

Surface Enhanced Alumino-Silicates as an Alternative to Synthetic Silicas in Inkjet Receptor Coatings

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Abstract

Synthetic silica, the traditional matte ink jet paper coating pigment, cannot be coated at commercial speeds without significant sacrifices in operating efficiency. Commercial results with a new surface-enhanced aluminosilicate (SEAS) pigment provide a viable alternative to silica in ink jet coating formulations, especially with metering size press (MSP) methods. The SEAS pigment has sufficient porosity to dry ink jet inks rapidly, so it allows coatings to resist lateral ink spread (or whiskering) and strike through.

Optimized SEAS-based coatings generally need less binder and other costly ingredients than silica-based coating formulations. A trial with an optimized SEAS-based formulation on a commercial MSP papermachine at 1050 m/min. produced over 100 tons of C1S matte ink jet paper. This paper compared favorably in sheet and print properties to commercial paper commonly used in ink jet printers, i.e., a silica-based coated grade and an uncoated, multipurpose grade.

Introduction

Demand for ink jet paper soared as color ink jet printers have become the digital system of choice at home and in the office. Most people use uncoated, surface-sized bond paper costing $0.01 to $0.02 per sheet in these printers. Those who need quality results rely on high-gloss coated grades priced at $0.50 to $2.50 per sheet.

The gap between these extremes in price and quality is filled by coated matte paper. These papers are more expensive to produce because they must be coated off-machine. A large market awaits papermakers who can make coated matte paper on-machine and price it at a slight premium over uncoated paper.

Most matte coated ink jet paper use silica-based formulations that must be run at relatively slow speeds and low solids level. The challenge in machine coating ink jet paper is to find a coating color with a workable viscosity at high application solids. Engelhard's new Digitex™ pigment does just this. Digitex pigment is a surface-enhanced aluminosilicate (SEAS) that has proven itself in high-speed papermachine and pilot trials on a variety of coaters.

These trials have shown that metering size presses (MSP) produce better results by placing more of the coating on the surface to provide the high water absorption needed in these papers. By contrast, blade and rod coaters, which tend to drive pigment into the fiber structure, make less pigment available on the surface. The contour coating formed by a MSP application also has a more uniform thickness, so the finished paper has less variable print density than that made by profile coating methods.

Commercial and pilot results show that MSP and SEAS give mills the ability to produce high-performing matte coated ink jet paper at a viable cost and generally sell it for $0.02 to $0.03 per sheet. This combination allows the industry to move up the quality pyramid (Fig. I) from commodity copy-bond grades to higher-value, matte coated ink-jet paper, opening the door to a relatively new market promising years of double-digit growth.

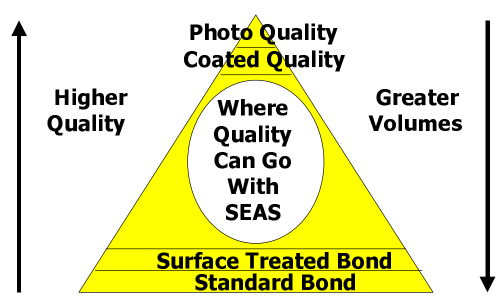

Figure 1

The Role of the Coating

The coating in matte ink jet paper performs several essential functions. It keeps the organic dyes in the ink from penetrating through to the substrate and regulates the spread and height of the ink droplet. It also speeds drying time by rapidly absorbing water from the high-water-content inks, and so limits bleed, wicking, cockle and curl.

Traditional coatings for matte ink jet paper use silica pigments to build capacity for ink liquids. While silica is effective once it is on the paper, its solids level is limited by viscosity and water absorption issues. For instance, silica slurries do not flow well above 15% to 20% solids without dispersants. Also, its high pore volume absorbs water to form a paste until all voids are filled before it is fluid enough for coating formulation. This forces mills to lower solids so enough vehicle is left to form a slurry. The water in the pores also demands extra energy during drying.

In attempting to make matte ink jet paper on-machine, papermakers have explored many alternatives to silica. For instance, they have added cationic components like styrene maleic anhydride to uncoated bond at the size press. This does not work well because these components pull water into the sheet. The need is for enough porous solids at the surface to absorb the water present.

SEAS pigment overcomes the solids issue and provides good runnability on-machine without sacrificing printability. As an enhanced aluminosilicate, it offers the comfort of a traditional coating ingredient altered to provide sufficient pore volume to dry ink jet inks rapidly. Its pore volume is comparable to that of precipitated silica, and its surface area is high enough to dry ink jet inks without causing the makedown problems of silica (Table I). In addition, SEAS slurries flow well at solids concentration of 50% to 53%, which can reach 58 to 60% with a cationic dispersant. They also have a TAPPI brightness of 92 or 94 and excellent color values (Table II).

