A High-Endurance Organic Photoreceptor Having a Filler-Reinforced Layer

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Abstract

The tandem color engines have entered the mainstream of electrophotographic color technologies. High durability and high stabilization in repeated electrophotographic cycles are the important properties for the organic photoreceptor to meet this trend. Therefore we have developed an organic photoreceptor having a protective layer, coated on the surface of a conventional organic photoreceptor. Assuming that the protective layer should possess both the abrasion resistance and the sufficient charge transport ability, a protective layer containing fine rigid particles was developed to achieve those requirements. Furthermore, we have developed the coating technology suitable for making the protective layer on the organic photoreceptor surface. This newly developed organic photoreceptor was used in Ricoh Aficio AP3800C launched into market in September 2001 and has been applied to other color engines of Ricoh since then. Here we introduce an outline of the technologies adopted in the new organic photoreceptor with the high durability and stability.

Introduction

The recent digitization and multifunction of electrophotographic printers and copiers have brought increasingly strong demand for high image quality and high reliability. At the same time, 4-link tandem systems with individually installed cyan, magenta, yellow, and black color image-forming units have become dominant in color printers and copiers for reasons of copying speed. Consequently smaller image-forming units have been strongly demanded.

Demand for smaller photosensitive member, a crucial structural element of image-forming units, has also created demand for smaller diameter drums and high durability [1].

The following technologies are considered to be necessary to obtain an organic photoreceptor with high durability. (i) Technologies to keep the stable voltage for non-exposure areas and exposure ones, (ii) technologies to decrease the abrasion rate of the surface during imaging process cycles, (iii) technologies to improve the resistance to chemically active gases generated from charging process and to contamination materials attaching during imaging process cycles. Ricoh has long sought electrical and mechanical durability technologies for organic photoreceptor and has produced highly durable, highly reliable organic photoreceptors. However, new technologies to bring about higher durability to organic photoreceptors have been significant by the rise of tandem engines in the color print field [1].

In response to these demands, we developed new technologies, which provides an organic photoreceptor with a protective layer reinforced by abrasion-resistant metal oxide particles (termed "filler" below). Here we introduce technologies on a high durable organic photoreceptor, termed FR-OPC (filler-reinforced organic photoconductor).

Technology

The Concept of Developing FR-OPC

First we explain the concept of developing FR-OPC. Figure 1 shows a cross-sectional model view of filler-reinforced layer (FRL) of FR-OPC. FRL is formed on a charge transport layer (CTL), and FRL includes filler. The purpose of the filler in FRL is to provide resistance to various abrasive elements (e.g., toner, toner additives, cleaning blades) and thereby reduce abrasion of an organic photoreceptor.

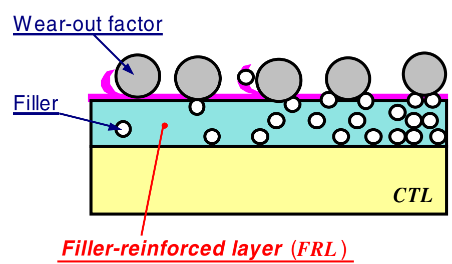

Figure 1. *Abrasion resistance model*

FR-OPC Structure

Figure 2 illustrates the layered structure of the FR-OPC. An undercoat layer (UL), a charge generation layer (CGL), a CTL, and an FRL are formed on an aluminum substrate sequentially from the bottom.

