# Advanced Water-based Latex-inks for Film Media

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## Abstract

*A novel water-based latex ink has been developed, which is capable of forming images with ink-jet printers on non-osmotic media such as plastic media. This water-based latex ink provides image quality and discharge reliability comparable with those of solvent inks applicable to non-osmotic media that have been widely used in the field of sign graphics. This water-based latex ink also provides images with safety and high quality on osmotic media that are used for wallpaper, etc. We have discovered that, for improving image quality with water-based latex inks, it is important to suppress aggregation of particles when the ink undergoes a drying process, which has a great relation to the SP value (i.e., Solubility Parameter) of solvents. We have also discovered that water-based latex inks form skin layer as water evaporates at the meniscus part of ink-discharge nozzle, decreasing discharge reliability.*

## Introduction

In recent years, digital printing has been rapidly spreading, which forms images with solvent inks on non-osmotic media such as plastic film media, mainly in the field of sign graphics. Containing large amounts of VOC (i.e., Volatile Organic Compound) with a concern of adverse effects on human health, disadvantageously, solvent inks need local exhaust ventilation when in use.

Thus, there is a need for water-based inks capable of forming images on non-osmotic media. Various manufacturers have been attempting to develop novel water-based latex inks capable of forming coating film on non-osmotic media by means of adding water-dispersible latex (i.e., resin particles) to water-based inks [1][2][5].

We have developed a novel hydrophilic latex ink which has solved the problems of water-based latex inks by achieving improvements in image quality and discharge reliability (see Figs. 1 to 2). The novel water-based latex ink has the following features. In this report, we introduce the outline of the novel water-based latex ink.

1. High safety, needing no GHS (Globally-Harmonized System) symbol mark
2. High discharge reliability for stable productivity
3. Wide media-applicability from non-osmotic media to osmotic media

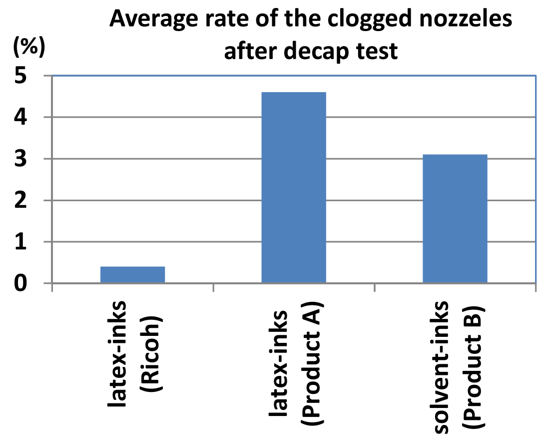


***Figure.1*** *Average rate of the clogged nozzles after decap test*

*Measuring conditions are shown as below.*
*(Ricoh: 30 minutes decap time, The print-heads are located near 70℃ heater. Product A: 20 minutes decap time, at room temperature Product B: 30 minutes decap time, The print-heads are located near 50℃ heater)*

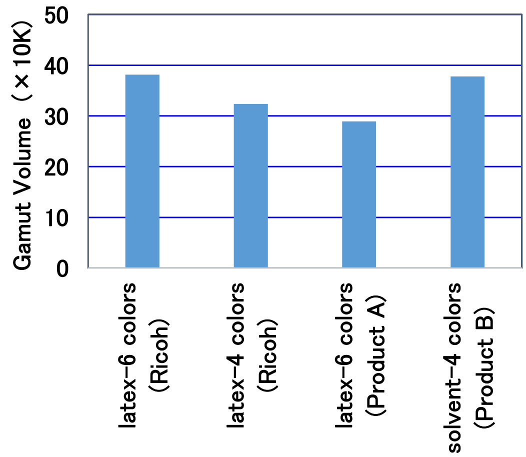


***Figure.2*** *Gamut Volume of the latex-inks and the solvent-inks*

*(Ricoh latex-6 colors include CMYK, Orange and Green. Product A latex-6 colors include CMYK, Light Cyan and Light Magenta. )*

## Water-Based Latex Ink Technologies

### *Problems in Achieving Higher Image Quality*

Water-based latex ink generally contains, as ink solvent components, water and a water-soluble organic solvent that imparts a function of wetting moisture-retaining or non-osmotic media. Main solid components included in the water-based latex ink are resin particles and pigment (see Table 1). They have high dispersibility in water but low affinity for the water-soluble organic solvent and it is confirmed that the water-based latex ink is inferior to solvent ink that contains organic solvent only in image quality. This is because the pigments are not evenly dispersed in the coating film that constitutes an image and as a result, the image gloss is decreased (see Fig. 3). Uneven distribution of the pigment also has an influence on smoothness of the surface of the coating film (see Fig. 4) [4].

