apple Cinema display records higher values than those measured in Acer display. For the LED backlight monitor the output levels of the white patch were mostly stable for the whole 2-hour test period and the same results were obtained for the gray patch under all tested profiles (matrix-based and LUT-based). On the other hand, in the case of the fluorescence backlight monitor...
the output levels for the white patch were decreased with the passage of the 2-hour time test, where the output levels for the gray patch under profiles that were constructed by ProfileMaker software had a different behavior that those where constructed by MonacoProfiler. Where, the measured XYZ values for gray level under profiles constructed by MonacoProfiler were more correlated to each other than those constructed by ProfileMaker, where Z values were significant higher.

Next, the average value of the correlated color temperature (CCT) was calculated for the white and gray patches of the whole warm-up test interval for each display using the measured XYZ values of both patches. Figure (4) shows the CCT of the displayed white and gray patches on Acer monitor under different native profiles.

![Figure 4: The CCT of the displayed white and gray patches on Acer monitor under different native profiles.](image)

For an accurate gray level display the CCT of the white and the gray patch need to be correlated to each other, which is not the case for the Acer display. These results might be due the lack of equal gamma in RGB channels, where equal RGB values should produce a natural gray level.

For the second phase of this study ProfileMaker was the only profiling software that was used to construct the new set of the monitor profiles using a gamma value of 1 due to lack of ability to set the same gamma value in Monaco Profiler software. Figure (5) illustrate one example of fit gamma graph to red channel obtained in Minitab software using matrix-based profile for Acer display. The axes of the graph represent the log red channel values from the vcgt tag against the log range values.

![Figure 5: Fit gamma graph of red vcgt channel in Acer display matrix-based profile.](image)
The inverse value of the graph slope represents the actual displayed gamma and in our experiment it would be considered as the native gamma of the display. The calculated gamma value for both displays was 2.2. For accurate behavior of a monitor profile with proper gamma setting the effective vcgt gamma value should be 1. Thus, the vcgt contents of the matrix-based profiles set that had a 2.2 gamma were read again using the C++ program code and were plotted in Minitab. The result values of the affective vcgt gamma value for both displays were 1 which indicates an accurate behavior of the newly set of matrix-based profiles.

The local transformation matrix would be constructed from the contents of the RGB primaries, which can be obtained from the contents of the XYZ matrix data tags (rXYZ, gXYZ and bXYZ) from the monitor profiles (refer to appendix – matrix 1 and 2 for both displays). To evaluate the accuracy of this matrix the XYZ values of RGB primaries along with white and black colors were calculated using the obtained matrices based on the following formula:

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} X_R & X_G & X_B \\ Y_R & Y_G & Y_B \\ Z_R & Z_G & Z_B \end{bmatrix} \begin{bmatrix} (R/255)^\gamma \\ (G/255)^\gamma \\ (B/255)^\gamma \end{bmatrix}$$

where \( \gamma \) is the display gamma. Since the output values from this matrix are normalized, the input values (in this case they are RGBWB color values) were also normalized by dividing them by the maximum color intensity which is 255. In addition the tested profiles had a gamma value of 2.2 which indicates that the color transformation wouldn’t be linear unless the input values were raised to the gamma value. The same primaries sets were displayed in Measure Tool software and measured and also the measured XYZ values were compared with the calculated XYZ values from the matrix.

Based on the compared XYZ values for the white color, the measured XYZ values from the matrix gave approximately D65 white point values, while the calculated XYZ values from the matrix gave D50 white point values. In addition, looking at the white point tag inside all the constructed profiles for both displays, the calculated white point gave a D50 white point value (Figure 6).

![Figure 6: White point tag value inside matrix-based profile for Acer display.](image)

Looking for more correct matrix the measured XYZ values for the RGB primaries were used as new entries for the new constructed transformation matrix for each display (Acer and Apple cinema) (refer to appendix – matrices 3 and 4 for both displays). The same RGB primaries set along with white and black color were used.

