Pigmented Inks and Media Systems for Photofinishing

Takao Abe

Konica Corporation
Konica Corporation
1873 Business, started in Tokyo

1936 “Konishiroku Photo Industries Co. Ltd.”, registered

1987 New company name: “Konica Corporation”

About 4,200 people in Konica Corporation

About 21,450 people in whole Konica Group

Annual net sales ¥540,000M or US$4,500M
Main Products

- Photographic Materials (film, paper, etc)
- Cameras
- Copy machines
- Printers
- Ink jet materials
- Optical units including plastic lenses
I will talk and discuss with showing some products from Epson, HP and so on in my presentation. My intention to do so is not to show superiority or inferiority of the products but to understand present state of ink jet printing in terms of technology. Accordingly, I have chosen typical printers being on the market and considered to be first-class at present.
1. Application of ink jet printing technology to photofinishing

Ink jet printing technology has enough potential to produce continuous-tone and full-color images.

Ink jet has a few advantages over silver halide photography in photofinishing application.
1.1 Various application of ink jet technology and important factors for photofinishing

- POD
- Computer output
- Label, POS, Ticket
- Copy
- Textile printing
- Medical photorecording

**Application of Ink Jet Technology**

- ID card
- Sign & Display
- Production tool for Organic LED, Color filter, etc
- Marking tool in factories

**Photofinishing**

- Print Quality
- Touch
- Post processing
- Productivity
- Maintenance
- Cost performance
## 1.2 Comparison of Ink Jet to AgX

### (1) Print quality

<table>
<thead>
<tr>
<th>Ink Jet</th>
<th>AgX Photography</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Clear Color</strong></td>
<td>- Continuous tone</td>
</tr>
<tr>
<td><strong>Clear line image</strong></td>
<td>- Excellent graininess</td>
</tr>
<tr>
<td><strong>Excellent whiteness</strong></td>
<td>- High gloss</td>
</tr>
<tr>
<td><strong>Repeatability</strong></td>
<td>- High optical density</td>
</tr>
</tbody>
</table>

- Continuous tone
- Excellent graininess
- High gloss
- High optical density
(2) Touch

**Ink Jet**

Since ink jet glossy paper and AgX photographic paper can use the same RC paper for their base sheets, stiffness is almost the same. However, .....  

**AgX Photography**

Stiffness depends on a base.

