

DEVELOPMENT AND ANALYSIS OF COATED PAPER FOR HIGH SPEED INKJET PRINTING

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ABSTRACT

Within a global market for printing and writing that is at best flat, consumption of paper for coated reel-fed (high-speed) inkjet is growing. Growth is driven by the potential to print on demand, reducing the need for high inventory of printed material and making it possible to personalize the content. The rate of growth and ultimate target market size is widely debated by analysts and commentators, with the key difference being whether coated inkjet can also take market share in coated magazines from traditional offset printed grades.

One of the most significant hurdles to delivering mass commercialization of coated inkjet paper for magazines is the availability of a cost-effective paper substrate in a range of grades which has the look and feel of traditional magazine paper. This is because making good quality inkjet-compatible coated paper is challenging. Most inkjet inks contain 60%-95% solvent, often water; therefore, the difficulty is to evaporate the solvent whilst simultaneously fixing the ink at the paper surface. Amongst the requirements for such papers is that they have a high color density with both dye and pigment based inks, whilst minimizing ink spread and bleeding. Fast drying time is required to prevent set off of the ink; a problem especially prevalent with pigment based inks, and an even, mottle free print is also essential.

IMERYS has been working to overcome these issues, and our philosophy has been to concentrate on more traditional mineral pigment types from our extensive portfolio of materials and grades to enable relatively high application solids.

In this paper, we will expand on our view of the coated inkjet market, its size and technical needs. We will introduce the techniques that we have developed for characterizing these papers and share application data of our proposed formulation concept, benchmarked against appropriate commercial grades.

Keywords: coated paper, inkjet.

INTRODUCTION

Market Directions

Much of the revenue from magazines and newspapers is derived from the advertisements within them. As a result, the demand for graphic papers has traditionally been linked to the growth in advertising spend. Historically, there has been a correlation between paper consumption and GDP (Gross Domestic Product), but recently this correlation has disappeared due to the rapid growth of the internet, which has taken a large and increasing proportion of the available advertising spend. Zenith Media reports that internet advertising has grown substantially in the past and is predicted to continue with a corresponding loss in share for printed media, such as newspapers and magazines [1].

However, research has shown that when advertisements are personalized for the consumer, their effectiveness is increased and the resulting response rate is much greater. Several recent marketing studies have reported that although direct marketing fell rather out of fashion for a few years, it's been increasing again recently, as the trend moves towards integrated marketing campaigns spanning both digital and print. QR (Quick Response Code) codes or NFC (Near Field Communication) tags on printed material allow customers to go straight from a brochure to a website, while CRM (Customer Relationship Management) data gathered online is the starting point for a personalised print campaign. Email spam now has reached such limits that electronic advertising is often largely ignored, and that people appreciate receiving personally addressed advertisements as letters in printed form [2].

Personalization also increases advertising efficiency. For example, with direct mail, Kodak has reported that people only look at an advert for approximately three seconds before discarding, whereas if the advert is placed on a transactional document such as a gas bill, then it may be studied for around forty-two

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seconds, leading to a higher response rate [3]. This provides a major incentive for growth in personalized and targeted mail and advertising, which can only be delivered using digital printing technology. In particular, the concept 'transpromo' has developed. In addition, digital printing markets are expanding into other areas such as books, where it can be highly cost efficient depending on the length of the print run and the potential to reduce inventory of finished articles. There remains considerable debate as to whether the technology will also be used for magazines, but publishers have commented on the desire to produce different versions or editions of a publication with a variety of regional 'accents'. This would be possible with digital printing. Personalized packaging is also an avenue of potential growth.

For all these reasons, inkjet printing is the fastest growing printing technology in Brazil, with an annual growth of more than 12% per year. The rest of South America follows a similar trend and the growth rate of this segment is more than twice the other technologies [4].

Printer Developments

In the past, the slower, higher cost inkjet technology gave poorer quality prints than standard offset technology and struggled to compete. Press technology, however, has been developing rapidly and has now reached a point at which mass adoption of inkjet printing is realistic. All the major machine manufacturers are offering web to web inkjet machines, which print at up to 200m/min, and at least one machine with a web width of >500mm is commercially available.

However, offset printers are working hard to develop their cost efficiency for shorter print runs by reducing waste and make-ready times, and the lack of standardization of inkjet technology together with the reduced availability of finishing and on-line converting equipment for inkjet printing means that progress is still needed before inkjet will be seen as a high volume challenger to offset.

