The Development of Pigment Ink for Plain Paper

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Abstract

Pigments that exist as particles are inferior to dyes in terms of color expression and transparency but exhibit excellent water-fastness, lightfastness, gas-fastness and other properties of stability and longevity. In addition, the penetration of pigments in the recording medium can be controlled. In 2000, Epson unveiled the StylusPhoto 2000P, our first inkjet printer equipped with μ-CRYSTA pigment ink. By shrinking the size of pigment particles and micro-capsulating them, we achieved high image quality on specialty media that turned the image of pigment upside down. The main target of this printer was specialty media, but the reason was that we had not yet developed ink that could support plain paper. The following year, in 2001, we released the EPSON Stylus C80, a four-color printer, equipped with ink that contained high density of pigment to improve performance on plain paper. The printing speed, print quality, and durability of the printed matter earned the printer high marks as a multipurpose model. However, the quality on plain paper was still not entirely satisfactory.

Further investigations into the realization of high print quality on plain paper confirmed that print density on plain paper is largely dependent on the state of pigment dispersion. This finding led us to optimize the dispersion of pigment and match it with the ink formulation, thereby developing a new pigment ink that exhibits dramatic improvement in print density on plain paper and that is compatible with many different types of paper. This paper discusses print head and pigment ink technology with which new Epson printers are being equipped in 2002.

Introduction

Nozzle clogging has been an extremely serious issue for inkjet technology, where micro-droplets of ink are fired from tiny nozzles. To solve this problem, water-soluble dyes were selected from the outset as the colorant of choice for producing "silver halide" photo-quality output in combination with glossy specialty paper. Whereas dyes, because they dissolve in water and exist on the molecular level, exhibit favorable transparency and color expression and produce high image quality, they come up short in terms of water-fastness and weather resistance, areas in which work is still being performed in the lab. Pigments, on the other hand, exist as particles. Although they are inferior to dyes in terms of reliability, transparency, and color expression, pigments demonstrate superior water-fastness, lightfastness, and other measures of durability and image permanence. It is these characteristics that make them a common choice for laser and industrial printers. We have been working to develop pigment inks for inkjet printers that overcome the weaknesses of pigments that exist as particles while taking full advantage of their strengths. As with dye inks, the basic thrust of our pigment ink development program was to develop super-penetrating inks. The first issues to be tackled were

(1) long-term dispersion stability;
(2) nozzle clogging and reliability; and
(3) print quality and compatibility with plain paper and specialty paper.

Reliability was secured by making the pigment particles ultra-fine, by micro-encapsulating them, and by optimizing pigment density. To improve print quality on plain paper, we developed a high pigment density ink and a new pigment dispersion, which led to the development of new color pigment ink technology. We also developed print heads that would match this ink development concept.

The EPSON Stylus C82 head technology and the new pigment ink technology for plain paper are described in detail below.

Feature of Our Technology

1. Head Technology

We have focused on the development of inkjet heads that employ piezo elements because they offer excellent control over menisci and ink droplets, as well as a high degree of freedom in ink selection. Since piezoelectric inkjet heads do not use heat in the ink droplet firing process, the ink is not subjected to thermal stress. Moreover, the viscosity of ink inside the nozzles is easily kept uniform by maintaining the meniscus is a constant state of agitation. Thus inkjet heads that employ piezoelectric elements have the superior property of being able to use ink having high pigment and resin content.

The first piezo-heads required a large number of mechanical processing steps to manufacture, earning them a reputation for being bulky and expensive. Subsequent use of layered, miniaturized MLAs (multi-layer actuators) enabled us to dramatically reduce the number of processing and assembly steps, as well as to reduce head size, cut costs, and boost performance. We have commercialized two

MACH head systems that employ MLAs. One is an MLP (multi-layer piezo) system that uses a d31 vertical vibration mode of the layered piezo elements introduced in this paper. The other is an MLChips (Multi-Layer Ceramic with Hyper Integrated Piezo Segment) system that is formed in layers by burning the piezo elements and zirconia (ZrO_2) in ceramic integrated and using flexure vibration mode.

1) Structure of the Newly Developed MLP

Figure 1 provides an external view of the newly developed MLP used on the Epson Stylus C82. The nozzles are arranged in two one-inch lines. One line has 180 nozzles, all allocated to black ink. The other line consists of 177 nozzles, 59 nozzles for each of the three colors of ink.

