Implications of Thermochromic Ink

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Abstract

In a global economy the packaging industry has explored the usage of thermochromic ink to create a visual impact. The purpose of this study was to measure the color intensity of Matsui Chromicolor screen printing ink. The appearance of a product has the ability to attract attention from potential consumers.

For this study both the scientific method and elite and specialized interviews were used to determine the reliability of Matsui Chromicolor ink. Samples of both Brilliant Green Type 27 and Fast Yellow Type 27 ink were heated in a scientific oven according to Matsui specifications. The results indicate that Matsui has been able to reach a degree of consistency in their ink, which could lead to consistent production, and appearance of color on products printed with thermochromic ink. There are potential areas for improvement within the thermochromic ink industry. However, further research is needed to test the accuracy of thermochromic ink.

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Chapter 1: Introduction and Purpose of Study

Screen printing, also identified as silk screening, qualifies as a versatile printing process that can be printed on a variety of substrates including paper, plastics, glass, metals, and fabrics. Common products created by the screen printing industry include labels, decals, signs, posters, and textiles. Screen printing consists of three elements: ink, a rubber blade (squeegee), and the mesh (screen), which is the image carrier. To create a physical image a stencil is produced on porous mesh. The mesh is stretched over the frame, which creates the screen. Thick screen printing ink is placed on the screen and is forced through the mesh opening using a squeegee. Pressure applied by a person or a press causes the ink to pass through the mesh onto the substrate, ultimately forming a design. This screen printed design creates a unique visual impact.

In a competitive marketplace dynamic images can be screen printed to differentiate a product and garner attention. Water-based thermochromic ink has emerged as a new technology for screen printing. Thermochromic ink is a specialized dynamic ink that changes color with exposure to different temperatures. In the 1970s, mood rings demonstrated temperature-changing ink as the ring changed color depending on body temperature. Novelty uses of thermochromic ink include measuring the temperature of a liquid in a coffee cup or knowing when to take a bottle of syrup out of the microwave by the color of the label. Even though packaging is primarily printed with offset lithography and flexography, there is a market for screen printed thermochromic ink.
This study asks: What are the prominent applications of thermochromic ink for the packaging industry? Broadly this research question could be answered as any screen printed or packaged product that needs to change color or appearance at a specific temperature. However, the

reliability of thermochromic ink may be a limiting factor. Successful applications of commercial products printed with thermochromic ink include battery life indicators and temperature markers on drink containers. Thermochromic ink incorporates dynamic images into packaging, where the ink is activated when the temperature of the contents change. These inks are activated electronically through a thin layer of polymer that is printed as a laminate on the reverse side of the substrate. An example of this is the Coors Light can in which the mountains turn blue when the liquid is cold (Johansson 7).

Similar to other printing processes there are a few factors to consider when screen printing thermochromic ink including the mesh count of the screen, amount of ink laydown, and the temperature sensitivity of ink. The purpose of this study is to measure the color intensity of Matsui Chromicolor screen printing ink. This variable directly impacts the appearance of a product, which contributes to its ability to attract more attention. Once reliability is established, then thermochromic ink will be successfully adapted to the screen printing process.

Chapter 2: Literature Review

During the hunter-gather period (Paleolithic), humans consumed fresh produce from the surrounding area, thus there was little need for transportation or storage. In time, sophisticated societies arose, leading to containers formed from natural materials, including hollowed logs, woven grass and animal organs. Finally, other types of metals and pottery were discovered leading to other packaging forms (Berger 1). Currently, packaging is prevalent from preserving to distributing goods. According to Joseph F. Hanlon, Robert J. Kelsey, and Hallie E. Forcinio authors of *Handbook of Package Engineering* the major functions of a package are "to protect, contain, carry and dispense a product" (1). As stated by Dr. Paul Butler, a smart packaging consultant, smart packaging is defined as "packaging that does more than simply protect, store, and give information about the product" (Mohan 158). Smart packaging integrates mechanical, chemical, electrical or electronic forces within the package (Mohan 158). According to a technical report from BCC Research published in January 2008 "the global market for active, controlled, and intelligent packaging for the food and beverage industry is expected to grow from $15.5 billion in 2005 to $23.6 billion in 2013" (Mohan 158). As the packaging industry expands it becomes increasingly important to differentiate products in order to gain revenue.

The package design, otherwise known as the silent "salesman" plays a crucial role in the profitability of a package. The competitive marketplace for packaging instigates the need for a package to increase its visual impact to attract more attention. One viable competitive advantage for packaging is creating printed dynamic imagery or text through the application of thermochromic ink. Dynamic images are created through the combination of static ink layers and

dynamic color changing ink layers. The dynamic ink layers can be "brought to different optical states where they change color or become more or less colorless revealing underlying static ink, thus changing the image" (Johansson 39). Although thermochromic ink is more expensive than process ink it adds value to the product and has the opportunity to promote the product ("Packaging Design The Silent Salesman").

