Aqueous Surface-Smoothing Layer Compositions for High-Quality Photoreceptors

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Abstract

High-quality electrophotographic applications demand a photoreceptor drum that is "perfect" in many aspects, such as being defect-free—almost to the submicrometer level, environmentally insensitive, and possessing a well-defined photosensitivity that matches the electrophotographic rendering process. The surface quality of the substrate strongly influences the quality of the critical charge-generation layer. Every minute defect of the substrate surface is magnified in that layer. Almost always, a substrate surface-smoothing layer is required. This work describes the development of aqueous, environmentally green compositions for thick, uniform, defect-free, transparent, and conductive surface-smoothing layers.

Introduction

Organic photoreceptor drums have found wide use in digital printing applications. Production and color applications demand a photoreceptor drum that is "perfect" in may aspects. They should:

1. be defect-free, almost to the submicron level,
2. be environmentally insensitive, and
3. possess a well-defined photosensitivity that matches the electrophotographic rendering process.

These requirements can lead to a photoreceptor architecture involving as many as five precisely coated layers (Fig. 1). For high-quality applications such as digital printing, the charge generation layer uniformity needs to be high on both a micro and macro level. The surface quality of the substrate strongly influences the quality of the critical charge-generation layer. Every minute defect of the substrate surface is magnified in that layer. Almost always, a substrate surface-smoothing layer is required.

Aluminum substrate has been preferred for photoreceptor drum applications because of the ease of surface polishing, using diamond-turning techniques. Usually the finished aluminum drum only requires a relatively thin charge-blocking layer for high-quality imaging. The advent of four-color tandem printing introduces very stringent registration requirements, thus making substrate circular run-out very critical. This extra requirement drives up the cost and weight of aluminum drum substrates substantially. The use of a removable endless belt or tubular type of blanket on an intermediate roller has long been practiced in the offset lithographic printing industry. In particular, the use of electrodeposited nickel sleeves for such applications is well documented [1].

The circular run-out tolerance of electrodeposited nickel sleeves is generally very high; making them ideal substrates for tandem four-color printing. However, nickel is not as easily machined as aluminum. Surface defects such as "nodules," stress defects, etc., cannot be easily eliminated by diamond-turning.

This work seeks to develop discreet surface-smoothing layers that are thick enough to robustly eliminate nickel sleeve surface defects. Furthermore, the development of environmentally green formulations is emphasized.

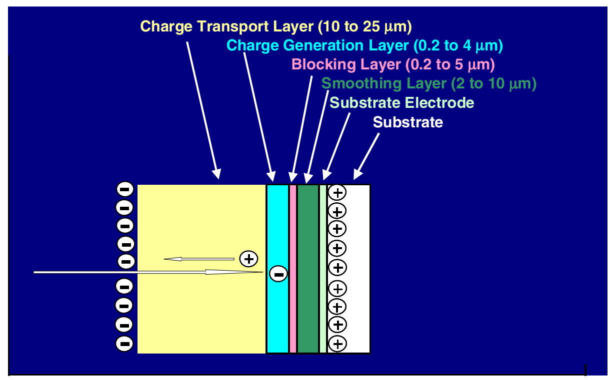

Figure 1. Photoreceptor architecture

Results and Discussion

Formulation

Water is the most environmentally acceptable solvent. Water is also desirable because many electrophotographic applications use pigment dispersions that perform better with smaller particle size distribution. In the aqueous medium, it is easier to stabilize such small particles electrostatically. Unfortunately, compositions based upon water have relatively low evaporation rates, and have been prone to produce nonuniform and very thin coatings. In addition, water-soluble polymers tend to be hygroscopic, thus sensitive to environmental conditions.

Given these considerations and concerns, we chose four basic components for our formulation approach [2]:

1. To provide environmentally insensitive and transparent conductive layers, we chose aqueous nanoparticle metal oxide dispersions.
2. Crosslinkable insulating binder polymers were incorporated as latex compositions.
3. The volatility of the mixture was enhanced using low molecular weight alcohols, such as methanol, ethanol, or propanol.
4. And lastly, solution viscosity was modulated by controlled incorporation of a water-soluble viscosity enhancer.

