Pigmented Ink Technology to Enable HP PageWide XL Printer Capability

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Abstract

The recently announced HP Pagewide XL printer delivers high quality output at very high printing speeds. The breakthrough speed of Pagewide XL is delivered via an array of nozzles covering the entire paper width (an order of magnitude more nozzles than traditional scanning systems). All the drops are fired in a single pass, which leads to a heightened sensitivity to nozzle errors for output quality, and to servicing drops for print production costs. Robust and reliable operation, along with economical print production are enabled by an inkset developed for this application. First, the Pagewide XL inkset uses pigment colorants that are quickly immobilized when contacting paper surface, leading to high color saturation and high black optical density at lower levels of ink coverage. The pigmented colorants, along with HP's polymeric binders also deliver better resistance to water, highlighters, and light fade. Second, the inkset has an additive that migrates to the ink/air interface in the nozzle. This film-forming additive produces a vapor barrier that slows water loss and enables extended uncapped periods while maintaining good drop ejection. Finally, the ink components work together to minimize the need for servicing spits to keep nozzles healthy, which improves uptime, productivity, and reduces print production costs.

Introduction

Achieving breakthrough black and color productivity in the computer aided design (CAD), geographic information systems (GIS) and point of sale (POS) applications required moving from a traditional scanning print head to a fully page wide print head architecture. The HP PageWide XL inkjet printers bring unmatched speed, 60% faster than monochrome LED. However, there are significant new challenges for printers with page wide print head architecture when compared to scanning print head architecture that had to be overcome in order to deliver a high quality product to market. In scanning inkjet print head devices, multiple passes and the ability to access spittoons at the end of the carriage swath to allow for opportunities to hide errors that may arise from failed nozzles and to replenish ink in the nozzles that may have degraded in performance due to water evaporation. This degradation in performance due to the evaporation of water is called decap. Furthermore, for the page wide print head architecture, more than 200,000 nozzles need to remain healthy for optimum performance. In order to accomplish this the inks needed to be designed for a high level of decap performance and reliability.

Inkjet Ink Composition

Inkjet inks are typically composed of colorant, water, high boiling solvents and other additives to optimize printability and reliability. For the PageWide XL printers the need to deliver prints robust to light fade and water resistance on a variety of media resulted in an ink system built on the foundation of pigment based colorants. From this foundation, the design and choice of solvents and additives were selected to deliver inks that maximized print quality and the necessary reliability such as decap performance, storage recovery and nozzle health.

Breakthrough Decap Performance

When an inkjet print head nozzle is left unfired and left uncapped water evaporates out the nozzle leading to changes in the ink locally in the nozzles that can lead to a degradation in print performance. The degradation can be due water evaporation which results in increased ink viscosity, increased solids content or localized surface tension changes in the nozzle. These changes for instance that lead to missing, weak or misdirected ejection of the inkjet drop from the nozzle. These weak or misdirected nozzles can result in missing or misplaced drops on the printed page resulting in streaks, grain or reduced color vibrancy.

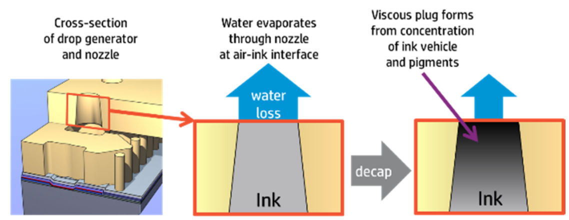


Figure 1 *Schematic of the nozzle of thermal ink-jet print-head nozzle showing one possible failure mode due to the evaporation of water.*

In scanning print head print systems decap is controlled by ejecting drops off of the printed page into a spittoon at the end of the print head swath. This arrangement allows for refreshing of the ink in unprinted nozzles after only a few seconds. In sheet fed PageWide printers, drops can be spit between sheets into a spittoon under the paper path. The HP PageWide XL family of printers are roll fed and thus required a different solution.

