Stabilized 3-Level High Light Color Imaging with High Resistance Developer

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Abstract

For the 3-level highlight color imaging, a 1-pass process with combinations of charged and discharged area developments is used. It has an advantage for excellent gradation images between black and color because of perfect color registration. Otherwise, there are some unique problems of fringe images, blur, white spots in the 2nd color images, etc. Employing very low resistance developer gives a solution for these problems. However, this method causes developing instability due to a charge leakage instead.

The highly stable 3-level process without the problems, employing the higher resistance developer without the charge leakage and applying newly developed edge effect control technology and the 1st color developing station with dual rotation rollers, are proposed in this study.

Finally a stable process and an excellent highlight color image can be provided.

Introduction

In 1980s, copiers and laser printers for printing color logo marks and/or small additional images had been on the market. Such a printing is called one point color or accent color because of additional color images in black and white main documents. Since early 1990s, corresponding to evolution of Print On Demand, more precise highlight color images, including under lines, the black and color gradation images, etc., with heavy duty printing for large area coverage such mark sheets have been required. The 3-level process, tri-level in other words, is suitable for such a use.

In the 3-level process, a charger and 1 exposure device form the charged, intermediate and discharged electric potential levels on the photoconductor. And then, the charged and discharged area developments with the black and color toners are performed. Since the black and color areas are formed by 1 exposure device, the process has perfect registration between the black and color areas and is essentially 1 pass. The perfect registration provides the precise highlight color image. On the other hand, since the charged electric potential is divided into 2 parts, the each development is necessitated to have very small imaging potential and back potential to the intermediate potential, and very large back potential to the other color imaging potential. They cause several problems uniquely in the 3-level process, which are small development performances, fringe images, blur at both color adjoining area in the 1st color image and white spots in the 2nd color (normally, black) images.

The 3-level process is originally appeared in Japanese patent laid-open publication No. 37,148/ 1973, "Two-color developing method", as far as the authors know.[1] In 1978, it appeared in the US patent 4,078,929, "Method for Two-color Development of a Xerographic Charge Pattern".[2,3] After many years from these inventions, investigations for the 3-level process were reported.[3-6] The reports include introductions and examinations for some of the unique problems.

In this study, the mechanism and peculiarity of the problems are considered further. Especially, relationships between the problems are examined and a solution for the process formation, employing the high developer resistance, is revealed. In the previous report, requirement for a soft conductive magnetic brush development is mentioned.[3,4] However, developing instability, due to charge leakage and other reasons, should be solved to employ the low resistance developer. For enabling the use of the high resistance developer process that has more stability, the technology development of the edge effect control for preventing the fringe images and the application the dual rotation developing station at the 1st color developing station for varnishing the blur are carried out.

Finally a highly stable process using the high resistance developer, which provides an excellent highlight color image, is proposed.

3-Level Process

Figure 1 shows schematic of the 3-level process. After a photoconductor drum surface is uniformly charged, one laser beam partly erases it to the intermediate and discharged potentials. Thus, 3 electric potential areas, which are for the color, white and black images, are formed. The distribution on the photoconductor is schematically shown in Figure 2. It is illustrated in Figures 1 and 2 that the color toner development is performed at the 1st color developing station and the black toner development is at the 2nd color developing station in Figures 1 and 2. At the 1st developing station, a positively charged color toner imaging with the charged area development is performed. Next, the discharged area development for negatively charged black toner in the 2nd developing station is performed. Even if the discharged area development for the negatively charged color toner is used for the 1st developing station, the 3-level process can be built up.[4] The black and color toner images, which have opposite polarities, are developed on the photoconductor surface at this point. Next, a pre-transfer charger makes the toner polarities uniform for enabling an electrostatic transfer process. And then, the toner transfer to paper is performed. Finally, the black and color images held on the paper is carried to a fuser and then fixed.

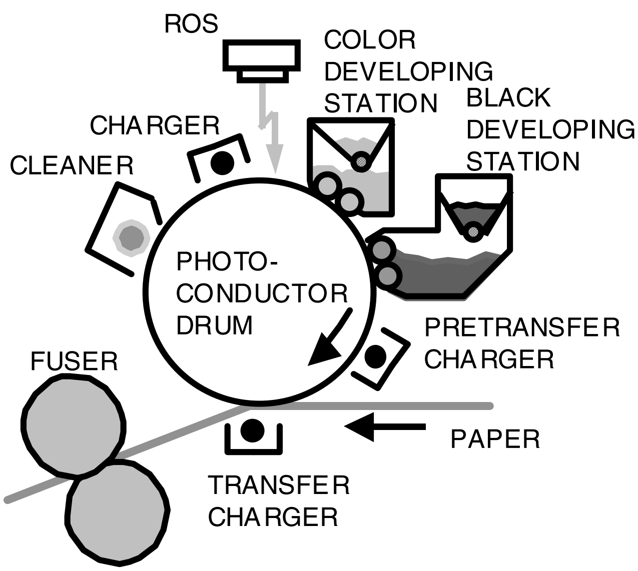

Figure 1. 3-level Process.