Effect of Alcohol Concentration

The effect of methanol on the quality of the dip-coated surface-smoothing layer was evaluated using the procedure outlined below:

Example	Methanol Wt%	Coating Quality
1	0	Non transparent
2	28.4	Non transparent
3	31.9	Non transparent
4	35.5	Transparent
5	40	Transparent

Table I. Methanol concentration series

Twenty-one grams of hydroxy ethyl cellulose (molecular weight of 90,000), obtained from Aldrich Chemicals, were dissolved in 200 grams of water. To that solution, 158 grams of a Witcobond W-240 anionic polyurethane latex dispersion, obtained from Crompton Company of New Jersey, and 1161 grams of a 30 wt % premixed water dispersion of tin oxide SN-100D, obtained from Isahara Company of Japan, were added.

To that composition, 408 grams of a water /methanol mixture were added to generate a 17.5 wt % dispersion. The ratio of methanol to water was adjusted to prepare the dispersions described in Table I at 100, 72, 68, 64, and 60 wt % water, respectively.

Each coating mixture was dip-coated at 0.05 inch per second on a 5-mil (0.005 inch) nickel sleeve and dried at 130 °C for 1 h 30 min.

The coated layers were examined for uniformity and transparency. Samples coated on polyethylene terephthalate (PET) substrate using the same conditions were evaluated for thickness by cross-section microscopy. The results are shown in Table I. It appears that a methanol concentration above 32–34% is required to avoid sagging, nonuniformity, and nontransparency.

Figure.2 Effect of tin oxide concentration

Effect of Oxide Concentration

A series of coating formulations were made using the procedure outlined above. The composition of the coating mixture was varied according to Table II to result in the appropriate tin oxide (SnO) contents shown. The coating mixtures were then dip-coated on nickel sleeves at conditions similar to those described above. The samples were evaluated for surface smoothness by microscopy and profilametry, conductivity, and electrophotographic sensitivity.

Figure 2 shows good surface smoothness for all the coating mixtures, except for the 90 wt % tin oxide, which had evidence of stress cracks. These cracks were not curing-induced. They formed even with room-temperature-dried samples.

Figure 3 shows the effect of tin oxide concentration on surface smoothing layer conductivity.

Effect of Viscosity Enhancer

Viscosity enhancers are broadly classified as nonassociative and associative [3]. The nonassociative viscosity enhancers impart their effect by the hydrodynamic, volume exclusion (HDV) mechanism. A substance in solution occupies some volume with

Example	W240** grams	SN100D*** grams	% SnO	Resitivity
5	1554	696	30	3.10E+09
6	1322	928	40	6.27E+08
7	1090	1160	50	7.30E+06
8	1164	1962	62	1.04E+06
9	582	1658	74	2.63E+05
10	380	1800	80	8.36E+04
11	159	2060	90	2.57E+04

***Witcobond W240 @ 27.2% Solid ***SN100DT in Oxide Water Dispersion @ 30 % solid*

Table II. Tin oxide concentration series

the solution, thereby excluding the possibility of any other substances occupying that same volume. As more solute is added, less volume is available within the solution, with the observable effect noted as an increase in solution viscosity. Examples of nonassociative viscosity enhancers include natural thickeners such as hydroxy ethyl cellulose (HEC), starch. The associative viscosity enhancers are usually the hydrophobically modified enhancers. Hydrophobic groups in an aqueous environment result in an inherently unstable, high free energy system. Association of the

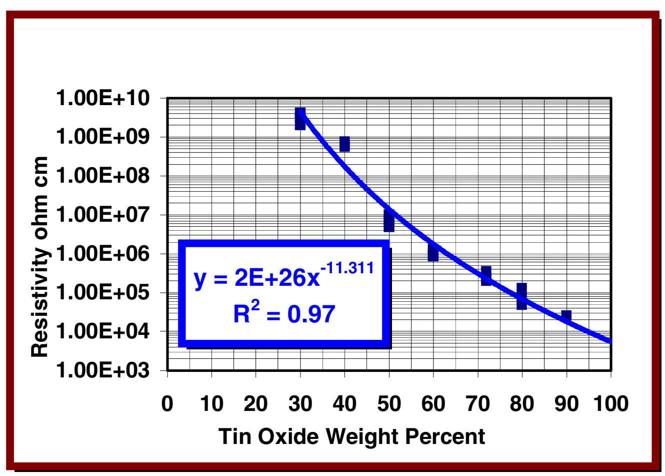

Figure 3. Layer conductivity Vs SnO concentration

hydrophobic groups with "other" hydrophobic species in the formulation creates hydrophobic "domain," ultimately providing a reduction in overall free energy of the system and a more structured compound. Examples of such systems include the hydrophobically modified hydroxy ethyl cellulose, such as Nitrosol PLUS 330 and Nitrosol 430.

