The Cracking of Inkjet Colorant Receiver Layers on Exposure to Light

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Abstract

The purpose of this investigation was to determine whether exposure to light or ozone increases the sensitivity of some inkjet-printed images to surface cracking during handling. In previous studies, several inkjet print examples showed a potential for significant cracking and flaking of the image area when handled after exposure to light and ozone. In these new experiments both printed and unprinted samples of two glossy porous photo inkjet papers from different manufacturers were exposed in separate experiments to 50 kilo-lux fluorescent and 50 kilo-lux xenon light in increments of time for up to twelve weeks and to 5 ppm ozone for one and two weeks. The exposed samples were tested for cracking according to the procedure described in ISO 18907 "Imaging Materials – Photographic Films and Papers – Wedge Test for Brittleness". The samples were evaluated visually both with and without magnification to determine the wedge diameter where cracking is first seen. The samples were also measured with a Gretag Spectroscan to determine if the increase in cracking came before or after noticeable colorant fade or paper yellowing occurred. Even though the two papers selected for this study were the same type, they behaved entirely differently. One paper showed sensitivity to crack before exposure and increasing propensity to crack with exposure to light and ozone. The other paper was not sensitive to crack before exposure and only after twelve weeks exposure to xenon light showed surface disintegration. Because of this, it is difficult to reach general conclusions that represent the entire spectrum of inkjet print media. Additional work is needed to provide a more complete picture of brittleness behavior of these materials after exposure to light and ozone.

Introduction

There has been considerable research on the effects of environmental factors such as ozone, humidity, heat and light on the fade and yellowing of digital prints, but there has been little investigation and no published research on the effects of cracking of these materials after significant exposure to light and ozone. A previous study explored the relative sensitivities of a variety of digital print types at 23°C/15% and 50% RH to cracking of image layers of papers without exposure to high intensity light or pollutant gases. [1]

The purpose of this project was to determine the cracking sensitivity of some inkjet media after exposure to 50 kilo-lux fluorescent and 50 kilo-lux xenon light in increments of time for up to twelve weeks and to 5 ppm ozone for one and two weeks, and whether the first cracking occurs before fading or yellowing is noticeable. Another objective was to determine where cracking occurs first, the unprinted area or the printed area.

The audience for this paper is primarily those charged with the task of caring for collections in cultural heritage institutions (e.g. museums, libraries, etc.). The goal is to provide them with good information on light and ozone exposure hazards. Other users may find benefit from this work, especially consumers, art galleries, professional photographers and manufacturers of imaging materials.

Sample Preparation, Test Procedure and Measurements

Each of two different inkjet porous glossy photo papers were printed by two different printers, one dye and one pigment and then exposed separately to both 50 kilo-lux xenon light in a chamber set at 25°C/50% RH and 50 kilo-lux fluorescent light in a chamber set at 25°C/50% RH for one, two, four, eight and twelve weeks. In another test, the papers were exposed to 5 ppm ozone for one and two weeks in a chamber set at 25°C/50% RH. Three replicates of each paper were cut into 11 x 5/8 inch strips. Half of each strip was printed in the length direction to a mid-tone neutral density (sRGB 128, 128, 128). Samples were conditioned at 21°C/50% RH for one week before exposure to light or ozone. The samples were removed from the light chambers after each time interval, preconditioned to 21°/50% RH and tested for cracking according to the procedure described in ISO 18907. [2,3] Cracking severity is measured by the largest diameter of paper flex that produces the first sign of cracking. Samples were evaluated visually and under magnification for cracking by a single observer to eliminate the possibility of observer variation. Also, the three replicates were read before and after exposure to light using a Gretag Spectroscan to quantify Delta E due to exposure. The average of the three replicates are reported here.

Results and Discussion

The two porous papers showed different cracking behavior, both initially and through twelve weeks exposure to either fluorescent or xenon light and through two weeks of ozone exposure.

