The Inkjet Prints Permanence of the Latest Dye Ink

Yasuhiro Oki, Kazuhiko Kitamura, Tetsuya Aoyama, Masahiro Hanmura, and Hiroshi Fukumoto
Seiko Epson Corporation Imaging & Information Division
Shiojiri, Nagano, Japan

Abstract

Accordingly, we have examined a new inks based on dyes that have excellent light- and gas-fastness(especially ozone-fastness). In this case, the following factors were considered to be important: (1) obtaining an approximate balance in the fading properties of the cyan, magenta, and yellow components; and (2) including the permanence behavior of the black component, due to the black ink, into the permanence evaluation. We have found that this latter factor, which typically has been ignored in conventional permanence evaluations of light- and gas-fastness, is very important with respect to improving overall image permanence.

In this report, we present our results on the improved permanence properties of "photo quality" prints of the latest dye ink set, especially the light- and ozone-fastness results.

Introduction

Since launching the six-color PM-700C inkjet printer in 1996, we have evolved our printing technology in many ways in our quest to achieve photo quality. Technical advances have enabled the creation of microdots, the firing of multiple different dot sizes, higher nozzle counts, faster printing speeds and many other improvements. Today, photos printed by an inkjet printer are nearly indistinguishable from traditional "silver-halide" prints.

Meanwhile, ink and media modifications have for all practical purposes nearly eliminated problems with photo-quality-print image fastness, comprising (1) light-fastness, (2) humidity-fastness, (3) water-fastness, (4) plasticizer resistance, (5) thermal resistance, and (6) ozone-fastness. Onishi et al[1] reported on image fastness characteristics (1) through (5) for dye-based inks at NIP17. First, dye inks were found to perform more than adequately in terms of characteristics (2) through (5) on porous media. Moreover, prints produced with dye inks were reported to last some 10 years according to accelerated lightfastness tests that simulated indoor storage behind a glass frame. While 10 years is hardly yet sufficient, this length of time is adequate for most practical purposes. On the other hand, Hayashi et al[2] reported at ICIS '02 that they had confirmed that exposure to ozone gas caused fading in a short period of time on porous inkjet media though they have outstanding color development, glossiness, quick-drying and water-fastness properties. Ozone-fastness can thus rightfully be considered to be an extremely important characteristic in terms of dye-ink image fastness.

Aside from this, the light-fastness, ozone-fastness and other image fastness characteristics of recent inkjet printer inks are customarily evaluated in terms of changes in yellow, magenta, and cyan; the performance of blank ink had never come under discussion. Silver-halide photos are based on the basic primary colors of yellow, magenta and cyan. In contrast, inkjet printers generally have the three primary colors plus black. Black is necessary in order to ensure the proper color development of monochrome print on plain paper and to increase the contrast of printed images on specialty media.

So-called "photo-quality" inkjet output is closing in on silver-halide prints. Since photo quality print is made possible by these four basic colors, it is easy to imagine that the performance of black ink is an important factor to consider when evaluating the image fastness of inkjet prints.

In fact, in the process of developing our new color dye inks, we used color patches and other methods to evaluate and confirmed performance improvements. After evaluating a variety of portraits—the type of images most typically printed by users—that had been printed using these improved color inks, we discovered that the areas where black was used lacked adequate fastness and that the image as a whole clearly lacked the level of fastness we had been aiming for. This made it more obvious than ever that improving the fastness of black ink in inkjet output is critical to improving the fastness of photo-quality prints in general. This realization set us on a course directed toward improving the fastness of the black ink as well.

In this paper, we describe the performance of the new dye-based inks, both color and black, which offer dramatically improved ozone-fastness.

Experimental

Test samples (patches) were printed on two types of porous photo-quality paper [Premium Glossy Photo Paper (PGPP) and Matte Paper-Heavy Weight (MPHW)] using two different Epson printers, the PM-G800, which uses the new dye-based inks, and the PM-930C, which uses the old dye-based inks. Pure color patches were printed using yellow, magenta, cyan, and black. Composite black was formed by mixing yellow, magenta, cyan and black. The reflective optical density (OD) was 1.0. Printed patches were allowed to dry naturally indoors for 24 hours.

