Development of High Abrasion Resistance Organic Photoreceptors using Cross-linked Overcoat Layer

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Abstract

Recently, electrophotographic high-speed digital printers have been making progress in the production printing market. The production printing market requires "high image quality", "high reliability and durability", and "high productivity" for high-speed digital printers, and "electrostatic stability" and "mechanical abrasion resistance" for organic photoreceptors. The conventional organic photoreceptors have not met such requirements, because the conventional surface layer is less durable to abrasion.

To solve the above problem, we have developed a novel overcoat layer having improved abrasion resistance, without reducing charge transport ability.

Introduction

Recently, high-speed digital printers have been making progress in the production printing market. The production printing market requires "high image quality", "high reliability and durability", and "high productivity" for high-speed digital printers[1]. In order to meet the requirement of "high reliability and durability", photoreceptors, which constitute the heart of the printer engine, are required to have a much longer lifespan. In view of this situation, Ricoh have been engaged in development of highly-durable photoreceptors.

The high-speed monochrome digital printer imagio MP1350 is equipped with a highly-durable photoreceptor which employs a blocking layer for preventing local charge leakage, and a thicker charge transport layer (CTL) for improving abrasion resistance and preventing the occurrence of background fouling[2]. Abrasion resistance has been further improved by provision of a protective overcoat layer including a filler, or application of a lubricant to the photoreceptor surface[3] [4]. Additionally, the production printing market further requires reliable halftone reproducibility especially for high-speed full-color digital printers.

Fig. 1 shows photo-induced discharge curves (PIDC) of a photoreceptor subjected to an enforced abrasion. PIDC has been considerably changed after the enforced abrasion, along with the considerable change in thickness of the photoreceptor. Because halftone potential is sensitive to thickness variation, it is necessary to improve abrasion resistance to reduce thickness variation, in order to achieve reliable halftone reproducibility.

In attempting to improve abrasion resistance, we have developed a novel overcoat layer in which a cross-linking reaction occurs upon exposure to ultraviolet ray (UV). This report outlines our development of the high-abrasion-resistance organic photoreceptor using the cross-linked overcoat layer.

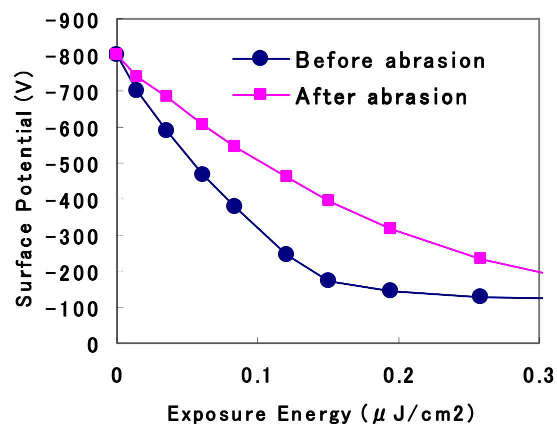

Figure 1 *PIDC of photoreceptor before and after abrasion.*

Overview of Cross-linked Overcoat Layer

Abrasion Resistance

Fig. 2 illustrates abrasion diagrams of (a) a conventional CTL and (b) the novel overcoat layer. The CTL disperses a charge transport material (CTM) in a resin. Referring to (a), the resin is comprised of entanglements of molecular chains, but the entanglements are more likely to be detangled as the concentration of the CTM increases in the CTL. In a case where a cleaning blade repeatedly abrades such a CTL in which the molecular chains are detangled, it is likely that the resin is considerably abraded.

On the other hand, referring to (b), the novel overcoat layer has a three-dimensional structure in which cross-linkable monomers are cross-linked with each other. In this case, even when a cleaning blade repeatedly abrades the overcoat layer to cut a part of the molecular chains, the other parts still remain. Thus, the novel overcoat layer has achieved high abrasion resistance.