Paper A buckled and tore in the tightest wedge setting (near complete fold) in the brittleness apparatus through eight weeks exposure to xenon light and twelve weeks exposure to fluorescent light but did not show cracking. Paper A showed disintegration and partial removal of the image layer in the unprinted area when tested with the next wider wedge setting but only after twelve weeks exposure to xenon light. The printed area showed disintegration after twelve weeks exposure to xenon light but only when subjected to the tightest wedge setting. Essentially the same disintegration behavior was seen in the printed areas whether the paper was printed with the dye or pigment printer.

Paper B showed cracking before exposure to light in a relatively wide wedge setting. Cracking increased with exposure to both fluorescent and xenon light, but exposure to xenon light produced a more severe result sooner than exposure to fluorescent light. After eight weeks exposure to xenon light, a type of cracking occurred which resembled reticulation. This type of cracking was not seen with exposure to fluorescent light through twelve weeks. Essentially the same cracking results were obtained in the printed areas whether the paper was printed with the dye or pigment printer.

It is difficult to relate these light and ozone exposures to what occurs in the real world because there are a wide variety of estimates for what light and ozone levels papers are likely to experience over time.

Photomicrographs of the disintegration of the image layer of Paper A and reticulation of the image layer of Paper B are provided in Figure 1.

Two weeks exposure to 5ppm ozone produced cracking in both papers, although as expected, cracking was first seen with a much larger diameter wedge for Paper B than Paper A. Also as expected, Delta E values after exposure to either light or ozone were much greater for both papers when printed with the dye printers as opposed to the pigment printers. Slight yellowing of Paper A occurred visually after exposure to fluorescent light and ozone, but almost none was seen with exposure to xenon light. Paper B did not show yellowing visually under any of the exposure conditions. No quantitative measurements of yellowing were made.

All of the data from these experiments are tabulated in Tables 1-4.

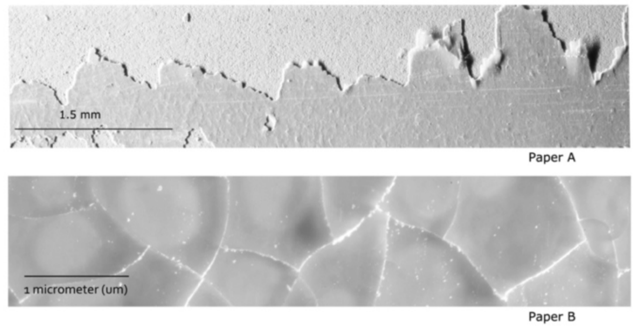

Figure 1: *Photomicrographs of disintegration of the Paper A image layer and reticulation of the Paper B surface after 12 weeks exposure to 50 kilo-lux of xenon light.*

Table 1: Brittleness and Delta E of porous glossy photo Paper A printed with dye printer A exposed to 50 kilo-lux Xenon light, 50 kilo-lux fluorescent light and 5 ppm ozone for various lengths of time

Paper ID	Printer Type	Treatment	Average Unprinted Deformation Type	Average Unprinted Deformation Diameter	Printed Deformation Type	Printed Deformation Diameter	Delta E
Paper A	IJ Dye A	None	-	0.14	-	0.13	
Paper A	IJ Dye A	Xenon - 1 week	-	0.17	-	0.17	10
Paper A	IJ Dye A	Xenon - 2 weeks	-	0.16	-	0.16	21
Paper A	IJ Dye A	Xenon - 4 weeks	-	0.15	-	0.15	34
Paper A	IJ Dye A	Xenon - 8 weeks	-	0.26	-	0.18	47
Paper A	IJ Dye A	Xenon - 12 weeks	Disintegration	Not Measurable	Disintegration	Not Measurable	48
Paper A	IJ Dye A	Fluorescent - 1 week	-	0.16	-	0.16	5
Paper A	IJ Dye A	Fluorescent - 2 weeks	-	0.18	-	0.18	8
Paper A	IJ Dye A	Fluorescent - 4 weeks	-	0.15	-	0.15	14
Paper A	IJ Dye A	Fluorescent - 8 weeks	-	0.16	-	0.17	26
Paper A	IJ Dye A	Fluorescent - 12	-	0.17	-	0.17	32
Paper A	IJ Dye A	Ozone - 1 week	-	0.17	-	0.17	25
Paper A	IJ Dye A	Ozone - 2 weeks	Crack	0.26	Crack	0.31	29