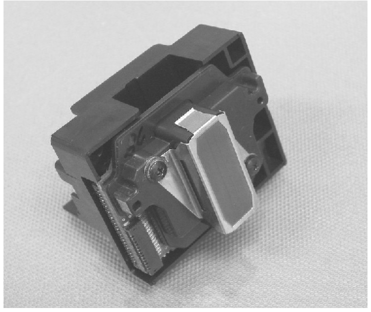


Figure 1. MLP used on the Epson Stylus C82

Figure 2 shows a schematic diagram of MLP head.[1] The multi-layer actuator is formed by alternately laying down and burning layers of approximately 20-μm-thick piezo green sheet and electrodes. The MLAs, processed in a fixed state on a stationary plate, arrayed in a pattern resembling a row of comb teeth, each "tooth" having a width of 50 μm and the pitch between "teeth" being 141 μm (180 dpi). The motion of the MLA is transmitted via a vibrating plate so that a pressure cell is expanded and contracted.

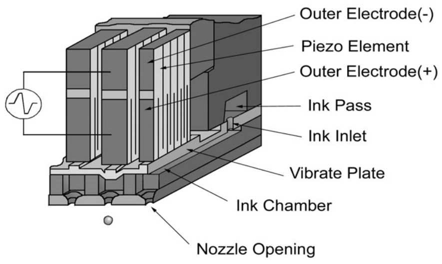


Figure 2. A schematic diagram of the MLP

As shown in Figure 3,4, ink chamber are formed at 180 dpi intervals by means of high-precision press processing of a metal plate made of nickel. The communicating holes that pass through the metal plate link the ink chamber and nozzle. The bottoms of the ink chamber are shaped like the bottom of a ship. This ship bottom shape is helpful in improving press accuracy and in both facilitating the flow of ink and preventing interference with the adjacent ink chamber via the partition wall. This shape also helps to dramatically decrease compliance by deformation of the partition wall and ink's compression qualities. As a result, the vibration of the MLA can be responsively transmitted to the agitation of the meniscus. The metal plate in which the channels are formed is outstanding in terms of materials costs, ease-of-assembly, and low number of technical limitations on size increases.

Figure 5 shows the supply ports formed in an elastic sheet. The supply ports, minute holes measuring 20 µm in diameter, are precision-punched out of an elastic plate having a laminar structure of a 30-μm-thick metal sheet and a resin film. Precision press technology allows the supply ports in a single head to be formed with extremely high repeatability, which enables the flight characteristics of propelled ink droplets to be made uniform within the same head.

