A Novel Coating Formulation for Silica Inkjet Layer Coatings

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Abstract

Silica based inkjet layer coatings made with the addition of special binders are widely used for inkjet coatings today. However, one limiting factor of the existing formulations is that they can only be used at low solids (<30%), which makes high speed coating very complicated. Another limiting factor is that most current formulations require the addition of special binders. However, the level of binder required is a compromise. Low levels of binders give good pigmented ink compatibility but poor physical properties. High volumes plasticize coating layer but reduce ink receptivity. This paper introduces a new nano structured silica coating formulation designed to overcome the limitations of existing inkjet technologies. The differentiating factors of this formulation are its high solids (up to 50%) and its self binding mechanism. Therefore, the ready-to-use formulation requires no organic binders. The rheology of the formulation gives very good runnability on various size presses and coaters. This new formulation has been proven in pilot and mill trials. Results showed high print density, dimensional stability, good water fastness and sharpness with most aqueous inkjet printers.

Introduction

The use of inkjet printing for narrow and wide format applications has become widespread due to the increase of on-demand printing. Inkjet printing main features are large color gamut, sharp detail, and long term water fastness. Inkjet printing requires the colorant to fixate onto the substrate surface by ink absorption into the coating [1, 2, 3]. The chemical interactions such as ionic or hydrogen bonding govern the fixation of the colorant to the paper and provide long term print stability [4]. Inkjet coatings containing amorphous silica are the state of technology for higher quality inkjet printing. Inkjet print quality is dependent on the ink-substrate interaction. The accepted theory behind the use of silica for inkjet printing is that silica is porous and hydrophilic and capable of taking up large volumes of water based ink into the coating [2, 5, 6, 7, 8]. Very absorbent coating is required for inkjet printing because ink contains large amounts of water. If the coating cannot absorb the ink's water, this will penetrate into the paper resulting in fiber swelling which can reduce print quality [9]. The specific surface area of silica makes the pigment very absorbent due to it's inter and intra particle pores [6, 10]. The high internal porosity of silica means it requires significant amount of binders [8, 11]. Svanholm et al [11] concluded that pigments with large pores require higher amounts of binder, which reduces the internal pore volume uptake and in turn reduces the color gamut area. Binders can optimize the coatings' solids promoting ink receptivity of the coating layer to the water based inkjet inks [12]. The most common binders, in addition to polyvinyl alcohol (PVOH) are polyvinyl pyrrolidone (PVP), and polyvinyl acetate (PVA) [13]. Other types of binders are aqueous emulsions of styrene acrylic and styrene butadiene latexes [1, 14] or gelatin and its derivatives [15]. To impart high print density cationic polymers such as poly-DADMAC are included in inkjet coatings as mordant.

The main limitations of existing inkjet micro porous silica coatings are their ***low solids, high binder requirement, cost, and on site formulation***. Low solids (below 30%) or high water content requires intense drying at slow coating speed [2]. This makes high speed coating very complicated limiting commercial applications [1, 16]. Additionally, low solids could contribute to bleed due to low or insufficient coat-weight [17]. Silica based formulations require large amount of binders (>40 wt. %), which not only affects print quality, but also cost. Inkjet coating formulations are seldom sold ready to use and on site preparation slows down production time. Several factors contribute to coating cost increase: energy for intense drying, high fumed silica cost; cost in time for both slow drying (low solids) and on site preparation of the formulation; cost of additional chemicals such as binders.

The coating introduced in this paper overcomes limitations presently found with the existing inkjet micro-porous coatings formulated with silica pigments. In contrast to existing silica based formulations, the new silica nano particle coating formulation (NPC) has ***high solids, is self binding, is ready to use, and has good runnability*** [1,17,18,19]. 1) High Solids (up to 50%): for ease of commercial applications on a wide variety of fast-speed coating equipment. 2) Self binding: no organic binder is required. 3) Ready to Use: NPC is very stable, has long shelf life, and requires no further preparation. 4) The rheology of the formulation gives this product excellent machine runnability.

Experimental

Coating Formulation

This paper introduces a technology for surface application consisting of a nano-particle inkjet coating (NPC), which does not require an organic binder. NPC contains amorphous spherical silica, which has been agglomerated to obtain a nano structured porous formulation. The silica used in the coating formulation has no internal pores and is manufactured by Eka Chemicals. The average secondary particle size is around 2 micrometers. The pigment is slightly cationic and the charge has been optimized for major inkjet printers [17, 18, 19]. NPC formulation is produced at up to 50% dry solids, with a Brookfield viscosity of 300 to 500 cps, water retention value of less than 80, and slightly acidic pH. The rheology of the formulation provides excellent runnability on a variety of equipment ranging from on-line rod metering size press to off line blade coaters to obtain coat weights ranging from 1.5 g/m^2 to 20 g/m^2 without changing or diluting the formulation.

