Digital Watermarking Using Clear Toner

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Abstract

It is often desirable to protect a document against unauthorized copying. This could be easily achieved by printing part of the image such that it can be readily observed by a human reader but not by a copier or scanner. An image can be printed using clear toner or ink so as to create a difference in reflected and diffused light that can be distinguished by a human reader who looks at the paper at an angle; however, this feature cannot be detected by copiers or scanners because they are restricted to reading at right angles to the page.

In the printing industry, clear or white toners are often used to produce digital watermarks that cannot be copied or scanned but can be observed by a human reader. These methods need specifically matched paper and toners that have a considerable difference in gloss. It works with the combination of glossy toner on matte paper or matte toner on glossy paper. However, this approach does not work when glossy paper is used with a toner that provides images in the same gloss range. Such a combination is very common in the field of digital commercial printing.

Several digital watermarking processes have been developed that embed a visually striking gloss image into one to four color images. In most cases, controlled angular dependence of image gloss is used to create visual differential gloss in the form of a digital watermark.

Printing equipment with fifth imaging station allows for the production of digital watermarks with clear or low-pigmented toner. It provides a method to produce digital watermarks on paper without the limitations described above. This approach is not limited by the color or gloss properties of the toner, the substrate, and/or the selected fusing technology.

This technology allows for the production of clear and visible watermarks using toners that produce an image of about the same gloss as the paper and image with the appropriate fusing technology.

The additional clear toning station allows, as well, the addition of clear toner to areas of the digital watermarking process that alone cannot provide a sufficient digital watermarking effect in low-density and high-density areas.

Introduction

Digital Watermarking

It is desirable to protect a document against copying. This could be done in a manner that part of the content can be readily observed by a human reader but not by a copier or scanner. An image that is printed using clear ink or toner (called dry ink as well), creating a difference between reflected light and diffused light that can be distinguished by a human reader who views the paper at an angle other than 90°, but cannot be detected by a copier or scanner that is restricted to reading at right angles to the page.

Sometimes clear or white toner is used to produce digital watermarks that cannot be copied or scanned but can be observed by a human reader. A method to achieve different diffused light characteristics at different angles using particular white paper and particular white toner was described earlier [1]. This method needs specifically designed toners and papers.

Another approach for noncopyable prints printing text uses clear toner [2]. It can be detected by the human eye because of the differential gloss but not by a conventional scanner. This method again needs specifically matched paper and toner having a significant difference in gloss. It works in the combinations of glossy toner on matte paper or matte toner on glossy paper but not by using, e.g., glossy paper and toner in the same gloss range that is common in the field of digital commercial printing.

A method for making nonreproducible documents is printing indicia on a document, which are nearly invisible [3]. The method consists of continuous screened lines of a desired pitch, and a background that will not reproduce by copying. It is formed by orthogonal reproduction of positive/negative images of continuous lines to produce broken lines of a desired width and pitch.

Another approach uses indicia on the top surface of a substrate [4]. The security term is composed of a pattern of security term elements. The background elements and/or the security term elements differ in element size, shape, angle, density, and/or frequency between adjacent areas.

A screen comprising columns and rows of halftone dot centers are described as well [5]. They are equally spaced in row-to-row, column-to-column, and column-to-row relationships; however, the columns are not geometrically orthogonal (perpendicular) to the rows.

An electrophotographic printing process could be used to create a secure document by the use of one or more colorless toner images in combination with at least one color toner image produced on a receptor element [6].

Finally a method should be mentioned that manipulates differential gloss of an image (picture or text) by selectively applying halftones with anisotropic structure characteristics that are significantly different in orientation while remaining identical in density [7]. A glossy image is thus superimposed within an image without the need for special toners/inks or paper. This method is limited to color halftone images. It cannot be used for low-density images or image areas specifically below 50–20% area density depending on toner and paper gloss and the structures selected. It cannot be used as well for high-density images or image areas above 60–80% area density, again depending on toner and paper gloss and the structures selected. Then the effect is too weak to be detected by the human eye.

The objective of this work is to provide a method to be used in digital production presses such as the Kodak NexPress product family, which allows for the production of digital watermarks on paper without the limitations described above, which means not being limited in the gloss properties of the toner, the paper, and/or selected fusing technology.

KODAK NEXPRESS 2100, 2100 Plus, 2500 and S3000 Digital Production Color Presses

The KODAK NEXPRESS 2100 Digital Production Color Press was first shown at DRUPA 2000 and introduced into the market the following year. The 2100 Digital Production Color Press with Kodak NexPress fifth imaging unit solutions was introduced at DRUPA 2004. Many new applications and solutions were now possible. With a changeable fifth color station and KODAK NEXPRESS Red, Green and Blue Dry Inks to choose from, using a pentachrome five-color multilevel halftone mixing process, the 2100 press expanded the available color gamut.