The solution was a combination of innovative ink design and a writing systems implementation that minimized the need to refresh unused nozzles resulting in accurate drop placement on demand. Without access to a spittoon, the solution was to spit unused nozzles onto the media surface while printing. However, there are limitations to this approach. If the 200,000 nozzles are fired too frequently the media will begin to take on a gray cast that is objectionable. Understanding what this limitation is and the frequency with which nozzles could be refreshed at the desired print speed, resulted in the need for an ink design that would deliver inks capable of having unused nozzles remaining healthy for upwards of 10 seconds and to remain in this state for print jobs lasting to upwards of approximately an hour.

This unprecedented performance demand led to two approaches that were used for the combined ink set that is present in the HP PageWide XL printer family. One design, present in the black ink, used a small surface active molecule to form a weak film at the ink-water interface in the nozzle (see ***Figure 2***).

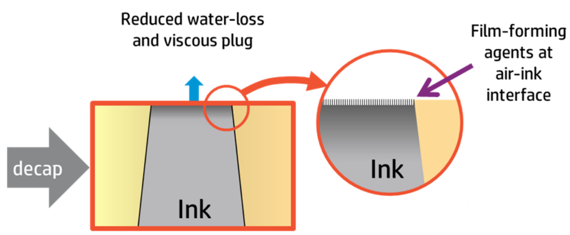


Figure 2 *Schematic of film formation in the print-head nozzle*

This film effectively decreased the rate of evaporation of water (***Figure 3***) from the ink resulting in a consistent print performance for unused and uncapped nozzles for extended period. This weak film was easily ejected at the next firing event.

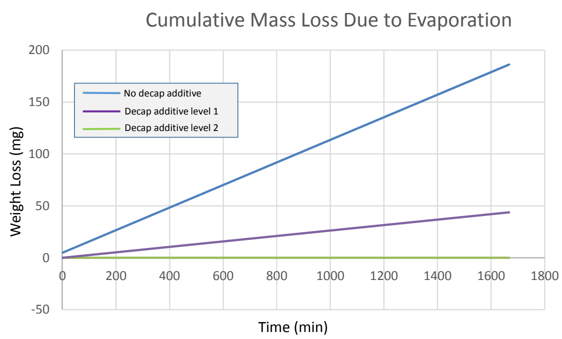


Figure 3 *The introduction of the decap additive significantly reduced the mass loss from the pens due to evaporation of water*

The performance of the small molecule design approach as demonstrated in ***Figure 4*** was an effective means of improving the decap performance of the ink for extended uncapped time periods. The diagnostic is representative of spitting on the printed page in a limited fashion, yet still maintaining optimum drop placement performance.

Figure 4 *In the above images row of nozzles are fired once every 10 seconds for 10 minutes.. Top image shows ink without decap additive resulting in missing lines. Bottom image shows ink with decap additive resulting in all lines being printed with good line quality.*

The effectiveness of the decap additive is dependent on several factors in the ink design including: solvent type, dispersion treatment, polymer type, solids loading and additive chemistry. Interactions of the decap additive with the other components of the ink formulation needed to be optimized to ensure a robust solution over the life of the ink.

For the color inks set, a slightly different approach is used. The color inks set required use of a binder to deliver good durability while maintaining good kogation performance. The polymer design achieved the durability and kogation performance as well as provided partial decap performance.

For the ultimate decap performance, a ternary system consisting of the polymer and two small molecule decap additives was utilized. The final color ink composition enabled good durability, kogation, decap as well excellent performance across many other page attributes.

The challenge in designing the polymeric binder was balancing the durability, kogation and decap performance. Kogation is when deposits from the ink are left on the resistor surface due to charring during the nozzle firing event. Kogation can be exacerbated by an increase in the hydrophobicity of a polymer. However, it is the balance of hydrophilic-hydrophobic characteristics that allows for the improved decap performance. To achieve a balanced performance, we tested and carefully selected a monomer set and then adjusted the monomer ratio to target the desired acid number. Once the monomer set and monomer ratios were determined, the process was optimized to achieve the desired molecular weight and the glass transition temperature suitable for good jetting performance.

