

The Evolution of Jet Inks to Meet New Application Needs

Carol K. Keller
Keller Associates, Winchester, MA USA

Abstract

The emerging markets for color ink jet printing have many new and specific requirements for ink jet inks. Today's inks were initially designed for the home and desktop market, or the addressing and labeling industrial market. Market requirements for new, emerging applications, often include both the quality of the desktop market and the durability of the industrial market, while adding highly specific needs for the application.

While highlighting these needs, this paper emphasizes the wide range of technical paths ink formulation is taking to fulfill these needs, from controlled colorant solubility, new ink solvents, radiation curing, and new colorants. Some of these formulation approaches are general and are able to impact several applications while others are specific-substrate driven.

Ink formulations are rapidly evolving to fulfill the multiple challenges of the emerging markets such as packaging, large format, textiles and decorative coverings. Further tailoring of chemistries to optimize ink ingredients for these new applications is needed, offering major opportunities for imaging chemical vendors.

Introduction

Today, new applications for ink jet printing are emerging almost daily. These applications span printing photographs from the Web to decorating cakes to wrapping a transit-bus in graphics. Inherent ink jet technology advantages of simple, one step, non-contact printing, and a wide color gamut underlie all of these applications. Jet inks, along with substrates, are key components to enable this breadth of usage of ink jet printing technology.

The major portion of ink development and manufacturing investments since the initial commercial success of ink jet technology, has been made in two very successful markets-the home or desktop often labeled the SOHO (small office/ home office), and the labeling or coding market often identified as the industrial printing market. In the latter often the printing is a step in a manufacturing workflow. These two markets were greatly divergent in needs, and they developed inks with different strengths-high colorfulness, high quality, moderate durability at low speeds for the SOHO, and high durability, limited colorfulness (often monochrome) and moderate quality at high speed for the industrial application.

Today's wide range of emerging applications, increasingly requires new combinations of these requirements. This often challenges the state of understanding of ink and media formulations. Therefore, these new applications drive new ink development paths. Today, the quality of photographic prints, for example, is desired along with the expected durability of industrial labeling for Point of Sale packaging (Figure 1).

	APPLICATIONS			
REQUIREMENTS	SOHO	PHOTO PRINTS	ENTERPRISE OFFICE	DIGITAL PRESS
Wide Color Gamut	High	High	High	High
Waterfastness	Medium	High	High	High
Lightfastness	Medium	High	High	High
Near Photo Quality	Medium	High	High	High
Photo Quality	Low	High	Medium	High
High Speed	Low	Medium	Medium	High
Large Size	Low	Low	Low	Medium
Long Runs	Low	Low	Medium	High
Reliability	Medium	Medium	High	High
Low Print Cost	Medium	Medium	High	High
Ink Safety	High	High	High	Medium
REQUIREMENTS	INDUSTRIAL	LARGE FORMAT	TEXTILE (SAMPLE)	PACKAGING
Wide Color Gamut	Medium	High	High	High
Waterfastness	High	High	Medium	High
Lightfastness	High	High	Medium	High
Near Photo Quality	Low	High	High	High
Photo Quality	Low	Medium	Medium	High
High Speed	High	High	Medium	High
Large Size	Medium	High	High	High
Long Runs	High	Medium	Medium	High
Reliability	High	Medium	Medium	High
Low Print Cost	High	Medium	Medium	High
Ink Safety	Medum	Medium	High	Medium

Figure 1. Value of each ink requirement to the application

Some of today's new ink developments can be applied across many applications but other applications require specific chemistry tailored to a given substrate or use. Textile inks, for example, use reactive dyes that require a final fixing step.

How are inks evolving to fulfill these requirements? What remains for the future?

Widely Applicable Ink Improvements

Today's new applications will benefit from improvements in printing speed, print permanence, print durability, image quality, and system reliability, to support longer run lengths and larger format sizes. Many of the new applications will not be commercially successful unless these improvements are attained. Current ink developments are therefore aimed at these goals. The examples which follow, briefly illustrate some of the breadth of chemistry being applied today to these problems.

Print Permanence

The most pronounced improvement in permanence in recent years has been due to the tailoring of dispersed pigments for both solvent and water base jet ink systems. This success was driven first, by the need for more permanent text for the desktop, and then by the requirements for large or wide format printing, or even grand format printing. These inks bring light permanence, based on the pigment particles, and often greater waterfastness and durability based on the polymeric, steric, and ionic properties of the pigment dispersants.