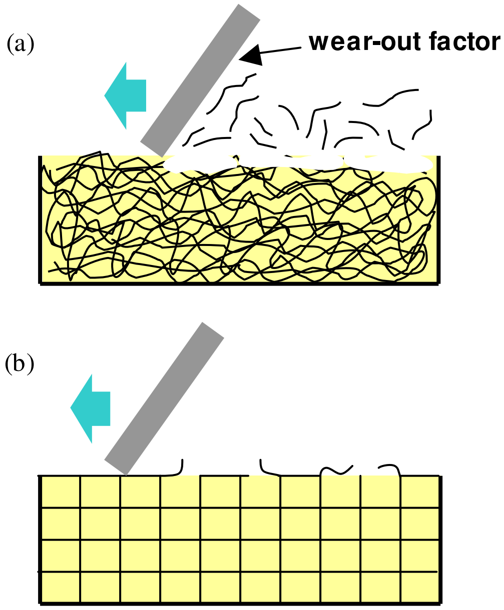

Figure 2. Abrasion diagrams of (a) conventional charge transport layer and (b) cross-linked overcoat layer.

Charge Transportability

As described above, the conventional CTL disperses the CTM in a resin. Of course, the novel cross-linked overcoat layer may include the CTM to give charge transportability to the layer. However, there has been a problem that the CTM cannot be reliably fixed within the cross-linked overcoat layer, resulting in deterioration of abrasion resistance. To solve this problem and give both charge transportability and abrasion resistance to the layer, the novel cross-linked overcoat layer is formed by copolymerizing the cross-linkable monomer with a charge transport monomer (CT-monomer illustrated in Fig. 3) having a charge transport unit and a reactive unit.

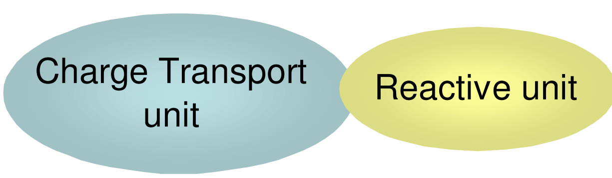

Figure 3. CT-monomer model.

Fig. 4 schematically illustrates a charge transporting model in the overcoat layer. We consider that charges injected from the CTL to the overcoat layer migrate to the surface of the overcoat layer by hopping between the charge transport units of the CT-monomers. Simultaneously, the reactive units of the CT-monomers copolymerize with the cross-linkable monomers upon exposure to ultraviolet ray, thus fixing the CT-monomers within the resultant three-dimensional cross-linked overcoat layer.

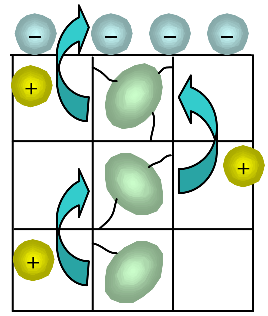

Figure 4. Charge transporting model in overcoat layer.

Fig. 5 compares surface potential attenuation curves of the overcoat layers with or without the CT-monomer. In the overcoat layer without the CT-monomer, the surface potential gently attenuates with increase of light exposure time. By contrast, in the overcoat layer with the CT-monomer, the surface potential rapidly attenuates with increase of light exposure time. These results show that the overcoat layer with the CT-monomer has better charge transportability than that without the CT-monomer.

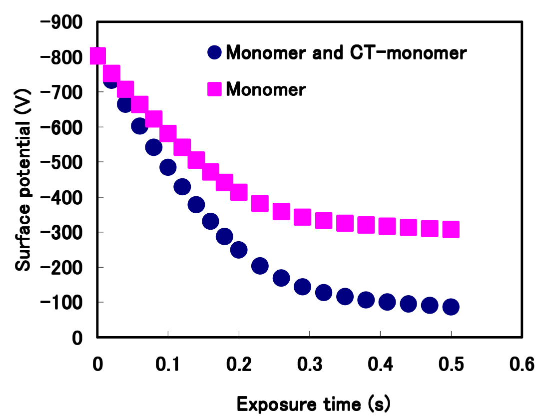

Figure 5. Effect of CT-monomer.

Formation of Cross-linked Overcoat Layer

A procedure of forming the cross-linked overcoat layer is described below in detail.

First, an overcoat layer coating liquid, comprised primarily of the cross-linkable monomer, the CT-monomer, and an initiator, is coated on the CTL, and then exposed to ultraviolet ray, so that the monomers are cross-linked. Fig. 6 schematically illustrates the procedure of forming the cross-linked overcoat layer. A mechanism of the copolymerization between the cross-linkable monomer and the CT-monomer has not been cleared yet, however, we assume a mechanism that the initiator produces radicals upon absorption of ultraviolet ray and the produced radicals conduct a chain polymerization between the cross-linkable monomer and the CT-monomer.