If a Clear Dry Ink (CDI) is used in the fifth station, along with the standard CMYK Dry Inks in an Intelligent Coating process that apply CDI in selective areas of the image, significant improvement on image abrasion resistance and further reduction of color granularity have been demonstrated. The end result exceeds the capability of offset printing with aqueous coating for image protection. Other applications for CDI in the fifth station of the Kodak NexPress 2100 press are, e.g., spot coating or clear watermarking for design or security purposes.

With the introduction of a near-line Kodak NexGlosser glossing unit, the CDI image with clear overcoat can be further glossed up to a very high and uniform gloss (G20 = ~90 can be achieved) in the glossing process for photo-rich applications. In addition to that, it has been shown that the optimized process can increase the color gamut of the entire printing system for many substrates (typically in a range of 10% increase in gamut volume).

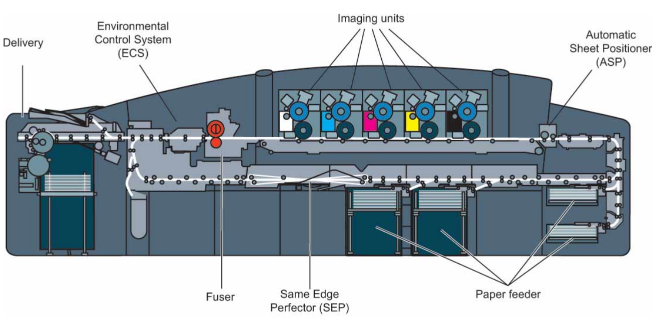

Figure 1 *Kodak NexPress 2100 plus, Kodak NexPress 2500, and Kodak NexPress S3000 digital production color presses equipped with four paper deliveries and high-capacity delivery*

At Print 05 in Chicago, Kodak announced two new color offerings: the Kodak NexPress 2100 plus and the Kodak NexPress 2500 presses [8], followed by the KODAK NEXPRESS S3000 Digital Production Color Press, announced at the On Demand Show in April 2007 [9] (Figure 1). All are differentiated from the Kodak NexPress 2100 press by a number of factors [8], including larger print format size, broader substrate capability, expanded feeding and finishing capabilities and options, new standard delivery or new single (or dual) high-capacity delivery, inline finishing architecture, an expanded number of operator-replaceable components (ORCs), and an improved throughput feature called “Productivity Optimizer”.

The 2500 and S3000 presses offer a faster speed (2,500 and 3,000 4/0 and 5/0 A3 sheets per hour) as well in relation to the 2100 and 2100 plus presses (2,100 4/0 and 5/0 A3 sheets per hour).

Digital Watermarking Using Clear Toner

The present work relates to a method for producing clear watermarks, low-density watermarks, and high-density watermarks using clear toner or ink. The related digital watermark technology known for some time [7] controls the differential gloss of an image using the steps selecting a first halftone image having a first anisotropic structure, selecting a second halftone image having a second structure different from that of the first halftone, applying the first halftone to at least some portion of the halftone image, and applying the second halftone to another portion of the halftone image. The second structure may be anisotropic as well.

The number of structures is not limited. In a specific embodiment two halftone structures are used. The second halftone may be applied to the remaining part of the halftone image or to only a part of it. It may cover part of the print or the remaining part of the print area not covered by the first anisotropic structure. The first anisotropic structure and the second anisotropic structure orientation maybe 90° apart.

Halftone in this context means screened structures of toner layers with a preferred area coverage of ~20–80% or limited to the range of 40–60% depending on toner and paper gloss and the structures selected. In this range anisotropic structures are visible. In areas with low (10%) or high (90%) area coverage the effect is not sufficient to be observable by the human eye.

The method described also relates to a process whereby the gloss of the paper and the gloss of the toner measured separately on 100% of the covered areas are about the same. In this case the existing methods to achieve differential gloss using clear toners without using anisotropic structures fail, as in this case no differential gloss exists.

Low-density areas in this context mean areas with an area coverage too low to observe anisotropic structures by the human eye. These are area coverages below the area coverage limits mentioned above, especially area coverages of 30%, 20%, or even 10%.

High-density areas in this context mean areas with an area coverage too high to observe anisotropic structures by the human eye. These are area coverages above the area coverage limits mentioned above, especially area coverage of 80%, 70%, or even 60%.

