Photo-Quality Print Media

Mridula Nair, Narasimharao Dontula, and Joseph Sedita; Eastman Kodak Company; Rochester, NY/USA

Abstract

This paper will describe a photo-quality print media comprising a specially developed image-receiving surface layer (IRL) that accepts the printing ink/colorant material from the appropriate printing process, and serves to embed it in the glossing step, providing for better image protection and better image properties without additional coatings or a lamination step. The IRL is extrusion coated as an extruded monolayer or co-extruded along with other layers to both sides of the base. The backside of the media can be tailored for specific applications (writability before and after printing, fuser oil management in electrophotographic applications, etc.).

A unique advantage of the IRL is the fact that its final surface finish can easily be altered for specific applications. This media can provide a matte surface for printing directed to specified applications. Alternatively, the same material can be glossed to an even gloss finish by passing the printed media through a glossing unit, such as a belt fuser, to yield a highly glossed printed surface without additional coatings. Such versatility, an unprecedented and unobvious technical advance in the world of printed media, is a unique economic advantage offered by the media described here.

Introduction

Marking technologies commonly used in the printing world develop color by the deposition of the colorant material directly on the surface of the media. These processes typically rely on an extrinsic color development process to achieve the desired density in a print. These are distinctly different from the photographic process, in which the receiver or the specially sensitized media has built-in chemistry to develop the appropriate colors and densities from within, which is intrinsic to the media. A limitation of the extrinsic image formation process is that the image physicals are harder to control because the colorant materials are exposed at the surface. Recently, a new xerographic photo paper was disclosed by Fuji Photo Film Co., Ltd, which was capable of producing a high gloss photo print and high image quality using xerographic printing and a new fusing device [1].

We have developed a novel media based on an image-receiving layer (IRL) melt extruded or coated on a paper base such that the IRL serves to embed the marking particles in the extrinsic imaging methods and enable glossing with a calendaring device or a belt fuser afterwards, so the final image is protected and has the look and feel of a photograph. The IRL is mainly composed of a thermoplastic polymer or thermoplastic blend of polymers. The composition is usually adjusted such that at least one component of the thermoplastic blend of polymers has a glass transition temperature (Tg), or melting point (Tm) close to that of the thermoplastic component of the toner that is transferred onto the IRL during electrophotographic (EP) printing. Consequently, both the toner and the receiving layers soften or melt when the toner is fixed to the IRL by heat and pressure as with roller fusing. This contributes to the good adhesion of the toner to the IRL, minimum differential gloss, and good image protection.

Properties such as stiffness, opacity, colorimetry, gloss, print resolution, sharpness, and image granularity are all-important parameters, which need to be closely controlled in order to achieve the appropriate "look and feel" desired by the consumer. Producing near-photographic-quality images using extrinsic printing technologies is highly useful especially if such images are produced using media that render the print with the look and feel of a typical photographic print.

Of all the properties attributed to a photographic print, gloss as a property is critical because it provides printed products with a snappy, overall attention-getting look while providing greater depth of color and chromaticity and exhibiting higher gamut. Media that can provide gloss both in various digital and conventional printing modalities such as EP printing and offset printing are highly desirable. At present, a variety of coated substrates are commercially available for the different printing modalities. Despite this fact, high surface gloss is difficult to attain without an added foreign component in a second operation. Usually, it is achieved by either lamination of the print with a sheet of plastic, or by coating over the print with either an aqueous or UV curable layer. Also, there is no one universal media that can give the same look and feel no matter what the printing method. With hybrid printing jobs that combine both offset and digital components, there is a need for media that can run on both types of machines and produce the same look and feel and a high degree of gloss.

Further, when printing calendars, greeting cards, and post cards, it is important that the backside of the media be receptive to writing with a pen or pencil.