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Examples of stiffness

<table>
<thead>
<tr>
<th>RC Paper for Base</th>
<th>MD</th>
<th>CD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Sample 1 (221 micron)</td>
<td>2.02</td>
<td>1.57</td>
</tr>
<tr>
<td>Test Sample 2 (213 micron)</td>
<td>1.82</td>
<td>1.46</td>
</tr>
<tr>
<td>Test Sample 3 (180 micron)</td>
<td>1.23</td>
<td>1.04</td>
</tr>
<tr>
<td>Color Agx (Konica)</td>
<td>1.76</td>
<td>1.12</td>
</tr>
<tr>
<td>Color Agx (Fuji)</td>
<td>1.93</td>
<td>1.11</td>
</tr>
<tr>
<td>Color Agx (Agfa)</td>
<td>1.87</td>
<td>1.04</td>
</tr>
<tr>
<td>Color Agx (Kodak)</td>
<td>1.86</td>
<td>1.03</td>
</tr>
<tr>
<td>Color Agx Thick (Fuji)</td>
<td>2.53</td>
<td>1.34</td>
</tr>
<tr>
<td>Color Agx Thick (Agfa)</td>
<td>2.54</td>
<td>1.48</td>
</tr>
<tr>
<td>Color Agx Thick (Kodak)</td>
<td>2.41</td>
<td>1.45</td>
</tr>
</tbody>
</table>
```

Measured by Taber stiffness tester determined in JIS P 8125 (ISO 2493).
(3) Applicability of post-processing

**Ink Jet**
- Not only aqueous pens but also oil-based pens including ball-point pens can be used. Micro-porous type media brings better result than swellable ones.

**AgX Photography**
- Oil-based pens cannot be used because of smear.

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HAPPY BIRTHDAY

Direct writing
(4) Productivity

**Ink Jet**

- Capability to make large size prints
- Relatively low print speed
  (less < 400 L-size/hr)

**AgX Photography**

- More >1000 L-size/hr

L-size = 89mm x 127mm

4”x6”-size = L-size x 1.37
## (5) Maintenance

**Ink Jet**
- Basically automatic machine check
- Waste of paper and ink

**AgX Photography**
- Check with a control strip by people every day
- Need for keeping materials in a cool and dark room
- Waste of Dev&Fix solutions
- Washing of Dev&Fix tanks

*Big problem*

Acidic and alkaline solutions containing chemical agents are needed.
(6) Cost performance

Ink Jet | AgX Photography

Cost of ink jet printing is still higher than silver halide color photography.

¥**/L-size

L-size=89mmx127mm

4”x6”-size=L-size x 1.37

(Not including Film Dev)
1.3 Advantages of ink jet printing systems compared with AgX photography

- Various size prints are easily made.
- Printing systems can be placed everywhere.
- Conditioning and maintenance are easy.
- Color reproduction is excellent.
- Machine cost is relatively small.
- Special skill is unnecessary to print images.
2. Position of Ink Jet Technology in *Continuous-tone Color Printing* *(Pictorial images)*

Both image stability and print quality must be improved to apply ink jet printing method to photofinishing.

There are two routes to reach the target of photofinishing application. One is a dye-ink route and the other a pigment-ink route. We have chosen the latter.
Binary and continuous-tone images

<table>
<thead>
<tr>
<th>Binary Image</th>
<th>Continuous-tone Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Letters, lines)</td>
<td>(Photographs)</td>
</tr>
</tbody>
</table>

**Ink Jet**

**Thermal Dye Transfer**

**Electro-photography**

**Color Photography**

Ink jet printing technology covers both images.
## Image quality and image stability

<table>
<thead>
<tr>
<th>Print Quality</th>
<th>Image Stability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tone levels [bits]</td>
<td>Light Fading</td>
</tr>
<tr>
<td>Granularity at OD=1.0</td>
<td></td>
</tr>
<tr>
<td>Color</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>X</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgX</td>
<td>8</td>
<td>0.3</td>
<td>1</td>
<td>26.7-40.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>Thermal Dye*</td>
<td>8</td>
<td>0.3</td>
<td>1</td>
<td>26.7-33.3</td>
<td>0.4-0.6</td>
<td>0.9</td>
<td>0.1</td>
<td>3.6-5.4</td>
</tr>
<tr>
<td>Ink jet</td>
<td>5</td>
<td>0.7</td>
<td>1</td>
<td>7.1-10.0</td>
<td>0.2</td>
<td>0.9</td>
<td>0.9</td>
<td>1.8-16.2</td>
</tr>
<tr>
<td>Electrophotography</td>
<td>5</td>
<td>0.5</td>
<td>0.5</td>
<td>5.0-7.0</td>
<td>1-1.2</td>
<td>1</td>
<td>1</td>
<td>100-120</td>
</tr>
</tbody>
</table>

* with protective layer, color: Dye=1, Pigment=0.5

\[
X = A \times \frac{1}{B} \times C \\
Y = D \times E \times F \times 100
\]
Position of imaging methods in terms of print quality and image stability.

- Thermal Dye Transfer
- Ink Jet
- Electrophotography
- AgX Photography

Ink Jet with glossy paper