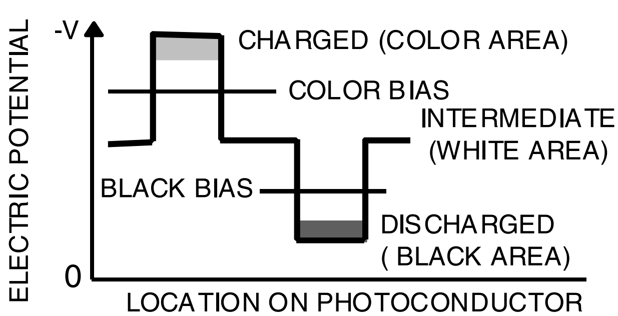

Figure 2. Electric Potential Distribution

The charged electric potential is divided into 2 parts, the each color development is necessitated to have very small imaging potential and back potential to the intermediate potential, and very large back potential to the other color imaging potential. The very small imaging potential causes a problem of poor development performances, namely difficulty to have sufficient image densities. Other characteristics cause several unique problems, which are fringe images, white spots in the 2nd color (normally, black) images and blur at both color adjoining area in the 1st color image.

Fringe Images

Figure 3 shows schematics of the fringe image and its electric field distribution.[4] The fringe image is a ghost image by the opposite color toner which appears at an image edge. It is observed that it occurs at a down side of an image and at a narrow gap between parallel lines or tapered lines for the developing roller rotation. It means that the fringe images occur at locations on the photoconductor where the strong edge effect is affecting and where the charged toner of the fringe image is blocked with surface electric field. At the area without the block, even if the fringe image is developed, it is swept out by the developing roller and is disappeared during developing. Therefore, the fringe is a development by a strong edge effect of the electric field and its appearance is affected by mechanical scrubbing factors by the developing roller rotation.

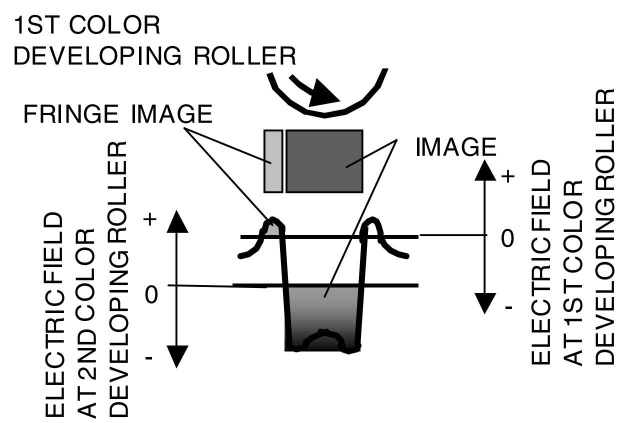

Figure 3. Electric Field and Fringe Image.

A use of the higher resistance developer promotes the fringe image because the electric field at the edge is increased. And, getting the bias voltage of the opposite color closer to the intermediate potential also promotes the fringe image.

White Spots

Figure 4 shows a schematic of the white spots. In conditions that a difference between the 1st color bias voltage and the discharged area potential is too large and the developer resistance is too small, spotty discharges from the magnetic brush to the discharged area on the photo-conductor occur when magnetic brushes touch the photoconductor surface during the 1st developing. The spotty discharged marks in the discharged area appear as the white spots in the black images. They have a less possibility to appear in the 1st color image. The effective difference between the 2nd color bias voltage and the charged area potential is not large because it is decreased by an existence of the 1st color toner image.

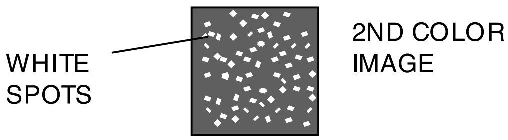

Figure 4. Schematic of White Spots.