The fusing system in a dry EP printer often uses silicone oil as a lubricant for the surface of the fuser roll. The oil, although it is applied only to the fuser roller, transfers to the surface of the pressure roll. During printing, when fixing the image on the face side of the receiver media, fuser oil is transferred to the backside of the media from the pressure roller. Under such a situation, during duplex printing, when the sheet is reversed for printing on the backside, fuser oil will be transferred from the backside to the surface of the imaging modules such as the intermediate substrate. The oil transfer is more evident in the nonimage areas compared to the image areas. When a large number of sheets are duplex printed, the quantity of oil transferred to the intermediate substrate can increase, causing the surface energy of the intermediate substrate to vary, influencing the transfer performance of the toner. This can result in the appearance of ghost images in subsequent sheets and other artifacts such as oil streaks. Plastic substrates are especially prone to this problem. Residual oil can also make the media difficult to write on.

We have therefore developed an optional backside for our photo-quality media such that a writable oil-absorbing layer (WAL) manages the fuser oil and minimizes imaging artifacts described above. The WAL is such that both sides of the media can be imaged using different printing modalities and where desired, one side can be selectively glossed. The WAL is formulated to enable writing on it before and after printing.

This new, essentially universal media described here bears a specially developed enveloping layer that accepts the colorant material from other marking technology in addition to dry EP, such as liquid EP, offset printing, flexographic printing, or gravure printing, and has the ability to be glossed to provide near-photo-quality prints from all.

Experimental

Resin coating has been used since the late 1960s to develop silver halide photographic media [2, 3]. The photo-quality media described here was constructed similarly, for example by melt extruding onto both sides of a 160 µm thick rawbase (paper), about 5–50 µm of an IRL derived from a polymer melt at temperatures ranging from 200–340ºC in a resin-coating machine at coating speeds ranging from 400–800 fpm. The polymer melt compositions typically consisted of a blend of low-density polyethylene (LDPE), maleated polyolefin, titanium dioxide (TiO_2), colorants, and talc along with special performance-enhancing additives such as polylactic acid (PLA) and copolymers of ethylene and methyl acrylate (EMA). Where desired, on the second resin-coated side of this media, the WAL derived from an aqueous dispersion of colloidal silica or clay, a sodium 2-sulfoethylmethacrylate latex, and matte particles, was coated as a thin layer such that the coating was rich in silica. The typical properties expected from the inorganic coating were oil sorption, toner adhesion, and writability. This structure is schematically depicted in Figure 1.

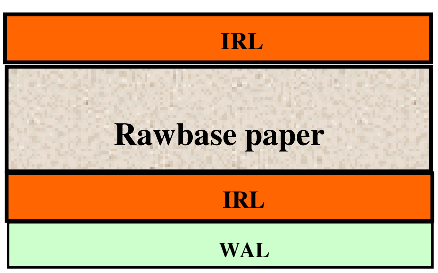

***Figure 1**. Photo-quality media construction*

Opacity of the media was measured according to ASTM method E308-96, specular reflectance was included, and the testing was done by measuring one sheet black-by-black followed by black-by-white (Baryta). Colorimetry was measured on an UltraScan XE Colorimeter made by Hunter Associates Laboratory using a D 6500 light source with UVI light excitation and without UVO light excitation of the sample. Stiffness was measured using a Lorentzen and Wetter type tester according to Tappi Method T 556. The bending resistance in milliNewtons of a 20 mm wide vertically clamped sample is measured for a 15º deflection angle.

EP printing was done in a Kodak NexPress 2100 digital production color press. Glossing of the printed samples was done using a glosser that consisted of a belt fuser, which used a polyimide belt. This belt was set at a temperature of between 140 and 170ºC.

Printed media were evaluated for gloss, image quality, durability and image protection, fuser oil management, and writability.

Gloss measurements (60º) were made on printed samples using a BYK Gardner Glossmeter in the Dmin (white) and Dmax (black) areas. Differential gloss was determined by measuring the difference in 60º gloss values between the Dmin and Dmax areas. The contact angle measurements on the substrate were made using a model 2500 contact angle goniometer produced by Advanced Surface Technology.