Table I. Physical Properties of Silica and SEAS Pigments*

Pigment	Particle size (μ)	Pore vol. (c^3/g)	**Surface area (BET,m^2/g)**	Bulk density $(lb./ft.^3)$
Precipitated silica	1.0-10.0	1.58	700-730	7
SEAS pigment	1.0-2.0	1.24	85-110	25

* Average qualities

Table II. Typical Properties of SEAS Pigments

	Grade	
	Standard	High
Property	Brightness	Brightness
TAPPI brightness, %	92	94
Moisture, %	3.8	3.0
pH	10.8	10.8
CIE L*	97.4	98.2
CIE a*	-0.46	-0.51
CIE b*	2.63	1.6

Formulating Considerations

Ink jet coatings use binders to promote strong films and enhance printablity. Coatings based on silica need more than 40 parts of a strong binder like polyvinyl alcohol (PVOH) because of the pigment's high surface area. Those based on SEAS can often use less than 20 parts PVOH in combination with a less costly cobinder. The decrease in PVOH also aids coating runnability because this ingredient thickens the coating.

Silica-based coatings often contain cationic dispersants, defoamers and optical brighteners (OBA). They also contain a cationic dye fixative, usually poly-DADMAC, which aids waterfastness, restricts lateral dye movement and helps keep dye from entering the base. SEAS formu-lations generally use less than half the amount of other additives than silica-based coatings with no loss in performance. In addition, SEAS pigments have a pH of 10 to 11, which creates a near-neutral coating once cationic ingredients are added.

Silica formulations are limited to about 1% poly-DADMAC, because this ingredient reacts with silica surfaces to cause rheology problems. A recent article that looked at this issue noted that "if the viscosity increases too much, there could be a need to lower the solids content, leading to concomitant on-machine runnability problems[1]." Viscosity build does not occur in SEAS-based formulations due to poly-DADMAC, so the needs of the formulation can determine how much of this material should be added.

Runnability becomes an issue for silica-based coatings by the time pigment solids reach 20%. This is illustrated in tests of a basic formulation consisting of PVOH, cationic starch and an OBA and either precipitated silica, fumed silica or SEAS pigments. The SEAS pigment had a maximum pigment make down of 52.6% solids, which was more than twice the maximum for precipitated and fumed silica at about 20.0% solids (Fig. II).

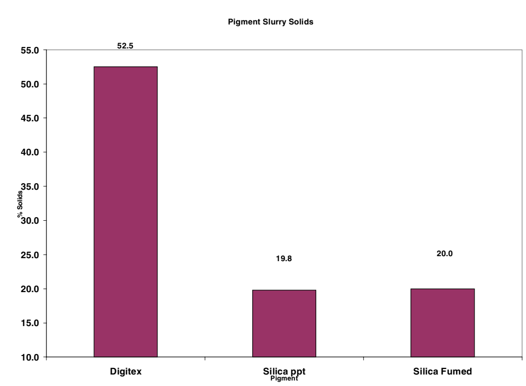

Figure II

The viscosity of these formulations was striking and illustrates why coatings using SEAS pigment work well at commercial speeds, while silica must be coated off line.

Brookfield viscosity (at 20 rpm) of the SEAS-based coating at 34.2% solids was less than that of the precipitated silica at 16.7% solids and much lower than that of the fumed silica at 11.7% solids (Fig. III). The Hercules End Points (4400 rpm with an 'E' bob) were even more pronounced. In addition, the SEAS pigment formulation at 34.2% solids had a HEP of 28 versus 52 for 18.9% precipitated silica and 60 for 11.7% fumed silica. (Fig. IV).