1993 - The Invention of the Digital Printing Press

In 1993, the current rival and potential replacement of offset printers was introduced to the world. Digital printing consists of the reproduction of digital images on a physical surface. Though it was traditionally developed for short runs the cost/benefit of increasing the run length has been on the rise and it may soon be a better alternative to offset printing in a commercial setting.
again to calculate their equivalents XYZ value for each display, with the new constructed matrices. This time, the calculated XYZ values for the white point gives an approximate D65 white point values, which is consistence with the pervious measured XYZ value of the displayed white patch. Therefore, these inconsistent results indicate that there is some deficiency in either the ICC profile file itself or the measuring instrument. This requires more investigations.

Another evaluation test for the newly constructed matrix involves constructing a gray scale ramp consisting of a series of gray patches, where its values starts with (0,0,0), (15,15,15) and ends with (255,255,255). The patches were displayed and measured and also were used to calculate their equivalent XYZ values using the new constructed matrix. The compared XYZ values for all the gray patches in the scale ramps were nearly identical, which indicates good behavior of the constructed matrix.

Omitting the luminance information, the chromaticity of the primaries should remain the same. Thus, the chromaticities (Yxy) of the RGB primaries along with the white patch were calculated using their measured XYZ values and the following equation:

\[
x = \frac{X}{X + Y + Z}
\]

\[
y = \frac{Y}{X + Y + Z}
\]

The calculated chromaticity values were then compared with their equivalents that are recorded in the ICC profiles for both displays. For both displays the compared values were close but not identical, which reflects a well calibrated display.

**Conclusions**

Since the evaluation tests verify the accuracy of the new matrix, and based on previous calculations, we were able to determine the native gamma value of a display. Both of these results could be used as an input for a newly constructed matrix-based profile, where a C++ program code would be used to build this new profile. This procedure would overcome the noise or the errors that could be occurred from the profiling software or the instrument itself. If the new matrix-based profiles improved its accuracy, the transformation matrix would be then used to construct the LUT-based profiles, which is the main focus of this study.

**References**

Adams II, R. M. and Weisberg, J.B.  

Apple Computer  

Bala, R.  

Gill, G.
1993 - The Invention of the Digital Printing Press

There are many ways this process differs from the other traditional methods of printing including lithography, gravure, flexography and the letterpress. One of the most coveted advantages this method has over its competitors is the ability for variable-data printing. Every page can be different because there is no requirement for printing plates as there is in most other alternatives. This means that direct mail can be printed and each separate piece can be produced with a different name and address on it. This revolutionized the industry. Also changes can be made to the design or content of the print at a moment’s notice, unlike in other forms where a new plate would have to be produced before the changes can go into effect.
Digital Proofing of Spot Colors for Flexo Packaging

By Sangmeshwar L. Sangmule
Digital Proofing of Spot colors for Flexo Packaging

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Keywords
Digital proofing, Spot color, SmartColour™ iVue, Overprint, Color management

Abstract

Spot colors have a wide range of applications in commercial as well as packaging printing. Accuracy in spot color matching, and its consistency—depends on the pre-media software and digital printers used for the proofing is crucial to the quality control process. Due to the advancements and development in digital printers, inks, proofing substrates and systems, the spot color proofing can be much cheaper compared to the conventional method. Currently, pre-media software does not have ways to deal with spot color overprints, and therefore, there is no way to predict final spot color, in the case print order changes. This research was aimed to study the reproduction of the spot colors with the help of pre-media software such as SmartColour™ iVue, Photoshop, CGS-ORIS through ink-jet printers for flexo packaging.

A test chart was created with three different types of spot color inks—Red, Green, Orange through ProfileMaker 5.0.8. This test chart was printed on a Comco Commander flexographic press with different print sequences on C1S SBS board. The CIE L*a*b* values of printed test charts were measured using MeasureTool software with an X-Rite i1-iO scanning spectrophotometer. The spot colors were proofed on a semi-matte substrate printed on two different Epson Stylus Pro printers. This substrate was printed, using different prepress and color management software: - SmartColour™ iVue, Photoshop, and full CGS-ORIS color tuner. Finally the CIE L*a*b* values for the press and digital printed test chart were compared and for different print sequences ΔE values were calculated, considering the press sheet as standard, which showed the proofing of the spot color and its reproduction through SmartColour™ iVue was better compared to CGS-ORIS and photoshop.

