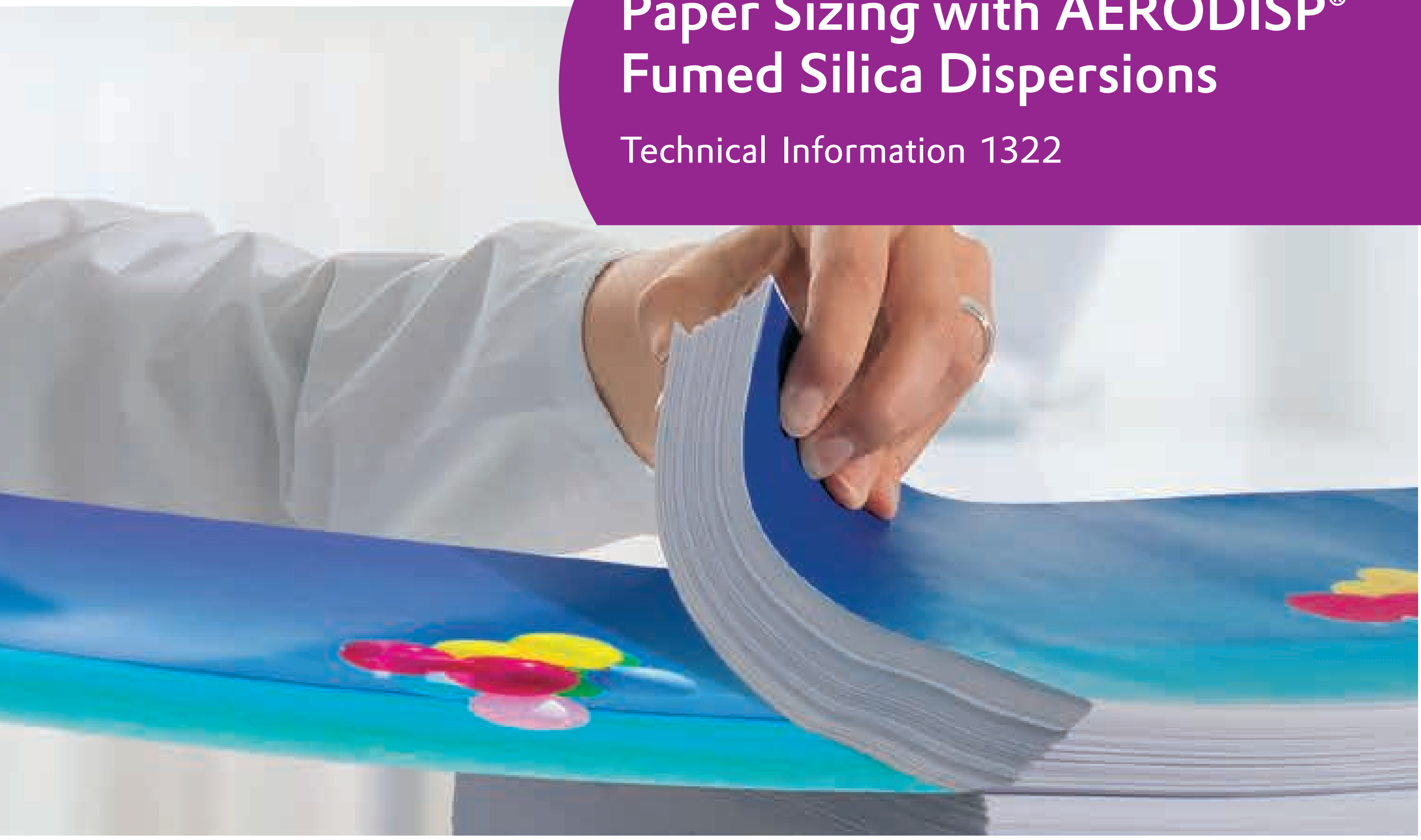
Paper Sizing with AERODISP® Fumed Silica Dispersions

Technical Information 1322



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1 Overview

Commercial inkjet printing will compete fiercely with traditional printing processes in the forthcoming years. While special paper is already available for offset printing and other impact printing processes, papers that meet the requirements of high speed inkjet printers are just in the infancy of their development. Standard office papers still exhibit significant weaknesses in such important properties as optical density, color gamut, and water resistance.