One method of adding value to your product is printing with dynamic ink. Thermochromic textile screen ink, a dynamic ink, is defined as a "change in color of a substance as its temperature is varied" (Johansson 9). Thermochromic printing ink is a mixture of thermochromic pigments and a binder. Thermochromic textile screen inks activate due to temperature-induced chemical incorporated into the ink. This color change can either be permanent (irreversible) or the original color can be regained (reversible) upon cooling. Irreversible thermochromic inks are invisible until exposed to high temperature, at which point an intense color develops. Once this color progresses it will remain constant or it will change colors leaving a permanent indication of a temperature change. Reversible thermochromic inks develop color when heated and return to original color when temperature decreases. Reversible and irreversible inks fall under two categories of thermochromic ink ("QCR Solutions Corp").

The two major types of thermochromic inks are leuco dyes and liquid crystals. Leuco dyes are used more frequently in screen printing than liquid crystals. The activation temperature of thermochromic leuco ink "is determined by the temperature where the solvent changes from solid to liquid state, causing the color forming components to be in contact below the transition temperature (coloured state) and separated above this temperature (discoloured state)" (Kular,

Gunde, Friskovec 203). Leuco inks can be printed through offset lithography, letterpress, gravure, flexography, or screen printing. The leucodye inks can be printed using water-based or UV-cured inks (Kular 203). A leucodye requires chemicals to work simultaneously in a system to function. This special system of materials is microencapsulated to protect the materials from the ink. These microcapsules "contain the complete color-changing thermochromic system, which, when added to inks, give them their color-changing properties" (Homola 2). The microcapsules average between three to five microns, which is ten times larger than average pigment particles. To screen print large particles course screen mesh and heavy ink laydown are necessary. The advantages of leuco dyes are the cause of their popularity over liquid crystals, the second type of thermochromic ink (Homola 2).

The second type of thermochromic ink is liquid crystals. Two disadvantages of liquid crystals are they are difficult to work with and are more sensitive to temperature change. Liquid crystal thermochromic ink is not recommended to use with packaging due to sensitivity to small changes in temperature. Liquid crystals start at the color black under their temperature range, go through the colors of a rainbow, then return to black above their temperature range. Liquid crystals are used in mood rings, which change color from black (when cold) to another color then back to black upon heating. Other applications of liquid crystals include aquarian thermometers and medical forehead thermometers. Although liquid crystals are a type of thermochromic ink they will not be explored further in this research due to their limited printability (Kular 203, Coloroyal).

Matsui International Company produces both leuco dyes and liquid crystals. Matsui International Company, Inc., was founded in 1911 offering a range of inks, pigment and ink products with a variety of applications including wallpaper printing, textiles, and specialty markets. Matsui's specialty department provides quality thermochromic ink to a broad range of industries. Chromicolor, Matsui's thermochromic ink line consists of temperature-sensitive, color-changing inks, resin and paint concentrates. Chromicolor inks continue to expand "leaving a colorful mark on international markets" (Matsui). Matsui's two-part Chromicolor inks are water-based.

Thermochromic water-based screen ink provides optimal shelf life due to an easily mixed two-part ink system that increases the possibility of controlling color intensity, press performance, and opacity. The appearance of a product is dependent on factors such as the type of printing press, substrate and additive. Ideally, thermochromic water-based screen printing ink is suited to flat bed screen printing processes onto paper or board substrates. For thermochromic ink that will be activated at a cold temperature, one should use matt laminate for optimum effect. In order to obtain a glossy finish, a laminate or spot varnish is used. This laminate or spot varnish will also increase rub resistance, which is an important factor in packaging. A package needs to retain its quality throughout transportation and hold similar ink color to appeal to a customer. However, there are other factors that contribute to the appearance of a product aside from the type of press, substrate and additive ("Thermochromic").

To ensure that a quality thermochromic product is reproduced properly the mesh count, activation temperature, and color intensity must be controlled. The optimal screen configuration in screen printing is contingent upon the desired opacity and color of the finished product. Hence, the ink film thickness and color intensity of thermochromic ink are directly related. Using a higher ink volume will increase a product's color intensity "below its activation point and also the level of residual color when above its activation point" ("Thermochromic"). Color intensity is defined as "the sheer amount of light from a surface or light source, without regard to how the observer perceives it" (Frasier 544). Intensity is measured with a spectrodensitometer, which measures the full spectrum of light and color including density and LAB, which is a color space (Frasier 31). Screens with a 60 to 120 mesh count are required to achieve the heavy laydown necessary for adequate opacity and color intensity. Another factor for acquiring proper color intensity is the activation and deactivation temperature of thermochromic ink. These temperatures are based on the specifications released by the ink manufacturer. After thermochromic ink is activated it must be cured at the proper temperature, 266 degrees Fahrenheit for approximately two minutes in order to be set. The temperature at which the ink becomes fully cured is called the fusion temperature. Once the printer controls these factors, reliability is established and further unique applications will be probable ("Thermochromic").