Introduction

Spot colors are the colors, which are made by special mixing of colorants of the inks to create a particular shade (Pekarovicova, 2009, Chung, 2008, Suchy, 2005, Wu, 2007). These spot colors are used for the brand building, company logos, product branding in packaging industry. Due to advancements in pre-media software, instead of using single opaque spot color, the trend of printing overprints of spot color is increasing. As spot colors are mainly used for the packaging industry, therefore maintaining consistency and accuracy of spot colors or overprint of spot colors, right from pre-press to press is the most important from the point of view of brand of company or its logo.

1993 - The Invention of the Digital Printing Press

This method of printing is also more efficient because there is less wasted paper and less chemical waste because the press does not need to get up to color and there is no need to adjust registration and page position relative to the print. Because of these advantages this form of printing is very useful and cost effective for small print runs. HP is a current market leader in this technology with their HP Indigo press. The main uses for this press include general commercial printing, flexible packaging, label printing, folding cartons, and specialty printing.
This accuracy and consistency of colors are dependent on the printers used for proofing, color management system (Sharma, 2004, Hulsman, 2000), media, inks used for proofing printers, and finally the printing process used. In the case of overprinting of spot colors, a few print attributes, such as dot gain, trapping, opacity or transparency, and print order i.e. sequence of the printing color on press, also affect the accuracy, consistency and reproducibility of the final color on press. The results were produced by evaluating color difference between the colors from press versus the proofing devices as well as by studying the effect of print order on the color consistency and accuracy. Three different proofing strategies were tested for correctness in generating solids tones and overprints of spot colors.

**Spot colors**

Spot colors are also called as special colors and are not part of a process set (CMYK). They are manufactured by pre-mixing the colorants to attain certain color renditions. These colors are defined by printed samples or Lab values. These Lab values are independent of the printing press or device. Use of spot color in addition to CMYK increases the color gamut; this increase in color gamut allows more choice from a wider range of colors. Spot colors are used without CMYK for specialty jobs, such as decorative laminates, or for specialty packaging applications printing. Generally, the spot color inks are opaque as opposed to the process colors. Spot colors have been used in all printing process because many times the process colors ink could not produce a specific color required by the customer. Trademarks, product branding, logos of the companies, or package branding are the areas utilizing spot color inks. In many cases, only one color is printed (e.g Coca Cola label), thus it is simple and easy to maintain the accuracy and consistency of the spot color.

**Spot Color Overprint**

Overprint color is obtained when two or more colors overlaps and the process of printing two or more colors overlap is called “overprinting” or “trapping” of colors. Overprinting could be of two or more process colors or spot colors. Use of two or more spot colors gives advantages over process colors for brand building and specialty jobs printing.

**Proofing of colors**

In the printing industry, proofs (Calmer, 2006) are required for the final approval of the job from the customers. Therefore, it is very important for both printer and customers to have accurate and correct proofs before final printing. The proof must be able to reproduce the colors exactly the same as they will appear on press after printing. In order to have the mutual agreement and final acceptability of the proof, printers make a final proof and get approval from the customer, this is known as a “contract proof”. As this contact proof decides the final outcome of the job on the press, so it must be as close as possible to the final printed job on press, with respect to color and quality. The conventional method of proofing used by any printing process is tedious and much more time consuming. In the case of gravure printing, small gravure cylinders are manufactured and prints for proof are taken using the same substrate and ink. This process is costly and more time consuming. Due to the advancement in the digital printing, it is possible to print on digital printers and proofers short run jobs with high quality and desired level of consistency in color at low cost. The unique properties of the ink jet printers to produce...
short run jobs in a simple way makes their use more versatile for pre-press proofing for the commercial printing. The digital printer can create the prints, which can mimic the press proof using color management workflow, including ICC profiles for different devices such as printers, scanners, or monitors.