The substantially clear toners used are of essentially the same composition as color toners used in the art, except for the dyes and pigments. The clear toners are substantially transparent, such that the inherent colors of the applied color toners are not materially masked and the relative amount of reflected light from the image is essentially maintained and not materially diminished by the clear toner. The clear toner may be slightly tinted, pigmented, or dyed up to a degree where it is substantially transparent uniformly over the visible spectrum (400–700 nm).

The method is particularly suitable for electrophotographic printers using dry toners as these toners have a median particle size in the range 5–10 µm, which when fused may show a significant digital watermarking behavior.

Visibility of Anisotropic Impressions

The visibility of an anisotropic impression to the human eye depends on the total coverage of toner/ink of the same gloss level on the paper independent of the pigmentation.

Figure 2 [10] shows the measured gloss level at an angle of 60˚. A standard glossy paper is used having a measured gloss of 39. The gloss value at area coverage 0% is the paper gloss. The toner is a standard color toner fused to the paper using a standard hot roller fuser. The temperature of the hot roller is 160˚C. The paper speed when passing through the fuser is 30 cm/s.

Figure 2 shows that the gloss decreases with increasing area coverage. At 10% area coverage it reaches a value of 30. The gloss difference between paper and image gloss at 10% area coverage is only 9. This difference is thus too small to observe a clear watermark effect with the human eye. Using low-pigmented toner or adding substantially clear toner enhances the gloss difference to paper and thus the visibility of the watermark effect. The measured gloss level decreases with increasing area coverage and reaches saturation at about 50%. If the area coverage is further increased the gloss level remains stable, but the watermark effect decreases as the percentage of toner/ink covered paper decreases.

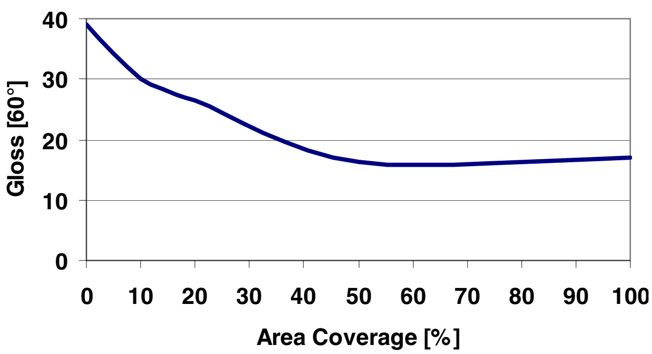

***Figure 2**. Gloss level of a toner for hot-roller fusing on glossy paper depending on area coverage.*

Figure 3 [10] shows the dependence of gloss measured at an angle of 60˚ on the area coverage for another toner/paper combination fixed by an alternative noncontact fusing method. A standard glossy paper is used showing a measured gloss of 35°. The gloss value at area coverage 0% is the paper gloss. The toner is a color toner for noncontact fusing fused to the paper using noncontact fusing.

Figure 3 shows that the measured gloss level decreases and thus the gloss difference to the paper gloss increases with increasing area coverage. At 10% area coverage it reaches a value of 30. The gloss difference between paper and image gloss at 10% area coverage is only 5. This difference is too small to observe a clear watermark effect with the human eye. Using low-pigmented toner or adding substantially clear toner enhances the gloss difference to paper and thus the visibility of the watermark effect. The measured gloss level decreases with increasing area coverage and reaches a value of 19 at 50%, resulting in a gloss difference of 15 to the paper that is easily detectable to the human eye. If the area coverage is further increased the gloss difference to the paper further increases, but the watermark effect decreases again as the percentage of toner/ink covered paper decreases.

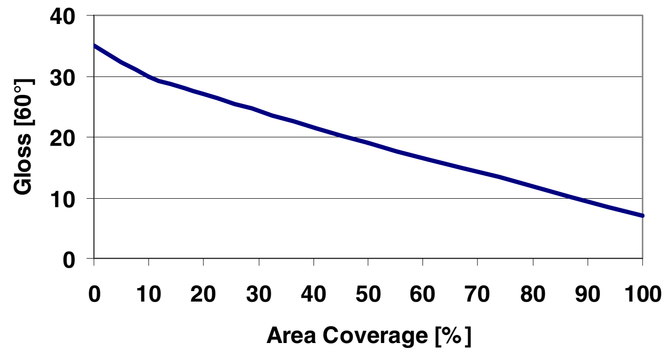

***Figure 3**. Gloss level of a toner for noncontact fusing on glossy paper depending on area coverage.*

Digital Watermarking Using Substantially Clear Toner Alone

In the case of clear images, differential gloss of an image is controlled using the steps selecting a first halftone image having a first anisotropic structure, selecting a second halftone image having a second structure different from that of the first halftone, applying the first halftone to at least some portion of the halftone image, and applying the second halftone to another portion of the halftone image whereby a toner is used that is substantially colorless to realize the first and second halftone images [10].