The commonly available Bright White type "inkjet paper" is perceived to be superior to common "office paper" for inkjet printing. The most outstanding feature is, as the name implies, high brightness values, which deliver high contrast between the printed image and sheet. In reality, there is minimal distinction in their performance on an inkjet printer, relative to the less expensive "office papers".

At first glance, it may seem scant attention was given to improving the quality of the inkjet image. The reason might well be the lack of a viable technical alternative to the polymeric surface treatments which currently dominate at the size press of the paper machine.

At the high end of the inkjet media market, glossy photo-realistic inkjet papers are using AEROSIL® fumed silica and AEROXIDE® fumed alumina based microporous paper coatings to realize performance benefits in terms of instant dry times, water-fastness as well as excellent color gamut and image resolution. This approach, which emphasizes the benefits of a micro-particle network, can also be used for everyday paper products such as office and printing papers to truly enhance their imaging performance.

Paper sizing with AERODISP® fumed silica dispersions impart a consistent pore structure on the paper surface allowing ink to be absorbed uniformly and efficiently (**Figure 1**). AERODISP® fumed silica dispersions, when combined with commonly used sizing agents such as starch or polyvinyl alcohol, will enhance:

- Color gamut and optical density
- Print uniformity (mottle & grain)
- Print resolution (line width, raggedness & blurriness)
- Reduction of print-through (strike through)

The thin fumed silica coating behaves like an inorganic sponge with a well defined void and capillary structure to absorb ink.

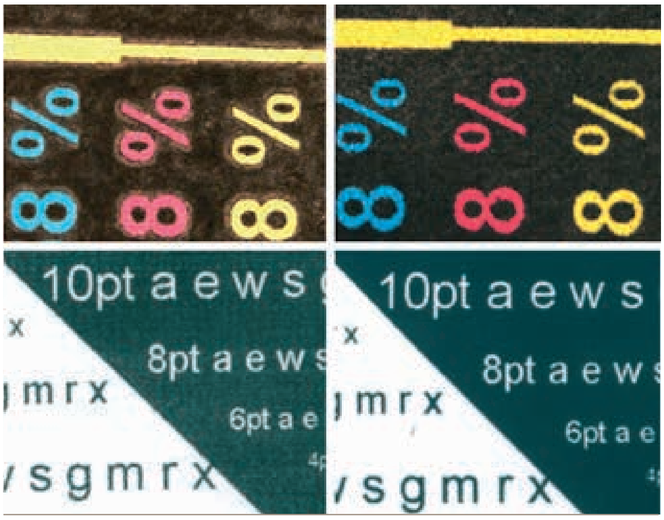


Figure 1
Inkjet prints after surface sizing of plain paper with cationic starch (**left**) compared to a combination of AERODISP® WK 7330 and cationic starch at a ratio of 2:1 (**right**)

AERODISP® fumed silica dispersions are extremely efficient – coat weights of as low as 0.5 – 1.0 g/m^2 (corresponding to 5.5 – 11.0 kg/metric ton paper) are sufficient to achieve these performance characteristics. They are compatible with most sizing formulations and equipment. The addition of AERODISP® to many polymer based formulations – starch and polyvinyl alcohol included – is also accompanied by a reduction in viscosity. For a given viscosity requirement, higher application solids can be achieved at the size press. The combination of high solids (less water to be evaporated) and a porous structure (more efficient evaporation) may reduce the energy required during the drying process.

Sizing formulations based on AERODISP® fumed silica dispersions can be applied with all common size press types, such as a puddle or metering type size press, a gate roll or calendar box.

2 Manufacture and Properties of AEROSIL® and AERODISP®

Paper-sizing with AERODISP® does not only improve the inkjet print performance but enables the manufacture of multifunctional papers which can be used on various printing platforms such as flexography. Although other non-impact printing processes such as laser printing do not benefit from the thin microporous layer, the papers nevertheless remain compatible and can be printed without any loss in quality.

