The Effects of Various Adhesives on Dye and Pigment-based Inkjet and Dye Sublimation Prints

Nino Gordeladze, Daniel Burge and Andrea Venosa; Image Permanence Institute, Rochester Institute of Technology, Rochester, NY, USA

Abstract

This study explored the reactivity of various adhesives on dye and pigment inkjet and dye sublimation prints. Consumers have reported adverse experiences including colorant bleed and yellowing in areas that were in contact with mounting adhesives. An accelerated test was conducted to study chemical interactions that might result in colorant fade, colorant bleed, yellowing, adhesive transfer or physical distortions of the digital prints. Fourteen different adhesives were applied to fine art, polymer and microporous photo papers, inkjet-sized and plain document papers, and dye sublimation paper. Images were printed on the photo and document papers using various inkjet printers and on the dye sublimation paper using a dye sublimation printer. The types of adhesives tested included water-based liquids, pressure sensitive tapes, laminating films, self-sticking notes and spray photo-mounting adhesives. The test combinations included prints without adhesives, prints with adhesives kept at room conditions (21°C and 50% RH) and prints with adhesives incubated at 70°C and 50% RH for 84 days as specified by ISO 18932 Imaging materials—Adhesive mounting systems—Specifications. This study provides a better understanding of the vulnerability of inkjet and dye sublimation materials to certain types of adhesives. The results showed colorant bleed, yellowing, adhesive transfer and physical distortions of the digitally printed materials can be caused by some of the adhesives tested in this study.

Introduction

The Image Permanence Institute (IPI) has received numerous reports of yellowing and colorant bleed on digitally printed materials after adhesive application. For example, pressure sensitive adhesives applied to fine-art inkjet paper have caused yellowing of the paper over time. In addition, an article in *Picture Framing Magazine* reported irreversible discoloration of matte dye-inkjet prints when hinges are applied under the print [1]. In response to growing concern in the field, IPI attempted to reproduce the described effects. The yellowing effect was easily reproduced by applying a pressure sensitive adhesive to fine-art papers and leaving them in a light-tight metal drawer for two months (Figure 1).

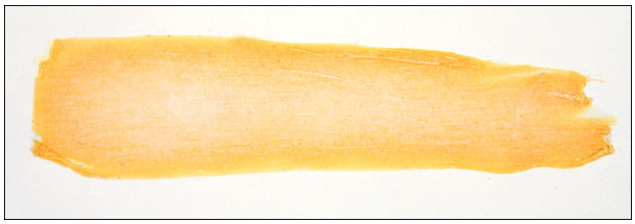

Figure 1*. Shows yellowing of pressure sensitive adhesive on the fine art inkjet paper over time.*

One test that is commonly used to predict the long-term interaction between materials in contact with photographic prints is the Photographic Activity Test (PAT, ISO 18916). However, many adhesives reported by consumers to have caused damage to photographic materials did, in fact, pass the PAT. This research sought to replicate the anecdotal evidence, evaluate test methods (ISO 18916, ISO 18932, and real time exposure), and find the most reactive interactions between prints and adhesives.

Adhesive-induced damage was well documented on traditional photographic prints long before consumer inkjet and dye sublimation printers came into common use. The discoloration and degradation of black-and-white photographic prints due to poor mounting adhesives has long been a problem [2]. For example, according to Wilhem, rubber cement, glues, and most double-sided tapes are among the adhesives to avoid using with black-and-white and color photographs. The sulfur and other chemicals used in rubber cement may cause discoloration of black and white photographic prints [2]. In 1989, conservators from the National Geographic Society reported drawbacks to using yellow self-sticking notes on some papers [3]. The study showed that sticky note adhesive residue was transferred to the clay-coated magazine paper and that self-sticking notes applied to text pages of a lower grade paper pulled the fibers from the paper. However, the effects of adhesives on digital prints have just begun to be observed.

This project was developed in light of the need for information on the effects of adhesives on digitally printed materials. The interaction between diverse types of adhesives in contact with a variety of digital prints that might result in colorant fade, colorant bleed, yellowing, and physical distortion of the print over time was investigated in this study. The results will provide a better understanding of the vulnerability of some digitally printed materials to certain types of adhesives.

Methodology

Sample Selection

Fourteen different adhesives (Table 1) were applied to fine art, polymer and microporous photo papers, and inkjet-sized and plain document papers containing images printed using either dye- or pigment-based inkjet printers, and to a dye sublimation paper containing images printed using a dye sublimation printer (Table 2). Two brands of fine-art inkjet paper were printed using three different printers (two dye and one pigment). The brand containing optical brightening agents (OBAs) is abbreviated as 'F.A. with OBAs.' The brand that did not contain OBAs is abbreviated as 'F.A.'.