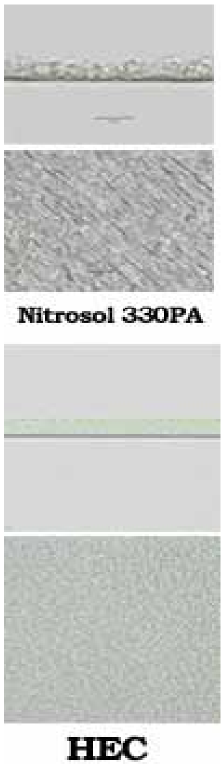

Figure. Associative and non-associative viscosity enhancers

Replacing the hydroxy cellulose of our baseline formulation with various associative enhancers tested their effectiveness. The coated layers were nonuniform and opaque. Samples coated on a PET substrate using the same conditions were evaluated for thickness by cross-section. The photomicrography of the coatings indicated very nonuniform coatings (Fig. 4). The hydrophobic "domains" formed by the associative viscosity enhancers are locked in place during the fast drying induced by the highly volatile alcohol. This locked-in structure imparts nonuniformity to the dried coating, resulting in a rough and opaque film.

Electrophotographic Performance

We have optimized a formulation containing about 74 wt % tin oxide, 24 wt % of self-crosslinkable W240 Polyurethane latex dispersion, and 3 –wt % of nonassociative hydroxy ethyl cellulose viscosity enhancer. The solvent mixture incorporates 35–45 wt % methanol. The formulation provides uniform, transparent, and conductive layers. Figure 5 demonstrates the effectiveness of the resulting layer in smoothing surface defects of the nickel substrates.

Photoreceptor sleeves coated with this smoothing layer composition, and a thin injection barrier containing naphthalene bisimide moieties [4], were tested at 70F/30% RH on a single module Kodak NexPress 2100 digital production color press for over 250,000 consecutive cycles. The results of Fig. 6 show very stable electrical regeneration.

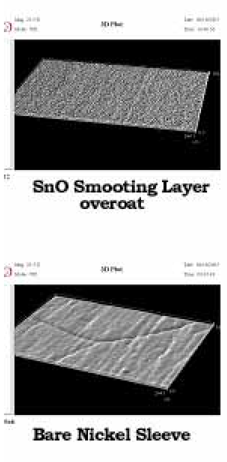

Figure 5 Smoothing of nickel sleeve substrate

Conclusion

We have developed environmentally green surface-smoothing layer compositions that can be coated thick, uniform, transparent, and conductive. The coated layers smooth the surface defects of electrodeposited nickel sleeves for high-quality photoreceptors. Those photoreceptors are environmentally stable and resistant to solvents, including water.