One approach to stabilize jet ink pigment formulations incorporates pigment dispersions stabilized with a wide range of dispersants, or surfactants. For example, underpinning the initial successes of pigmented inks for text applications, are the use of copolymers to create hydrophillic and hydrophobic parts which associates with both the pigment and the aqueous system, and eventually the substrate.[1] More recently the same attributes were attained with the cyclopolymers.[2] Other methods use chemically reacted or modified pigment surfaces, for example, by covalently bonding ionic groups onto the carbon particle surface,[3] or the application of the same approach on colored organic pigment surfaces.[4]

Further improvements in waterfastness have been attained with additional additives for the chemically modified carbon black inks, for example. Utilizing long chain (C12 to C18) N,N dimethyl amine oxides as an zwitterionic surfactant, improves the attachment to the substrate of the carboxylated or sulfonated carbon black [[5]].

Waterfastness is not the only form of permanence being addressed with additives. The effective use of additives whether present in the ink, or on or in the substrate, has recently yielded greater light permanence of colorants, including dyes. Work on the use of porphines as the color stabilizer, with additional metal salts appears to produce effective protection from radiation across ink sets. The porphine can be also be associated with cyclodextrins, for example, for increased solubility in aqueous solutions.[6,7]

These methods have all been successful at attaining increased permanence while also preserving the other ink properties required for jetting properties.

Print Quality and Ink Drying Time

Print speed today, in many applications is limited by the drying time of the jet ink. This is especially true with water-based inks. The challenge is to lower drying times while retaining reliability and high print image quality. Incremental improvements are continuously being implemented in the drying domain with the use of penetrants for clearing the ink quickly from the substrate surface to yield fast drying. This is combined with the use of selective deposition of resins or other mechanisms to increase ink viscosity which limits spreading of the colorants to inhibit bleeding and feathering, and thereby, preserves image quality.

Further development of these concepts, utilize specially prepared ingredients such as pectic acid and properly selected penetrants. Here the pectic acid is especially sensitive to the small amount of multivalent cations present in plain papers, and gels, preventing the colorant from spreading.[8] Reduced feathering/line width leads to improved print quality, while reliability and drying times are maintained.

Tailoring of inks for efficient coupling of microwave energy is also being pursued for interest in assisted drying. Building on previous microwave drying work,[9] the formulations use optimized combinations of organic co-solvents, and salts for the microwave coupling, which lead to the absence of paper curl after drying and also still maintain jetting latency.[10]

Application Specific Ink Improvements

Each application also seems to have specific ink requirements determined by either the substrate to be used, or often a history of the printing process for which an ink jet applications is substituting.

Textiles

Printing textiles requires much larger quantities of ink, or more concentrated inks, to yield the desired colorant levels or color depth throughout a fabric. A larger color gamut is required to equal traditional screen-printing with multiple color inks. Total color permanence to washing and even perspiration, as well as maintaining the hand or feel, are also required. These needs are in addition to the expected jet ink formulation requirements.

Traditionally permanence in textiles has been obtained with high concentrations of reactive dyes followed by a both heat/steam fixing and wash steps. Not surprisingly, today these custom dyes for textile coloration, are seen with specialized additives in ink jet formulations. Reactive dyes containing vinyl sulfone or monochlorotriazine groups, in an aqueous medium which includes dicarboxylic to tricarboxylic acids, and their Li, Na, and K metal salts are seen in jet formulations. Malonic, succinic,or citric acids are used for cellulosic and polyamide fibers.[11] This composition meets both the jetting requirements of thermal ink jet inks as well as the color dyeing properties for textile printing using the traditional wash and heat fix treatments. The interaction between dye molecules is inhibited in the aqueous liquid due to the presence of the di and tri acids, while reactivity of the dye to fiber is enhanced, along with the shelf-life stability.

Additional innovative approaches for textiles, which attempt to eliminate the traditional pre- and post treatments, include UV curing of the ink on the fibers, with the ink containing appropriate monomers, oligomers and initiator; also inks with small particle, polymer lattices and pigment have been thermally cured on the fibers.[12]

Decorative Arts

Much like textiles, the decorative arts field—wallpaper and high pressure laminates for counter tops, cabinets, floors, ceilings—is exploring ink jet printing for proofing, and for short run production, or custom designed orders.