**Table.1 Basic component of the inks for the sign-graphics**

| | Water-based latex-ink | Solvent ink |
|---|---|---|
| Color material | Pigment | Pigment |
| Resin | water-based emulsion | Soluble resin |
| Solvent | Water and Water-soluble organic solvent | Organic solvent |

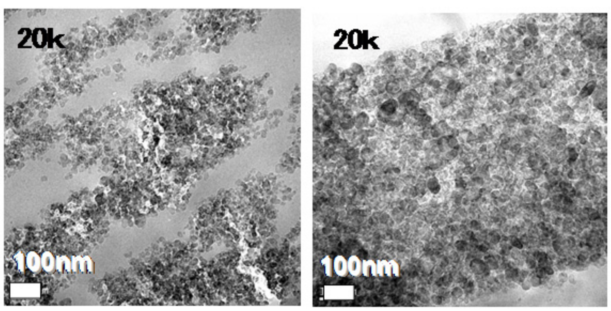


*Figure 3 Cross-section surface of the black ink's coated film layer on a PVC film (Left: Water-based latex-ink(Product A), Right: Solvent-ink(Product B))*

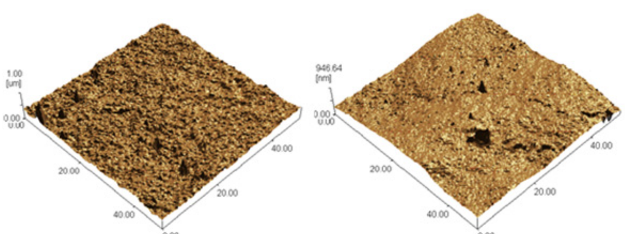

***Figure 4*** *Surface of the black ink's coated film layer on a PVC film (Left: Water-based latex-ink(Product A), Right: Solvent-ink(Product B))*

### *Factorial Analysis of Gloss Decrease*

When the water-based latex ink undergoes a drying process, water evaporates first among the solvent components, causing a rapid increase in the rate of the organic solvent in the ink. If the resin particles and pigment included in the water-based latex ink have low affinity for the organic solvent, it is predicted that the resin particles and pigment will aggregate. Based on the prediction, we have studied how the gloss and surface roughness are effected by various combinations of pigment dispersion, resin particles, and organic solvent.

**Table.2 Ink formulations of the study**

| | Color material | Binder | Solvent |
|---|---|---|---|
| Ink.1 | Carbon dispersion A | Resin.A | Solvent.A |
| Ink.2 | Carbon dispersion A | Resin.A | Solvent.B |
| Ink.3 | Carbon dispersion B | Resin.A | Solvent.A |
| Ink.4 | Carbon dispersion A | Resin.B | Solvent.B |

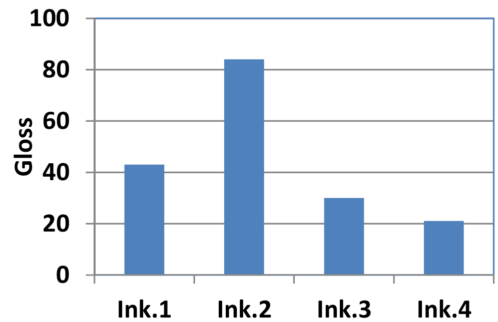


***Figure 5.*** *60°gloss of the test formulations*

Comparison between the results of Inks 1 and 2 indicates that the kind of organic solvent has a great effect on image gloss. However, comparison between the results of Inks 2 and 4 indicates that a specific organic solvent does not always provide high image gloss, but that the combination of resin particles and solvent has an influence on image gloss.

Based on the above results, we have studied how the SP value (i.e., Solubility Parameter) of organic solvent effects gloss of image formed with water-based latex inks. As shown in Fig. 6, image gloss has a correlation with the SP value of organic solvent. The greater the SP value of the organic solvent included in water-based latex ink, the higher the image gloss. It is also confirmed that image gloss is also effected by the kind of the resin particles.