Important subject of IJ

Post-chelate thermal dye transfer
How to bring ink jet images to photofinishing application

- **Dye Ink Jet with glossy paper**
  - With glossy paper like **Konica QP**
  - With improvement of dye inks

- **Ink Jet, Pigment ink**
  - With improved pigment ink and special paper

**Target**

- **Photofinishing quality**

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Sept. 24, 2002
Which route should we choose?

*To reach the target early without a heavy load...*

<table>
<thead>
<tr>
<th>route</th>
<th>colorant</th>
<th>serious issue</th>
</tr>
</thead>
</table>
| A     | dye      | color fading (gas, light)  
|       |          | image blur (or dye migration)  
|       |          | low clarity  
|       |          | high cost, if lamination is applied  |
| B     | pigment  | bronzing  
|       |          | coarse grain  
|       |          | non-uniform gloss and low clarity  |

We have chosen B.
3. Features of printing with pigment inks

Pigment inks have different characteristics from dye inks. We must overcome some difficulties to use pigment inks for photofinishing application.
3.1 Influence of ink jet printing media

Electron microscopic photographs of coated layers

- Micro porous/silica
  - Konica QP (x 30000)
  - Konica QP (x 100000)

- Cast-coated paper
  - Epson Photopaper (x 500)
  - Epson Photopaper (x 10000)

- Coated paper
  - Coated paper[HR-101] (x 1000)
  - Coated paper[HR-101] (x 30000)
Konica “QP” paper

- Micro-porous structure
- RC paper
- Plural functional coated layers
- PVA (binder)
- Hardener, mordant, etc
Solid dots were printed on a fresh media surface.

Firstly yellow solid patterns and then black dots were printed.

Accurate dot formation is one of key factors to obtain high print quality.
To make colorants fix to printing media...

**Micro-porous structure**

**Pigment**
- pigment covered with dispersing agent
- attractive force
- silica covered with cationic polymer
- micro-porous ink absorptive layer
- substrate: RC-paper

**Dye**
- Cationic polymer shell
- attractive force
- PVA

Dye

Pigment
3.2 State of ink droplets landed on paper

Pigment ink  ⇔  Same size  ⇔  Dye ink

Ink absorptive layer

Rough surface

Effect of cohesive force

Image dot

Smooth surface
Cohesive force operates among pigment particles.

Image dot becomes smaller.

Graph showing the relationship between dot diameter (µm) and ink droplet (pL) for pigment ink and dye ink.
3.3 Image Blur

After kept at 40°C, 80%RH for 3 days, dye ink image blur does not occur.

Pigment ink
3.4 Strong and weak points of pigment-ink printing

**Strong points**
- Excellent image stability
- No image blur

**Weak points**
- Bronzing
- Lack of gloss uniformity
- Weakness in scratching
- Coarse grain
3.5 What should we do?

- Bronzing
- Lack of gloss uniformity
- Weakness in scratching
- Coarse grain

- Improvement of printing conditions
  - dot size, dot arrangement, ink volume

- Improvement of inks
  - Polymers to cover pigment particles

- New media + Post-treatment
  - Special layer
  - Similar to QP
4. Present state of print quality of ink jet printing with pigment inks

Low glossiness and coarse grain are weak points of pigment-ink images. High sharpness and non color migration are strong points. Color gamut of pigment inks is large contrary to popular opinion.

Excellent glossiness is obtained with our new developing system, in which special printing media and pigment inks are used.
4.1 Glossiness

Pigment; smaller → Surface; smoother → Gloss; higher

Surface Roughness on Konica Photolike QP Paper

- PigmentYellow74
- PigmentRed122
- PigmentBlue15:3

Pigment; smaller → Surface; smoother → Gloss; higher
pigment:smaller $\rightarrow$ Surface:smoother $\rightarrow$ Gloss:higher
When surface tension of ink decreases, dot diameter increases.

Leveling of ink on paper: Smooth surface

High gloss

Dot Diameter on Konica Photolike QP Paper

\[ R^2 = 0.8273 \]
Glossiness increases with affinity of inks to paper through surface tension.

*Subjective evaluation*
Clarity and 60-degree Gloss

Black solid pattern printed portion

1: Our new paper and pigment ink
2: Glossy paper and dye ink (PM-950)

Fresh media surface

3: Satin surface paper and pigment ink (PM-4000PX)
4: AgX Photography (Fuji Frontier)
Clarity

The determination of clarity is filed in JIS K7105.

Generally clarity fits our perception better than 60-degree gloss.