Ozone exposure tests were performed by setting the samples in a controlled environment where the ozone concentration was 10 ppm, under conditions of 24°C and 60%RH. The samples were tested in the bare state; that is, the printed side was not covered by a sheet of glass. The ozone exposure volume was expressed as an integrated value (ppm・h), the product of ozone concentration and exposure time.

Fluorescent light-fastness tests were also performed. We set the samples in a holder that left a 2-mm layer of air between the print and a 2-mm-thick sheet of glass. The samples were exposed to illuminance of 70,000 lux from a white fluorescent lamp, under conditions of 24°C and 60% RH.

Fading in each test was evaluated based on the percentage of reflective density (OD=1.0) remaining for each of yellow, magenta, cyan and black. Discoloration was judged on the ΔE of the composite black.

In the case of ozone-fastness, image life was estimated by simulating conditions in which a print is stored indoors, and not framed behind glass. Drawing from the research of Kitamura et al.[3] we assumed an ozone exposure volume of 40 ppm・h to be equivalent to one year of bare, indoor display, and we calculated the integrated illumination at which the reflected OD value (1.0) decreases 30% to be the limit point.

Fluorescent light-fastness was estimated by simulating conditions in which a print is stored framed behind glass under indoor fluorescent lights. Assuming the integrated illumination per day to be 10 hours at 500 lux, we calculated the exposure dose at which the reflected OD value (1.0) decreases 30% to be the limit point.

Results

< Ozone-Fastness of the New Color Inks >

The results of ozone-fastness tests involving the new and old dye-based color inks on PGPP are shown in Figure 1. By dramatically improving the ozone-fastness of the cyan inks (cyan and light cyan) and magenta inks (magenta and light magenta) in the new dye-based inks, we achieved an approximately 40-fold improvement (display life is equivalent to approximately 10 years) over the old dye-based inks. Moreover, we sought to do more than just improve the characteristics of the inks on an individual basis. The smallness of the ΔE of the composite black indicates that yellow, magenta, cyan and black colors have been precisely formulated and adjusted so as to bring their fade characteristics into mutual proximity (fade balancing technology). When the same evaluation is performed using the MPHW, the new inks exhibit ozone-fastness that is approximately 10 times (display life is equivalent to approximately 18 years) better than that of the old dye-based inks.

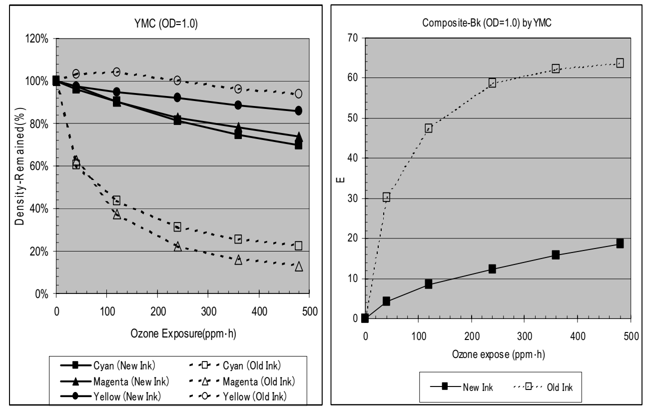

Figure 1. Test results of Ozone-fastness of New Inks and Old Inks on PGPP

< Ozone-Fastness of the New Black Ink >

As stated above, it is important to improve the fastness of black ink as well as of color inks. Figure 2 graphically shows the difference that black ink fastness can make in photographic images after ozone exposure testing. Both photos were printed using the new dye-based color inks. However, the photo on the left used the old black ink, while the photo on the right used the new black ink.

Figure 2. Test samples of Ozone-fastness(after 480ppm・h) of New Black Ink and Old Black with New Color Inks on PGPP

The two inksets are calculated to have equivalent ozone-fastness according to the evaluation criteria above, because the inksets use the same color inks. However, as the samples above illustrate, a large quantity of black ink is used in typical photos, and differences in the fastnesses of black inks have a very significant affect on photo images. To accommodate the myriad possible images, color ink fastness has to be enhanced, while the black ink's characteristics have to follow those of the color ink.