Table 1: Adhesives tested

Starch[1]
Polyvinyl acetate (PVA) glue[1]
Liquid hobbyist glue[1]
Rubber cement
Gummed linen-tape[1]
Gummed photo paper corners[1]
Spray photo-mount adhesive
Pressure sensitive adhesive
Linen tape self adhesive
Invisible tape
Book tape
White mailing labels
Self-sticking notes
Laminate film

[1] The adhesive is water-based

Table 2: Printer/paper combinations tested

Abbreviations	*Paper Type*	*Printer*
Dye/F.A.	Fine art	Dye inkjet
Dye/F.A. with OBAs	Fine art with OBAs	Dye inkjet
Dye/porous	Porous	Dye inkjet
Dye/polymer	Polymer	Dye inkjet
Dye sub	Dye sub	Dye sub
Dye/plain	Plain	Dye inkjet
*Dye/inkjet-sized doc	IJ-sized document	Dye inkjet
*Pig/F.A. with OBAs	Fine art with OBAs	Pigment inkjet
*Pig/porous	Porous	Pigment inkjet
*Pig/plain	Plain	Pigment inkjet

**Selected samples were only tested with starch, PVA, liquid hobbyist glue, spray photo-mount, and self-sticking notes.*

Sample Preparation

The printed samples contained a test target with 1.0 x 0.5 inch patches of 10% and 100% cyan, magenta, yellow, as well as D_{max} black, and paper D_{min} along with a pictorial image. Printed samples were dried in a controlled room environment at 21°C and 50% RH for one week. Some adhesives required a backing material. Those adhesives were evenly applied to the back of the prints and mounted on a non-buffered, acid-free backing material. All samples were left to dry for 12 days after the adhesive application.

Measurements

Measurements of the patches were made using a Gretag Spectrolino/Spectroscan spectrophotometer both before and after adhesive application and after incubation. CIELAB (D50, 2º observer, no UV cut filter) values were collected and ΔE^*_{ab} was calculated for all patches to show the colorimetric change.

Test Conditions

The experiment used three different test conditions: before vs. after adhesive application, high-temperature incubation test, and room condition test. The incubation test condition followed *ISO 18932 Imaging materials—Adhesive mounting systems—Specifications* [4], where prints with adhesives were incubated at 70°C and 50% RH for 84 days. The room condition experiment was conducted at 21°C and 50% RH after 112 days.

Photographic Activity Test

All adhesives used in the experiment were tested using the photographic activity test (PAT), described in ISO 18916 [5]. This test is designed to predict the potential harm produced by long-term interaction between photo-storage materials and photographs including inkjet prints.

Results and Discussion

Before vs. after adhesive application

Some of the samples showed almost immediate bleeding of the magenta patch after adhesive application. The target printed on plain paper using a dye printer was very sensitive to water-based adhesives. The plain paper showed bleeding ten minutes after starch adhesive application and an hour after PVA and liquid hobbyist glue were applied. Figure 2 shows the ΔE^*_{ab} of a D_{max} magenta patches. While cyan and yellow also bled, the magenta ink was the most prone to bleed.

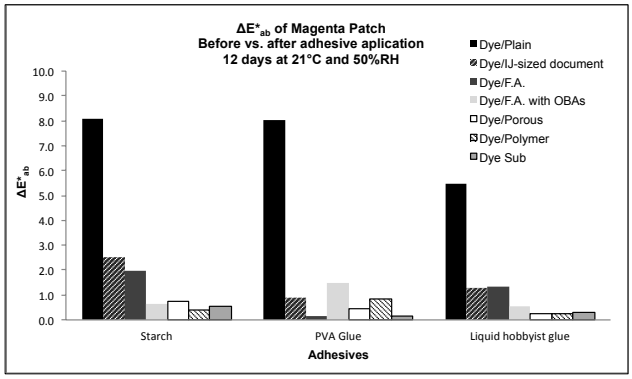

***Figure 2:** Before vs. after adhesive application.*

The ΔE^*_{ab} of the magenta patch for plain papers with starch, PVA, and liquid hobbyist glue was large. This result was expected because plain paper is thin and uncoated, so the moisture from the adhesive was easily absorbed by the paper causing the dyes to migrate. The patch became lighter as a result of the dye migration. Inkjet-sized document paper was damaged only by the starch adhesive two hours after application. The additional coated layers or thickness of the paper helped it to resist bleed longer than the plain paper. High magnification imaging revealed that samples with small ΔE^*_{ab} (less than 2) color differences did not show any visible dye bleeding.