Mixed offset/inkjet developments are also possible. Legislation is beginning to enforce Inkjet QR (Quick Response) marking code of pharmaceutical packages, and hybrid presses, where the bulk of the print is made using a conventional printing press such as offset lithography or flexography, but personalized content added at the end using inkjet heads attached to the press are also becoming commonplace.

Requirements for Inkjet Compatible Paper

However, perhaps the greatest hurdle to be overcome to allow the adoption of inkjet papers for mass market printing of graphic paper is the quality and affordability of the substrate.

An 'offset-style' coated inkjet paper grade has several technical requirements. Among these is that the paper should be similar in appearance and feel to conventional offset magazine papers. This is needed to enable publishers to insert targeted and personalized content into a publication otherwise printed using conventional printing methods.

The substrate design also needs to be compatible with the chosen ink type (pigmented or dye based). Pigmented inks tend to be more expensive, but are generally more durable in terms of water and light-fastness, which is very important in some applications, such as billboard displays. To provide good print density, the ink needs to be held close to the surface of the paper and additives are typically employed to aid this through the precipitation of the ink from the ink formulation. Particular care must be taken with dye based inks to ensure that the colored dye does not penetrate too far into the coating with the fluid carrier, and result in a low print density.

Cationic fixatives are commonly used to induce this reaction in anionic inks. However, the use of cationic coating chemistry causes major production related issues for the papermaker, who must spend considerable time ensuring there is no mixing of cationic and anionic formulations between production campaigns.

Another important property of the paper is its ability to remove the fluid phase of the ink quickly from the printed area (either by absorption into the paper or evaporation). This is particularly important in inkjet, as the inks contain large quantities of fluid (e.g. water) and this places extra demands on the paper substrate. As a result, the paper must be designed to provide a pore structure suitable for fast drainage and a receptacle capable of holding the large fluid volume. Fast drying of the print is necessary in order to prevent set-off and smearing within the press and onto other surfaces in the reel or stack of paper. Drying the print quickly helps to immobilize the ink while still close to the paper surface and prevents the wet ink from flowing across the surface of the coated layer, causing wicking and bleeding (feathering) into other surrounding printed colors. This needs to be controlled in order to give good line definition and clarity to the print. Finally, the high fluid content of the inks places another demand on the paper, that of high dimensional stability in order to withstand cockling in highly printed areas.

Expensive silica mineral pigments are often used to absorb dye based ink into their fine pore structure, thereby physically fixing the dye in position close to the paper surface. The weakness of silica coatings - in addition to the raw material cost - is that application must be performed at low solids (30wt% is common) due to the high specific surface area and large internal pore volume of the mineral. These factors also often lead to higher binder requirements in the formulation, which further increases cost and can influence drying rates if not carefully formulated.

In the next sections we present an alternative approach to silica minerals, which combines the advantages of high porosity with the ability to surface treat at high solids whilst using formulations based on anionic chemistry.

One other problem of inkjet printed papers is that of the recycling of the printed material. Water based inkjet inks, in particular, are harder to recycle using the currently installed technology. This is not discussed in this paper; however, this is an area of intense research activity [5].

METHODS

Analysis of Inkjet Performance

As described above, there are several critical challenges associated with developing such an inkjet paper, which have to be assessed in the laboratory during the development phase. In Imerys, we have a suite of printers which contain a range of different inks from various high-speed printers. A test print is made using each of the different inks and then assessed for color density, line and line edge quality and, finally, drying time. These methods are presented and discussed below.

Print Density

The color density is a key criterion for a good print, where vibrant colors give perceived quality. Owing to the rather variable nature of the desktop printers used, controls are always included, and the color is referenced against a silica-coated paper. A 'print index' also gives a single number, which makes it easier to compare many samples.

The Print Density of four printed colors (black B, cyan C, magenta M and yellow Y) is measured using a Gretag Spectroeye Densitometer. The print index was calculated in reference to a control paper, HP Premium.

$$Print\ Index = \left[\frac{B_n}{B_0} + \frac{C_n}{C_0} + \frac{M_n}{M_0} + \frac{Y_n}{Y_0} \right] \times 100$$

where X_n = color density of the sample, X_0 = color density of HP Premium and $X = B, C, M, Y$.

A higher number is better. The silica control paper always has a value of 400, and other samples are referenced against this.