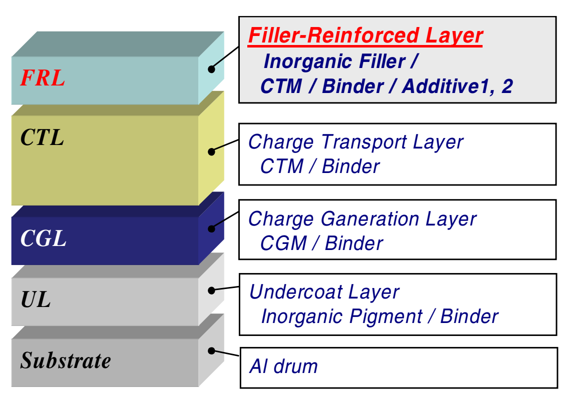

Figure 2. *Structure of FR-OPC*

A conventional organic photoreceptor is constructed of layers progressing from a substrate to a CTL. In the case of this conventional structure, when used in an image-forming unit, the CTL at the outermost layer is gradually abraded, with a consequent decline in the important electrical functions of the organic photoreceptor, i.e., charging performance and photo-decay performance, and ultimately, fogging, decreased image density, or other such problems that lead to demise of the organic photoreceptor. The abrasion of CTL is fast, since it is constituted of low-molecular charge transport material (CTM) in the polymer binder represented for the polycarbonate [2], and it becomes a dominant factor deciding the organic photoreceptor life.

Therefore, we constructed the organic photoreceptor provided with FRL at the outermost surface to improve the life span of it for which the rate of abrasion is the life determing factor. And we also endowed the FRL with a charge transport property by including a CTM as well as the filler, seeking thereby to provide both abrasion resistance and electrical durability.

Selection of Filler Kind

Many characteristics were required of the filler included in the FRL: (i) the rigidity required to demonstrate abrasion resistance, (ii) transparency to image-recording light, (iii) good dispersion in a binder matrix, and (iv) little or no adverse effects on the charging and photo-decay characteristics of the organic photoreceptor [3]. From the standpoint of requirements (i) and (ii), we studied a large number of materials, mainly metal oxide particles, and after comprehensive evaluation of a variety of characteristics, we selected a specific alumina particle.

Selection of Dispersion Stabilizer

For the polymer binder (the polycarbonate resin) of the FRL, the dispersion of the selected alumina was insufficient. After investigating various dispersion stabilizers, we adopted an unsaturated polycarboxylic compound with superior dispersion and stability characteristics and little adverse effect on electrical characteristics [4].

Acid Gas Durability

The organic photoreceptor may be exposed to various gases. They are the acid gas (the especially, NOx gas) from the charger and heating appliance, etc., and it is necessary to also sufficiently evaluate the adverse effect to the electric property and printing image [5, 6]. Therefore, it is necessary to sufficiently evaluate it, because the similar effect on the FR-OPC is considered. So we conducted NOx gas exposure experiments to investigate these effects.

Figure 3(a) presents image evaluation results following gas exposure. It was recognized that the FR-OPC of this examination produced remarkable image deterioration by NOx gas exposure in high density.

In response to this issue, we examined various additive groups, found an effect of a specific antioxidant and adopted it. Figure 3(b) shows images after NOx gas exposure testing of FR-OPC including the antioxidant.

The effect of this antioxidant additive was substantial and successfully resolved the degradation of image quality by NOx gas, that was problematic prior to addition.

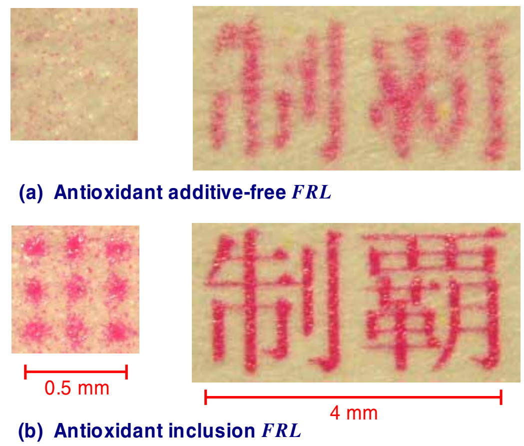

Figure 3. *Effect of antioxidant additive on NOx gas-induced image quality degradation (after NOx gas exposure)*

Abrasion Rate

Abrasion rates of an organic photoreceptor are known to differ widely depending on usage conditions and the type of system used.

Figure 4 shows the filler content dependence of FR-OPC abrasion rates in three systems, in which the charging system, type of toner, and other factors affecting abrasion. Though the absolute values of abrasion rates in each system differed, we found that, in each system, abrasion rates differed greatly depending on the filler content in the FRL. This fact showed that FRL abrasion rates can be specified by the design quantity of FRL filler.