**Principle of Ink-jet Digital Printing**

Ink-jet printers print small droplets of ink (Bandyopadhyay, 2001, Brett, 2001, Cameron, 2006, Kipphan, 2001), which flow through an array of nozzles, onto paper. Ink droplets are formed by controlling the pressure applied onto the liquid in the ink reservoir, as these ink droplets flows through the nozzle. Currently many techniques are available for achieving this type of printing. Two main principles of ink jet printing are drop-on-demand and continuous ink jet printing. The ink-jet digital proofing devices used for this project are an Epson Pro Stylus 7900 printer, an Epson Pro Stylus 9800 printer. These printers use the drop-on-demand technique to form droplets of ink on the substrate. The important feature of drop-on-demand technology is, its ability to generate ink droplets only when they are required, due to this reason there is no need to control the excess droplets and their re-circulation. To form the ink droplets electronically for these printers, piezoelectric technology is applied. It is a simple and widely used technique for ink-jet printing. Using the phenomenon of the piezoelectric effect, small electronic pulses are given to a crystalline material, which expands it. The piezoelectric effect helps to generate the pressure pulses intermittently depending upon the electronic signals received. Mechanical simplicity, simple logic, low cost of hardware, and simpler ink formulation are few of the advantages of the drop-on-demand technology. Slower dot ejections, and sensitivity towards vibrations, are the disadvantage of drop-on-demand.

**Ink-jet Digital Proofing System**

An ink-jet printer works with spectral data of the inks for printing a proof. Digital printing uses numbers for the printing the color. Accuracy of matching the proof to press will depend on how accurately the digital color numbers can be altered in accordance with the printing characteristics. Use of color management allows ease of handling in digital color data processing, which can help to print digital proofs that mimic the printing press. Ink-jet printers, substrates for printing (Bandyopadhyay, 2001, Cameron, 2006, Graindourze, 2001) inks, and controlling software of color management system are the main component of ink-jet proofing system. All these components

1993 – The International Color Consortium was Founded

In 1993 Adobe, Agfa, Apple, Kodak, Microsoft, Silicon Graphics, Sun Microsystems, and Taligent formed the ICC. The purpose of this group was to promote the use and adoption of open, vendor-neutral, cross-platform color management systems. The current version, 4.2, allows the matching of color when an image is moved between applications and operating systems, from the point of creation to the final print.
affect accuracy of proof-press color matching in digital proofing systems. There are ongoing efforts to develop new proofing systems that will meet the requirements like simulation of color of paper, effect of gloss, spot color reproduction and remote proofing.

Print Media for Proofing

Print media (Bandyopadhyay, 2001, Cameron, 2006, Graindourze, 2001) properties are important from the point of view of ink and paper interaction and achieving desirable color matching quality, and reproducibility. Color gamut and color stability of proofing systems are completely dependent on the combination of ink and media, and predetermine color gamut and color stability of proofing systems. Therefore, final color matching quality and detailed rendering quality is dependent on the print media, namely their physical properties. These physical properties help to control ink penetration, and ink spreading and absorption. Thus porosity of the substrate decides the penetration of ink droplet into the fibrous network. The ink receptivity of the paper network determines how well the ink interacts with the paper. Print defects like feathering and bleeding may be observed, so in order to avoid these print defects, the ink droplets must absorb quickly. To have better control on the strike in or absorbency of ink-jet ink droplets, print media usually have a coating layer on its surface. Absorbency of ink is determined by the smoothness or roughness of the surface print media, pore structure, and surface energy. Low roughness and porosity gives low absorbency of the ink, resulting high ink holdout, and glossy print along with high print density. Whereas high roughness gives more ink absorbency, which results in more penetration of ink vehicle into the pores, giving a dull and matte finish to the print. Properties like gloss, optical density, dot shape, image brightness, color, drying time of ink and it’s compatibility with surface depends on the coating layer are very important. They also play a significant role in lightfastness and water fastness of the print.

