Preparation of high-quality ink-jet paper

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【**Abstract**】 Ink-jet printing is a rapidly growing method of communication due to its low printer cost and ability to produce high-quality color reproduction. Accordingly, we strive to develop high-quality ink-jet papers that are compatible with the commercial ink-jet printers on a laboratory scale. Specific coating color applied to the surface of base paper can impart the vivid color through ink jet printing. Edge sharpness of printed area can be evaluated by the ratio of L1/L2 (length of the boundary of alphabet "I" divided by the length of zigzag or fuzzy edge of printed "I"). When L1/L2 ratio closing to 1 represents clear edge sharpness. Polyvinyl alcohol-containing coating appreciably improved color density and edge sharpness (L1/L2 ratio > 0.9) while comparing to Epson coated ink-jet printing paper. A specific coating color consisted of Polyon, one kind of synthetic binder, mixing with PigX, a kind of pigment with higher pore area ratio of the surface, and silica gives admirable color density and higher L1/L2 ratio. This color formulation suggests the possibility to prepare good color density and clear edge sharpness of ink-jet printing paper with acceptable levels.

【**Key words**】 Ink-jet paper, coating color formulation, edge sharpness, pigment, binder, L1/L2 ratio.

高品質噴墨印刷紙配方之研究

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【**摘要**】噴墨印刷由於價廉物美，如雨後春筍般流行全世界。吾人力試在試驗室中做出可比美進口質優噴墨印刷紙。塗佈適當塗料於原紙上之特殊塗佈紙方可印出鮮艷之色彩，並使圖文邊緣銳利才是上質噴墨印刷紙。利用度量英文大寫“I”字母之原始邊緣長度L1與經噴墨印刷後“I”字母之長度L2之比值L1/L2之大小可用來評定噴墨印刷紙之印刷圖文邊緣清晰度。 紙面塗料中若含聚乙烯醇（PVA），則可獲L1/L2大於0.9之高值，且可比美進口之EPSON質優噴墨印刷紙。此外，吾人經多次試驗得到多孔性顏料PigX，矽化合物及添加一種高分子膠合劑Polyon所製出之塗佈紙可比美進口噴墨印刷紙之印刷性。

【**關鍵詞**】噴墨印刷紙、塗料配方、邊緣清晰度、顏料、膠合劑、L1/L2比值。

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I. Introduction

Ink-jet printing is a process which creates a permanent image from the projection of droplets of ink in a controlled pattern onto the paper surface. Typically, bright color, clear edge sharpness and fast ink drying on paper surface of coating are important quality of high-grade coated paper for ink-jet printing. Most aqueous ink-jet inks have no binders to hold the colorants in position and remain mobile even when most of their solvent volume is removed. For good printed appearance, the colorants must fix on the paper surface with only enough lateral spreading from the position of drop impact to merge adjacent drops in solid colors. In addition, the key parameters affecting proper dye fixation are as follows (Varnell 1998, Donigian 1999):

1.High sharpness of ink boundaries.

2.Bright or high intensity of the color.

3.Low image show-through to the back side of the paper.

Recently home and office ink-jet printers are becoming prevalent in Taiwan. Although imported higher quality ink-jet papers are popular for Taiwan users, very little work has been reported on their coating formulations. So we attempt to develop the promising formulations to prepare high-grade ink-jet papers.

II. Experimental

(I) *Material and sample preparation*

Commercial ink-jet papers were purchased from local market. Table 1 shows the commercial coated paper for ink-jet printing. We also prepared several grades of coated paper, these coating color formulations are shown in Table 2. The base paper (basis weight: 70g/m^2) was supplied by local coated paper mill. The coating was applied on the surface of base paper with a wired bar. After coating, the sample was immediately pressed on a hot press with a flat surface at a surface temperature 105 ° C and pressure 45kg/cm^2 for 5 minutes, dried, and then removed. The coating weight of the coated color was in the range of 15-23 g/m^2. The coating colors were applied to the surface of dried coating paper by wired bar.

(II) *Evaluation of edge sharpness by L1/L2 ratio* **(Kuo *et al.* 1998, Tsen 1998)**

Figure 1 shows a simple relationship L1 /L2 ratio which can express the edge sharpness of image. This is the ratio of the length from the marginal length of original image to the length of zigzag or fuzzy edge after ink-jet printing. Usually, clear edge sharpness of ink-printed image can be obtained when the L1/L2 ratio was close to 1.