Our polymer design provided needed durability, kogation and partial decap performance. To meet the ultimate decap performance requirements, we investigated and optimized a ternary system consisting of the polymer and two small molecule decap additives in the ink vehicle. ***Figure 5*** shows effect of different decap additives on the cumulative weight loss (due to water evaporation) from a HP TIJ pen. The decap additives introduces a delay in water evaporation and reduce the rate of water evaporation.

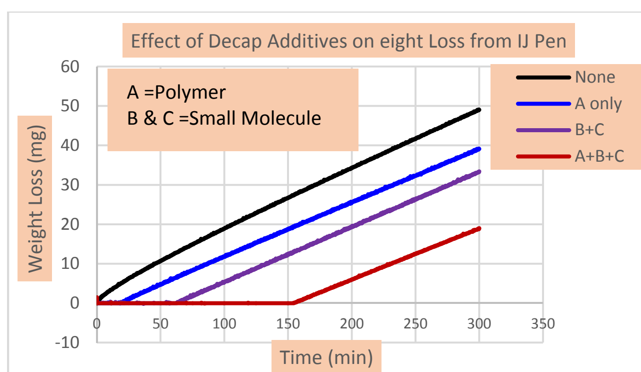


Figure 5 *Effect of Color Decap Additive on Pen Weight Loss*

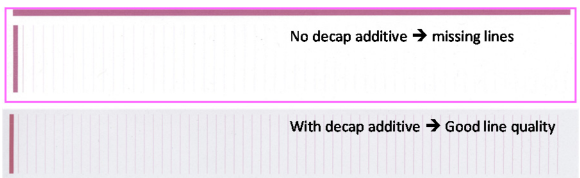
Table 1 shows the delay in onset of water evaporation and the rate of water evaporation.

As shown in **Table 1**, the ternary system consisting of the polymeric binder and the small molecule decap additives provided best performance with maximum delay in onset of water evaporation.

Figure 6 shows decap print assessment of magenta ink. The top prints shows ink without decap additive leading to missing drops/lines. The bottom print shows ink with the ternary decap additive (polymer + small molecule) where all drops/lines are printed and show good line quality.

Decap Additive	Decap Additive	Approximate Delay in Onset of Water Evaporation (min)	Rate of Water Evaporation (mg/min)
None	None	0	0.15
A only	Polymer only	19	0.14
B+C	Small molecules	63	0.14
A+B+C	Polymer + Small Molecules	155	0.13

Table 1 *Effect of Color Decap Additives on Water Evaporation*



Decap Assessment

- Row of nozzles are fired every 10sec for 10min ➔ Maximum 60 lines
- Best decap ➔ All 60 lines are printed

Figure 6 *Decap Performance of PageWideXL Magenta Ink Relative to another Ink without the Decap Additive Solution.*

Other Aspects of Ink Design

A key part in enabling a PageWide XL print bar is to maintain the health of the nozzles even after extended periods of time in an unused state. When pigmented inks are left idle for extended period of time, the colorants tend to settle in the print head. In improperly designed inks, this can result in plugged nozzles that are not recoverable and leads to poor print performance or potentially a damaged print head.

A healthy print nozzle pattern is shown in ***Figure 7***. This is the state in which a pen and ink have started up properly after being in storage.

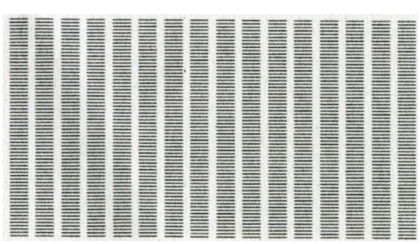


Figure 7 *Nozzle patter image of a fully healthy pen*

In ***Figure 8***, it can be seen that the lower half of the nozzles are missing. The full nozzle length is equivalent to the bar length on the left of the image. The missing nozzles are due to the settled material plugging the nozzles.