Toner adhesion and overall image durability were quantified using a commercially available microscratch tester from CSM Instruments. Specifically, ramped load scratches were generated in the 3–300 gram load range in imaged areas of a conditioned sample using an angled Silicon Carbide cylinder with a 5 mm edge radius at a fixed angle of 45º relative to the surface of the sample. An optical microscope was used to examine scratch morphologies and determine the load required to initiate color removal, which was used as a measure of toner layer durability (adhesive and cohesive) and interlayer adhesion within the media structure.

The photo-quality media was also EP printed in a duplex mode to test for silicone fuser oil contamination resulting from oil present on the backside of the paper after printing the first side. The printing was done such that the WAL side was printed second. If the side opposite the first printed side could not retain fuser oil, the oil would be deposited back into the imaging modules of the press during printing of the backside in duplex mode. The amount of oil introduced to the press by any media during duplex printing by such a mechanism was evaluated by printing 36 sheets of the media, using a black-and-white striped image and immediately thereafter, printing on standard clay-coated paper, large black and gray patches (flat fields), and examining the patches for oil streaks and other image artifacts caused by the residual oil transferred from the backside of the previously printed duplex job onto the imaging modules of the printer. Media that could not manage the fuser oil showed visible oil streaks in the flat fields.

Pen writability was evaluated using an instrument with an arm holding a ballpoint pen at a 45º angle to the surface of the paper. 250 grams of weight were applied to the arm while it touched the paper. The arm was drawn across the paper attempting to create a 1" line. The pen was then lifted and moved to another spot and the process repeated 10 times. The lines were then examined for skips, smears, and other defects. A sample that possessed good writability did not exhibit any visible skips in the lines.

The photo-quality print media was also printed on the IRL side in a Hewlett-Packard Indigo 3000 printer (liquid EP) and compared to a commercially available paper printed the same way. The print media was further printed in a Heidelberg Speedmaster (offset press) using a silicone-based ink. This was compared against a standard paper used in the offset industry. Colorant adhesion to the media was measured using the tape adhesion test that was performed by placing a piece of 3M 2600 tape on a 100% black patch. The tape was rolled once with a rubber roller weighing 5 lbs. The tape was peeled at a 180° angle using a slow, steady pull. The printed media was then observed visually and given a percentage removal number based on the amount of colorant removed.

Results and Discussion

Photographic media are typically constrained by consumer preference and processing machine restrictions to a stiffness range of between ~50 mN and 250 mN and a thickness range of between ~100 µm and 400 µm [4]. The rawbase used for the photo-quality media described here was hence chosen to satisfy the criteria set by the customer requirements for stiffness. Similarly, based on voice of the customer, typical photographic receivers are designed with L*UVO greater than 90. Additionally, to enable duplex printing with minimum show through, the opacity of the photo-quality media had to be very high.

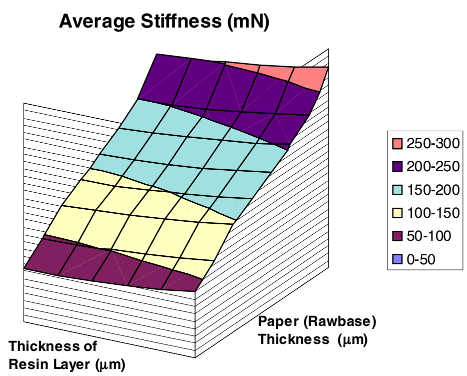

***Figure 2**. Average stiffness of media vs. thickness*

Figure 2 is a plot of average stiffness of a paper (rawbase) coated with polymer resin. This plot was obtained by simulating rawbase thickness varying from 127–190.5 µm, and resin layer thickness ranging from 0–63.5 µm on either side of the rawbase. The resin in the simulation had properties of extruded LDPE. It was observed that the driving force in controlling stiffness was the rawbase thickness and its inherent physical properties. Therefore, the choice of a 160 µm rawbase helped produce media with the feel of a photograph.