Fig.1. The definition of L1//L2

III. Results and Discussion

Fundamental properties of commercial ink-jet paper

Table1. Fundamental properties of commercial ink-jet paper.

Specimen	Basis weight g / m^2	Thickness, mm	Density g/cm^3	Porosity sec/50 mL	pH	Roughness (μ m)	Sizing (HST) sec	Ash %	L1/L2[b]
A	108.7	0.128	0.85	19.4	8.6	1.8/3.3[a]	397	33.0	0.92
B	103.5	0.120	0.86	44.0	8.3	3.7/3.8	207	34.3	0.89
C	100.2	0.111	0.90	83.5	7.7	3.9/5.1	10	21.2	0.88

a.Top side / bottom side

b.The marginal length of the alphabet "I" divided by the length of printed one on the surface of ink-jet paper.

Table 1 shows the basis weight, thickness, density and pH of commercial ink-jet papers. The density over 0.8 g/cm^3 influences the physical properties i.e., porosity, rigidity, hardness, and strength of paper. Because of the dense ink-jet paper, it will lead to a micro-pore structure in which facilitates the dye fixation on paper surface. With the high basis weight over 100 g/m^2, it will reduce the show- through results during printing. Due to the pigment formulations and binder impregnating materials are often alkaline, you can see the alkaline surface (pH > 8.0) for commercial ink-jet paper.

Porosity is a property of utmost importance in ink-jet paper, since it is a factor affecting the absorption of inks. It is apparent that sample A with high porosity 19.4 sec gives a higher L_1/L_2 value (fast ink setting and good edge sharpness) than other two samples.

Roughness of the sheet surface has a profound effect on the rate of wetting as well as on the depth. Table 1 shows that the coated side with lower roughness contributes to an admirable ink-jet surface. In the Hercules Sizing Tester, the black liquid is contained in a ring, and the change in reflectance expressed as time (sec) is measured photoelectrically from the bottom. In this test, a reduction in reflected light of 20 % is chosen as the end point. Higher L1/L2 ratios of sample A and B showed that high sizing degree led to an optimum transport of liquid into the coating colors when compared to sample C. An important ink absorption property of ink-jet paper is the amount of ash i.e., silica, $CaCO_3$ etc. in coated papers. So the ash content of the commercial ink-jet papers varies from 21.2 to 34.3% as shown in Table 1.

(I)***White spot on solid black print***

A bright color including black is an important quality of coated ink-jet paper in ink-jet printing. Recent studies(1,2,3) show that the following factors affect print color:

a. Silica-based pigments are suitable for their high porosity, hydrophility and surface area.
b. A high-strength and hydrophilic polyvinyl alcohol- based binder increases edge sharp ness of the print image.
c. All the above factors promote fast absorption of the aqueous ink vehicle, which speeds up ink drying time.

Unexpectedly, some amorphous white spots on the solid black print were obtained with the HP 692C printer on PVA containing coated ink-jet paper. It seemed that this black print with white spot was related to the surface phenomena between black colorants i.e., soluble dye or pigment insoluble in ink vehicle and coatings. Additionally, different coating rheological behaviors existed between mill practice and a laboratory scale by the introduction of manual and mill's application methods - with emphasis on an extremely low speed in application by semi-automatic rod coater. Furthermore, the white spot was not come up on the same coated-paper when measured with other ink-jet printers.

Table 2. Coating color formulation.

	I	II	III	VI	V
SiO_2	100	75	70	75	70
PigX	0	25	30	25	30
Polyon(binder)	3	3	3	3+3[a]	3+3

a: Polyon was added in the coating at 3%, and then applied a 3% Polyon size to the surface of dried coating paper by wired bar.

(II)***Effect of density and sizing on the black print and edge sharpness of SiO_2 filled paper***

Influence of paper properties on ink-jet printing with ink jet printers varies greatly. Print qual-

ity-edge sharpness, bright color, fast ink drying time and less feathering - were controlled by the coating compositions (pigments and binders), and hydrophobicity within the paper etc.

With the HP 692C printer, considering the sizing and density of the ink-jet paper , it is interesting to note " Which one affects the color of black print mostly?". Apparently dense SiO_2 containing ink-jet paper with micro-pore surface had great positive impact on blackness (express as BL*, see Kuo.1998) compared to sizing degree. That is why most commercial ink-jet papers exhibited higher density (> 0.8 g/cm^3).