Line Quality

The printed black on yellow line is scanned using a HP Scanjet G4050 scanner at 600 dpi resolution, and a 500 x 300 pixel image. This analysis is carried out using the black on yellow scan, and specifically captures any spread of the yellow ink into the black line. A line profile is taken through the black band. For a good print, the profile is relatively smooth (low mottle) and is very angular with very steep sides and a flat bottom. For a poorer print, there is much more variation and the black band is much more variable (see **Figure 1a** and **1b**).

The width of the profile is taken at 25% and at 75% between the black and yellow intensity levels. The ratio of these widths is the line quality, with a value of 1 indicating a perfect line.

The ink wicking and bleeding (black into yellow) is also picked up by the edge analysis. The scanned print is converted to a black and white image and the pixels at the edge of the line are analyzed. At the interface, a "good" black pixel has only 1 white pixel next to it. "Bad" black pixels have either 2 or 3 white pixels next to them (see **Figure 2**). Any black pixels with 4 white pixels around them are



Figure 1a. The scan is taken along the red line. Any transfer of the yellow ink into the black line will be captured

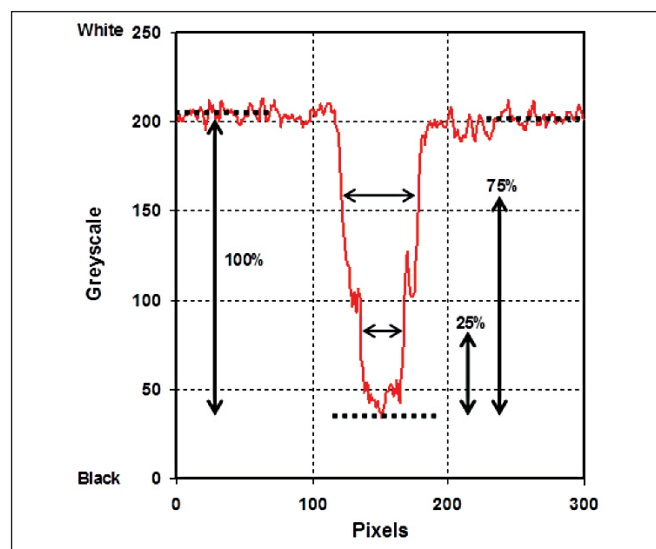


Figure 1b. Line width parameter = width at 25% / width at 75%. Similar width values are better, so, a value of 1.0 would be perfect

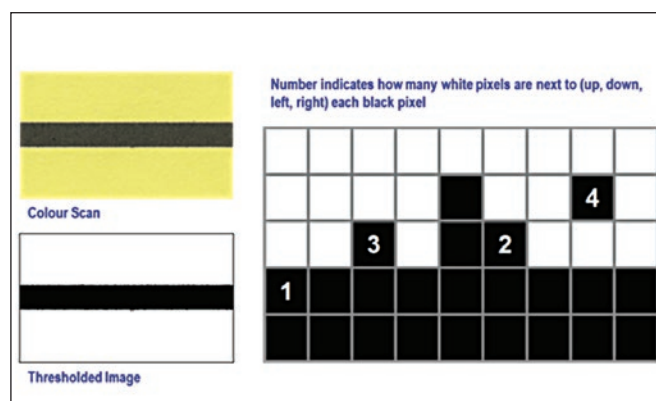


Figure 2. Edge quality = % interface black pixels with 2 or 3 adjacent white pixels. A lower number indicates a smoother edge

unattached to the black area. A measure of how smooth the edge is can be obtained by determining how many pixels have 2 or 3 adjacent white pixels.

