Finishing! How Does It Affect Ink Jet Photo Prints?

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Abstract

A lot has been written about image permanence and stability of ink jet photo prints. This has been primarily due to the fact that many ink jet prints are not very stable nor are they durable. Light fastness, moisture sensitivity, pollution sensitivity and physical durability have been deficient compared to silver halide prints. This paper addresses these issues and the factors that affect the performance of ink jet products. It also describes studies on laminated ink jet prints in a search for optimum performance.

Introduction

As the image quality of ink jet photo printing has continued to improve, even with low cost desktop ink jet printers, more and more people are considering producing or purchasing ink jet prints instead of conventional silver halide paper prints. As a result the performance expectations of those choosing ink jet have increased significantly. Many now expect performance at least equal to what they believe they will get from a traditional photographic print. This is especially true for prints produced by professional photographers who sell the prints. The purchaser of the prints may frame them and display them on a wall or on a table. There they are likely to be exposed to high levels of light including indirect and sometime direct sunlight. In addition to light they will be exposed to varying levels of moisture, pollution and potentially physical abrasion.

We have been examining the differences in performance between ink jet prints and photographic silver halide prints in their practical end use characteristics and have been searching for a product solution that will provide the best set of properties in the final ink jet print.

Some of the characteristics of the performance of the final finished product can be surmised from the nature of the components used and the performance they provide in other applications. Lightfastness is another matter. Actual customer end use light exposure suggests the need for an upgraded, more demanding lightfastness test than has been used traditionally for testing the lightfastness of photographic images.[1] An improved product structure and its performance are the focus of this paper.

Ink Jet Prints vs. Silver Halide Prints

A silver halide paper print is generally composed of a polyethylene clad paper substrate with a silver halide emulsion coated on one side. The structure is not durable until processed. The substrate provides the reflective surface, one that survives the developing and fixing operations, and provides the look and feel of a "photograph". The silver halide emulsion is exposed then developed, fixed and washed. During the fixing step the gelatin binder in the emulsion coating is chemically cross-linked with "hardeners" in the fixer. Prior to processing the silver halide structure is not very durable since it must swell to allow rapid penetration of the developer and then the fixer to enable formation of the image in an automatic processor where dwell time needs to be short. After fixing, the cross linking provides a dramatic increase in physical durability, seals the dyes into the emulsion layer preventing the dyes from attack by pollutants and protects against many of the effects of moisture.

Ink jet photo prints are generally not so fortunate. Typical ink jet inks used for photo printing are water based, using either water soluble dyes or dispersed pigments and the substrates on which they are printed must absorb water rapidly to enable the printing of photo quality prints. The same types of photo papers are used with water absorbing ink receptive layers coated on the surface. Typically nothing further is done to the prints except to allow them to dry. They don't benefit from the cross linking reactions. Users of the prints frequently compare ink jet prints with the silver halide prints for durability and stability and expect them to perform at least as well. This is of course an unrealistic expectation. Without making the structure more durable following printing the coating will continue to be water sensitive and some will enable pollutants to attack the image. In addition not much abrasion resistance is provided. Ink jet prints will perform much like undeveloped and unfixed silver halide photo papers.

Substrates

Unlike silver halide papers a wide variety of substrates may be used with ink jet: vinyls, polyester films, fabrics and many others can be printed to produce high quality photographic images using ink jet. In addition ink jet may use dyes which offer better lightfastness and color gamut since they are not required to be photochromic and may use components in the ink jet paper coatings to add stability. Inks utilizing pigments offer the potential for much improved lightfastness compared to silver halide papers especially on carefully designed substrates.