Table 4 shows the effect of silica dioxide on the black print and edge sharpness of ink-jet printings at 10-30% levels. Since SiO_2 retained adequate ink densities following ink liquid exposure on the surface of dense paper when density is greater than 0.8 g/cm^3, therefore SiO_2 reduced ink bleeding into neighboring ink areas with the high L_1/L_2 ratios. More importantly, low BL* values indicated dull black print can be resulted. In general, despite the SiO_2 filled uncoated paper we prepared, the printed samples with HP 692C printer showed superior black print and low ink bleeding.

(III) ***Effect of Pigment PigX and binder Polyon on the edge sharpness and color***

This study tries to study the optimum ink-jet coating formulation that can give desirable color and clear edge on the ink-jet paper. A water soluble polymer, so-called binder Polyon increases the viscosity of pigment PigX, one kind of porous and highly water absorbent tint yellowish fine powder, containing coating formulations, but they give comparable L_1/L_2 values on the printed sheet (Table 5).

The effect of PigX and binder Polyon on the print quality (expressed as color and L_1/L_2 value) of coated ink-jet paper when used in combination with SiO_2 is shown in Table 5. In coated paper, particularly ink-jet coated, color print is of particular interest. SiO_2 makes a larger contribution to the black print than does PigX. Additionally, the use of viscosity-enhancing binder Polyon makes a contribution to reduce the color bleeding. As would be expected, due to the big differences in rheological property, dispersing and applicating between mill and laboratory in coating it is not easy to prepare comparable coating formulations to that of com-

Table 3. Effect of sizing and density on the color and BL* of ink-jet papers.

AKD %	Density g/cm^3	Sizing degree HST, sec	CIEL*a*b* L*/a*/b*	BL*
0.5	0.52	1647	27.41/0.84/3.12	31.37
0.5	0.84	>2400	22.23/0.68/2.23	25.14
0.7	0.53	2065	30.61/0.86/3.55	35.02
0.7	0.85	>2400	27.86/0.79/3.00	31.65

BL* = L* + | a* | + | b* | , the less figure means darker black (Ref.4)

Table 4. Effect of varying SiO_2 dosages and densities on the black print of ink-jet filled papers.

SiO_2 %	Density g/cm^3	CIEL*a*b* L*/a*/b*	BL*	L1/L2
10	0.84	21.92/0.28/1.11	23.31	0.89
20	0.85	22.38/0.40/1.31	24.09	0.90
30	0.86	23.28/0.54/1.47	25.29	0.90

Table 5. Comparison of Color print, L_1/L_2 and color difference from different coated samples.

Samples	CIEL*a*b*	△ L*/ △ a*/ △ b*	△ E	L_1/L_2
Epson-B[a]	38.30/ -3.72/-44.98	control	0.00	0.90
IJP-048[b]	41.04/ -2.53/-38.77	2.73/ 1.19/ 6.22	6.89	0.87
Epson-R[a]	41.10/ 54.98/ 24.67	control	0.00	0.91
IJP-048[b]	43.91/ 46.78/ 21.64	2.82/-8.21/ -3.02	9.18	0.88
Epson-G[a]	36.57/-32.94/ 13.04	control	0.00	0.90
IJP-048	40.98/-27.56/ 13.27	4.41/ 5.38/ 0.23	6.96	0.86
Epson-Y[a]	82.92/ 1.63/ 90.97	control	0.00	0.90
IJP-048[b]	81.25/ 2.80/ 76.30	-1.68/1.17 /-14.67	14.81	0.90

a: B-- blue ink (HP printer), R--red ink, G--green ink, Y--yellow ink.

b: Pigment-SiO_2/PigX , Adhesive level: 3% binder Polyon, Coating solids: 30%, Add on - 15g/m^2.

mercial ones on a laboratory scale. However, the useful information of high-quality ink-jet coating preparation we proposed in this study might benefit the papermakers to a certain extent.

IV. *Conclusions*

The major conclusions of this work are as follows:

a. L1/L2 ratio can express the edge sharpness of image on the surface of ink-jet paper more objectively.

b. Silica dioxide and PigX contain more fluid holding capacity.

c. Specialty Polyon films retard in-jet dye movement that may give a pleasing color on the paper surface.

d. The goal of this paper is to suggest an accessible color formulation for the preparation of one kind of high-grade ink-jet paper on a laboratory scale.

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