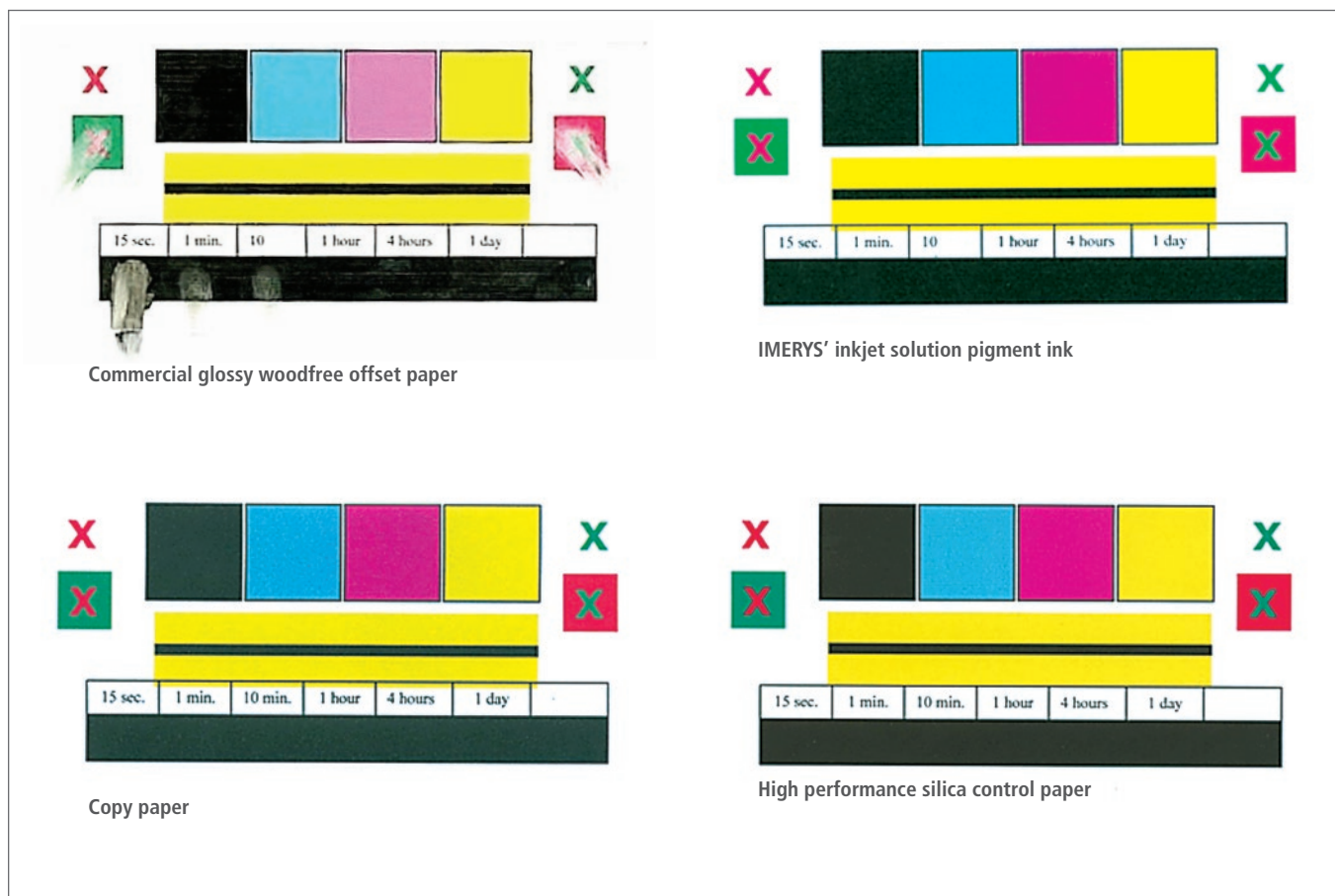


Figure 3. Scanned images of selected prints showing the degree of ink smearing

RESULTS AND DISCUSSION

IMERYS has been developing a formulation which combines an optimal blend of different minerals and formulation ingredients to address the paper requirements of fast water evacuation with rapid fixation of the ink at the surface: "Imerys Inkjet Pigment". Our design philosophy has been to maintain an anionic formulation, which can be applied at high solids on modern high speed coaters. In this work, our Inkjet Pigment slurry has been combined with 12 pph 6-98 polyvinyl alcohol (PVOH) in a simple formulation. The color has been applied to a suitable wood free base paper using a hand draw down technique. The data below show the performance of our inkjet pigment using the methodology described above.

Figure 3 shows scanned images of inkjet prints on different substrates. The images show the color density of the four colored inks in the boxes. The black line on the yellow background gives a good indication of the wicking and bleeding tendency, while the red and green crosses give a good indication of ink bleeding, since they are made from a mixture of colored inks. The black rectangles at the bottom of the print are used for assessing smear resistance with time. In this simple measure, the index

finger of a trained operator is pressed against the ink at set times after printing and pulled firmly across the print to determine the ink drying/smearing tendency.