Proposed Mechanism

The new nano silica formulation contains, in contrast to the silica gel, surface active silanol groups. The binding capacity is explained by the condensation of these silanol groups to siloxan bridges between the silica particles. This means that strong covalent bonds will form between silica particles.

Pilot and Mill Trials

NPC formulation for the pilot trials and mill trials were produced in Eka Chemical's industrial production plant in Sweden. Several pilot and full scale mill trials were performed.

Western Michigan University (WMU) Pilot Trial

The speed of the rod metering size press ranged from 210 to 450 m/min. Steel to steel calender pressure was 1,030 kPa, 1,400 kPa, and 2,750 kPa. Smooth and grooved rods used were IPI 004, IPI 005, IPI 0.33, 12.7 mm smooth and 35 mm smooth. The unsized (50# Offset) provided by WMU had a grammage of 76 g/m^2. The NPC coating formulation at 48% solids had a viscosity of 560 cps. The coat weights ranged from 1.5 g/m^2 to 11.5 g/m^2. The NPC runnability was excellent.

UMV Coating Pilot Trial

Two pilot trials were conducted at UMV Coatings using a TWIN^{TM} Sizer, Gravure roll coater and a BILLBLADE^{TM} blade coater. The speed for both coaters was 400-500 m/min and the paper grammage was 130 g/m^2. To produce semi gloss inkjet paper, a pre-coating consisting of GCC and starch was applied on the base sheet followed by a top layer of NPC. Coat weights (3 - 18 g/m^2) were achieved without changing the dry content of the formulation. NPC showed very good runnability.

Alco Pilot Trial

The pilot trial took place at the Alco pilot plant on a LCL coater. The speed of the coater ranged from 1,000 to 1,300 m/min. NPC coat weight ranged from 2 to 20 g/m^2. The runnability was very good.

Mill Trials

Two mill trials were conducted in Europe at two different mills (Mill A and Mill B). For the trial in Mill A, a puddle size press was used at 200 m/min. The base sheet was wood free with a basis weight of 180 – 220 g/m^2. For the trial in Mill B, a rod metering size press was used at a speed of 450 m/min. The basis weight of wood free base sheet was 120 g/m^2. Both these trials, like the pilot mill trials ran very smoothly.

Results

This section shows a comparison of NPC to commercially available papers that were selected according to their end use. NPC was applied at either a pilot coating facility or at a mill.

Kodak Versamark Comparison

Rolls of paper coated with NPC during the WMU pilot trial were sent to Kodak Versamark to print in their high speed industrial printer and to evaluate the performance of the NPC coated paper. Table I shows a comparison between paper coated with NPC and commercially available papers used for Kodak Versamark Transactional Communications. The data for the commercial papers was taken from the Kodak web page and the results for the paper with NPC were tested by Kodak Versamark. Results show that NPC perform at least as well as commercially available papers for the parameters given in Tables I and II.

Table I: Comparison of Papers coated with NPC and Transactional Communication Papers

Paper Name	Gram-mage	Optical Density	Cockle 1-10	Show Thru
	g/m^2	(High is better)	(Low is better)	(Low is better)
Targets		**1.2**	**3**	**0.06**
NPC - WMU11	78	1.23	3	0.07
Image Grip VIP 20#	76	1.17	6	0.09
Dataspeed Inkjet Pro	92	1.16	5	0
Z-Plot 650	90	1.15	5	0.06
HSIJ 24#	93	1.17	5	0.08
Pixelle Bond VM	91	1.03	7	0.05
Ultra White Ink Jet	88	1.09	7	0.08

Table II: Comparison of Papers coated with NPC and Transactional Communication Papers

Paper Name	HST	%Water Fast Test	%Bleed	%Wet Rub
	sec	(High is Better)	(Low is Better)	(Low is Better)
Targets	**<300**	**99**	**10**	**10**
NPC - WMU11	7	104	7	6
Image Grip VIP 20#	29	104	26	13
Dataspeed Inkjet Pro	1	97	20	10
Z-Plot 650	2	103	0	0
HSIJ 24#	4	101	11	12
Pixelle Bond VM	10	107	7	17
Ultra White Ink Jet	1	102	1	2

NPC optical density shown in table I is 1.23 and Figure 1 shows the other optical density values obtained with higher coat weight during the same pilot trial. As the coat weight increased from 0 (for the base paper) to 11.7 g/m^2, the optical density also increased from 1.18 (for the base paper) to 1.45.