In the specific case of the Kodak NexPress digital production press the clear toner is applied using the fifth print module of the electrophotographic printer equipped with five print modules. Five image units are installed along the paper pass and transfer their color separation to the paper one after the other via a blanket cylinder.

Digital Watermarking of Low-Density Images

In the case of low-density images, the differential gloss of a low-density image is achieved with pigmented toners using the same steps as described above for clear toner, but in this case substantially colorless toner is added to the pigmented toner structures so that the total area coverage of pigmented plus substantially unpigmented toners is in the ranges between 20% to 80% and 40 to 60% depending on toner and paper gloss and the structures selected. Alternatively, the concentration of pigment in the toner is reduced so that the total area coverage of the toner is in the same range [10].

In the specific case of the Kodak NexPress digital production press, the clear toner or the low-pigmented toner, specifically either low-pigmented cyan or low-pigmented magenta toner, is applied using the fifth print module of the electrophotographic printer equipped with five print modules as described above.

The image units contain, for example, the different toners in the following order: black, yellow, dark magenta, dark cyan and light magenta, light cyan or light black (gray). The dark black, cyan, and magenta image units are equipped with a toner that results in an image density of 1.6 or more; the image unit equipped with light cyan or magenta toner or gray toner results in an image density of 1.0 or less, preferably half of the image density achieved with dark cyan or magenta black toner. Low-density yellow toner may be used as well. Both density values relate to development of full area coverage, which means area coverage above ~95% depending on the morphology of the substrate.

The light cyan, light magenta, or gray image stations in the fifth position can be easily exchanged, including their toner hopper. The selection of the light toner in the fifth imaging unit is based on the image content and is either done by the operator or by the color separation software.

The area coverage of the anisotropic halftone images is enhanced using either low-pigmented cyan, low-pigmented magenta, low-pigmented yellow, or low-pigmented black (gray) toner of similar gloss so that the total area coverage of the pigmented toner is in the range of ~20−80% or limited down to the range 40−60% depending on toner and paper gloss and the structures selected. Using low-pigmented toner, the area coverage R to achieve the same image density can be increased by the relation:

$$R = CN/CL$$

where CN is the concentration of the pigment in the normal pigmented toner and CL is the concentration of the same pigment in the lower pigmented toner. The reduction of image density at the same area coverage can be achieved as well by using pigments with lower tinting strength or by addition of other pigments that reduce the image density at the same area coverage. This may be white or silver pigment or another light-colored pigment (e.g., titanium oxide, zinc oxide, or titanium strontium oxide).

The gray toners may be low-pigmented black toners with a low percentage of black pigment (typically 0.1−2%)—preferably carbon black, magnetite, or black nonmagnetic composite particles comprising hematite or black iron oxide hydroxide particles as core particles optionally surface treated. If white or silver pigments are used as described above, the black pigment concentration is in the range 0.2–5% and the white or silver pigments in the range 5−10%.

Digital Watermarking of High-Density Images

In the case of high-density images, the differential gloss of an image is achieved with pigmented toners using the same steps as described above for clear toner, but in this case substantially colorless toner is added to the pigmented toner structures so that the total area coverage of pigmented plus substantially unpigmented toners is >100% [10].

In the specific case of the Kodak NexPress digital production press, the clear toner is applied using the fifth print module of the electrophotographic printer equipped with five print modules as described above.

Summary

We have described a method to control differential gloss of halftone areas produced using substantially clear or low-pigmented toner. It is an objective of this work to provide a method that allows one to produce digital watermarks on paper without being limited in the gloss properties of the toner, the paper, and/or selected fusing technology.

The present work relates to a method of producing clear, low-density, or high-density watermarks using low-pigmented toner or clear toner. We control the differential gloss of an image using the steps selecting a first halftone image having a first anisotropic structure, selecting a second halftone image having a second structure different from that of the first halftone, applying the first halftone to at least some portion of the halftone image, and applying the second halftone to another portion of the halftone image.

The specific use of this technology in a Kodak NexPress digital production color press equipped with imaging units was described as well.

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Author Biography

Detlef Schulze-Hagenest studied physics and intellectual property law in Hamburg and Berlin and received his Ph.D. in physics from Kaiserslautern-University. Since 1980, he has been working in the field of platforms, processes, and materials for digital printing, with a special focus on electrophotography and inkjet. He is currently the Senior Engineer of Technology Development at Kodak Digital Printing Solutions (NexPress GmbH) in Kiel, Germany. He is the author of approximately 50 patent families, and enjoys classical music and gardening. He is a member of IS&T and serves as the Publication Chair of this conference.