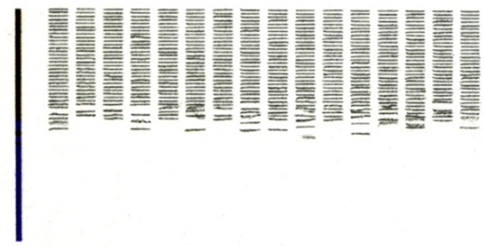


Figure 8 *Nozzle Health Pattern With Missing/Clogged Nozzle in Lower Half of the Nozzle Swath*

Nozzle health pattern shown in ***Figure 8*** is not the only failure mode of a poorly designed ink. A second failure mode is a pattern where the bad nozzles are not bunch of adjacent nozzle, but are randomly scattered throughout the entire nozzle swath as shown in ***Figure 9.***

Figure 9 *Nozzle Health Pattern with Missing/Clogged Nozzle Rrandomly Scattered*

Having optimum nozzle health after storage is critical particularly in a print bar with 200,000 nozzles and no possibility of multiple pass printing to hide missing nozzles. The inks in the PageWide XL were tuned through the vehicle and dispersion design to maximize the nozzle health after long term storage.

Conclusion

The unique nature of the PageWide XL printer family with page-wide print head architectures and over 200,00 nozzles has led to novel ink designs that ensure HP print quality through specialty formulated pigmented inks that use additives to inhibit water loss and ink designs to maintain nozzle health over the life of the product.

Biography

Jayprakash Bhatt received his Ph.D. in Organic Materials Chemistry from the University of Oklahoma in 1991. He joined HP in 2002 and since then has worked in development of Laser imaging CD/DVD disks, security inks, dye and pigment based thermal IJ inks and UV inks. Most recently he has contributed in the development of color inks for HP's Large Format Page-Wide printer systems. Prior to HP, Dr. Bhatt was involved in development of Liquid crystalline material, non-linear optical materials and different analog and digital printing technologies including direct thermal, thermal transfer and 3-D printing.

Larrie Deardurff received his Ph.D. in Physical Organic Chemistry in 1985. After a post-Doctoral position at the Pacific Northwest Laboratories, he worked for 8 years at a small start-up company developing oxygen scavenger systems for the food industry. He joined Hewlett-Packard in 1994 as an ink development chemist. He has developed many dye-based and pigment-based inks. He was the HP *representative on the ISO photo standards group for 11 years and is co-inventor on 20 plus patents.*

Vladimir Jakubek received his Ph.D. in Inorganic Photochemistry from the Chemistry Department at State University of New York in Binghamton, NY in 2000. Later, he worked at IBM, Material Science and Engineering Department at Cornell University and PharmAssist Analytical Laboratory. He joined Hewlett-Packard in 2007 as a material scientist/ink chemist in the field of printing inks specializing on thermal inkjet technology with focus on ink innovation with respect to ink formulation development, print performance evaluation, ink-media interactions and ink reliability.

Richard McManus received his masters in chemistry from the University of Michigan in 1995. He joined HP in 1996 developing coatings and papers for inkjet and laserjet devices and has worked since 2006 on developing inkjet inks for desktop and large format applications.

Cory Ruud received his Ph.D. in Polymer Chemistry from Michigan State University in 1999, and joined Hewlett Packard in 2003. He has been a member of the ink design team formulating and troubleshooting the next generation of high performance inkjet inks.

Sundar Vasudevan received his Ph.D. in chemistry from the University of Kentucky in 1994. After working in the biopharmaceutical field for several years, he joined Hewlett Packard as an ink chemist in 2002. He has worked on technology and product development of several dye and pigment based inks serving multiple market segments.