Photo Paper Grades Comparison

Paper with NPC were printed and tested for surface strength and compared to commercial paper as in Figure 2. It can be seen that the paper coated with the NPC formulation has higher surface strength than the benchmark. In addition to Dennison, the paper was also tested using the IGT method. Results showed that when NPC was applied over a GCC pre-coat, the surface strength was similar to a commercial glossy inkjet paper, meaning that the picking at 2 m/s, 350 N, started at 0.7 m/s. NPC coated directly on the paper (without a pre-coated layer) showed no picking.

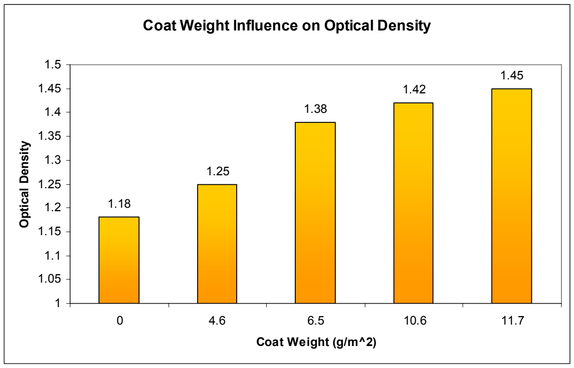

***Figure 1**. Effect of coat weight on optical property*

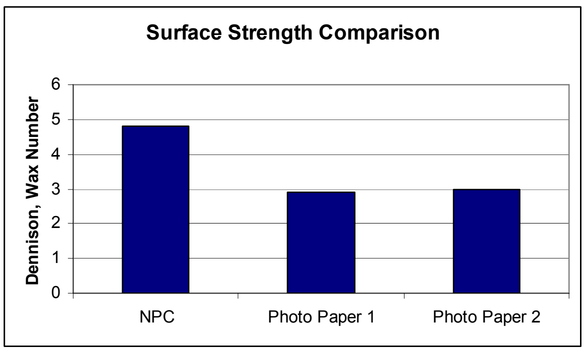

***Figure 2**. NPC coated paper's surface strength comparison to benchmark*

NPC Coating Compared to Kodak Photo and HP Brochure and Flyer Paper

NPC coated paper (UMV pilot trial) were sent to Rochester Institute of Technology (RIT) for printing, evaluation (bleed and raggedness) and comparison to the benchmark (Kodak Matte Photo Paper and HP Brochure and Flyer paper). The papers were printed with the Epson C-86 and HP 5650 printers. Figure 3 shows the line bleed is similar or better for the NPC coated papers than the benchmark. Similar results were obtained for raggedness as can be seen in Figure 4.

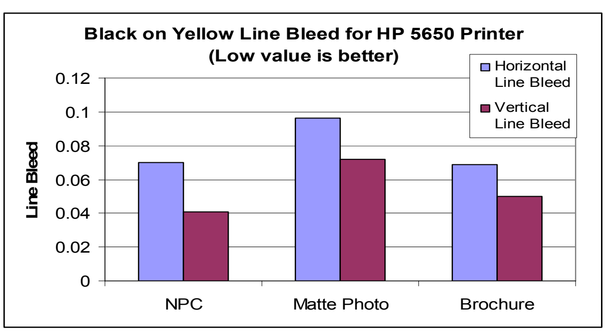

***Figure 3**: NPC line bleed comparison with commercial papers (benchmark)*

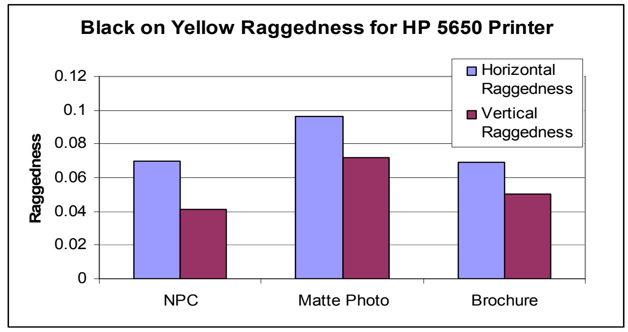

Figure 4: NPC raggedness comparison with benchmark

Conclusions

Results showed that NPC is suitable for narrow format desktop and wide format industrial inkjet printing. NPC has good print quality (optical density and show through), color gamut (area and volume), water permanence (water fastness, bleed, and wet rub), ink spread (black line raggedness), color performance (color to color bleed and raggedness), dimensional stability (curl, visual, and cockle) and good surface strength. In spite of having no organic binder, there was no dusting during application or printing. NPC rheology (high solids and low water retention value) gave excellent runnability on different coaters using paper ranging from 65 to 230 g/m^2. Apart from ease of application and fast speed a wide range of coat weights ranging from 1.5 g/m^2 to 18 g/m^2 of NPC were obtained.

Future Work

Next phase will look at image permanence and visual appearance metrics.

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