Physical Effects on Image Quality of Inkjet Printing Media; Polymer and Nanopigment Sol

Tai Sung Kang
Research Center of Hanmi filmtech Company, Choongbuk, Korea

Myung Cheon Lee
Department of Chemical Engineering, Dongguk University, Seoul, Korea

Abstract

When it comes to the quality of inkjet printing image, it has been well known that inkjet receiving media is acting the most important role in the quality of inkjet printing image. Therefore, to get a high quality of inkjet printing image, it is general to use polymer resin as a binder to diffuse some kinds of pigments, silica sol and/or alumina sol, and etc. We used different kind of water-soluble and/or water-dispersible polymers blended with PVA and nano-size silica and alumina sol, which were different in shape and size. From a series of test, observable improvements were obtained in physical properties such as drying time, light stability, water-fastness, glossiness. We discussed the test results.

Introduction

As the computer digital printing is getting widely used, many users want high-quality small format color inkjet printing media to get better color inkjet printing images. Currently many manufacturers of inkjet printers are also providing inkjet printing media in their own brand name, meanwhile users prefer a media which has a wide range of compatibility with any inkjet printers in the way of getting excellent color images. This is the point that inkjet media manufacturers have to provide technical solutions.

The ultimate goals of development of color printing ink receiving media could be said enhanced ink absorption speed while maintaining a favorable dye fixing property, excellent color density, high coloring property, high glossiness and maintaining conventional photo quality images[1] even through the chemicophysical changes in the situation after printing. In manufacturing ink absorption layer of inkjet printing media, it is general to use inorganic and organic pigments that already have micro porous so as to speed up ink absorption. Also it is usual to make a binder with water soluble ink solution, water dispersible polymer and water soluble hdrophilicity of the functional groups polymer in absorbing solvent.

The ink receiving layer water soluble binder polymers in use are polyvinyl alcohol,[2,3] cellulose derivatives such as hydroxyethylcellulose,[4] polyvinylpyrrodidone,[5,6] gelatin or its modified polymer or water dispersion latex such as styrene-butadiene copolymer,[5,6] acryl-styrene copolymer, acryl-butadiene-styrene copolymer or hydrophilicity of the functional groups such as polyurethane, polyacrylates, polyacryl-urethane copolymer, polyacrylamide,[7] etc. For the absorption pigments, porosity silica sol or porosity alumina sol in narrow sizes are being frequently used nowadays.

Because color printing ink has anion, it is necessary to make binders have cation in order to disperse them easily in mixing procedure and to increase ink absorption speed. Those binders which make ink receiving layer of inkjet printing media are water soluble polymer, hydrophilic polymer, water dispersion latex, silica sol and alumina sol. But it is generalized that water-soluble and hydrophilic polymers have a nonion character while water dispersion latex has an anion character. An nonion polymer can be easily mixed with SiO_3,[2,5,6] sol or alumina[8] sol of cation, but the mixture doesn't have enough micro porous to absorb ink quickly and satisfyingly. The mixture of cation pigment and other mixture , anion latex mixed with nonion polymer, generally causes a shocking so it's very difficult to disperse the mixture even with a high-speed homogenizer and it frequently goes to matt. To solve these problems, it is used to water soluble modify polymers (PVA)[9] with cation in order to make it mix well with pigment and to formulate micro porous easily. With this method, ink absorption speed increase.

For this study, we have samples of ink receiving layers by mixing silica sol and alumina sol by adding cation surfactant into hydrophilic polymer and modified polymer, both are binders. We conducted color printing tests on these samples and as results of the tests, we had observable improvements on physical effect, drying time, light stability, water-fastness and glossiness.

Experimental

Formula Preparation

To make a water soluble bind polymer, we used modified cation Quat amine by Epoxide reaction with 2.3-Epoxypropyltrimethylammoniumchloride (Quat188 from

Dowchemical Company) into Polyvinylalcochol poval 235 (Kuraray Company, Japan). And we made urethanized polyvinylalcohol ester by a reaction with poval 235 and urea. As water soluble hydrophilicity of the functional polymers, we used polyacrylurethane copolymer (Rhom & Hase), polyacrylstyrene copolymer (Dongguk University, Korea), polyurethane (SamHo Chemical Company, Korea), polyacrylamide. We also used four kinds of cation surfactant such as bisimidazolium methyl sulfate, dodecyl benzyl dimethyl ammonium chloride,tetradeyl methyl ammonium chloride, and alkyl trimethyl ammonium methyl sulfate. Silica sol we used was sylojet 4000C (Grace) and the alumina size of porosity alumina sol (ANR, Korea) was 40-60nm. Boehmite's crystal and porosity 0.83ml/g were in use. To prepare formula, we mixed water soluble modified polymer and water soluble hydrophilicity of the functional polymer. Then we stirred silica sol and alumina sol respectively with homogenizer.