AERODISP® fumed silica dispersions are a family of water based dispersions of fumed silicon dioxide. One of the most distinct characteristics that set AERODISP® dispersions apart from common colloidal systems, for example colloidal silica sols, is the "aggregate structure" and the high purity of the fumed silica particles. The following products are especially efficient for paper sizing:

- AERODISP® WK 7330, a cationic water-based dispersion that contains 30 % by weight of fumed silica. It im-proves print performance and water-fastness, combined with cost-efficiency and high formulation flexibility. It is the product of choice for most paper products.
- AERODISP® W 7330 N, a water-based alkaline dispersion with 30 % by weight of fumed silica, is well suited for acid free sheets where formulation flexibility and cost efficiency are key and water-fastness is less important.

Evonik Industries filed several patents pertaining to fumed silica dispersions and their use in the paper industry.

Information on further AERODISP® fumed silica and fumed metal oxide dispersions are given in the corresponding literature summarized in Chapter 8.

2.1 Manufacturing Process

AERODISP® fumed silica dispersions are produced by dispersing AEROSIL® fumed silica powder in the appropriate solvent. AEROSIL® fumed silica in turn is manufactured by the hydrolysis of volatile silicon compounds, for example silicon tetrachloride, in a hydrogen/oxygen flame accord-ing to the following chemical reaction:

$$SiCl_4 + 2H_2 + O_2 \rightarrow SiO_2 + 4\,HCl$$

Since it is produced by flame hydrolysis, AEROSIL® is considered a fumed silicon dioxide or fumed silica. Because of its fine particle structure, the product is also referred to as highly dispersed silicon dioxide. Other metal oxides, such as aluminum oxide, and titanium dioxide, can also be produced using the AEROSIL® process. They are marketed under the trade name AEROXIDE®.

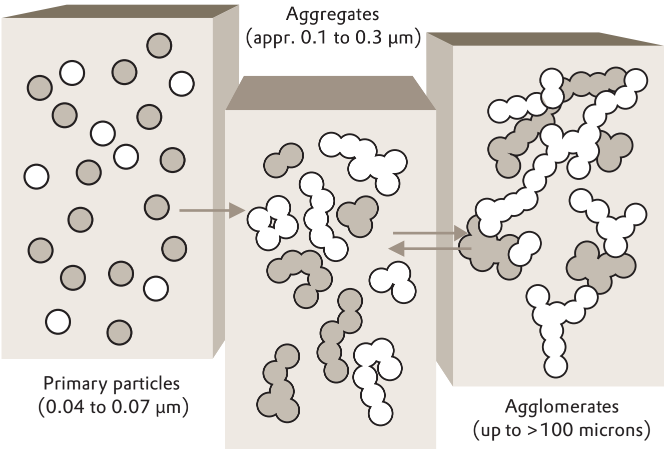
2.2 High Purity

AEROSIL® fumed silica has a silicon dioxide content of more than 99.8 % by weight and is pure amorphous silica. The heavy metal content is below the detection limit of most current analytical methods.

2.3 Fine Structure

During the manufacture of AEROSIL® fumed silica, the vaporized silicon precursor reacts with water (formed by hydrogen and oxygen gas) to form the individual particles of silicon dioxide (**Figure 2**). However, these particles do not remain isolated, but collide; bond and sinter together, resulting in branched chain aggregates with a length of approx. 0.1 to 0.2 µm. The aggregates are the smallest actual units of fumed silica. Once the aggregates cool down below the fusion point, additional collisions result in mechanical entanglement and hydrogen bonding of the chains, called agglomeration. The size of the agglomerates may be several hundred microns. Because agglomerates are only bound through weak forces, they can easily be broken down to aggregates during dispersion.

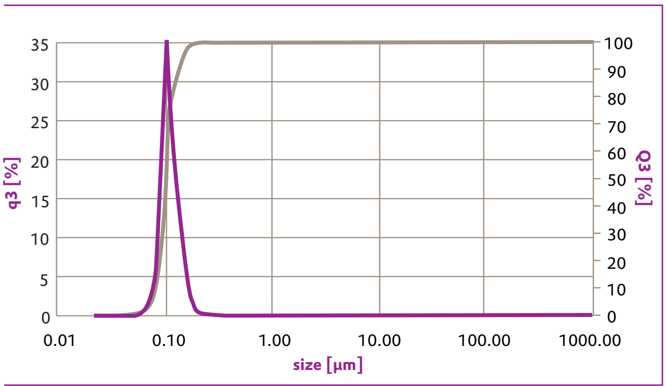
Figure 2 Schematic representation of AEROSIL® fumed silica primary particles, aggregates, and agglomerates.