Figure 3 shows the results of a comparison between the ozone-fastness of the new and old black ink.

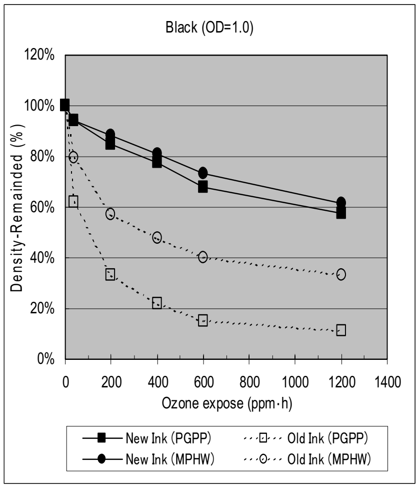

Figure 3. Test results of Ozone-fastness of New Black Ink and Old Black Ink on PGPP and MPHW

The new black ink offers vastly improved ozone-fade resistance (the percentage of density remaining) compared to the old black ink — some 18-times (display life is equivalent to approximately 14 years) better on PGPP. The same evaluations performed on MPHW indicate that the new black offers approximately 7-times (display life is equivalent to approximately 20 years) greater ozone-fastness.

In fact, the ozone-fastness of this new black ink is equal to or better than that of the new color inks. The combination of new color inks and new black ink gives the new dye-based inkset the high level of ozone-fastness shown in Figure 4.

Figure 4. Test samples of Ozone-fastness（after 400ppm·h） of Old Ink and New Ink on PGPP

The new dye-based inks also exhibit vastly improved display life even when used in combination with porous glossy inkjet photo paper offered by third-party vendors. In fact, as shown in Table 1, the new dye-based ink offer display life that is anywhere from 10 to 40 times longer than that achieved with the old ink.

Table 1. Display Life(Years) and Limiting Color of Ozone-Fastness on Several Media

Media	New Ink		Old ink	
	Display life	color	Display life	color
PGPP	12.80	C	0.34	C
A	4.83	M	0.45	M
B	4.73	M	0.32	C
C	4.35	C	0.28	C
D	9.17	M	0.46	M
E	6.08	M	0.36	M
F	14.72	C	0.36	C

It is interesting to note the fact that the color of ink that limits the display life differs according to the media. This suggests that, aside from the inks themselves, the inks' match with the media is an important consideration in attempts to improve image fastness. Figure 5 shows the fading behavior of cyan and magenta on Premium Glossy Photo Paper and on Media-D. Even though Media-D is a better match with cyan than PGPP, the poor performance of magenta means that image life on Media-D is shorter than that on PGPP.

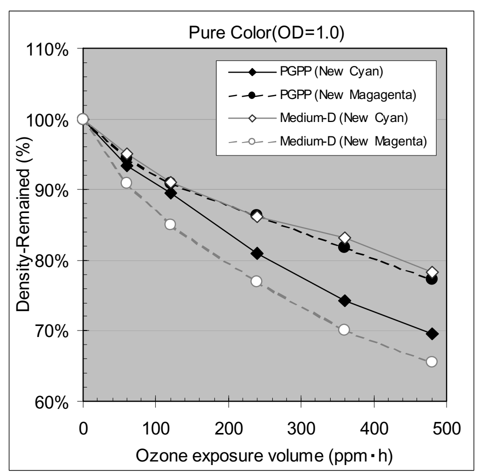

Figure 5. Test Results of ozone-fastness of new cyan and magenta inks on PGPP and media-D

< Light-Fastness with the New Inks >

In addition to having sharply improved ozone-fastness, the new dye-based inks also offer approximately two-fold better fluorescent light-fastness (display life is equivalent to about 20 years) on PGPP than the old dye-based inks. As shown in Figure 6, the new black ink performed even better in fluorescent light-fastness tests than the new color inks. On

PGPP, the new black ink is about nine times (display life is equivalent to about 70 years) more lightfast under fluorescent light than the old black ink. It is about 5 times (display life is equivalent to about 60 years) more fluorescent-lightfast on MPHW.