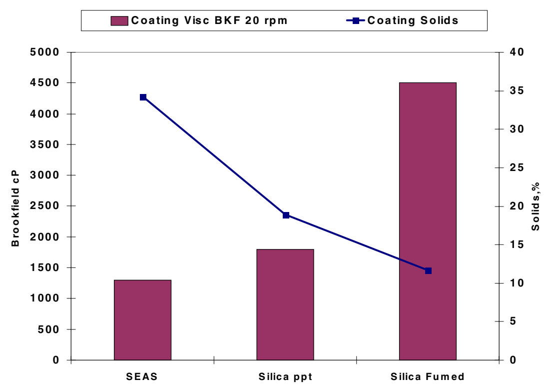

Figure III

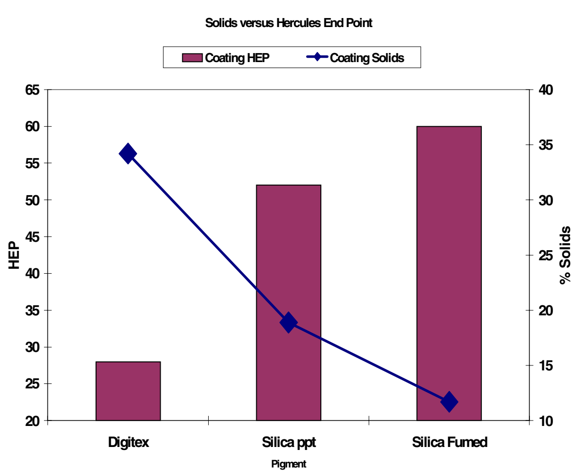

Figure IV

Producing Coated Ink Jet Paper On-Machine

The optimized SEAS-based formulation developed through lab and pilot coater tests was run in a commercial trial. This trial manufactured more than 100 tons of a premium matte ink jet C1S paper on a MSP coater at 1050 m/min.

The formulation contained a SEAS pigment dispersed to 58% by 1.5% poly-DADMAC (Table III). Another 3.5% poly-DADMAC was added to the formulation to aid waterfastness. To meet the customer's requirements for ink drying time, the coating color also included 15% precipitated silica. This amount of silica did not hinder the formulation's runnability on the papermachine.

Table III. MSP Commercial Trial Formulation

SEAS pigment	85% (a 58% cationically dispersed aqueous slurry)
Cationic dispersant	1.5 parts poly-DADMAC (in the SEAS dispersion)
Binder	20 parts 98% hydrolyzed PVOH (medium molecular weight)
Cobinder	20 parts cationic starch
Precipitated silica	15% slurried in water
OBA	1part wet-on-dry
Cationic polymer	3.5 parts poly-DADMAC

The coating color had 37% to 39% total solids, a Brookfield viscosity of 340 cP (100 RPM, 64°C) and a Hercules End Point of 50 (4,400 RPM, E-bob). The LWC paper made had a coat weight of 5 to 7 g/m^2 , as well as good brightness and opacity (Table IV). Evaluating all costs for the paper indicated that it could be sold at a competitive price to multipurpose grades with the performance of a silica-coated sheet.

Table IV. MSP Commercial Trial Finished Paper Qualities

TAPPI brightness, %	92.0
TAPPI opacity, %	91.7
75° sheet gloss, %	5.1
Basis weight, g/m^2	90.0
Coat weight, g/m^2	5 – 7
Moisture, % s/p	2.9 – 3.2
Total ash, % dcs	14.8

The paper had the SEAS-based coating on one side and a normal size press starch on the other to control curl. All papermachine conditions were within the usual range of operations (Table V), and the entire operation went smoothly. The SEAS-based coating was formulated like a normal kaolin-based coating using a conventional cooked binder. With an average pH of 8.0, it needed no pH adjustment. It was applied without orange peel, misting, web steal or other defect and needed no additional drying beyond that normally associated with conventional pigmented MSP coatings.

The C1S paper from the commercial trial was compared to paper commonly used in ink jet printers from both sheet and print quality standpoints. The paper had a TAPPI brightness of 92.0 and an opacity of 91.7, which compares well with commercially available silica-coated matte and uncoated, surface-sized ink jet paper (Table VI). When printed in a Hewlett-Packard 690C ink jet printer, the SEAS-based sheet had CYMK color density values that compared favorably with values obtained when printing with commercial silica-coated and uncoated grades (Table VII).

Table V. MSP Commercial Trial Papermachine Parameters

Sizer Conditions

Bottom rod diameter (pigment coating)	35 mm
Top rod diameter (starch)	10 mm

Rod Hose Loading

Top hose loading	90 KPa
Bottom hose loading	180 KPa

Machine Speed 1050 mpm

Table VI. Paper Property Comparisons*

	SEAS-based coated sheet	Silica-based coated sheet	Uncoated surface-sized sheet
Brightness, %	92.0**	94.1	87.0
TAPPI opacity, %	91.7	91.2	86.0
75° Gloss, %	5.1	9.2	7.0

* 90g/m[2] basis-weight C1S base sheets. The silica-based and uncoated sheets are commercially available and commonly used in ink jet printers.