Blur at Both Color Adjoining Area

Figure 5 shows the schematic of the blur and the potential distribution. The blur occurs in the 1st color image at the both color adjoining area at a down side of a 1st color image next to the 2nd color image for the 1st color developing roller rotation. At first, 1st color magnetic brush scrubs and passes through the 2nd color developing area without toner image, assuming it as discharged area. And then, electric potential suddenly changes to the charged area potential on the 1st color area. The change from the discharged to the charged potentials is significant. As to development current, the current direction is changed quickly. If the resistance of the magnetic brush is high, the change involves some response delay in transient phenomena. During transient responding, developing performance is not enough and it causes the blur.

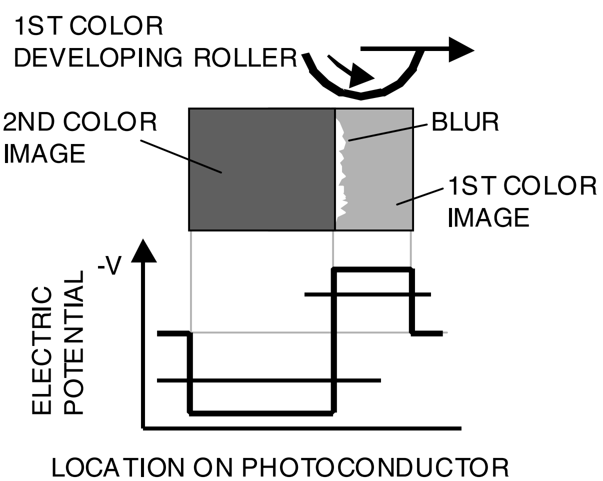

Figure 5. Blur at Both Color Adjoining Area.

Process Formation

Method by Low Developer Resistance and Low Charged Area Potential

Figure 6 shows the fringe images at circumference of the 2nd color image and the white spots appearance levels with kinetic specific resistance of 1st color developer. The level in the vertical axis is a rating from no fringe images or no white spots, rate 0, to the worst, rate 4. It is found that the white spots and the fringe images appearances have a tradeoff relationship, which means that the fringe images get worse and the white spots decrease as increase of the resistance. From comparison potential patterns A and B, both the fringe images and the white spots appearances are better in the pattern A. For the fringe images appearance, the electric field that is a cause of the fringe image is smaller in the pattern A because the charged area potential, (a), is lower. For a reason of the white spots appearance, the potential difference between the 1st color bias voltage and the discharged area potential, (b), is smaller in the pattern A. After all, this is caused by the lower charged area potential, (a), in the pattern A. Cross point of fringe images and white spots curves, which is shown in triangle symbol, is decreasing from the patterns B to A along a gray broken line. This means that prevention of both the fringe images and the white spots can be provided in a range of the lower charged potential and the lower effective resistance. Roughly speaking, the charged area potential and the kinetic specific resistance without the fringe images and white spots appearances are expected to be less than $|-650V|$ and $10^6 \Omega m$ in Figure 6. Such a low developer resistance has high developing performance; the sufficient image density can be obtained. And it also has quick response performance and is effective for preventing the blur at the both color adjoining area. On the other hand, such a low developer resistance has a problem of charge leakages and makes the process unstable.

	POTENTIAL PATTERN A (V)	B (V)
(a)	-780	-880
(b)	-530	-630
(c)	-350	-350

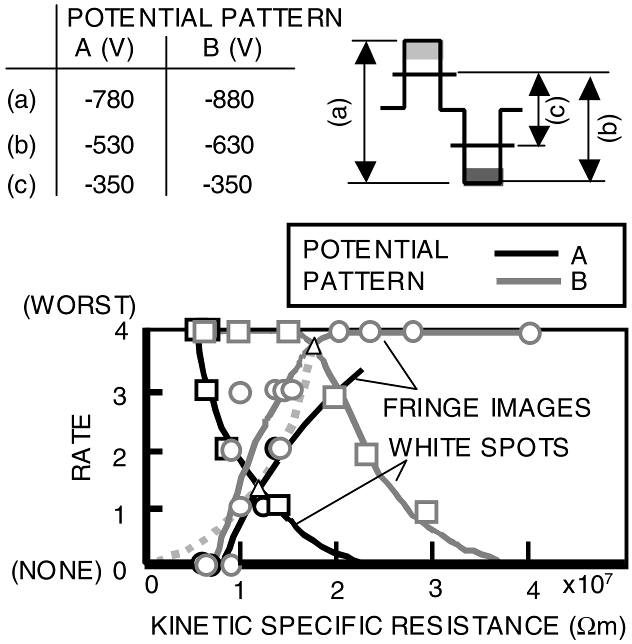

Figure 6. Characteristics of white spots and fringe image.