Table 2: Brittleness and Delta E of porous glossy photo Paper B printed with dye printer B exposed to 50 kilo-lux Xenon light, 50 kilo-lux fluorescent light and 5 ppm ozone for various lengths of time

Paper ID	Printer Type	Treatment	Average Unprinted Deformation Type	Average Unprinted Cracking Diameter	Printed Deformation Type	Printed Cracking Diameter	Delta E
Paper B	IJ Dye B	None	Crack	0.75	Crack	0.71	
Paper B	IJ Dye B	Xenon - 1 week	Crack	0.87	Crack	0.90	9
Paper B	IJ Dye B	Xenon - 2 weeks	Crack	0.99	Crack	0.94	15
Paper B	IJ Dye B	Xenon - 4 weeks	Crack	0.99	Crack	0.90	22
Paper B	IJ Dye B	Xenon - 8 weeks	Reticulation	>1.60	Reticulation	>1.60	29
Paper B	IJ Dye B	Xenon - 12 weeks	Reticulation	>1.60	Reticulation	>1.60	32
Paper B	IJ Dye B	Fluorescent - 1 week	Crack	0.94	Crack	0.91	4
Paper B	IJ Dye B	Fluorescent - 2 weeks	Crack	0.99	Crack	0.93	6
Paper B	IJ Dye B	Fluorescent - 4 weeks	Crack	1.06	Crack	1.04	11
Paper B	IJ Dye B	Fluorescent - 8 weeks	Crack	1.06	Crack	1.07	17
Paper B	IJ Dye B	Fluorescent - 12	Crack	1.04	Crack	0.97	22
Paper B	IJ Dye B	Ozone - 1 week	Crack	>1.60	Crack	>1.60	17
Paper B	IJ Dye B	Ozone - 2 weeks	Crack	>1.60	Crack	>1.60	21

Table 3: Brittleness and Delta E of porous glossy photo Paper A printed with pigment printer A exposed to 50 kilo-lux Xenon light, 50 kilo-lux fluorescent light and 5 ppm ozone for various lengths of time

Paper ID	Printer Type	Treatment	Average Unprinted Deformation Type	Average Unprinted Cracking Diameter	Printed Deformation Type	Printed Cracking Diameter	Delta E
Paper A	IJ Pigment A	None	-	0.14	-	0.15	
Paper A	IJ Pigment A	Xenon - 1 week	-	0.17	-	0.17	1
Paper A	IJ Pigment A	Xenon - 2 weeks	-	0.16	-	0.15	3
Paper A	IJ Pigment A	Xenon - 4 weeks	-	0.15	-	0.14	2
Paper A	IJ Pigment A	Xenon - 8 weeks	-	0.26	-	0.16	2
Paper A	IJ Pigment A	Xenon - 12 weeks	Disintegration	Not Measurable	Disintegration	Not	4
Paper A	IJ Pigment A	Fluorescent - 1 week	-	0.16	-	0.15	1
Paper A	IJ Pigment A	Fluorescent - 2	-	0.18	-	0.16	2
Paper A	IJ Pigment A	Fluorescent - 4	-	0.15	-	0.16	2
Paper A	IJ Pigment A	Fluorescent - 8	-	0.16	-	0.15	3
Paper A	IJ Pigment A	Fluorescent - 12	-	0.17	-	0.16	3
Paper A	IJ Pigment A	Ozone - 1 week	-	0.17	-	0.17	5
Paper A	IJ Pigment A	Ozone - 2 weeks	Crack	0.26	Crack	0.21	5