Not only are thermochromic inks changing the packaging world, but they are also influencing the office environment. A unique application of thermochromic ink is dynamic wallpaper. A prototype of dynamic wallpaper explores the potential of ambient information decoration. By glancing at the wallpaper employees and customers are able to get a general sense of how busy the office is during the week by observing the abstract pattern of triangles that appear. Yellow

shapes symbolize an hour of the week. Dark purple shapes change color to a lighter purple when an event is scheduled to take place. These shapes change color due to heating pads that are placed between the wall and the ink-coated paper. The activation occurs due to a "phidget interface kit that connects the heating pads to a laptop, so that the data from a Microsoft Outlook calendar generates the pattern" (Xing). This wallpaper demonstrates the wide range of capabilities of thermochromic ink once ink film thickness and color intensity are controlled.

Chapter 3: Research Methods and Procedures

The purpose of this study was to measure the tolerance of color visibility of Matsui Chromicolor ink. Thermochromic ink has applications in both the screen printing and packaging industries. In order to provide inclusive research I employed the scientific method coupled with Elite and Specialized interviews and content analysis derived the answer to my research question.

The Scientific Method was the primary research method I used. According to Dr. Harvey Levenson the Scientific Method involves five steps:

1) Identify and define the problem
2) Formulate a hypothesis
3) Collect, organize and analyze data
4) Formulate conclusions
5) Repeat, verify, and modify the research (Levenson 22)

The fifth and final step was crucial and set apart this research method. It is critical that one is able to repeat and verify the experiment while reaching the same conclusions. Some critiques of the Scientific Method "claim that the results and conclusions drawn from such research are often inapplicable in a practical situation because they do not address issues of market interest and demand, and other human considerations" (Levenson 22). The purpose of using Scientific Method was to limit human variability in the testing process. To counter these drawbacks of the Scientific Method I performed Elite and Specialized interviews. Elite and Specialized interviews are an applied research method. These interviews are performed through gathering information

from professionals and executives in the graphic communication industry who view themselves as important (Levenson 22).

I hypothesized that Matsui thermochromic ink would visually appear and disappear according to the specifications set by Matsui. In order to measure the tolerance of color visibility I used a scientific oven, Lab Companion Model ON-01E. According to Matsui specifications the Type 27 Chromicolor ink color should appear below 75.2 degrees Fahrenheit and the color should disappear above 91.4 degrees Fahrenheit (Matsui). Thus, I visually tested these specifications by setting the Lab Companion oven to 75.2 degrees Fahrenheit and 91.4 degrees Fahrenheit.

Along with the scientific method, I also employed Elite and Specialized interviews as my second research method. In order to glean information from those interviewed, I demonstrated my knowledge of thermochromic screen printed inks, hence the interviews took the form of a conversation. Those who were interviewed became part of the research team and, as the researcher I gained additional information about thermochromic ink (Levenson 27). I interviewed three members of the graphic communication industry. The first interviewee was Ryin Kobza, a Senior Designer at Landor Associates. Kobza has been working closely with the Coors Light cans that are printed with thermochromic ink. The second interviewee was Rosella Braden, a sales supervisor at Matsui Inc, who has over ten years of experience of using and selling thermochromic ink in both the United States and other countries. I used the following interview questions as a guideline and starting point for the interviews I conducted.

Interview Questions

1. What is your experience with thermochromic ink?
2. What applications of thermochromic ink have you seen?
3. What kind of variability in color of thermochromic ink have you seen?
4. How susceptible is thermochromic ink to temperature change?
5. What percent of your sales are based on thermochromic ink?
6. Using thermochromic ink, what are the most popular products?
7. How would you describe or picture the future of thermochromic ink?

After performing the above Elite and Specialized interviews content analysis was completed. Content analysis is a "method for quantifying qualitative information gathered from Elite and Specialized interviewing" (Levenson 31-32).

Chapter 4: Results

The purpose of this study was to measure the color intensity of Matsui Chromicolor screen printing ink. These variables directly impact the appearance of a product, which contributes to its ability to attract more attention. Using the scientific method a sample of the Brilliant Green Type 27 ink was placed in a Lab Companion oven and set to the following temperatures for one minute: 70 degrees Fahrenheit, 75.2 degrees Fahrenheit, 91.4 degrees Fahrenheit, and 98 degrees Fahrenheit. This process was repeated for the Fast Yellow Type 27 ink. These results were visually assessed and the results are indicated in Table 1.