The prints show that copy paper gives excellent smear resistance and line clarity, but tends to lack the color density of the coated papers. However, while commercial offset coated paper can provide good color density, it is not properly compatible with the inkjet ink, as can be seen by observing the high mottle and smearing tendency. Commercial coated silica paper remains the quality benchmark, but it cannot be produced at a price that makes it suitable for commodity applications. The IMERYS coating has a reasonably low smearing potential and yet similar print density and wicking/bleeding characteristics to the silica control paper.

Typical Performance of Imerys Inkjet Pigment – Dye Based Ink Printer

Figures 4 to 6 show the performance of the Imerys Inkjet Pigment for a commercial high speed dye based ink. In Figure 4 the Print Index is a measure of the color density (higher value better). The Imerys

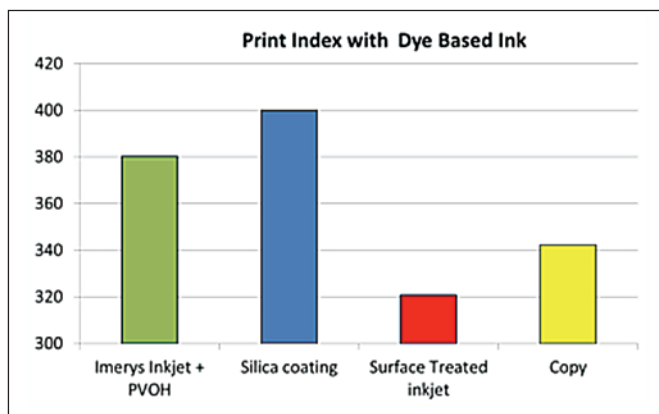


Figure 4. Color density (print index) dye ink

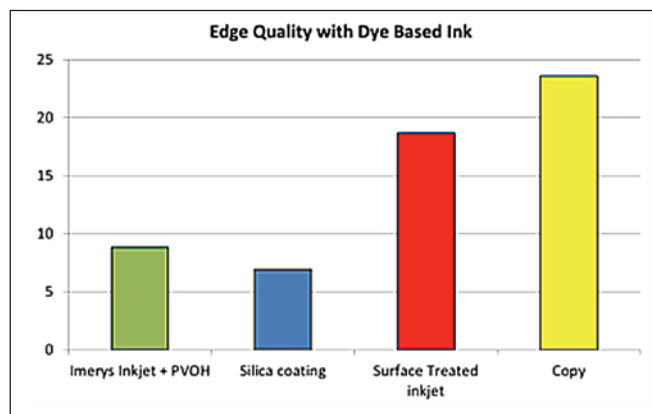


Figure 5. Edge quality dye ink

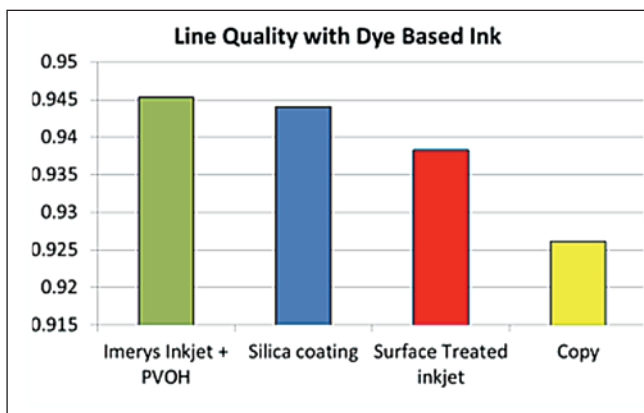


Figure 6. Line quality dye ink

- Color density similar to silica
- Superior edge quality and line quality to copy paper
- No smudging (see smearing images -Figure 3)