Sample Coating

In coating of ink receiving layer, we selected 270g polyethylene coated paper of OJI (Japan). The coater was a slot die coater with 25 inch-width. We dried the sample paper for 15 seconds on 5°C and 20 seconds on 20°C, 60 seconds on 50°C, forty seconds on 80°C, forty seconds on 110°C, thirty seconds on 60°C, forty seconds on 30°C. We made the thickness 34-37 μm. We cut the sample paper into 4" x 6" and printed it with Epson stylus PHOTO 810 to make a QEA test chart. Colors of Y, M, C, B were printed on the paper and we exposed it to Light Stability Xeno Lamp (2873°K) for 10 hours. After the exposure, we tested the paper with conditions and equipments as follows;

Density Measurement

Photospectrometer (X-light Co) was used to measure the density

Gloss Measurement

Measured at 85" and 60" with Micro Gross Ref-160 (Sheen Co)

Water Fastness Test

Immersed the paper into deionized water of 20°C for 3 hours and dried. Photospectrometer (X-light Co) was used to measure the density.

Results

We have found that the points of speeding up ink absorption and drying time after printing are how binding polymers formulate BET model with micro porous to absorb anion ink fast as well as how are shapes or sizes of grains of silica sol and alumina sol that have porosity. If this points were solved, we feel that there should be significant improvements on water fastness, drying time, printing quality and glossiness, etc. To make these conditions satisfied, we added cation surfactant into water soluble hydrophilicity of the functional polymer and cation modified polyvinylalcohol (PVA), hydroxypropylmethyl-cellulose (HPMC). After the procedure, we homogenized silica sol and alumina sol to conduct a couple of tests.

We conducted two different tests, one without pigments the other with pigments. In the test without pigments we used polyvinylalcohol and polyvinylpyrrodine.[10] In the same test, we modified PVA and HPMC, exactly the same with the ones in the other test, as they are shown in the Table 1. We mixed them with water soluble hydrophilicity of the functional polymer, which was added surfactant. This mixture was coated on the polyethylene coated paper and we did magenta ink printing on the coated paper. What we found was that ink was not completely absorbed into the receiving layer but the magenta ink stayed on the surface and dried as it is shown in the Figure 1.

Table 1. Sample formulations of ink receiver emulsion blended with silica or alumina gel. Total volume is 1000ml.

Polymer	Ratio	silica Gel (20%)	Alumina Gel (24%)	cation sulfactant (ml) added				pH
				A 3%	B 5%	C 5%	D 5%	
Cation PVA	4							
Cation HPMC	1.5							
Ester PVA	1							
Nonion polyacrylurea	0.5	200ml	180ml	5	5	5	5	3.5
Nonion polyacrystyrene	1.0			7	5	5	5	
Nonion polyacryamide	0.5			5	5	5	5	
Cation polyurethane Latex	0.5							

A: bisimdazolium methyl sulfate
B: dodecyl benzyl dimethyl ammonium chloride
C: tetradecyl methyl ammonium chloride
D:alkyl trimethyl ammonium methyl sulfate

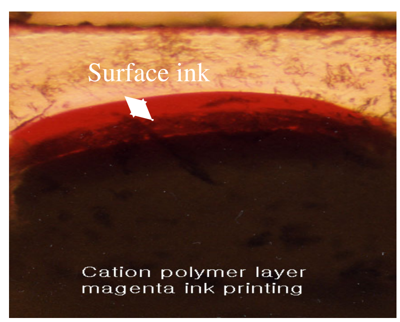


Figure 1. Cation polymer layer penetrated by magenta ink.

However, when we mixed cation silica sol and cation alumina sol into the mixture, we observed that all the magenta ink was absorbed into ink receiving layer and there remains nothing on the surface as it is shown in Figure 2. As a UV absorption, we dissolved Tinuvin 109 in ethylacetate, homogenized it and vaporized ethylacetate to put into the mixture. Also, Boric acid and sodium boric acid were mixed and put into as a cross linkage.

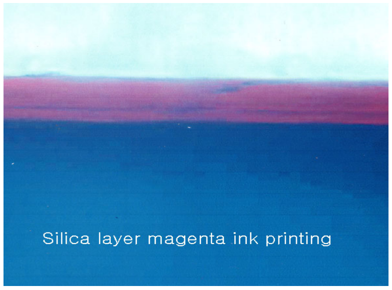


Figure 2. Silica layer penetrated by magenta ink.

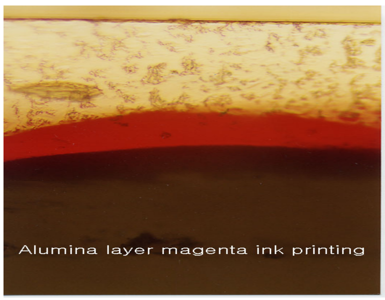


Figure 3. Alumina layer penetrated by magenta ink.