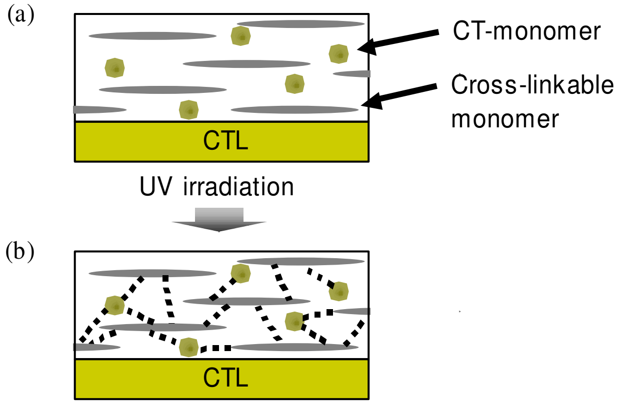

Figure 6. *Diagram of forming cross-linked overcoat layer.*

Durability Test

We conducted a durability test to evaluate performances of the novel overcoat layer, using a high-speed monochrome digital printer imagio MP1350.

Layer Structure of Photoreceptor

Fig. 7 schematically illustrates the layer structures of (a) the novel photoreceptor and (b) a conventional photoreceptor.

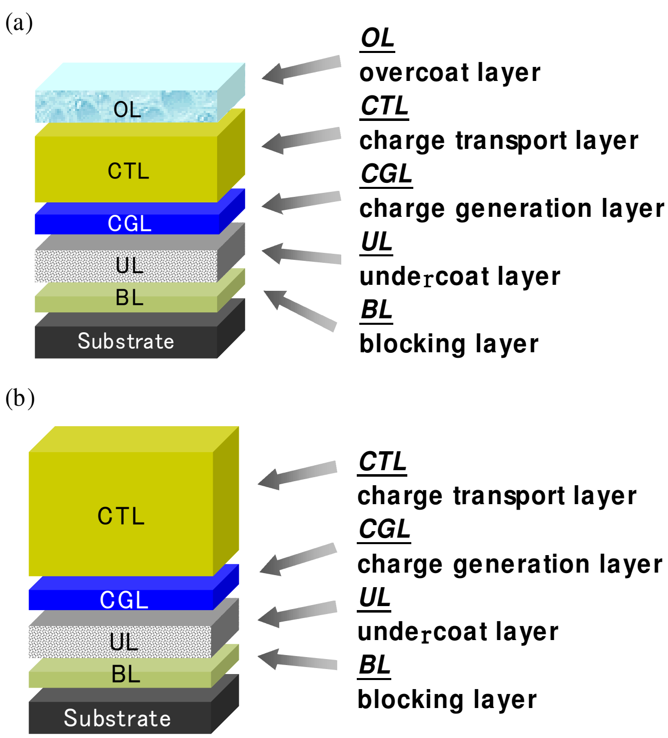

Figure 7. *schematically illustrates the layer structures of (a) the novel photoreceptor and (b) a conventional photoreceptor Diagram of forming cross-linked overcoat layer.*

Abrasion Resistance

Fig. 8 shows the evaluation results of abrasion resistance. More specifically, Fig. 8 shows a relation between the number of printed sheets and the abrasion thickness. In the conventional photoreceptor, the overcoat layer is abraded for a thickness of approximately 7.5 μm after printing 1,000K sheets. By contrast, in the novel photoreceptor, the overcoat layer is abraded for a thickness of only approximately 1.9 μm after printing 1,000K sheets. The novel photoreceptor having the three-dimensional cross-linked overcoat layer has improved its abrasion resistance to approximately 4 times greater than that of the conventional photoreceptor.