The remaining adhesives resulted in small ΔE^*_{ab} color differences (Table 4). Nevertheless, some damage was visually observed in some samples. For example, the rubber cement caused pink stains outside of the target measurement area of the fine art and porous-coated paper (on coated side). In addition, starch, PVA glue, liquid hobbyist glue, and gummed linen tape, caused physical distortions (planar deformation or cockling) of all tested materials. Starch, gummed linen tape, and spray photo-mount applied to dye sublimation prints did not adhere well. Spray photo-mounting adhesive caused yellow stains on the fine art paper with OBAs on the D_{min} and printed areas.

Table 4: ΔE^*_{ab} of a magenta patch before vs. after adhesive application.

Adhesives	*Dye/Plain*	*Dye/F.A.*	*Dye/F.A. with OBAs*	*Dye/ Porous*	*Dye/ polymer*	*Dye Sub*
Spray photo-mount	1.2	1.2	3.2	1.5	0.3	0.8
Rubber cement	0.8	1.1	0.9	0.9	0.4	0.2
Gummed linen tape	1.1	0.9	0.7	0.4	0.2	n/a
Gummed photo paper corners	1.5	1.4	2.1	0.9	0.6	1.1
Pressure sensitive adhesive	0.5	1.3	1.4	1.6	0.3	0.3
Linen tape (self adhesive)	1.3	1.3	0.7	0.8	0.3	0.2
Invisible tape	2.2	1.6	1.7	0.7	0.6	0.4
Book tape	1.6	1.5	1.4	0.7	0.4	0.4
White mailing labels	1.5	1.2	0.3	0.6	0.6	0.3
Self-sticking notes	1.1	1.2	1.8	0.6	0.8	0.8
Laminate film[2]	5.3	5.4	4.5	6.8	7.8	6.5

[2] *The high ΔE^*_{ab} is a result of no laminate vs. the laminate.*

Self-sticking notes caused two types of damage – ink lift or adhesive transfer. The self-sticking notes lifted ink from all patches on the fine-art pigment inkjet print; just the black ink from the plain paper pigment print; the cyan, magenta, yellow and black D_{max} patches on fine-art dye inkjet print; and from the black patch on the inkjet-sized document paper using dye-based ink (Figure 3). In the second case, adhesive residue particles transferred from self-sticking notes to the porous paper surface causing the damage. Polymer-coated paper was not damaged by the self-sticking notes. However, the data does not show the changes that were observed visually.

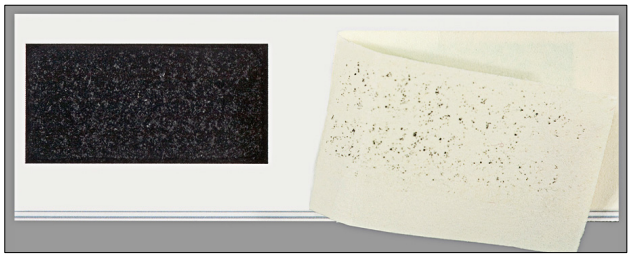

Figure 3: *Self-sticking note lifted ink from the black patch.*

Incubation Test (ISO 18932)

The test followed ISO 18932 section 5: bleed test (penetration of adhesives through paper), which specified incubation at 70°C and 50% RH for 84 days. The pressure sensitive adhesive caused yellowing of both the fine art papers on the image-receiving layer. In addition, the pressure sensitive adhesive reacted with the black patch on the back of the plain paper print causing yellowing of the adhesive and slight discoloration of the black patch on the front side. Further investigation revealed the black patch in the dye-based fine-art print was in fact pigment. This accelerated test condition was found to be not appropriate for water-based adhesives because the adhesives dried out, preventing any further damage. In addition, most of the samples yellowed due to thermal effects, and the high-temperature induced dye bleed in the dye sublimation prints. IPI believes that results from this incubation test will not be useful for predicting long-term interactions between prints and mounting adhesives.

Room Condition Test (21°C and 50% RH for 112 days)

The ΔE^*_{ab} color difference between the magenta patch after the adhesive application and 112 days later was calculated. PVA glue, rubber cement, gummed linen tape, and book tape showed small ΔE^*_{ab} color differences for plain and fine art papers; however, there was no visible change in the fine art prints. Over the 112 days, the magenta dyes continued to bleed for the dye inkjet prints on plain paper with the starch adhesive, while the samples with the PVA and liquid hobbyist glues did not. This is probably because starch adhesive is hydrophilic even after drying. Rubber cement and gummed linen tape turned yellow.

In the room condition test, only the fine art paper with OBAs showed yellowing caused by the pressure sensitive adhesive on the front or back of the paper, whereas in the incubation test pressure sensitive adhesive caused yellowing on both fine art papers and plain papers.