2.4 Dispersions

Evonik's comprehensive and innovative dispersion know-how is the key to the commercial production of AEROSIL® fumed silica dispersions. Offered under the trademark AERODISP®, they are characterized by high fumed silica contents and narrow particle size distributions between 100 and 200 nm (**Figure 3**).

Figure 3 Particle size distribution of the fumed silica dispersion AERODISP® WK 7330



One of the most distinctive features of AERODISP® fumed silica dispersions is their "aggregate structure" (**Figure 4**), whereas common colloidal systems, for example colloidal silica sol, consist of isolated (non-aggregated) primary particles. The "aggregate structure" yields excellent results in paper products, even when very small quantities are used.

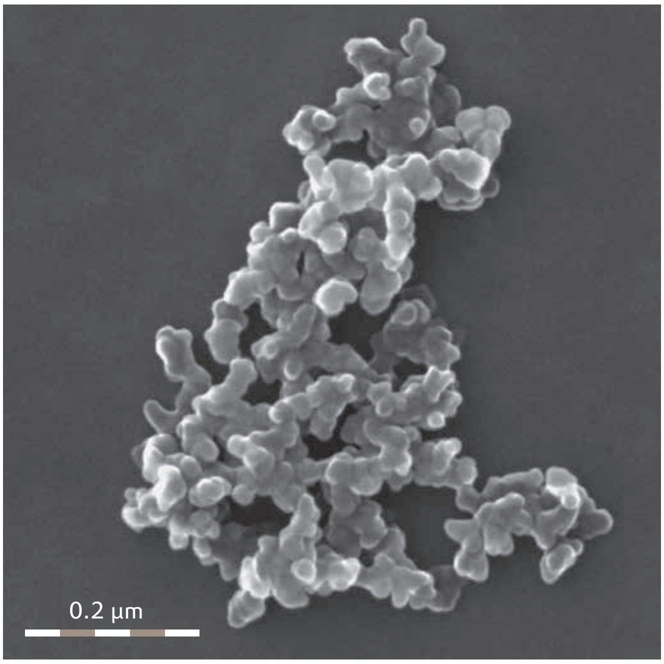


Figure 4
AEROSIL® aggregate structure

Due to their negative zeta potential throughout most of the pH range, fumed silica dispersions are especially stable in alkaline pH ranges. An example for an alkaline fumed silica dispersion is the previously described product AERODISP® W 7330 N.

Cationized fumed silica dispersions, such as AERODISP® WK 7330 are ideal to use in paper products. Their zeta potential curve is modified through the addition of a cationic polymer and resembles that of fumed aluminum oxide dispersions (**Figure 5**).

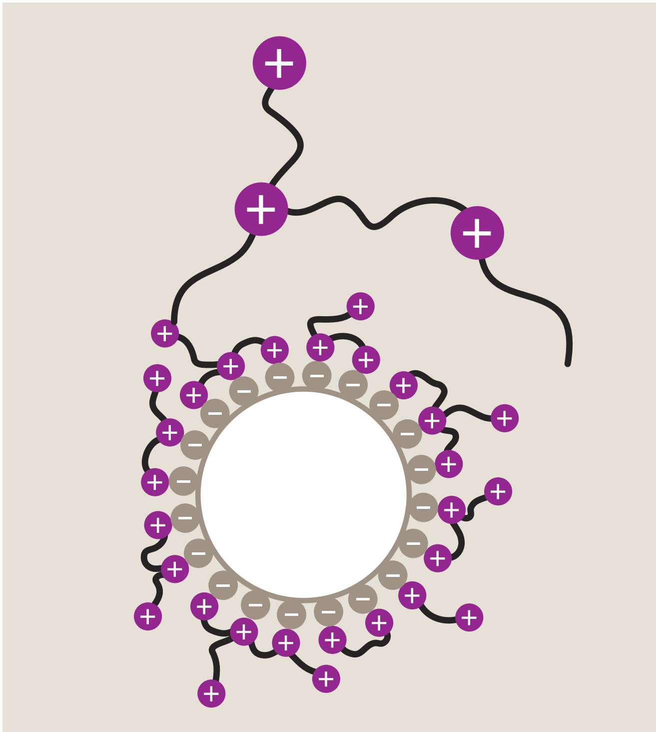


Figure 5
Schematic representation of a silica particle interacting with a cationic polymer

The choice of special polymer types and suitable dispersing techniques prevents flocculation and, at the same time, stabilizes the system at an acidic pH. The cationic surface charge enables the production of paper coatings with strong dye / pigment bonding, resulting in brilliant colors and high water-resistance.