Table 4: Brittleness and Delta E of porous glossy photo Paper B printed with pigment printer B exposed to 50 kilo-lux Xenon light, 50 kilo-lux fluorescent light and 5 ppm ozone for various lengths of time

Paper ID	Printer Type	Treatment	Average Unprinted Deformation Type	Average Unprinted Cracking Diameter	Printed Deformation Type	Printed Cracking Diameter	Delta E
Paper B	IJ Pigment B	None	Crack	0.75	Crack	0.77	
Paper B	IJ Pigment B	Xenon - 1 week	Crack	0.87	Crack	0.84	1
Paper B	IJ Pigment B	Xenon - 2 weeks	Crack	0.99	Crack	1.03	2
Paper B	IJ Pigment B	Xenon - 4 weeks	Crack	0.99	Crack	1.10	4
Paper B	IJ Pigment B	Xenon - 8 weeks	Reticulation	>1.60	Reticulation	>1.60	7
Paper B	IJ Pigment B	Xenon - 12 weeks	Reticulation	>1.60	Reticulation	>1.60	10
Paper B	IJ Pigment B	Fluorescent - 1 week	Crack	0.94	Crack	0.83	1
Paper B	IJ Pigment B	Fluorescent - 2	Crack	0.99	Crack	0.97	1
Paper B	IJ Pigment B	Fluorescent - 4	Crack	1.06	Crack	0.94	2
Paper B	IJ Pigment B	Fluorescent - 8	Crack	1.06	Crack	1.04	3
Paper B	IJ Pigment B	Fluorescent - 12	Crack	1.04	Crack	1.04	5
Paper B	IJ Pigment B	Ozone - 1 week	Crack	>1.60	Crack	>1.60	4
Paper B	IJ Pigment B	Ozone - 2 weeks	Crack	>1.60	Crack	>1.60	4

Conclusions and Recommendations

1. Even though the two papers tested were the same type, they did not show the same behavior.
2. For both papers printed with dye printers, fading was observed before significant changes were noted in cracking or buckling behavior.
3. When the papers were printed with the pigment printers, damage (cracking, reticulation and disintegration) occurred before noticeable fading was seen either visually or from Delta E data.
4. No different brittleness results were seen whether the papers were printed with the dye or pigment printers.
5. Printed and unprinted areas showed about the same brittleness behavior.
6. Slight yellowing of one paper occurred after exposure to fluorescent light and ozone, but not to xenon light. This yellowing could be seen before disintegration or cracking of the paper was observed.

Because the two papers behaved so differently, it is difficult to reach general conclusions that represent the entire spectrum of digital print media. Additional work is needed to provide a more complete picture of brittleness behavior of these materials after exposure to light and ozone.

References

[1] Salesin, E., et al. 2009. “Brittleness of Digital Reflection Prints”. Technical Program and Proceedings NIP 25. Society for Imaging Science and Technology 25th International Conference on Digital Printing Technologies, Louisville, KY: IS&T. 138–141.

[2] ISO 18907:2000(E) “Imaging Materials-Photographic Films and Papers-Wedge Test for Brittleness” ISO 18907 First Edition 2000-05-15, Reference Number ISO 18907:2000(E)

[3] P.Z. Adelstein, “Wedge Brittleness Test for Photographic Film,” Photographic Science and Engineering, Volume 1, Number 2, October 1957

Author Biography

Gene Salesin, Research Assistant, received a B.S. in chemical engineering from the University of Michigan and an M.S. and Ph.D. in chemistry from Case Western Reserve University in 1960 and 1962, respectively. He retired in 1997 after 36 years of employment in the research laboratories and several manufacturing divisions at Kodak. He held a management position during his last few years there, leading the staff involved with providing the technical instructions and specifications for the manufacture of black-and-white films. Dr. Salesin joined IPI in 2004 and has been involved in the permanence properties of magnetic tape and digital prints.