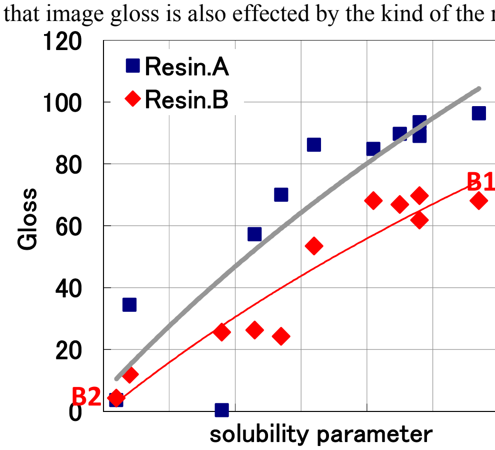


***Figure 6*** *Characteristic of the solubility parameter and 60° gloss*

It is presumed that the reason why image gloss largely depends on the SP value of organic solvent included in water-based latex ink is because water evaporates first to cause a rapid increase in the rate of low-SP-value organic solvent, degrading stability of the resin particles and pigment to accelerate their aggregation.

We have conducted a verification experiment for the above presumption. Two water-based latex inks (i.e., Inks B1 and B2 shown in Fig. 6), each containing a different organic solvent with a different SP value, were put in a separate petri dish and left in a 50ºC constant-temperature bath for accelerating evaporation of water. At the time the weight of the ink was reduced by 40%, the number of coarse particles included in the ink was counted with an instrument Accusizer 780A available from Particle Sizing Systems. The experiment results indicate that the number of coarse particles measured during water evaporation is quite different between Inks B1 and B2. With respect to Ink B2 exhibiting low image gloss, the number of coarse particles with a size of 5 μm or more is increased with an increase of the water evaporation rate. This indicates that the particles were getting aggregated as water was evaporating from the ink before a coating film in which the pigments are evenly dispersed was formed (see Fig. 7).

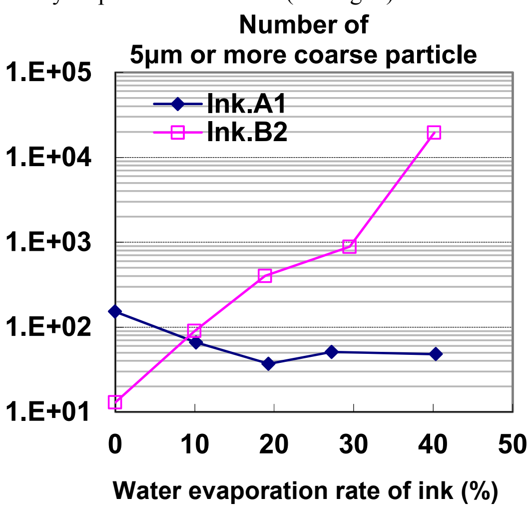


***Figure 7*** *Coarse particle behavior induced by water evaporation of ink*

## *Means for Achieving Higher Image Quality*

Water-based latex inks are required to have a function of dissolving non-osmotic media for increasing adhesiveness thereto and another function of wetting the media by spreading thereon. Thus, it is necessary for the inks to include an organic solvent having a similar SP value to non-osmotic media, which is relatively low. Since such organic solvents will cause gloss decrease, the solvent rate in the ink droplets discharged on non-osmotic media should be kept as high as possible while water is evaporating from the ink.

Combination use of a low-SP-value organic solvent with a high-SP-value organic solvent while further including a high-boiling-point solvent, prevents increase of the rate of the low-SP-value solvent during water evaporation, which improves image quality (see Table 3 and Fig. 8).

**Table.3 Solvent formulations in inks of the study**

| Organic solvent | | Ink. 1-4 | Ink.5-8 |
|---|---|---|---|
| High SP value solvent | Low boiling point | 30% | - |
| | Medium boiling point | - | 30% |
| | High boiling point | 0 – 10% | 0 – 10% |
| Low SP value penetrating solvent | Medium boiling point | 13% | 13% |