The durability of the conventional organic photoreceptor is greatly dependent on system parameters. But FR-OPC facilitates response to systems because of one new control factor for abrasion resistance.

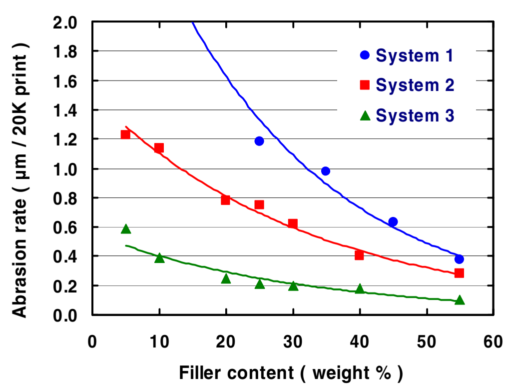

Figure 4. *Correlation of the abrasion rate and the content of filler in FRL*

Surface Refresh Characteristics

Improving abrasion resistance means suppressing the refresh effect on photoreceptor surface (the new photoreceptor surface is exposed in order by the abrasion).

In other words, too great an improvement in FRL abrasion resistance leads to some problems. One is the generation of toner filming. Another is system problem such as image deletion by accumulation of ionic materials.

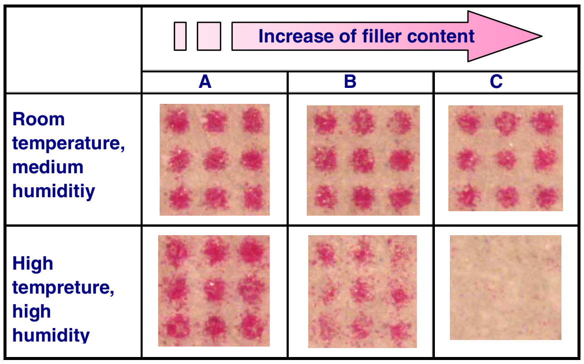

Figure 5. *Images after 30K image formations*

In Figure 5 we examined the relationship between the amount of filler and image quality. Filler quantities increase from A to C and the images were formed in a high-temperature, high-humidity environment after 30,000 copying cycles. In this image-forming system, with increases in the amount of filler, the image resolution becomes worse in a high-temperature, high-humidity environment. We attributed these results to an inadequately low abrasive rate of FRL (poor refreshiment) and found that, in this system, the optimal amount of filler for extended life and good image quality was between A and B.

The final level of filler content incorporated in the Aficio AP3800C color printer was determined in advance, in conformance with the image-forming engine.

Stable Coating Process for FRL

Next we describe the FRL coating technology.

If the FRL is coated by conventinal dip coating method,CTL dissolves by the solvent, so we can't make the FRL. Therefore we need a new spray coating method for the FRL formation.

Our investigation of spray coating methods addressed the following issues in efforts to improve the quality of the FRL coating applied.

(i) Inhibition of filler aggregation and sedimentation and uniform coating formation

(ii) Reduction of the unevenness of FRL thickness

(iii) Reduction of FRL surface roughness

(iv) Assurance of stable mass-production

To address issues (ii) and (iii), the unevenness of thickness and surface roughness, we attempted to improve quality both through coating formulation (e.g., solid concentration in the FRL dispersion, solvent composition ratios), and through coating parameters (e.g., transport and atomization conditions). To achieve (i) and (iv), inhibition of filler aggregation and sedimentation and stable mass-production, our primary approach was optimization of the structure and parameters of the spray-coating apparatus.