Up to now we have focused principally on the role of the coatings in achieving durability. With ink jet's flexibility in substrates we have the opportunity to provide much better durability in this component of the print structure than is typically found in polyethylene clad photo papers. Polyethylene when exposed over time to light tends to yellow. Even in a photo album after many years the dyes fade and the prints yellow. If polyester is used instead of polyethylene the durability in long-term storage and with exposure to UV light can be improved significantly. An example is white polyester film used in some ink jet photo film products offered in the Pictorico® line[2] as well as DuPont Teijin Films Melinex® Photo ink jet media[3]. The polyester is more stable as a substrate than paper and especially polyethylene-clad paper. The white polyester is more resistant to yellowing with exposure to UV light[4]. Under similar intense UV exposure it remains essentially unchanged while photo papers turn yellow then brown and tend to delaminate. Chemical brighteners are frequently added to paper to achieve the bright white color. These are dyes convert UV light into blue light upon absorption and reemission of light from the paper giving a "whiter than white" look to the paper. These dyes like virtually all others are light sensitive and loose their brightening power over time. As this occurs the reflector beneath the photo image changes its response to illumination. The color shifts toward yellow or gray causing prints to become dull. This effect can also result in color shifts in the image as observed by the viewer who would likely interpret them as image instability. White polyester is made white by incorporating inorganic fillers like barium sulfate or titanium dioxide. The fillers provide some opacity and some whitening but the majority of the whiteness is provided by very small voids created by the particles as the polyester is stretched during manufacturing. These voids scatter the light adding to the opacity and whiteness of the structure. In addition voids cannot yellow! From this information our conclusion is that substituting white polyester thick enough to give the stiffness and feel of polyethylene clad photo paper should improve the physical properties and stability of the substrate component of the ink jet photo structure while maintain much of the "photo look and feel".

Ink Jet Coatings and Inks

Ink jet coatings evolved from pen plotter paper coatings. They were frequently based on gelatin binders. These coatings swell when ink is printed on them and the ink jet ink with dye penetrates the surface to form the image. With pigmented ink jet inks the pigment particle size is too large to pass into the swelled polymer layer so the fluids from the ink penetrate but the pigment remains on the surface. These layers remain water sensitive after printing unless coated or laminated. Even with coating or laminating the edges of the structure remain sensitive to moisture. At high humidity the edges of the print, not protected by the coating or lamination film can swell and cause delamination of the film or coating layer.

Newer technology has been developed to enhance the rate of drying of the ink allowing for faster printing speeds and excellent print quality. This technology was pioneered by Konica and Asahi Glass and utilizes fine silica and/or alumina particles with a small amount of polymer binder.

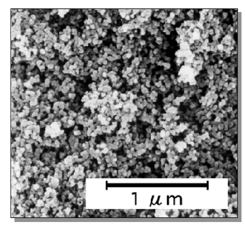

Figure1. Photomicrograph of Microporous Ink Jet Coating[5]

Instead of absorbing the ink fluids by swelling, these coatings have voids between the particles and utilize capillary action to absorb the ink fluids. Not only does this structure give excellent dry times and control of drop spreading but since it does not swell it is expected to be less likely to delaminate when a laminated print is exposed to moisture. Unfortunately this type of structure has been shown to have a very high sensitive to oxidative pollutants[6] as a result protecting the surface of the printed photo is very important for image stability and image permanence. Mounting under glass, laminating or coating should eliminate this problem.

Lamination

Lamination films come in several types and utilize several film and adhesive chemistries. In the search for the "best" performing system we chose a polyfluorinated polymer film with a pressure sensitive coating. We could have chosen a heat-activated adhesive like those used in hot laminators where light pressure and high temperatures are used. This adhesive and application system has significant quality disadvantages since the polymer film usually becomes permanently deformed during the lamination process and the adhesive, usually based on a polyethylene or a similar melt adhesive system, may not adhere well to the prints surface. Poor adhesion of this type of adhesive has been problematic with ink jet prints since the first large format printers were introduced. Glycols and other polyols that remain in the print long after it appears "dry" can interfere with the adhesion process. To achieve a high quality result a non-yellowing pressure sensitive acrylic adhesive is chosen and it is laminated at about 80 psi with heat assist. The heat, kept below the boiling point of the ink fluids, is used to aid in the flow of the adhesive into the surface of the print. Glycols and other organic components of inks are miscible with this adhesive and should rarely cause adhesion problems. The low temperatures should not lead to deformation of the film.