Printer Control Software

Generally, to control the ink-jet printer, two kinds of software are used. One is the ink-jet printer driver, which is provided by the printer manufacturer, and the second is third party raster imaging processor software, i.e. RIP software. Which kind of workflow is to be used, is dependent on the end application, whether RGB or CMYK workflow will be employed. Printers that are controlled by the printer driver software print the data files in RGB mode. The RGB printer is controlled by three channels. These printers convert the RGB image sent by the user into the internal CMYK separation using proprietary transformations that are unavailable to the user. PostScript printer drivers and third party RIP software are able to process to process the data directly. Vector and raster data are interpreted for a specific postscript printer either in RGB or CMYK mode, by a Postscript interpreter or the third-party raster imaging processor (RIP) software. When a job is to be processed, it is sent to the RIP software where the PostScript page description is interpreted and then vector and raster images are converted into bitmapped data files. This conversion of image into bitmapped data files helps to interpret and control commands of the output. Therefore, a RIP can control the CMYK inks directly, which results a more precise and accurate digital color reproduction. A RIP performs three main functions, which are handling color management, creating halftones and preparing the color separations for the device. The RGB components for each pixel of the original image are converted to CMYK or a spot color component through the color separation process. In order to have predictable and repeatable results through the printer, some of the RIPs also have functions of device
calibration and linearization processes. Due to linearization processes, the ink-jet printer is able to print the right amount of ink onto the substrate, which ultimately helps in obtaining a larger color gamut. Most accurate color matching can be obtained by integrating third-party ICC-profiling software and hardware along with the RIPs with the linearization process. Use of built in color management functions helps in defining the color space in software at pre-press and RIPing stage to attain the optimal end result.

**Color Management requirements for proofing**

The following are the requirement of color management and contract proofing:

- Consistency of reproduced color: All the proofs reproduced from same image or data must look the same in image quality, as well as in color reproduction.
- Color gamut: At least the color gamut of the all the printing presses (litho, gravure, and flexo) must be covered by the digital proofing machine.
- Color fastness: The output generated by the proofing machine must not change or fade its color for at least 3 months.

The basic requirement of color management in imaging is calibration, characterization, and adjustment (conversion) of all the devices, used in the entire workflow. This helps to reproduce color images more accurately and close to the original. Apart from color consistency and accuracy of proof, cost-effectiveness, and reliability are other basic needs for the proofs.

**CGS-ORIS and SmartColor iVueTM color proofing software**

CGS ORIS

CGS is third party RIP software used in the imaging industry. CGS provides ORIS software with many tools for the color managed workflow. This software takes into consideration the process and people, for producing accurate colors. The people involved might be designers, publishers, print buyers, and pre-press operators. ORIS software creates accurate color soft proof PDF files. A Few of the tools are ORIS Press matcher, ORIS Ink saver, ORIS package pro etc.

1) **ORIS Press matcher:** Color consistency is maintained by using the ORIS Press matcher irrespective of the printers or the printing processes used. It takes the defined characteristic of the each printer, and applies them to a single file, thus by creating an individual file for each output. Its main use is for applications, where the jobs are processed at various locations and on different press.

2) **ORIS Ink saver:** This tool helps to maintain the color consistency, even after automatically applying the UCR (Under Color Removal) and GCR (Grey Component Replacement) to the incoming files. Due to this application of UCR and GCR to the incoming files, it can reduce the requirement of ink consumption is reduced by almost 25%.

**1999 - Kodak Teams Up with Heidelberg and Announces DURALIFE Paper**

Kodak sold its digital printer, copier/duplicator, and roller assembly operations to Heidelberger Druckmaschinen AG. The two companies also expanded their joint venture, NexPress, which was created in 1998. Kodak also announced DURALIFE Paper, a revolutionary new photographic paper for snapshots. It set benchmarks in virtually every performance category, including tear-resistance, durability, brightness and whiteness, image sharpness, and resistance to curling.
3) ORIS Package pro: This tool is mainly developed for the packaging market. This tool manages the spot colors using separate color tables, instead of converting them to CMYK. This allows the use of the ICC profiles in all the aspects of packaging production.

**SmartColor iVueTM**

SmartColor iVue™ plug-in can be installed as an option in Adobe® Photoshop and Illustrator. The software is equipped with the SmartColour Color Picker (Figure 1), which enables using a specific ink on a discrete substrate and predicts color appearance of an actual print. The color picker allows individual selection of colors for any spot element, either from brand-specific libraries or general libraries. All libraries contain colors from common substrates and print parameters allowing selection among those colors that can be achieved on press. The iVue software enables one to predict how the job will look like on the press with a specific substrate and printing process used for it. Sun Chemical’s Global Shade Library has various color shades, which were developed by previously proofed, printed, and measured inks for particular substrates and printing processes.