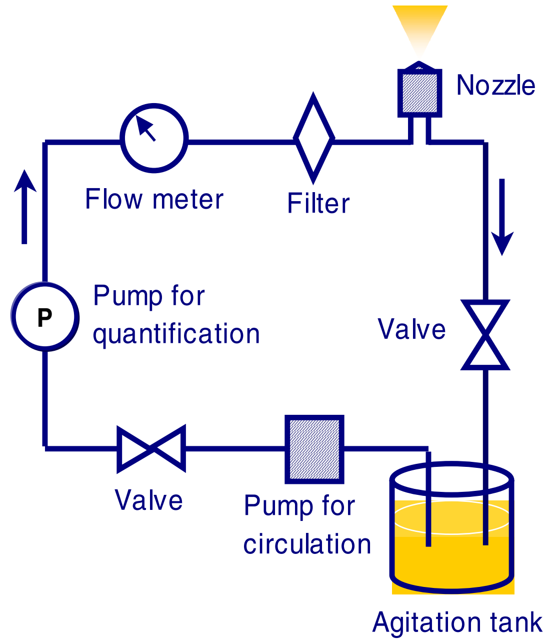

Figure 6. *Outline chart of new spray coat system*

Figure 6 is a schematic drawing of a circulating spray-coating system newly constructed for FRL formation.

Construction of this coating system achieved production of FRL coatings with the unevenness of thickness below 1μm and the surface roughness below 0.5 μm .

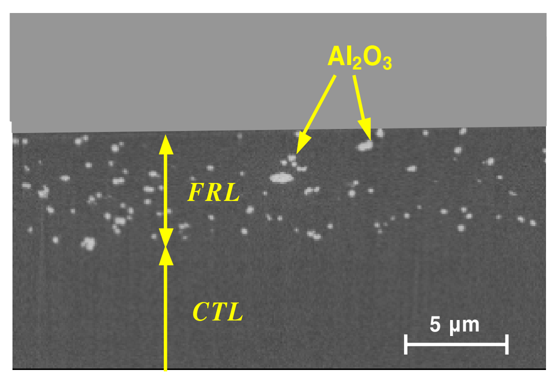

Figure 7. *SEM micrograph of FRL cross-section*

As shown in the SEM micrograph of the FRL cross-section in Figure 7, a dispersion stabilizer and uniform coating technology achieved distribution of alumina particles uniformly in the cross-sectional direction.

Actual Usage Test

Using the FR-OPC from our investigations, we repeated actual usage testing with a system including an AC charging roller with a high abrasion load. The results showed that reduction in the amount of abrasion allowed maintenance of electrical potential contrast for 500K sheets, even with a small diameter drum of 30mm (Figure 8).

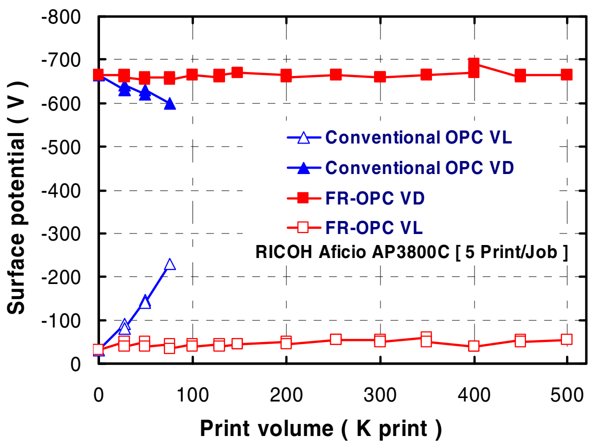

Figure 8. *Stability of FR-OPC surface potential*

Conclusion

The FR-OPC including filler in a surface layer allowed specification of abrasion rate even with various system parameters. This achievement in turn allowed high-temperature/humidity image deletion and other such system issues to be addressed through organic photoreceptor design. The FR-OPC shows endurance potential over the 500K sheets (30mm of diameter drum), and it is the technology of which future further improvement is expected.

The FR-OPC was incorporated in Ricoh Aficio AP3800C printer, and then developed for the Aficio 3228C and 3260C.

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Author Biography

Shinji Nohsho received his BS in physics from Kyoto Institute of Technology (1986). Since then he has worked in the research and development division at Ricoh in Numazu ,Shizuoka. His work has focused on photoconductor design and evaluation.