Choice of the film is very important. Polyester and vinyl are frequently used as film over laminates. Why did we chose a Teflon® type over lamination film? There are several reasons. The Teflon® films provide a better barrier to moisture and pollutants, they can be cleaned even with harsh chemicals without damage and they will not yellow and crack when exposed to light over time. Thin Teflon® films can stretch somewhat like vinyls and are not expected to cause much curl in the final print as polyester may. Vinyl films stretch even more but are not as clear and will yellow and crack with age. We chose several types of films for our testing based on the professional photographer's desire for both gloss and matte photo print structures.

One additional advantage offered by an adhesive that is able to flow into the surface of the ink jet print is to embed the pigments in the structure and eliminate the inherent characteristics of pigmented inks on the surface of glossy media. Since the inks are formulated with very little binder they sit on the surface of the media exposed to the air. The air/pigment interface provides a reflective and light scattering surface not encountered with dye-based inks since they penetrate into the surface and become part of the coating. These surface effects can cause gloss non-uniformity and dullness in the pigmented ink images. Lamination with a pressure sensitive lamination film results in encapsulation of the pigment particles by the adhesive eliminating the gloss uniformity problem and also the light scattering issue. The result is much brighter cleaner color and a much higher color optical density. The prints then resemble dye based ink prints on glossy media while maintaining the superior inherent light fastness of pigments.

Coatings

As an alternative to lamination, coatings can be applied. They can be effective in protecting the print and providing the surface desired by the print customer. The difficulties of applying the coating are many-fold. Most of the commercially available coatings for ink jet prints are solvent based. They are either sprayed or coated onto the substrate. The solvents may require ventilation and can raise OSHA and EPA issues in a business or large-scale production environment. These solvents may also present a fire hazard. Water based coatings may be compatible with some printed images but may redissolve the dyes reconstituting the ink and subsequently cause undesired movement of the colorants. This may cause image degradation and is a serious concern. For high quality applications the coating or spray uniformity becomes an issue. If the coating is to protect the print and provide high quality it will have to form a continuous uniform coating. This is not always easy to produce without sophisticated equipment and technique. After coating or spraying there is drying. Dirt and dust may be introduced in the drying process as prints are hung or laid out to dry. The coatings must also be chosen which are compatible with the ink colorant, the coating substrate and not lead to chemical, cracking, yellowing or other degradation over time. To do the job of designing these systems in a way that will guarantee a high quality result the ink, substrate and coating should be designed together. This is not frequently feasible. So in our search for the "best" photo printing solution we excluded coatings and believe lamination is the better route to high quality long lasting print production.

Testing and Lightfastness

From the inherent properties of the white polyester, the nature of the microporous ink jet coatings, the light fast pigmented ink jet inks and the durable Teflon® type over lamination film with pressure sensitive acrylic adhesive we believe we have put together the best potential combination of components we know how to assemble to give the best durability, image quality, image stability and longevity all in one structure.

Light fastness testing was conducted by Wilhelm Imaging Research[1] with commonly available pigmented inks on DuPont Teijin Melinex Photo, 9 mil white polyester, microporous coated ink jet media. With unlaminated films the wide format products show very good performance (Table 1).

Table 1. Lightfastness of DuPont Teijin Melinex® Photo Media[3]

Printers	Lightfastness in Years
Epson 5500/7500/10000	>100years
Epson 2000P	>100years
Epson C80	28.4 years[7]

With lamination we expect even better performance. But since we exceeded the maximum lightfastness capability of the test without lamination, to determine if we have made improvements we need a more challenging test to differentiate the good from the great.