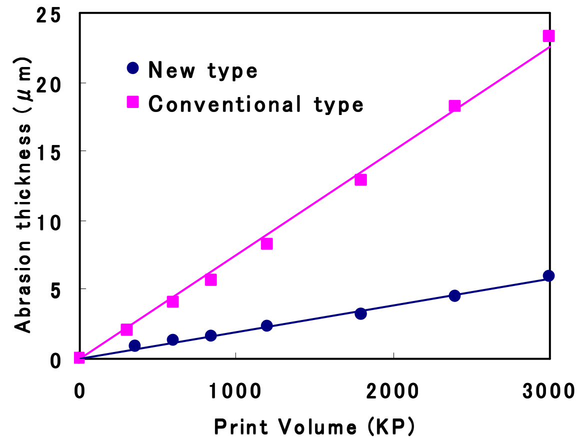

Figure 8. *Evaluation results of abrasion resistance.*

Halftone Potential Variation

Fig. 9 shows the evaluation results of halftone potential variation. More specifically, Fig. 9 shows a relation between the number of printed sheets and the halftone surface potential. In the conventional photoreceptor, the surface potential increases approximately 70 V per 1,000K-sheet printing. By contrast, in the novel photoreceptor, the surface potential increases only approximately 40 V per 1,000K-sheet printing. The novel photoreceptor has improved its resistance to halftone potential variation approximately 2 times greater than that of the conventional photoreceptor, which is achieved by improvement of abrasion resistance.

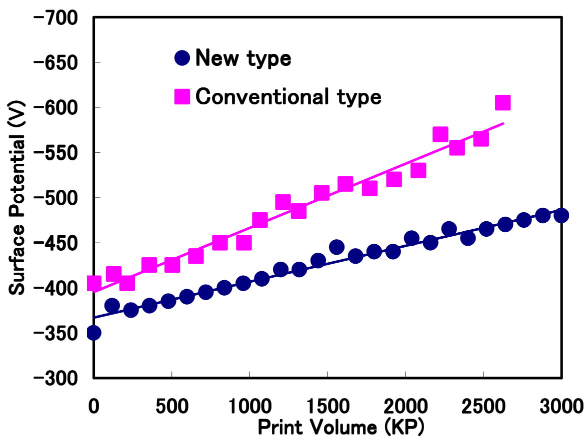

Figure 9. *Evaluation results of halftone potential variation*

Resistance to Background Fouling

Background fouling is a phenomenon which occurs in negative-positive development processes, in which background portions of an image is soiled with toner particles even without exposure to light. Background fouling is caused by various factors, such as photoreceptor, toner, and image forming process. Photoreceptors are likely to cause background fouling when local charge leakage occurs due to abrasion of the overcoat layer[2].

Fig. 10 shows the evaluation results of resistance to background fouling. More specifically, Fig. 10 shows a relation between the number of printed sheets and the background fouling level. The background fouling level is graded into 5 ranks, and the higher rank indicates the better result (i.e., the degree of background fouling is more slight). In the conventional photoreceptor, the background fouling level considerably declines after printing 2,000K sheets. By contrast, in the novel photoreceptor, the background fouling level never decline even after printing 3,000 K sheets. The novel photoreceptor has improved its resistance to background fouling than that of the conventional photoreceptor.

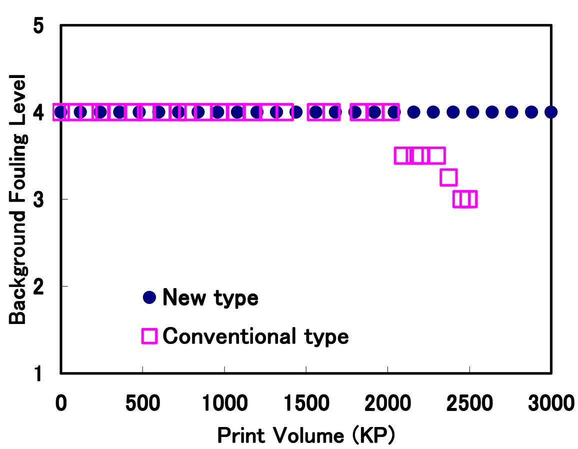

Figure 10. *Evaluation results of background fouling level*

Conclusion

We have developed a novel high-abrasion-resistance cross-linked overcoat layer, which is formed by copolymerizing a cross-linkable monomer with a charge transport monomer. This novel overcoat layer has improved the following performances.

(1) Abrasion resistance has been improved to about 4 times greater than that of the conventional CTL.

(2) Halftone potential variation has been improved to about 2 times greater than that of the conventional CTL.

(3) Resistance to background fouling has been greatly improved compared to the conventional CTL.

We believe that the novel photoreceptor with the novel overcoat layer can respond to the requirement of “high reliability and durability” in the production printing market.

References

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Author Biography

Yoshiaki Kawasaki received his Bachelor’s degree in applied chemistry from Himeji Institute of Technology (1988) and Master’s degree process engineering from Osaka University (1990) in Japan. Since then he has been with the Research and Development Division, Ricoh Company, Ltd., in Numazu, Japan, where he is occupied in for designing photoreceptors for new imaging systems.