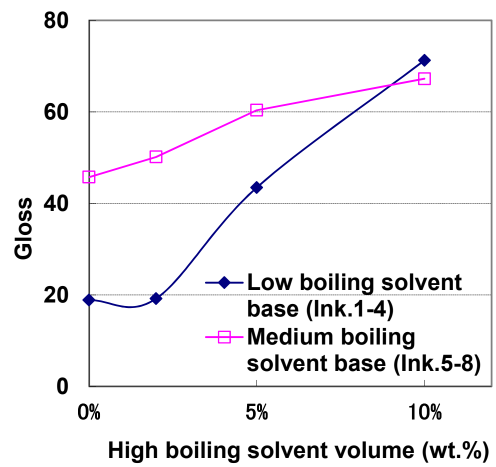


***Figure 8*** *60°gloss behavior induced by high boiling point solvent ratio of inks*

## *Evaluation Technology for Water-based Latex Ink Reliability*

Water-based latex ink droplets discharged on non-osmotic media should be dried within a short time period so as to form a coating film. Thus, it is difficult for the water-based latex inks to include humectant that has high moisture-retaining ability in terms of drying performance. Accordingly, water easily evaporates from the ink at the meniscus part of nozzle. The water-based latex inks are therefore difficult to provide discharge reliability comparable with that of water-based inks used for osmotic media. Since the water-based latex ink further contains a large amount of resin particles other than the pigment for forming coating film on non-osmotic media, the solid content concentration at the meniscus part is increased as water evaporates from the ink. This leads to easy formation of skin layer on the surface of the ink.[3][6]

We have investigated with a manipulator a capillary tube filled with the water-baesd latex ink having been stored in a constant-temperature bath for accelerating drying, and found that a skin layer is formed on the surface of the ink. The skin layer is peelable (see Fig. 9).

We obseerved Ricoh latex-ink and the comparing ink with this method. As a result, it is confirmed that peelable skin layer has an influence on discharge reliability (see Table 4).

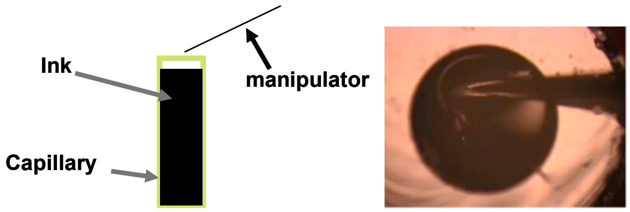


*Figure 9. Observational method of the air-ink interface*

**Table.4 Characteristic of the skin layer condition and the average rate of the clogged nozzles after decap test**

| | Ricoh Latex | Comparing Ink |
|---|---|---|
| Observation | Not Peelable | Peelable |
| Average of the clogged nozzles | 2.0% | 11.9% |

### *Media Applicability*

Ricoh's water-based latex ink provides image of excellent quality on a wide variety of media, such as non-osmotic media and osmotic media (see Table 5). By increasing the resin content in the ink, the ink provides its coating film with higher scratch resistance on non-osmotic media as well as image with higher density on osmotic media, such as normal paper, as shown in Fig. 11. It is presumed that the increase of the resin content enables formation of ink membrane on the surface side of the osmotic media and as a result, the pigment density is increased at the surface side of the media.

**Table.5 Ricoh black latex-ink's optical density on various substrates**

| Material | | Product | Optical density (Black) |
|---|---|---|---|
| non-osmotic media | PVC | 3M Controltac Graphic Film | 2.4 |
| | PET | TOYOBO E5100 | 2.3 |
| osmotic media | Synthetic paper | New YUPO FGS | 1.9 |
| | Coated paper | LumiArt Gloss | 1.7 |
| | Plain paper | Ricoh My paper | 1.4 |

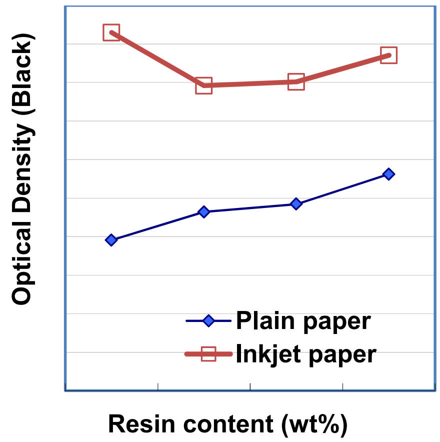


***Figure.11** Black-ink's optical density behavior induced by the resin ratio of ink*

## Conclusion

We have discovered that, for improving image quality with water-based latex inks, it is important to suppress aggregation of particles when the ink undergoes a drying process, which has a great relation to the SP value (i.e., Solubility Parameter) of solvents. We have also discovered that water-based latex inks form skin layer as water evaporates at the meniscus part of ink-discharge nozzle, which decreases discharge reliability.

Based on the above observation, we have developed a novel water-based latex ink which provides high safety, excellent image quality on both non-osmotic and osmotic media, and high discharge reliability.

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## Author Biography

*Naohiro Toda received the Master of Science in Physics from Keio University, Yokohama Japan in 1997. Since 1997 he has been with the research and development division, Ricoh Company,Ltd.,in Japan. He had occupied in for designing photocouductors for new imaging systems for 15 years. Since 2012 he has been occupied in for designing new inkjet-inks.*