Photographic Activity Test Results

The PAT uses two detectors that are sandwiched with a testing material, in this case adhesive, and incubated to predict long-term interactions between the material (adhesive) and photographs (including inkjet, electrophotography, and dye sublimation). The first detector, the image interaction detector, consists of colloidal silver in gelatin binder coated on a clear polyester film that predicts oxidation and reduction reactions between the adhesive and the imaging material. The second detector, a gelatin stain detector, is a white processed photographic paper that predicts discolorations of the gelatin binder. Table 5 shows the pass/fail image interaction results from PAT test.

All of the water-based adhesives, with the exception of liquid hobbyist glue, reacted with the image-interaction detector and failed the test. The pressure sensitive adhesive also failed the test. However, they all passed the gelatin stain portion of the PAT despite the fact that some adhesives did cause yellowing in digital prints in actual use. Some dye inkjet prints bled due to the water-based adhesives; however the PAT was not designed to predict those reactions. The adhesives that passed the PAT test were not safe for some of the inkjet materials for other reasons as well. For example, rubber cement, self-sticking notes, and spray photo-mount passed the PAT but were harmful to some inkjet prints. Therefore, the PAT results for adhesives are not always valid for digitally printed materials.

Table 5: PAT results.

Adhesives	*Image Interaction*	*Gelatin Staining*
Starch[1]	Fail	Pass
PVA glue[1]	Fail	Pass
Liquid hobbyist glue[1]	Pass	Pass
Rubber cement	Pass	Pass
Gummed linen tape[1]	Fail	Pass
Gummed photo paper corners[1]	Fail	Pass
Spray photo-mount adhesive	Pass	Pass
Pressure sensitive adhesive	Fail	Pass
Linen tape (self adhesive)	Pass	Pass
Invisible tape	Pass	Pass
Book tape	Pass	Pass
White mailing labels	Pass	Pass
Laminate film	Pass	Pass
Self-sticking notes	Pass	Pass

[1] The adhesive is water-based

Conclusion

This experiment showed that some digitally printed materials are vulnerable to certain adhesives. Adhesives caused colorant bleed, yellowing, and physical distortion of some inkjet materials. However, the results were variable. For example, the application of the starch adhesive caused different amounts of dye bleed when replicated. In addition, the spray photo-mount caused yellow stains on fine art paper only in the second test replicate. The pressure sensitive adhesive caused yellowing on both fine art papers and plain paper when tested in the oven (70ºC and 50% RH for 12 weeks); however, yellowing was only observed on one of the fine art paper in the room condition test.

The PAT test for adhesives did not predict the harmful interaction between self-sticking notes, rubber cement, pressure sensitive adhesive, and spray photo-mount on the inkjet materials. Although the water-based adhesives were not safe for dye inkjet on plain or inkjet-sized paper, they did not cause any other damage except physical distortion to the pigment inkjet prints on all paper types; dye inkjet on fine art, polymer or porous photo papers; and dye sublimation.

There needs to be a method for testing mounting adhesives for digitally printed materials as the PAT clearly does not accurately predict all interactions between adhesives and digital prints. ISO 18932 is not recommended as a replacement. There is still a need for further investigation of the long-term effects of adhesives on the inkjet materials because this study tested adhesives at room conditions for only 112 days.

In general, the following conclusions can be reached:

- Plain and inkjet-sized document papers with images printed using a dye printer can be very sensitive to water-based adhesives, especially adhesives that are still hydrophilic after drying.
- Fine art inkjet papers can be very sensitive to pressure sensitive adhesives and spray photo-mount. Pressure sensitive adhesive should also be avoided on all plain paper prints.
- Self-sticking notes should be avoided on fine art, plain, porous-coated papers printed with both dye and pigment inks.
- Dye sublimation prints were only sensitive to minor physical deformation by some adhesives.

References

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[4] ISO 18932 Imaging Materials—Adhesive mounting systems—Specifications (Organization for Standardization, Geneva, Switzerland, 2005).

[5] ISO 18916-2007 Imaging Materials—Processed Imaging Materials—Photographic Activity Test for Enclosure Materials (Organization for Standardization, Geneva, Switzerland, 2007).

Author Biography

Nino Gordeladze graduated from the Rochester Institute of Technology and received a B.S. in Imaging and Photographic Technology in 2010. She also received an A.S. in Business Administration from Hudson Valley Community College in 2007. She is currently a Research Assistant at IPI, working on the Digital Print Preservation Portal research project funded by the IMLS and Andrew W. Mellon Foundation. e-mail: nxgpph@rit.edu