Clarity = \frac{I_{\text{Max}} - I_{\text{min}}}{I_{\text{Max}} + I_{\text{min}}}

where $I_0$ is the incident light intensity, $I_{\text{min}}$ and $I_{\text{Max}}$ are the minimum and maximum detected intensities.

Sept. 24, 2002
Relation between clarity and surface smoothness

<table>
<thead>
<tr>
<th></th>
<th>Our new media</th>
<th>Konica QP for Pigment</th>
<th>Swellable media</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unprinted</strong></td>
<td>0.5 µm</td>
<td>50 µm</td>
<td></td>
</tr>
<tr>
<td><strong>Printed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Clarity</strong></td>
<td>+++++</td>
<td>+++</td>
<td>++</td>
</tr>
</tbody>
</table>

*) Unprinted surface
** printed with pigment ink

Printed surface of our new media.
Particles: pigment
4.2 Graininess

Print-head Direction

Paper feed Direction

- pigment: Epson PM-4000PX
- dye: Epson PM-950
- laser AgX: Fuji Frontier

Black image
4.3 Sharpness

MTF

Print-head Scanning Direction

Paper Feed Direction

Influence of dye migration

- Pigment (PM400PX)
- Dye (PM950C)
- AgX (Frontier)
4.4 Color

(1) Color gamut

Depending on coloring agent:
- Ink Jet > Silver Halide Photography
- I.J. Pigment = I.J. Dye

(2) Relation between hue and density
- Silver Halide Photography > Ink Jet
- Our new pigment system = I.J. Dye
  > Conventional I.J. Pigment
Change of hue at various L*

**Our new system: pigment**

**Epson PM-4000PX: pigment**

**Epson PM-950: dye**

**Fuji Frontier: laser AgX**
Color gamut

Our new system: pigment

Epson PM-950: dye

Fuji Frontier: laser AgX

Epson PM-4000PX: pigment
5. Image stability

Image stability of pigment-ink images is generally very good.
5.1 Light-fastness; Change in optical Density

![Graph showing light-fastness comparison between different materials and pigments.]

- **Pigment**
  - Our New media
  - Micro-porous, Satin (PM4000PX)
  - Micro-porous (PM950)
  - Dye Swellable (hp5551)
  - Micro-porous (DJ5000)
  - Silver halide Kodak

- **Xe-lamp:** 70000 lx

- **Original Density** = Y:0.6, M:0.9, C:0.55, K:1.0

About 30 years
5.1 Light-fastness; Change in $\Delta E$

- Pigment Micro-porous, Satin (PM4000PX)
- Dye Micro-porous (PM950)
- Dye Swellable (hp5551)
- Pigment Micro-porous (DJ5000)
- Silver halide Kodak

Xe-lamp: 70000lx

Original Density = Y:0.6, M:0.9, C:0.55, K:1.0
5.2 Ozone gas fading; Change in optical density

Ozone: 6ppm mixed in air

- Pigment
  - Our New media
- Pigment
  - Micro-porous, Satin (PM4000PX)
- Dye
  - Micro-porous (PM950)
- Dye
  - Swellable (hp5551)
- Pigment
  - Micro-porous (DJ5000)
- Silver halide
5.2 Ozone gas fading; **Change in ΔE**

*Ozone: 6ppm mixed in air*

- **Pigment**
  - Our New media
- **Micro-porous, Satin (PM4000PX)**
- **Dye**
  - Micro-porous (PM950)
- **Dye**
  - Swellable (hp5551)
- **Pigment**
  - Micro-porous (DJ5000)
- **Silver halide**

Exposure time (hrs):
- 0
- 5
- 10

ΔE:
- 0
- 10
- 20
- 30
- 40
- 50

Sept. 24, 2002
5.3 Durability: Resistance to scratching

1: Our new system
2: Dye + Micro-porous (PM-950)
3: Pigment + Micro-porous (DJ5000)
4: Pigment + Satin Micro-porous (PM-4000PX)
5: Dye + Swellable (hp5551)
6: Silver halide photography (Kodak)

Observation was made by B.

From top, we can not see a trace so well in case of #1.

We can see a trace.
5.4 Durability: **Resistance to wet abrasion**

1: Our new system
2: Dye + Micro-porous (PM-950)
3: Pigment + Micro-porous (DJ5000)
4: Pigment + Satin Micro-porous (PM-4000PX)
5: Dye + Swellable (hp5551)
6: Silver halide photography (Kodak)
### 5.5 Waterproof

<table>
<thead>
<tr>
<th>Print</th>
<th>23°C, 50%RH, 24hrs</th>
<th>In water, 1 hr</th>
<th>Dried, 23°C, 50%RH, 2hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigment ink, Micro-porous (Our New System)</td>
<td>After soaking</td>
<td>Dye ink, Micro-porous (PM950C)</td>
<td>Image blur</td>
</tr>
<tr>
<td>Pigment ink, Micro-porous / Satin media (PM4000)</td>
<td></td>
<td>Dye ink, Swellable media (hp5551)</td>
<td></td>
</tr>
</tbody>
</table>
6. Summary

(1) Ink jet printing technology can be used for photofinishing application.

(2) Both print quality and image stability can be satisfied together with ink jet printing systems by using pigment inks.

(3) Low and non-uniform gloss, and bronzing appearance are serious problems of pigment ink jet systems. Newly developed special media can solve these problems almost completely.