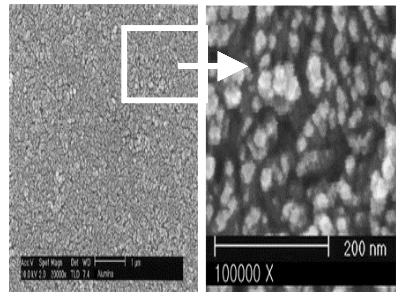
We have found that when we added four kinds of cation surfactant into nonion hydrophilic polymer, then they were dispersed well with silica sol and alumina sol by homogenizer.

Discussion

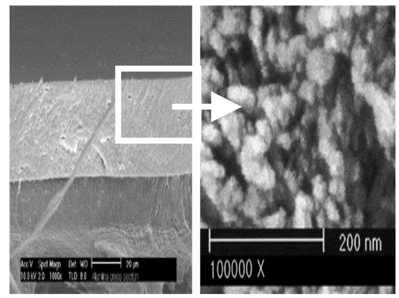
The most important technology to solve is to make fast absorption of ink and mixed solvents and water into the ink receive layer of small format color printing paper after printing. We can see that the excellent ink absorption capability comes from the controlled thickness as well as cation charged ink receive layer, which is made of cation modified or cation ionized binder blended well with cation silica sol or cation Alumina sol.

The SEM photographs of the surface of ink receive layer is shown in Figure 4, which exhibits the alumina and silica particles with polymeric binder in the enlargement scale of 20,000 and 100,000 partly. Figure 5 represents the SEM photographs of cross section of coated layer in the enlargement scale of 1,000 and 100,000 partly. In these photographs, the formation of BET model of micro porous through which the ink penetrates can be observed for the case of 30 – 60nm boehmite alumina core. In the case of silica core, thick ink absorption shell even though irregular micro porous is shown.

In designing an inkjet printing system, the drop absorption time is an important parameter with regard to printing speed, image transfer and image quality. In the case of porous ink receiver, capillary action is the mechanism for absorption of the ink drop. To predict the absorption speed, following model[11] can be used.

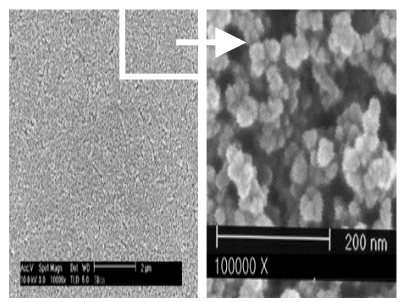


(A)

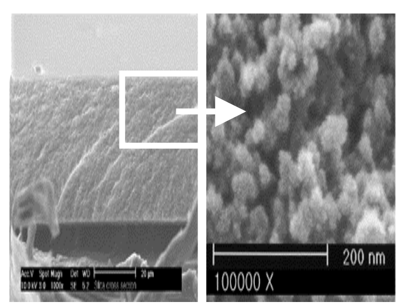


(B)

Figure 4. (A) Alumina layer surface: 2000X (left) and 100000X (right), (B) Cross section: 1000X (let) and 100000X (right).



(A)



(B)

Figure 5. (A) Silica layer surface: 2000X (left) and 100000X (right), (B) Cross section: 1000X (left) and 100000X (right).

$$t_d = \frac{V_0^{\,2}}{4\pi^2 R^4 \lambda \phi^2}$$

V_o : initial drop volume
R : maximum radius of the wetting area
λ : diffusion constant
ϕ : ratio of void volume to total volume of receiver

In experiments of dye fixing for silica sol and alumina sol, results such as fast drying time within 0.3 second, color stability against light, less than 5% of water-fastness, and high gloss were obtained as shown in Table 2.

Table 2. Physical properties of Alumina layer and Silica layer after ink printing.

Sample			Alumina gel	Silica gel
Glossiness	85"		93	91
	60"		77	68
Light stability	Normal	Y	0.52	0.55
		M	1.03	0.94
		C	0.7	0.64
		B	2.4	1.9
	After 10hr	Y	0.48	0.5
		M	0.94	0.9
		C	0.62	0.6
		B	2.15	1.83
Water Fastness	Decrease		5%	5%
Drying time	Sec		0.3	0.3

Conclusion

From the results of experiments, it can be concluded that the excellent ink printing quality and some subsidiary physical and chemical condition require fast ink absorption capability of ink jet receive media. Such capability can be obtained from good dispersion like Langmuir model of cationic polymer binder and cation pigment mixture as well as good distribution of micro porous like BET model after paper coating.

In future work, the measurements of power charge of pore radius maximum distribution will be performed.

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Biographies

Tai-Sung. Kang obtained Ph. D at ChungAng University, Korea in 1984. He had studied on AgX for more than 30years at the Korea Research Institute Chemical Technology. Since 1998, he has been the chief of R&D Center of Hanmi Filmtech Company and has been directing studies and projects on inkjet printing media.

Myung Cheon Lee received Ph.D at Purdue University, West Lafayette, IN., USA in 1991. His research area is adhesion and coating of polymer materials and specially emulsion recently. He has directed the Adhesive and Coating Research Center in Dongguk University for 6 years.