![SmartColour iVue Color Picker](image)

**Figure 1:** Example of SmartColour iVue Color Picker with the Gravure Library Shades.

**Methodology**

For this project, a special test chart was created called as ROG iO, with three different types of spot color inks-Red, Orange, Green, through Monaco profiler and ProfileMaker 5.0.8. For the flexo trial, the inks used were solvent based spot colors: orange, green and red. These inks were picked from the Sun Chemical’s global shade library via the SmartColour iVue software. C1S- SBS (One side coated solid bleached sulfite board) was selected for press printing.
Table 1: Physical properties of the C1S-SBS board.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Property</th>
<th>Instrument reading</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Emveco Roughness</td>
<td>Emveco</td>
<td>microns</td>
<td>1.08</td>
</tr>
<tr>
<td>2</td>
<td>PPS Roughness</td>
<td>PPS (1000 CP)</td>
<td>microns</td>
<td>1.52</td>
</tr>
<tr>
<td>3</td>
<td>Opacity</td>
<td>Technidyne</td>
<td>Percentage</td>
<td>94.3</td>
</tr>
<tr>
<td>4</td>
<td>Brightness</td>
<td>Brightimeter</td>
<td>Percentage</td>
<td>85.58</td>
</tr>
<tr>
<td>5</td>
<td>Caliper</td>
<td>Technidyne</td>
<td>mils</td>
<td>14.32</td>
</tr>
<tr>
<td>6</td>
<td>Gloss @ 75° angle</td>
<td>Technidyne</td>
<td>Unit</td>
<td>56.4</td>
</tr>
<tr>
<td>8</td>
<td>L* a* b* values</td>
<td>X-Rite i1-iO</td>
<td>Unit</td>
<td>95.8, -0.60, 4.35</td>
</tr>
</tbody>
</table>

**Flexo Press Run**

The test chart ROG iO has 264 patches with tone steps from 10% to 100% dot for each color along with this it has different overprints of the three inks. These overprints are of two color and three color overprints depending on the channel. The test target is shown at Figure 2. Flexographic photopolymer plates were used for printing the test chart on the Comco Commander flexo press in the WMU Printing Pilot Plant, with different print orders of spot colors on the C1S SBS board. The CIE L*a*b* values of the test chart were measured using MeasureTool software, using an X-Rite i1-iO scanning spectrophotometer. These CIE L*a*b* values were considered as reference values (treated as standard) for proofing overprints on the digital printers.

**2005 – Adobe Aquires Macromedia**

Adobe acquires Macromedia to create one of the world’s largest, most innovative and diversified software companies. Some of the programs aquired by Adobe in the merger were the HTML editing software Dreamweaver, Fireworks, and Flash.
Proofing Methodology

For proofing purposes, the Epson Semimatte substrate was used for both the printers, i.e. Epson Pro Stylus 9800 as well as on the Epson Pro Stylus 7900. The test chart ROG iO was printed with the aid of SmartColour™ iVue, Photoshop, and ORIS-CGS software. The tone value increase (dot gain values) obtained on the press were applied in SmartColour™ iVue, which has this special feature that takes in account the tone value increase for more accurate and consistent color reproduction. The opacities of inks were calculated by using the BYKO charts, which were printed with the three spot colors on a K-proofer and the X, Y, Z values were measured for each ink on the X-Rite i1-iO scanning spectrophotometer. These calculated opacities of ink were entered in Photoshop and CSG ORIS software for developing of the same design. The CIE L*a*b* values of all test charts printed on two different digital printers with different software were measured and compared with the press sheets overprinted test chart.
for spot color matching and comparing the level of accuracy.

ICC profiles were created for each substrate and printer. In the case of the CGS ORIS software, the printers were linearized and calibrated with the inbuilt tool provided by the software.

**Results and Discussion**

This project focused more towards finding the right substrate, proofing system, and proofing printers that will help to reproduce the spot colors digitally for flexo packaging more accurately and consistently. Along with this, we try to find out the ability of each software and digital printer for reproduction of the overprints of spot colors.