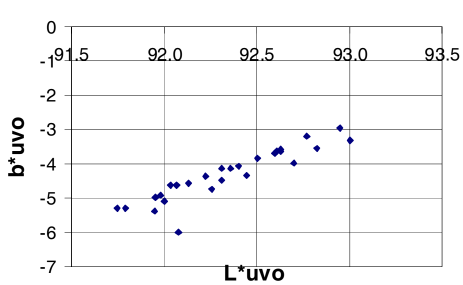

***Figure 3**. b*UVO vs. L*UVO*

Figure 3 shows a plot of b*UVO vs. L*UVO and Figure 4 shows a plot of b*UVO vs. Opacity for a rawbase coated with an IRL consisting of a resin blend of LDPE, EMA, talc, and TiO_2 at different coverages. These samples had a WAL of clay of GE brightness 90 coated at different coverages on one of the resin-coated sides. It was observed that for these samples near linear relationships existed for L*UVO and opacity vs. b*UVO, demonstrating the ability to tailor opacity, colorimetry, and lightness as required. This resin coverage was therefore modified to vary manufacturing properties such as coatability, and optical properties such as colorimetry, opacity, and gloss, while optimizing cost.

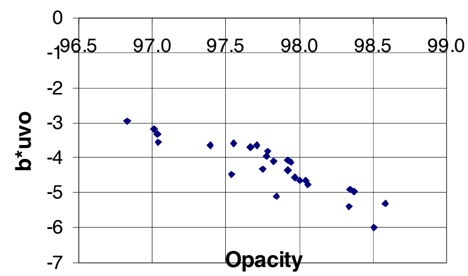

***Figure 4**. b*UVO vs. Opacity*

This photo-quality media paper was printed on both sides in the Kodak NexPress 2100 press and the advancing contact angle on both sides of the printed and the unprinted media was measured. The advancing contact angle of the back surface bearing the WAL, with water, was designed to be less than 90º in order to enable writability with a ballpoint pen. The WAL had a water contact angle from 0–60º even after printing, characteristic of a hydrophilic surface resulting from the inorganic coating on it, whereas the IRL had a contact angle greater than 100º, indicating a hydrophobic surface. This hydrophilic WAL of the print media was found to be writable and produced 10 lines without skips in the writability test, but without the coating the media could not be written on with a ballpoint pen.

The WAL containing silica further behaved like a standard clay-coated paper in minimizing fuser oil contamination from the second side in a two-sided printing operation because of the high surface area or porosity arising from the highly filled WAL. Such a backside is additionally expected to ensure that during dry electrographic printing, the fuser oil will not only penetrate the WAL on the backside at the fuser but will retain the oil within the layer during duplex printing because of the higher energy required for a highly nonpolar oil to traverse out of a hydrophilic WAL. Without the silica coating, the media did not retain the fuser oil as well during duplex printing and gave rise to some streaks and image artifacts. For oil-less fusing assemblies, this problem did not exist.

Gloss is sought because it provides printed products with a snappy overall attention-getting look, provides a greater depth of color and chromaticity, and exhibits a higher gamut. For example, a glossy black appears to be blacker than a matte black and a glossy red darker and more intense than a matte red. Gloss was typically adjusted for this media by varying surface roughness of the IRL. The surface roughness described here was achieved during the manufacturing of the media through melt extrusion coating of the resin and subsequent contact of the resin to a textured chill roll to obtain the desired surface pattern. R_a is surface roughness expressed as the arithmetic average height calculated over the entire measured array. A matte surface prior to printing typically has a R_a of 1–3 µm. The IRL had a R_a of between 0.5 and 10 µm prior to printing and 0.3–5 µm after printing but prior to glossing. When a higher degree of surface smoothness, gloss, and better image protection are required for the imaged IRL, the surface is further subjected to a calendaring operation in a second step using a belt fuser such as the Kodak NexGlosser glossing unit.