We confirmed that the new inks are able to offer a high level of fluorescent light-fastness because of their improved characteristics and because the fading of the colors is kept in balance (Figure 7).

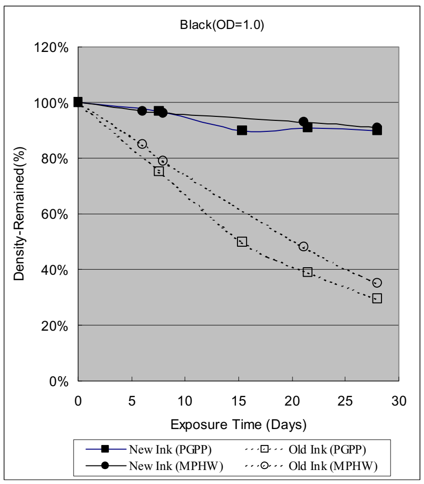

Figure 6. Test Results of fluorescent light-fastness of New Black Ink and Old Black Ink on PGPP and MPHW

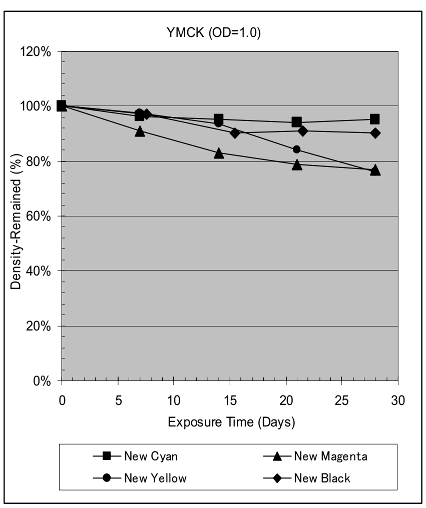

Figure 7. Test Results of fluorescent light-fastness of New Inks on PGPP

Conclusions

We have discussed the image fastness of photo-quality prints produced using our new dye-based inks. The discussion focused particularly on ozone-fastness and light-fastness. Improvements in colorants and the effective use of technology to produce inks from them enabled us to imbue the new dye-based inks with a high level of ozone-fastness and light-fastness, even on porous media with excellent characteristics, as shown in Table 2.

Table 2. Display Life of New and Old Ink on Porous Media

	media	New Ink	Old Ink
Ozone-fastness	PGPP	10years	0.3years
	MPHW	18years	1.8years
Light-fastness	PGPP	20years	10years
	MPHW	20years	20years

Like the old dye inks, the new dye inks also satisfy practical requirements for humidity-fastness, water resistance, plasticizer resistance, and thermal resistance.

Photo-quality photos produced using the new dye-based inks last long enough for most practical purposes, even when displayed bare indoors. We believe that, like traditional silver-halide photos, photos produced by an inkjet printer are now resistant to short-term image fading and can be enjoyed in a variety of ways.

Hopes are high for the future development of dye-based inks with performance that makes them capable of supporting everything from general usage applications through industrial applications.

References

1. Hiroyuki Onishi, Masahiro Hanmura, Hidemasa Kanada, Teruaki Kaieda, *Image Performance of Ink Jet Photographic Prints*, IS&T Proc. NIP17, 192-196 (2001)
2. Hiroko Hayashi, Kazuhiko Kitamura, Yasuhiro Oki, Gas-fastness of Photographic Prints of EPSON PM-950C, ICIS'02, Tokyo 539-542 (2002)
3. Kazuhiko Kitamura, Yasuhiro Oki, Hiroko Hayashi, Hidemasa Kanada, A study of fading property indoors without glass frame from an ozone accelerated test, IS&T Proc. NIP19, 416-419(2003)

Biography

Yasuhiro Oki received his B.Eng. in Chemistry from Ritsumeikan University in 1989. That year, he joined Seiko Epson Corporation and has been engaged in reseach and development of inkjet inks.