**Overall comparison of two digital printers for spot color reproduction**

As mentioned earlier that the spot color reproduction depends on the digital printers used, so we used two different printers, which were Epson pro stylus 7900 and Epson pro stylus 9800 for proofing the test chart, with the same substrate. The difference in two printers is in their inking system. The Epson pro stylus 7900 has High definition range ink technology, while Epson pro stylus has UltraChrome K-3 technology.

Figure-3 shows the comparison and performance of two different printers for the reproduction of the spot colors considering single color, two color and three color overlap for the test chart on same substrate. For this purpose the two different delta values i.e. \(\Delta E_{2000}\) and \(\Delta E_{CMC}\) were calculated for all the 264 patches for all the proofs produced on these two different printers.

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2007 – Amazon Releases the Kindle

In 2007 Amazon released their revolutionary e-book, the Kindle, which uses E-Ink and electronic paper to display text and images. With a completely wireless infrastructure, users can choose from a catalog of over 420,000 titles and can store thousands of titles on a single device. Though this trend is changing the publishing world, it does not signal the end to traditional books. Every year the publishing industry breaks its own records for the number of titles published annually. Many analysts feel that traditional books will co-exist with e-books for generations to come.
Figure 3: Comparison of two different digital printers.

It can be observed from the figure that the reproduction of the spot colors by the Epson pro stylus 7900 printers was slightly better compared to the Epson pro stylus 9800. The color reproduction capability of the Epson pro stylus 7900 is more compared to Epson pro stylus 9800 because of the HDR ink technology which has additional two colors i.e. orange and green, which Epson 9800 does not have. This is the main reason the ΔE values were less in both cases irrespective of the software used for proofing purpose. This result well explains that the use and technology of the digital printer affects the color reproduction and its consistency for proofing purpose.

Spot Color reproduction results for single color proofing

This part of paper discusses more about the reproduction of just a single spot color for two different printers and three different software. The ΔE values for all the single color which were in the channel#1 of the test chart were averaged for each printer and software and plotted as shown below for the two different ΔE’s.

![Proofing Results for Single Color](image)

Figure 4: Proofing results for Single color reproduction.

The Figure 4 clearly shows that SmartColor iTVue™ reproduced the single spot color more accurately compared to ORIS-CGS and photoshop on both the printers. SmartColor iTVue™ could reproduce the single color with ΔE CMC as low as of 2.7 on the Epson 7900 and 3.36 on the Epson 9800. As actual tone value increase observed on press for each spot color was entered into SmartColor iTVue™, this helped to reproduce the single spot color more accurately. This option was not available for ORIS-CGS and Photoshop. Though the proofs for ORIS-CGS and Photoshop were obtained using the actual calculated opacities of the inks, the reproduction of single spot color...
color on both printers showed higher values of ΔE CMC, which were in range of 5.5 to 7.7, and 7.8 -8.3 for ORIS –CGS and photoshop respectively.

Now considering the reproduction of two spot color overprints for three different software and two printers, the trend observed for reproduction of colors on digital printers was the same as that of single color, i.e. SmartColor iVue™ produced better colors followed by ORIS-CGS and Photoshop. But in this case the ΔE CMC values for all the software were higher compared to single color reproduction. One of the reason of these higher ΔE CMC values might be the ink sequence and trapping of ink on press.

2009 – HP Introduces the World’s First Web-Connected Home Printer
The HP Photosmart Premium allows users to print from the web using the printer as their only access device. A host of applications are provided, including the ability to search movies, buy tickets in advance, and print tickets at home as well as the ability to search for directions and print them off directly. This signals a new wave of web integrated printers that may soon become the industry standard within the next decade.
The color reproduction for three color overlap for all the software gives the highest ΔECMC values for both the printers. The ΔE CMC and ΔE 2000 for three color overlap are tabulated below in Table-1.

Table 1: ΔE Values for three software on two different printers.