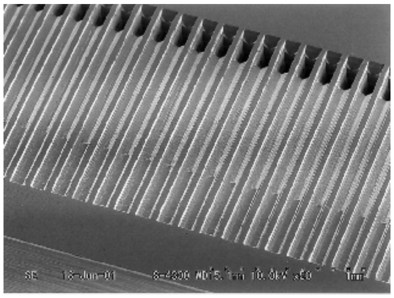


Figure 3. Ink chamber

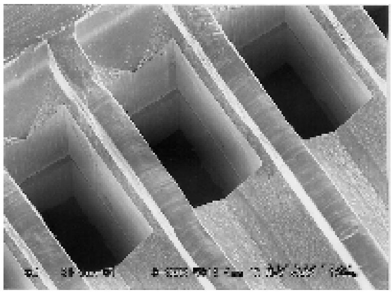


Figure 4. Communicating hole

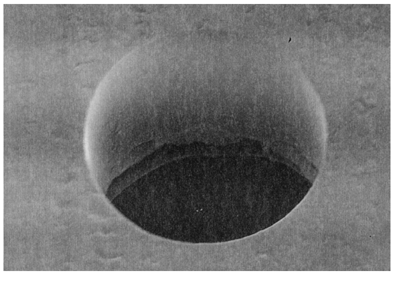


Figure 5. The supply ports

2) Driving Method of the Newly Developed MLP

The newly developed MLP head is capable of firing droplets of ink – even high-density pigment inks – as small as 3 pl. The drive waveform that is applied to the MLA when firing a 3 pl droplet of ink is shown in Figure 6. First, a sudden charge is applied to the MLA when the meniscus (C1) is stationary, causing the meniscus to rapidly pull back into the nozzle. Next, the ink chamber is contracted (C3) a very slight amount at the same time that the temporarily retracted meniscus starts to rebound back in the direction that fills the nozzle, causing a 3 pl ink droplet to be launched from the nozzle and begin flight. The second discharge operation (C4) after discharge is halted midway dampens the residual vibrations of the meniscus and MLA after the firing operation and also contributes to the arrest of satellites. The use of a metal ink chamber improves the ability of the nozzle meniscus to follow rapid changes in pressure, so even ink having a high pigment content can easily be separated from the nozzle in small droplets and fired out.

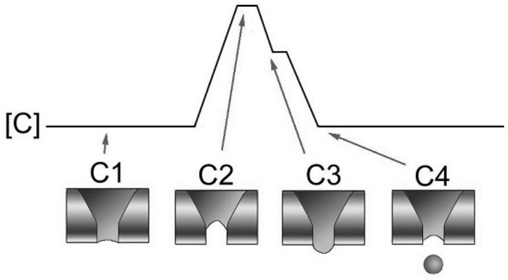


Figure 6. Drive waveform firing a 3 pl droplet

The drive waveform shown in Figure 7 is used to agitate the meniscus, diffusing the higher viscosity ink near the nozzle opening and preventing firing defects of the 3 pl micro-droplets of ink. At (B1) shows the meniscus in a stationary state. (B2) indicates the action where the volume of the ink chamber is expanded by gradually charging the MLA, drawing the meniscus slightly back inside the nozzle. Nozzles that do not fire an ink droplet perform this micro-vibration operation to get ready for the next fire command by making the concentration gradient of pigment ink inside the nozzle uniform in preparation for firing an ink droplet.

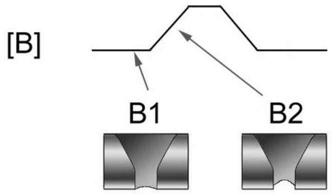


Figure 7. Drive waveform of used to agitate the meniscus

As described above, the newly developed MLP head is characterized by the fact that it is equipped with metal ink chamber and can fire 3 pl micro-droplets of ink, even high-density pigment ink.

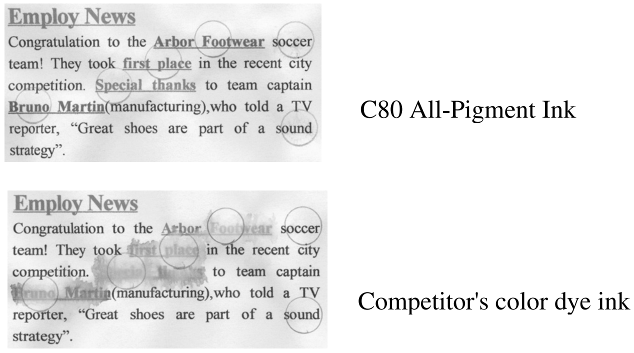
2. Ink Technology

First, we show the characteristics of the EPSON Stylus C80 ink that we developed for the plain paper. Then, we show the development concept of the new color pigment ink and its characteristics.

1. Characteristics of Epson Pigment Ink

1) Water-fastness

Figure 8 shows samples comparing the water-fastness of pigment ink and dye ink on plain paper. The pigment sample was printed on an Epson Stylus C80. The dye sample was printed using a four-color printer (Black: pigment; Col: dye) of another company. Both samples were printed on Xerox 4024 paper and allowed to sit for one day before the evaluation was performed. One can clearly see that the dye is running in the water while the pigment exhibits absolutely no change.



Employ News

Congratulation to the **Arbor Footwear** soccer team! They took **first place** in the recent city competition. **Special thanks** to team captain **Bruno Martin**(manufacturing),who told a TV reporter, "Great shoes are part of a sound strategy".

C80 All-Pigment Ink

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Competitor's color dye ink

Figure 8. Comparison of water-fastness

2) Lightfastness and Gas-Fastness

Figure 9 shows a model depicting the fading of a pigment particle exposed to light and gas. Even if the surface of the pigment particle fades, there is enough pigment left inside to obtain extremely high lightfastness and gas-fastness.