For example, ink jet inks are used which contain a heat activated dye (or pigment), to print an intermediate substrate which is then used for thermal transfer printing, where heat and pressure are applied to transfer the colorant to the final substrate. The formulation contain heat sensitive sub-micron pigments (sublimation or dye diffusion colorants) and appropriate dispersants such as sulfonated lignins which do not inhibit the heat transfer step but still exhibit proper dispersion properties for thermal ink jet printing, and for appropriate storage. The colorants exhibit a high affinity for polyester and other synthetic materials in the heated state; limited affinity for most other materials (metal, ceramic, wood, other polymers) where a final laminate is required.[13,14,15]

Wide Format and Packaging

The ability to print onto hydrophobic surfaces is a prime requirement for the use of ink jet inks in several new applications especially packaging and signage. Use of water based inks however, is desirable for their convenience and safety, and these conflicting requirements are being overcome in multiple ways.

Inks with reduced surface tension and improved wetting capabilities for hydrophobic surfaces have incorporated a mixture of siloxane and fluorinated surfactants along with polymer-dispersed pigments in aqueous base.[16] The siloxane surfactants include polyether modified dimethyl siloxane or nonionic silicone glycol copolymers; the fluorinated surfactants contain fluoroalkyl alcohol substituted monoether with polyethylene glycol.

Another approach for printing surfaces for packaging materials (polymer films, coated paper, plastics, metal, cardboard, glass) has been hot melt inks, or inks which are liquid at jetting temperatures, which solidify on the substrate. Improvements in these inks include better adhesion and resistance to offset and abrasion. The use of optimized combinations of waxes, a glycerol ester of a hydrogenated rosin, and plasticizers lead to compositions which stay fluid and maintains its low viscosity at lower temperatures enabling increased flow and thinner ink layers. It also enables printing without pre-heating the substrate.[17]

Other advances in hot melt inks show increased thermal stability at the elevated temperatures required for jetting, less shrinkage upon cooling, and better flexibility and adhesion. Use of selected ester amide resins combined with a tackifying resin such as polyterpene, along with colorants and other standard ingredients yield these results. The low shrinkage enables the ink's use in 3D printing for model making, another new application of ink jet.[18]

Summary

Many common needs are present across new jet ink applications, and these needs are being addressed through a broad range of inventive approaches. Some specially tailored ingredients however, are required for each application due to usage and unique substrate requirements. A significant need exists for further tailoring of chemistries to optimize inks for these new applications. Opportunities exist for addressing both the widely applied improvements, or to focus on the specific needs for a given application. Today we are still at the beginning of tailoring imaging chemicals for jet ink needs.

References

1. US patent 5,085,698, Dupont, (1992).
2. US patent 5,571,850, Dupont, (1996).
3. US patent 5,571,311, Cabot Corporation, (1996).
4. US patent 5,837,045, Cabot Corporation, (1998).
5. US patent 5,891,934, Hewlett-Packard, (1999).
6. US patent 5891229, Kimberly-Clark, (1999).
7. US patent 5855655, Kimberly-Clark, (1999).
8. US patent 5,871.572, Seiko Epson, (1999).
9. US patent 5,220,346, Xerox Corporation, (1993).
10. US patent 5,814,138, Xerox Corporation, (1998).
11. US patent 5,902,387, Canon, (1999).
12. Wayne Tincher, Qiang Hu, Xiaofei Li, Yingnan Tian, Jianming Zeng, Coloration Systems for Ink Jet Printing of Textiles, Proc. NIP, pg. 243 (1998).
13. US patent 5,830,263, Sawgrass Systems, (1998).
14. US patent 5,642,14, Sawgrass Systems, (1997).
15. US patent 5,640,180, Sawgrass Systems, (1997).
16. US patent 5,852,075, Dupont, (1998).
17. US patent 5,891,228 Markem Corporation, (1999).
18. US patent 5,863,319, Markem Corporation, (1999).

Biography

Carol Keller heads Keller Associates which offers consulting services in consumables for color digital printing. Services include product development for ink jet inks and media, and business and opportunity analysis for color digital printing.

Ms. Keller has worked extensively in color imaging systems, most recently heading the consumables business for Iris Graphics, a Scitex company. She previously lead product efforts in color ink jet and color electrophotography at Xerox Corporation, in digital photographic printers at Polaroid Corporation, and in charge deposition printing at a start-up. She holds a BS degree in chemistry and an MS degree in materials science from the University of Rochester.