Temperature	Brilliant Green, Type 27	Fast Yellow, Type 27
70 degrees Fahrenheit	Appeared	Completely Appeared
75.2 degrees Fahrenheit	Completely Appeared	Completely Appeared
91.4 degrees Fahrenheit	Color Still Visible	Color Still Visible
95 degrees Fahrenheit	Completely Disappeared	Completely Disappeared

Table 1

According to Matsui specifications Type 27 Chromicolor AQ ink should appear at 75.2 degrees Fahrenheit and disappear at 91.4 degrees Fahrenheit. The results are inconsistent with not only Matsui specifications, but between the two different Type 27 thermochromic ink colors.

Along with the results listed above elite and specialized interviews were conducted with three different industry experts. All three interviewees contributed knowledge from different experience of the thermochromic ink industry. The seven questions asked are as follows:

1. What is your experience with thermochromic ink?
2. What applications of thermochromic ink have you seen?
3. What kind of variability in color of thermochromic ink have you seen?
4. How susceptible is thermochromic ink to temperature change?
5. What percent of your sales are based on thermochromic ink?
6. Using thermochromic ink, what are the most popular products?
7. How would you describe or picture the future of thermochromic ink?

The first interview was with Ryin Kobza, a Senior Designer at Landor Associates. The Landor design team rebranded the Coors Light can and one of the features was the use of thermochromic ink. Kobza works primarily with thermochromic ink on aluminum cans and paper bottle label. However, he notes the variability of applications for thermochromic ink. According to Kobza there is a broad color palette available however the weakness of thermochromic ink is that precise color matching is difficult. Although Landor only influences the design of the Coors light can Coors sales have risen since the introduction of cold activated mountain. According to Kobza the most popular thermochromic products are fast moving consumer goods.

The second interview was with Rosella Braden, a Sales Supervisor at Matsui Inc., Braden sees thermochromic ink as a great marketing tool. According to her here are a wide variety of products from baby spoons that change color to indicate the temperature of food to toys to Barbie outfits. Thermochromic ink has been improving. In labs in Japan, Matsui has been trying to increase the accuracy of thermochromic ink color. The majority of specialty inks sold by Matsui

are thermochromic ink which also account for over a third of Matsui's overall sales. Braden sees a bright future for thermochromic ink.

In order to quantify the interview information content analysis was utilized and recorded in the evaluative matrix labeled Table 3 shown below. If Kobza and Braden agreed on a topic, a score of 1 was recorded in the appropriate spot in the matrix. If they disagreed, a score of 0 was recorded in the matrix labeled Table 2.

	Applications of Thermochromic Ink	Variability in color	increase of sales based on thermo-chromic ink	popular products produced with thermochromic ink
Ryin Kobza and Rosella Braden	1	1	1	1

Table 2

Ch 5: Conclusion

The packaging segment of the Graphic Communication industry is experiencing growth. With increasing amounts of choices in this global marketplace companies are looking for ways to differentiate their product. The appearance of a package is dependent on factors such as the type of printing press, substrate and additives used. Dynamic packaging, which should involve the usage of thermochromic ink, is a way to add value to your product.

The purpose of this study was to measure the color intensity of Matsui Chromicolor screen printing ink. This variable directly impacts the appearance of a product, which contributes to its ability to attract more attention. After testing Matsui thermochromic ink in a scientific oven, I proved my hypothesis that Matsui thermochromic ink will visually appear and disappear according to the specifications set by Matsui. In reviewing the data (see Table 1) Matsui Brilliant Green, Type 27 ink completely appeared at 75.2 degrees Fahrenheit and completely disappeared at 95 degrees Fahrenheit. Matsui Fast Yellow, Type 27 completely appeared at 70 degrees Fahrenheit and completely disappeared at 95 degrees Fahrenheit. However, according to Matsui specifications Type 27 Chromicolor AQ ink should appear at 75.2 degrees Fahrenheit and disappear at 91.4 degrees Fahrenheit. Although the visibility of color does not completely appear and disappear exactly according to specifications this experiment does indicates that Matsui has been able to reach a degree of consistency in their ink, which could lead to consistent production, and appearance of color on products printed with thermochromic ink. These results were confirmed by the interview with Ryin Kobza and Rosella Braden. Both Kobza and Braden spoke to consistency in color being one area that thermochromic ink could improve upon. Due to

slight inconsistency in thermochromic ink more research and development needs to be invested to continue improving the technology.

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