** Mill trial target brightness was 92.0

Table VII. MSP Commercial Trial Print Color Densities*

	SEAS-based coated sheet	Silica-based coated sheet	Uncoated surface sized sheet
Cyan	2.06	1.32	1.44
Yellow	1.15	0.93	1.03
Magenta	1.66	1.22	1.34
Black	2.0	1.98	1.7

* Printed on a HP 690C ink jet printer and measured by a Cosar densitometer with a polarized filter.

Additional testing with the SEAS-based sheet showed that it produces good color results in commercial thermal and piezo ink jet printers (the major types), because it has an optimum contact angle of 80° to 100° across a wide range of ink surface tensions.

Paper produced in pilot-scale tests supports the results from the commercial trial. One evaluation involved SEAS-based paper made in a MSP pilot coater at 1500, 2500 and 3300 fpm using coating solids levels of 40.8%, 37.9% and 34.8%, respectively. This test compared silica and SEAS formulations coated on the same base paper at 5.0 to 6.0 g/m^2. The SEAS-based coating was a non-optimized version of the one used in the commercial trial above.

Even though it was not fully formulated, the SEAS-based coating had an 88.6 TAPPI brightness, which was about 4 points greater than that with precipitated silica and fumed silica (Table VIII). The SEAS pigment paper also had somewhat higher opacity. When these sheets were printed with a Hewlett Packard 690C ink jet printer, print densities showed that the three coatings had comparable print performance (Fig. V), i.e., the basic printer colors (cyan, magenta, yellow and black) had the density values needed to give vibrant color prints across all potential colors.

Table VIII. MSP Pilot Coated SEAS-Based Coated Paper

Brightness, %	91.1
TAPPI opacity, %	92.6
Cyan density	2.50*
Magenta density	1.82*
Yellow density	1.25*
Black density	1.80*

* Printed on a HP 690C ink jet printer and measured by a Cosar densitometer with a polarized filter.

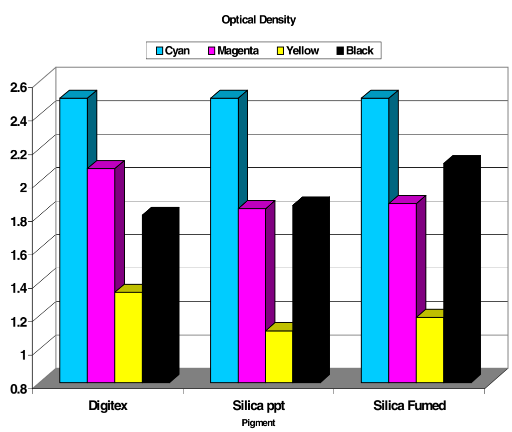

Figure V

In general, the mass of work done on SEAS-based coatings shows that they provide high color and black ink density, sharpness and definition when used in ink jet printers. SEAS-based coatings also have good surface strength at relatively low binder levels, while dusting can be an issue with silica-based coatings. One paper coated with a SEAS-based formulation containing 40 parts total binder had no noticeable dusting. The same paper with a precipitated silica-based coating had significant dusting. Both sheets had good color definition at this binder level. Lowering binder level of the SEAS sheet to 30 parts left color definition and dusting unchanged, but dramatically increased dusting severity in the silica-coated sheet.

Conclusions

SEAS-based pigment slurries have much higher solids content yet much better rheology than silica-based pigment slurries. This allows SEAS-based coatings to run at commercial speeds on MSP paper machines. In addition, optimized SEAS coating formulations can contain much less binder and other costly ingredients than silica-based ink jet coatings. A commercial trial using a SEAS-based formulation on a MSP papermachine at 1050 m/min. produced over 100 tons of matte C1S paper. The properties of the paper and print results on a HP 690C ink jet printer compare favorably with commercial silica-coated matter ink jet paper and an uncoated, surface-sized multipurpose grade.

References

1. Ryu, R.Y., Gilbert, R.D. and Khan, S.A., "Influence of Cationic Additives on the Rheological, Optical and Printing Properties of Ink-Jet Coatings, " TAPPI Journal, 2(11), pp. 128-134 (1999)

Biography

Michael Londo received his BS in Chemistry from St. Norbert College. He has worked in the paper/paper coating industry for the last 16 years. He worked 10 years in the Carbonless paper coating and product development of coatings and microencapsulation. He worked for Sandoz Chemicals on various projects including a project for ink jet inks. Currently, he works for Engelhard and has spent the past four years in product development. In particular, his main project is development of ink jet receptor pigments.