As expected, the surface roughness decreases significantly after glossing the print (see Table 1). This is also reflected in the 60º gloss values that show the printed media's ability to be transformed into a glossy image from a matte look. Using a single media, thus it is possible to obtain a gloss and/or matte output depending on the final application of the print.

Table: 1

IRL Surface	60º gloss	Surface Roughness Ra (µm)
Printed and Unglossed	21	0.44
Printed and Glossed	80 - 95	0.09

Simple modifications to the IRL formulation can also result in significant improvements in certain physical properties, such as toner adhesion. In the specific example summarized in Table 2, the addition of PLA to the IRL resulted in a 2.5× increase in the load required to scrape the fused toner from the surface of the media.

Table: 2

Performance-Enhancing Additive in IRL	Scrape Adhesion Onset (grams)
No Additive	27
Polylactic Acid	69

The prints obtained by printing this media using liquid EP and in the offset press were also glossed using the belt fuser. The check papers were not glossable using the belt fuser. As Table 3 shows, the liquid EP and the Offset samples from prints made on the photo-quality print media glossed nicely, showed little differential gloss, and had an absolute number 60º Gardner gloss value greater than 60. Using the same papers then, both matte and glossy finished prints could be produced without additional coatings or lamination, whereas the standard commercially available paper could not be converted to a glossy print without the use of additional material such as an overcoat. The adhesion of the colorant material to the photo-quality media was comparable to or better than the standard papers used currently.

The image quality of prints obtained using this media and any of these printing modalities was excellent. Most of the studies and analyses were conducted on prints obtained by printing in the Kodak NexPress 2100 press. Media constructed with various surface finishes and degrees of roughness for the IRL were printed. Depending on the surface finish, the prints were glossed using the belt fuser. Both glossed and unglossed prints had the intended excellent photo-quality look and feel and excellent image quality, while providing environmental protection and writability where needed.

Table: 3

Paper and Printing Method	Glossed	Tape adhesion (percent ink removal)	60º Gloss (Dmin)	60º Gloss (Dmax)
Photo-quality Media Liquid EP	Yes	0	71	77
Commercial Print Media Liquid EP	Not uniformly glossable	10	35	22
Photo-quality Media Offset	Yes	0	86.	93
Commercial Media Offset	Not glossable	0	21	35

Summary and Conclusions

This paper describes a versatile photo-quality media that can generally be used with several digital and analog printing modalities. In all cases it is possible with this media to achieve both a matte finish and high surface gloss, notwithstanding the printing technology, without additional coatings or lamination. Adhesion of the printed ink on the media was very good. Furthermore, the media was constructed such that it is printable on both sides and either glossable on both sides or glossable on one side and writable on the other side.

Acknowledgments

The authors gratefully acknowledge the contributions of Tamara Jones, Joseph Hoff, Terry Heath, Faye Transvalidou, Daniel Leusch, Michael Brickey, Cumar Sreekumar, and Dinesh Tyagi, all during their tenure at Eastman Kodak Company.

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Author(s) Biography

Mridula Nair is a project leader in Kodak's Research Laboratories. She received her Ph.D. in Chemistry from The Ohio State University, and was a postdoctoral fellow at Columbia University. She has over 20 years *of R&D experience in the fields of polymer and colloid synthesis, formulation, liquid and dry inks, receiver design, liquid film coating processes, and complex system integration, and holds 68 US Patents.*

Narasimharao Dontula has been with Kodak for 7 years and is a project leader at Kodak. He has been involved in material formulation and polymer melt processing and receiver design and holds 27 US patents. He has a Ph.D. in chemical engineering from Clarkson University and was a postdoctoral fellow at Michigan State University.

Joseph Sedita is currently a group leader in Kodak's Research Laboratories. He received his B.S. degree in Physical/Analytical Chemistry from the State University of New York. During his 20 years at Kodak, he has worked on providing both material science expertise for product development and analytical support in the areas of micromechanics and thin-film mechanical characterization.