These formulations are also

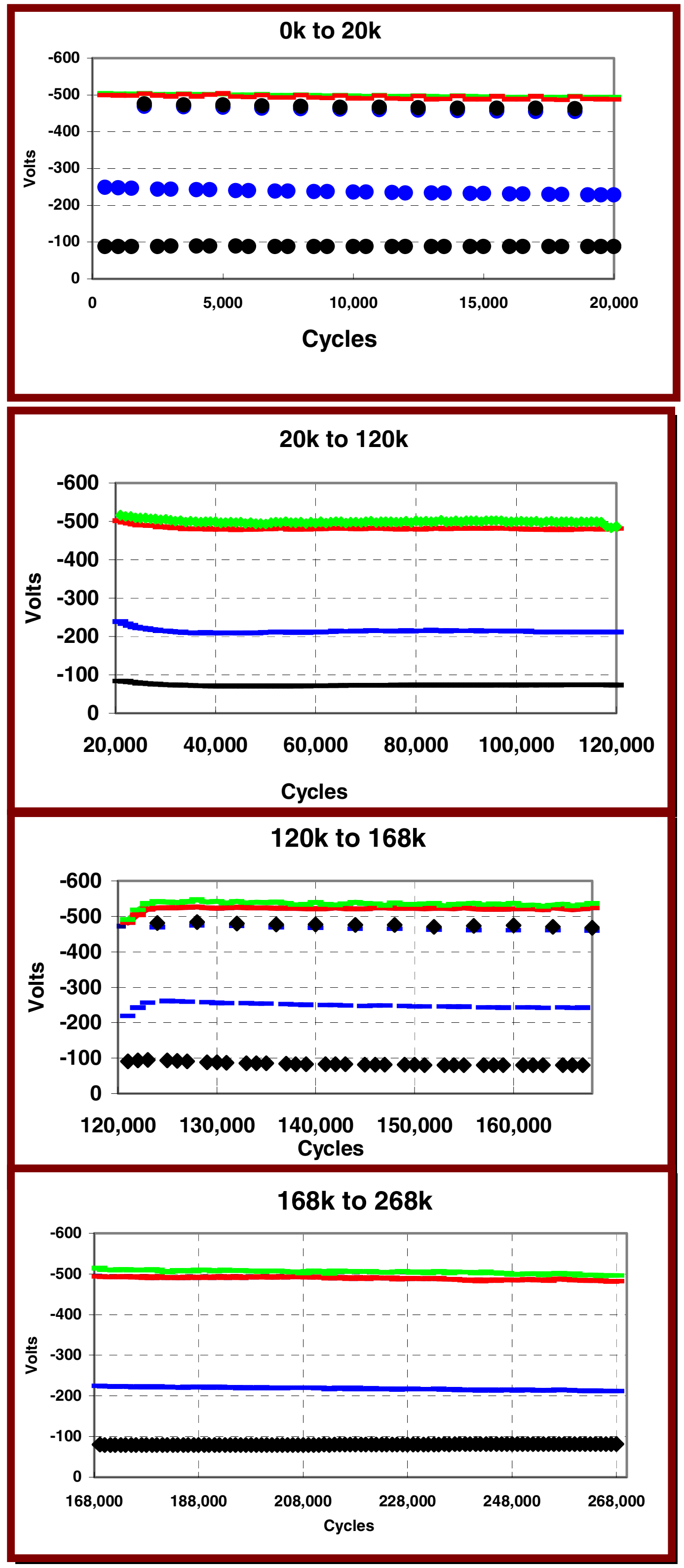

Fig. 6 Electrical cycling of a photoreceptor incorporating a SnO surface smoothing layer composition.

excellent coatable conductive layers for nonmetallic substrates such as seamed and seamless plastic substrates.

Reference

[1] W. Gelinas, U.S. Patent 5,894,796.

[2] M.F. Molaire, U.S. published patent application 20020009563.

[3] J.D. Cloyd, K.C. Carico, and M.J. Collins, Rheological Study of Associative Thickener and Latex Particle Interactions. . Presented at the International Waterborne, High-Solids, and Powder Coatings Symposium, Feb 21-23, 2001, New Orleans, LA, USA.

[4] L.J. Sorriero, M.F. Molaire, M. B. O'Regan et al., U.S. Patent 6,866,977.

Biography

Michel (Mike) Frantz Molaire *is currently a research associate scientist at Eastman Kodak Company. He received his B.S. in chemistry, M.S. in chemical engineering, and M.B.A. from the University of Rochester. His research experience includes polymer synthesis, photo-polymerization, organic monomeric glasses, optical recording materials, photo-electrophotographic masters, organic photoconductor formulation, infrared sensitive pigments, and dip-coating technology. Mr. Molaire is the recipient of 45 US patents, more than 100 foreign patents, and author of several scientific publications. In 1984, he received the Eastman Kodak Company Research Laboratories C.E.K. Mees Award for excellence in scientific research and reporting. In 1994, he was inducted into the Kodak's Distinguished Inventor's Gallery (Inventor Hall of Fame) for reaching the milestone of 20 or more patents. He is a member of the American Chemical Society, The Federation of Society for Coating Technology, and the Image Science & Technology Society. He is presently VP of programs for the IS&T Rochester local chapter.*