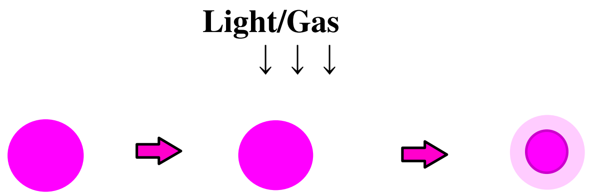


Figure 9. Deterioration due to light and gas exposure

3) Ensuring Adhesion on Specialty Paper

It is generally necessary to add a binder to cause pigment to adhere to the media and, consequently, printing inks usually contain a large amount of binder for this purpose. Inkjet inks require a binder to affix the ink to the printing surface of glossy specialty paper in particular, where pigment remains on the surface. In the case of inkjet printers, however, the ink must adhere as efficiently as possible, because of the effect that binders have on ink properties, head firing characteristics, and so forth. Therefore, we have chosen to use capsule type and resin type pigments that are dispersed by resins. This enabled us to obtain adhesion on specialty paper that is virtually as good as that of dye inks. To obtain favorable printing density on plain paper, either a dispersion type or a surface treatment type of Black pigment is selected, depending on the application of the printer. For the EPSON Sytlus C80, which supports printing on plain paper, high density was achieved by using a surface treatment pigment.

4) Reduced Bleeding Along Fibers In Plain Paper

Figure 10 shows a model of ink penetrating and colorant spreading due to penetration. Pigments, which exists as particles, bleed less than dyes and are capable of achieving sharp print.

Actual printing samples are shown in Figure 11. The enlarged photo on the left shows the print quality of Black text that was printed out in Quality mode on an EPSON Stylus Color 980. The photo on the right shows the same thing, only printed out on a EPSON Stylus C80. The text printed using pigment ink is plainly clearer and has sharper edges. The Stylus C82 uses the same Black ink as the C80.

We have described the characteristics of the pigment ink that we have developed, but we strove to further improve image quality on plain paper with a new type of color pigment ink for the EPSON Stylus C82.

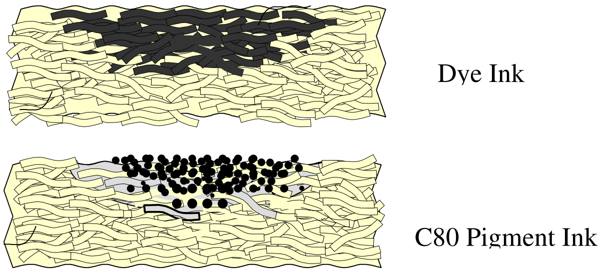


Figure 10. Ink penetration on plain paper

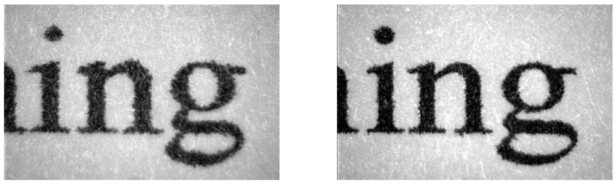
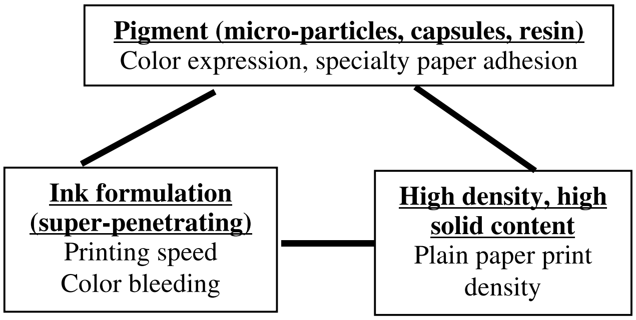


Figure 11. Stylus Color 980 (L); Stylus C80 (R)

2. Development of New Color Pigment Ink for the EPSON Stylus C82

Our pigment ink development concept is shown below. New color pigment ink technology was developed, with particular emphasis placed on the pigment and ink formulation concepts.