<table>
<thead>
<tr>
<th>Software</th>
<th>iVue</th>
<th>ORIS-CGS</th>
<th>Photoshop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epson 7900</td>
<td>7.80</td>
<td>5.96</td>
<td>7.40</td>
</tr>
<tr>
<td>Epson 9800</td>
<td>8.41</td>
<td>6.91</td>
<td>11.82</td>
</tr>
</tbody>
</table>

Conclusion

• From the results obtained for two different printers on the same substrate, it can be said that the ink technology used for digital printers affects the quality and consistency for reproduction of spot colors and their overprints. The accuracy and consistency can be improved with the latest ink technologies used for proofing purposes.
• Considering the proofing systems for digitally matching of spot colors for flexo packaging - SmartColor iVue™ software produced the best results compared to CGS-ORIS and Photoshop. As it produced the lower ΔE values on Epson pro stylus 7900 and Epson pro stylus 9800 digital printers, for all the channels of the test chart relative to the press sheet.
• SmartColor iVue™ was able to produce the lowest ΔE CMC of 2.7 for single spot color proofing.
• Other than color management systems, proofing substrates, digital printers, factors such as print sequence, trapping and actual ink opacities also affect the reproduction of spot colors as it was clearly observed that the ΔE values were increasing as the number overprint colors increased.

Literature Cited


Examining The History of Print

After examining the history of print, it is easy to see the parallels between major developments in the print industry and major advancements culturally for mankind and I think this speaks to the importance of this science. It is a driving force for social change, and often times it goes completely unnoticed.
Appendix
Production Notes

Design and Prepress

The “Evolution-A History of Print” journal was designed and built by the WMU TAGA students. Adobe Illustrator, InDesign, and Photoshop were utilized when designing this journal. Adobe InDesign was utilized for page layout and imposition for the journal.

Production

The student journal “Evolution” was entirely produced by the members of the WMU TAGA Chapter unless otherwise noted.

The WMU TAGA student chapter chose to print the Evolution journal entirely in-house in 2010. The bottom gold bar utilized for the background of the timeline was produced on the Shinohara 60 II P offset press. The printing of the gold bar was a double hit on both sides to obtain optimal ink coverage and esthetic appeal. A clear varnish was applied on the gold bar to seal the metallic ink in preparation for digital printing. The variable data for the Evolution journal was printed utilizing the Cannon imagePRESS C1+. Sappi Flo Gloss Cover 100# was utilized for the cover and Flo Gloss Digital Text 80# was utilized for the text of this journal.

Problems Encountered

When dealing with a hybrid of digital and offset printing methods we found that the gold bar must be covered with a varnish. This varnish sealed the gold ink to the page to ensure that no rub-off would occur on the electrostatic drum of the Cannon imagePRESS C1+. We also found that the gold ink had drying problems because of the thickness of the ink film that was layed down.

Outside Assistance

Thompson-Shore in Dexter, MI assisted with the folding and binding of this journal. The WMU TAGA members traveled to the Dexter, MI plant to assist with the binding of all journals. The Evolution journal features a case bound book. Xpedx graciously donated the paper utilized during the printing of this journal.
The student journal “Evolution” was entirely produced by the members of the committee at the Department of Paper Engineering, Chemical Engineering, and Imaging at Western Michigan University unless otherwise noted. This section provides production notes including materials and methods utilized in the preparation of this journal.

**Software Used**
- Adobe InDesign CS4
- Adobe Illustrator CS4
- Adobe Photoshop CS4
- Adobe Acrobat 9 Professional
- Microsoft Office 2007

**Typography**
- Vivaldi, Times, Calibri, 1454 Gutenberg Bibel, SWGothi, AquilineTWO, Francisco Lucas Briosa, Century, Garamond, Baskerville Oldface, Times New Roman, Helvetica

**Paper**
- Cover: Flo Gloss Cover 100#
- Text: Flo Gloss Digital Text 80#

**Ink:**
- Kohl and Madden Pantone Gold

**Toner:**
- Vivid-Toner (V Toner)
- CMYK + Clear Coat

**Printing:**
- Shinohara 60 II P Offset
- Cannon imagePRESS C1+
- This journal was printed at Western Michigan University

**Finishing:**
- Hard cover binding was performed at Thompson-Shore in Ann Arbor, MI.
Industry Support

WMU Printing Pilot Plant

Department of Paper Engineering, Chemical Engineering, and Imaging
The WMU TAGA Student Chapter members would like to acknowledge the following people who supported us throughout the preparation of the technical papers and production of the Evolution journal in both the printed and electronic version.

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References