Method by High Developer Resistance and High Charged Area Potential

For avoiding the charge leakage in the process formed by the low developer resistance and the low charged area potential, and for obtaining the stabilized process, a use of higher developer resistance is needed. The charge leakage problem can be neglected in the developer resistance range above $10^7\Omega m$ in Figure 6. To compensate the low developing performance in the high developer resistance and to obtain sufficient image density, wider developing potential, (a)-(c) in Figure 6, should be set together with the use of the high resistance developer. The high charged area potential setting, namely the pattern A or B in Figure 6, makes it possible.

In the use of the high developer resistance and the high charged area potential, the white spots can be avoided. For example, in the difference between the 1st color bias voltage and the discharged area potential, |-530V|, as shown in the potential pattern A, choosing the developer resistance range above $2.3x10^7\Omega m$ provides no white spots. However, in this condition, the fringe images appear and it is hard to avoid the blur. Some special counter measurement methods are expected for these 2 unique problems.

Measure for the Unique Problems

The counter measurements for the fringe images and the blur at the both color adjoining area, in conditions with the high developer resistance and the high charged area potential, are proposed in this chapter.

Edge Effect Control Technology

For preventing the fringe images, the edge effect control technology (EECT) is examined. The cause of the fringe images is the edge effect at an image circumference as mentioned above. The fringe images appear in the specific area, which are at a down side of an image and at a narrow gap between the parallel lines or the tapered lines for the developing roller rotation. Avoiding dramatic potential changes on the photoconductor can loosen the edge effect. In EECT, an auxiliary exposure level is supplied to the area where the fringe image is to be appeared on the photoconductor. The exposure point is selected by a pattern matching technology for an image signal. Figure 7 shows an electric potential and field distributions when auxiliary exposure level is applied. A case for which the auxiliary exposure level is applied to the 2nd color image is shown in Figure 7. EECT is also effective for the 1st color image. The auxiliary exposure level should be set as its potential is to be placed between the intermediate potential and the bias voltage for avoiding a ghost image by the auxiliary exposure level itself. For more precise optimization, the edge effect caused by the difference between the discharged and auxiliary potentials shown as “A” in Figure 7 and caused by the difference between the auxiliary and intermediate potentials shown as “B” should be at the same levels. Thus the fringe image preventing effect is earned most effectively. A case of 1 auxiliary exposure level is shown in Figure 7. It is experimentally confirmed that multileveled auxiliary exposure makes more performance for preventing the fringe images.

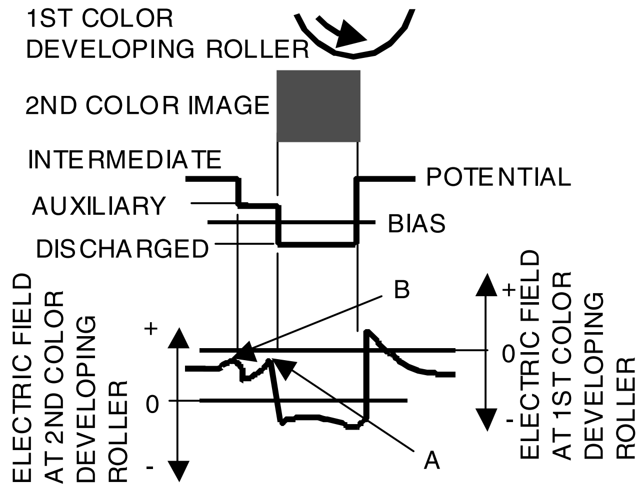

Figure 7. Edge Effect Control for Preventing Fringe Images

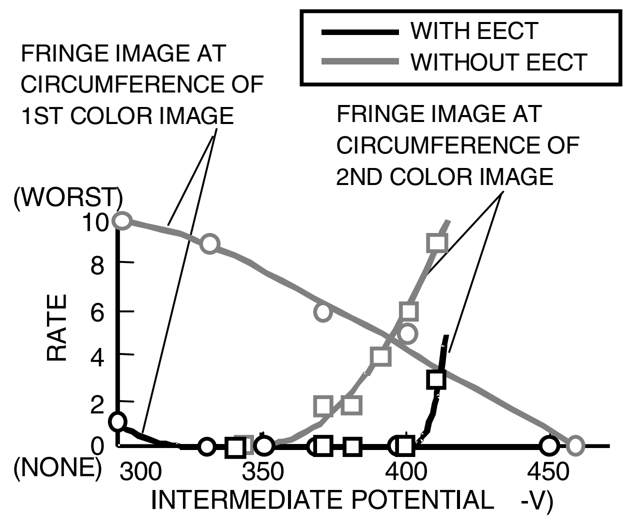

Figure 8. Effect of Edge Effect Control.