As for the character quality of the EPSON Stylus C80 on plain paper, bleeding was reduced by using a super-penetrating pigment ink, but the print density of color pigment inks was insufficient. Unlike dye inks, which penetrate the paper and dye the paper fibers to express color, pigment inks express color by residing on the paper surface. Therefore, the task facing researchers developing the new pigment ink was to maximize the amount of pigment left on the surface, even with super-penetrating pigment inks.



1) Development of the New Color Pigment Dispersion

Plain paper, our target, generally has a sizing agent added to prevent water from easily penetrating the medium, making the surface hydrophobic. Conversely, the dispersion resin used for pigments had to be as hydrophilic as possible to ensure stable dispersion of pigment throughout the ink. As a result, the surface of the pigment dispersion that was being used with the EPSON Stylus C80 was strongly hydrophilic, causing the pigment surface and hydrophobic components of the paper surface to mutually repel one another when the pigment was deposited on the paper. Hence, we speculated, the pigment failed to remain on the surface, instead penetrating into the medium, thereby lowering density.

With the new color pigment ink, therefore, the resin formulation in which the pigment is dispersed was made as hydrophobic as possible. In addition, to ensure stable dispersion in ink, we found an appropriate level of surface hyrophilicity and a matching ink formulation, thereby finding a happy medium between two contradictory properties. Figure 12 provides an image of the dispersion of the pigment that comes with the EPSON Stylus C80 and the new color ink that comes with the EPSON Stylus C82.

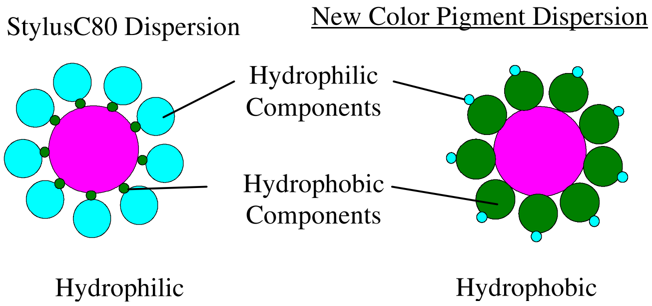


Figure 12. Dispersion in Ink

As previously described, the new color pigment ink's dispersion resin was changed to realize high color expression on plain paper. The pigment density within the new ink is almost same as C80 ink.

2) Optimization of the Ink Formulation

We developed a new color pigment ink. The pigment is stable within the ink and, when the ink penetrates the paper, the hydrophobic components of the pigment exhibit a mutual affinity with the hydrophobicity of the paper surface such that the colorant flocculates and resides on the paper surface, thereby realizing high density on plain paper.

These two programs enabled us to maintain the basic reliability of the ink while achieving a mutual affinity between the hydrophobic components of the pigment and the hydrophobic paper surface when the ink penetrates the paper, thereby causing the colorant to flocculate and reside on the paper surface and realizing high density on plain paper.

Conclusion

Table 1 shows the characteristics of the ink of the C80 and C82 color pigment inks, as well as their performance in terms of print quality, reliability.

The EPSON Stylus C82 achieves higher OD value and wider color gamut on plain paper. And achieves wider plain paper adaptability including many kinds of recycled paper.

Table 1. Comparison of C80 and C82 Color Pigment Ink Characteristics

	C82	**C80**
Characteristics of dispersion	Hydrophobic	Hydrophilic
Viscosity(20℃)	About 4mPa・s	About 4mPa・s
Storage Stability	Good	Good
Clogging Reliability	Good	Good
Plain Paper (Xerox 4024)	Plain Paper/ Quality mode	
	258 k	184 k
OD value		
Y	**1.31**	1.06
M	**1.32**	1.02
C	**1.21**	1.09

References

1. T. Kitahara, *Proc. IS&T's 11th, International Congress on Advances in Non-Impact Printing Technologies*, pp 346-349 (1995)

Biography

Minoru Usui is a deputy chief executive in the Imaging and Information Products Operation Division of Seiko Epson Corporation. He received his B.E. from the University of Tokyo, Japan, in 1979. After he joined Seiko Epson Corporation, he has developed a variety of printing technologies that include a video printer using thermal transfer. In 1989, he developed a new inkjet print head using micro piezo technology and for this work he won "Technology Prize of the Society of Electrophotography of Japan" in 1996. His primary responsibilities are management of research, development and design of inkjet printers.