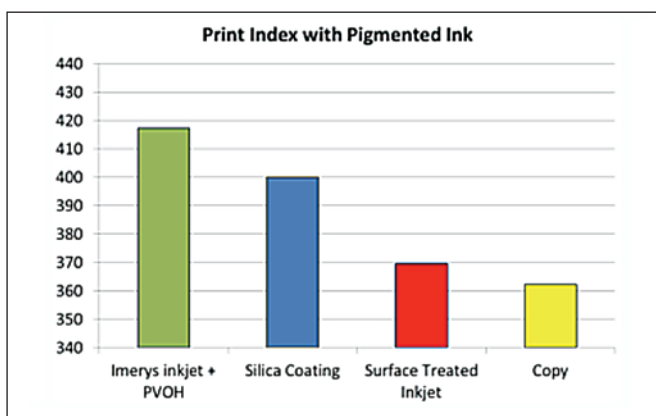


Figure 7. Print index pigment ink

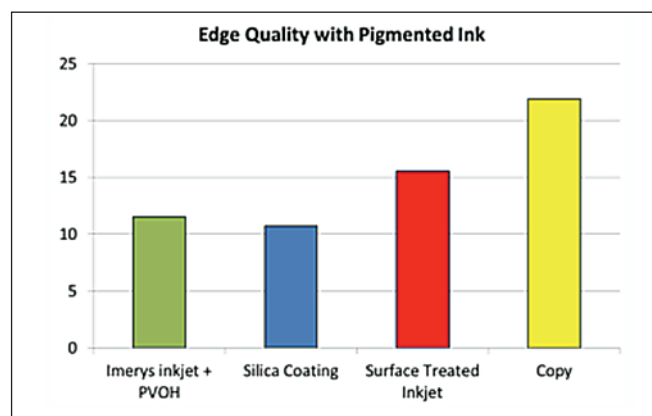


Figure 8. Edge quality pigment ink

pigment is similar in color density, edge (Figure 5) and line quality (Figure 6) to the silica paper, and significantly better than the surface treated inkjet paper and copy paper.

Typical Performance of Imerys Inkjet Pigment – Pigment Based Ink Printer

The papers were printed in desktop printers, whose cartridges

had been filled with inks specially sourced from commercial high-speed presses. In **Figure 7** it can be seen that the color density is intermediate in value between the high quality silica paper and the copy paper, and close to that of the silica grade. The line and edge quality shows that there are no bleeding issues (**Figures 8 and 9**). Importantly, there was no smudging of the ink after printing, which is difficult to achieve with pigment-based inks (Figure 3).

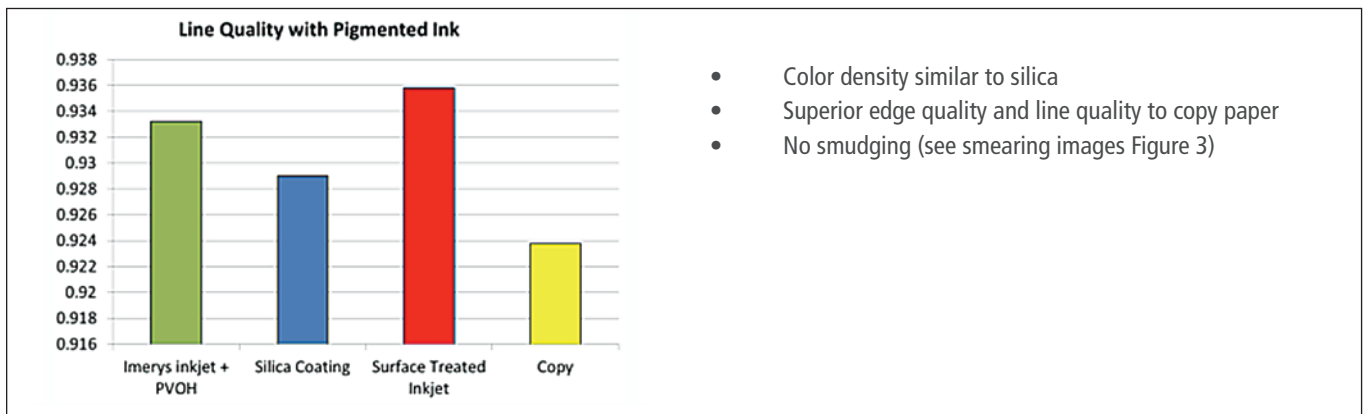


Figure 6. Line quality dye ink

CONCLUSIONS

In conclusion, it is our belief that market dynamics are moving towards personalized print and that this is helping fuel the growth in digital printing and inkjet in particular. There remains a requirement for a coated offset type paper, which can give vibrant colors, low wicking and bleeding and fast drying at an economically-sensitive price. This inkjet compatible paper should be made under anionic conditions and be able to be applied on a modern high-speed coater. The IMERYS inkjet

development seeks to fulfill these requirements. In summary it provides:

- An anionic cost effective inkjet solution
- Potential for high solids application
- Good color densities close to that achieved with silica paper with both dye and pigment inks (at 5gsm/side)
- Good line quality and edge quality and no wicking and bleeding
- Fast drying and low smearing

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