Figure 8 shows an experimental result for the effect of EECT. The fringe images appearance levels with the intermediate potential is shown. The level in the vertical axis is a rating from no fringe images, rate 0, to the worst, rate 10. Multileveled auxiliary exposure is applied. The high resistance developers above $10^7\Omega m$ for the both color are employed and the white spots are not appeared. In the experiment, the charged potential is changed with keeping power of each exposure level constant. Thus, the intermediate potential and the auxiliary potentials are changed with the charged potential. When the absolute value of the intermediate potential is increased, the edge effect caused by the difference between the discharged and the intermediate potentials is enhanced. In addition to it, since the intermediate potential gets closer to the 1st color bias voltage, the fringe image at the circumference of the 2nd color image is apt to occur. When the absolute value of the intermediate potential is decreased, the fringe image at the circumference of the 1st color image is apt to occur since the intermediate potential gets closer to the 2nd color bias voltage. In condition without EECT, at least the either color fringe image occurs in any intermediate potential. On the other hand, a wide range of the intermediate potential without occurrence of the both color fringe images can be obtained with the use of EECT.

The 1st Color Developing Station with Dual Rotation Rollers

The schematic of the developing station is shown in Figure 9. The 1st color developing station with developer feeding in a facing gap of 2 different rotation direction rollers is employed for vanishing the blur. Since the blur is a directional phenomena which occurs at a down side of a 1st color for the 1st color developing roller rotation, the counter measurement by the dual rotation developing roller is effective. Prevention of the blur provides very excellent color gradation images between the black and color toning images, making the most of the perfect color registration.

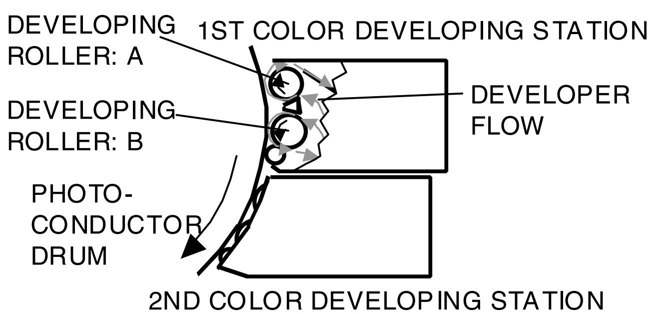

Figure 9. 1st Color Developing Station.

As a secondary advantage of the 1st color developing station with the dual rotation rollers, dual bias voltage setting can be made. For roller A shown in Figure 9, the lower bias voltage than that of roller B is set. It is found that even if the fringe image and background toner is developed at roller A, caused by the low bias voltage setting, roller B sweeps them out and vanishes. Finally, the lower developing roller bias voltage setting for roller A provides the high developing performance for the 1st color developing station.

The edge effect control technology for preventing the fringe images and the dual rotation developing station at the 1st color developing station for varnishing the blur make the use of the high resistance developer possible. Thus, the stabilized 3-Level highlight color imaging is obtained.

Conclusions

The problems of the fringe images, the white spots and the blur at the both color adjoining area, and the process formation for the 3-level highlight color imaging is examined. And then, the technology development of the edge effect control for preventing the fringe images and the application of the dual rotation developing station at the 1st color developing station for varnishing the blur are carried out. Finally, these technologies make the use of the high charged potential setting and the high resistance developer in conditions with preventing the white spots possible. Thus, the stabilized 3-level highlight color imaging is obtained.

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Biography

Teruaki Mitsuya was born in Aichi-Pref., Japan in 1957. He received his BE, ME and Dr. Eng. degrees in 1980, 1984 and 1997, respectively. He had designed video equipment in Hitachi, Ltd., from 1980 to 1982. He has been researching imaging technologies in laser printers, in Hitachi, Ltd. from 1984, California Inst. Tech. from 1994 and Hitachi Koki Co., Ltd. since 1995, respectively. He is a member of IS&T, ISJ, ASME, JSME, etc.