As pigmented inks have found acceptance in the ink jet photo printing marketplace giving lightfastness numbers

>100 years it is time to reconsider the testing and what it is supposed to show us. It is our understanding that the current test was designed to simulate light exposure representing "museum conditions" and was appropriate for photographic materials and early dye based ink jet prints since the test provided lightfastness results which could be compared with photographic materials with which everyone was familiar[1]. Since typical prints using pigmented inks greatly exceed the lightfastness of silver halide prints, implementation of a more demanding test seems appropriate to us. The ANSI/ISO standards committee working to develop color print stability standards recognizes the need for additional testing as well and is considering a new test method[8]. We believe that this test is more representative of conditions commonly experienced in home or office display. It is more severe in both intensity and spectral energy and is referred to as a "sunlight through a window" test. Both this test and the "museum conditions" test give good information on what to expect in longevity from a print depending on display conditions.

We have begun testing a series of materials using three different sets of popular commercial pigmented inks and a popular lightfast dye ink on DuPont Teijin Melinex® Photo media with and without Teflon® lamination films. Since the product is very stable, the testing, even with the more demanding lightfastness test, requires longer exposure times than is usually the case for dye inks. As a result we have no data yet on the performance of these structures only that they have not yet faded. Data will be available at the time of the presentation of this paper in October. At that time a supplement to this paper will be available both at the conference and on the web.

Conclusion

We conclude from this work that an extremely durable, high quality, ink jet photographic product structure has been demonstrated using the materials described above. It can provide the best overall performance that we can make available today. We believe and professional photographers we asked agree that this structure exceeds the durability, and quality of silver halide photographic papers.

We look forward to sharing more details of the light fastness testing of these materials using the newest widely available photographic quality printers and inks and expect to make it available to consumers in the near future.

References

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3. See: http://www.lexjet.com
4. Private communication DuPont Company
5. Kenzo Kasahara, *Journal of The Society of Photographic Science and Technology of JAPAN* Volume 62 (1999)
6. Private communication RIT Research Corporation
7. The Epson C80 is sold as a low priced entry-level desktop printer advertised as a plain paper printer. The yellow-pigmented ink in this product shows higher color strength and considerably poor lightfastness compared with the wide format products. Compared to other printers designed for this purpose it provides a high level of lightfastness and water resistance.
8 ANSI/ISO IT9-3 Indoor Light Stability Task Group **Draft Standard** "5.2 Simulated indoor indirect daylight through window glass filtered xenon arc ID65 illuminant. A sample-plane illumination intensity of 30 to 50 klux shall be used (maintained at ± 2% of the aim point intensity). The surface temperature of the specimen shall be 23°C ± 2°C, maintained by an adequate airflow across the specimens; the ambient relative humidity shall be 55% RH (± 5% RH). The test unit shall consist of a xenon arc lamp (or the equivalent) with a quartz burner tube assembly. In addition, two pieces of the standard window-glass filter shall be inserted between the lamp unit and the test specimens [table 5 of ISO 18909]."

Biographies

Dr. Ray A. Work, III retired from DuPont Imaging Technologies in June 2001 and was New Business Development Manager in DuPont Color Proofing. He holds BS and PhD degrees in Chemistry and has held a variety of positions in DuPont in research, management and business for over the past 28 years. He holds 7 US Patents and has over 20 publications. Dr. Work is a frequent speaker at conferences and symposia world wide on the subject of ink jet inks and ink jet printing. He is President of his consulting business, Work Associates, Inc. (see http\\:www.workassoc.com) and a member of the IS&T.

Dr. Edwin S. Iracki is currently Senior Technology Consultant for the DuPont Fluoroproducts Strategic Business Unit where he has responsibility for new product development, applications development, market development as well as new business development. He has been a member of committees of UL and ASTM. Dr. Iracki earned a Ph.D. in Chemistry from the University of Illinois and served as an assistant professor at Clemson University before joining DuPont in 1974. Since that time he has held a variety of technical and managerial positions.