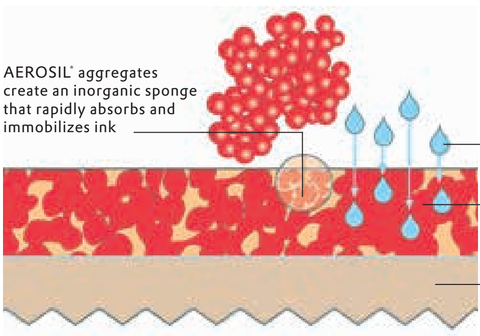
High solids contents in combination with low viscosities make AERODISP® fumed silica dispersions especially easy to handle and work with.

3 Paper Sizing with AERODISP®: Mode of Action

Paper is a low surface area material which has an irregular structure of large voids / pores. This aspect allows the liquid ink to travel randomly into the structure and along the fibers resulting in prints that have a ragged and blurred quality. Sizing with AERODISP® imparts a consistent high surface area pore structure at the paper surface to enable inks to be absorbed uniformly and efficiently. This leads to printed images with high gamut values, uniform ink absorption and low raggedness and blurriness.

The fractal structure of the fumed silica aggregate is the basis of the microporous matrix within coating / sizing layer. Its sponge-like structure with well defined pores and channels provides the capillary action needed to quickly transport the ink vehicle away from the paper surface and to prevent spreading along the fibers. Liquid absorption via capillary action in a microporous system is much faster than in purely polymeric systems that rely upon diffusion and solvation. The resulting penetration properties allow the use of high speed printers while maintaining optimum image quality. The dyes and/or pigments are absorbed on the surface of the solid particles with pin-point accuracy resulting in brilliant colors, excellent print uniformity and high resolution.

Figure 6 Schematic drawing of an AERODISP® size press treated paper



4 Experimental Part: Paper Sizing with AERODISP® Fumed Silica Dispersions

AERODISP® fumed silica dispersions impart a consistent pore structure on the paper surface enabling uniform and efficient ink absorption. AERODISP® dispersions can be combined with commonly used binders such as polyvinyl alcohol or starch, are compatible with most sizing formulations and equipment and can reduce drying energy required. Sizing formulations containing AERODISP® fumed silica dispersions can be applied with a puddle or metering type size press, a gate roll or calendar box.

This technical information discusses laboratory experiments using wire wound rods and an extensive online-sizing trial with a puddle-type size press at a small Kämmerer paper machine to apply the functional treatments. While differences were noticeable between laboratory and machine trials, in all cases we observed significant improvements of the print quality in comparison to the corresponding papers with pigment-free sizing solutions.

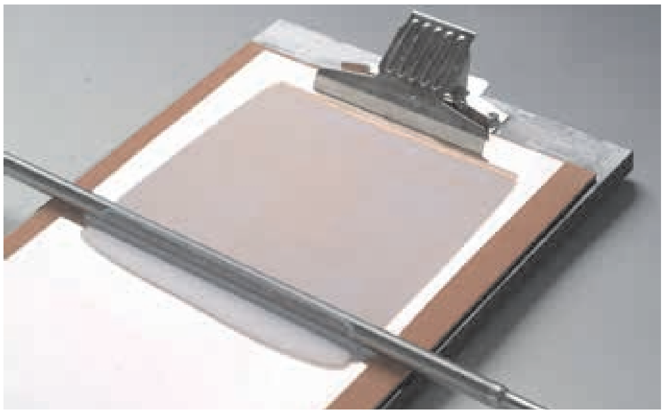


Figure 7
Laboratory procedure for the preparation of coated paper samples (dye added for better visibility of the coating)

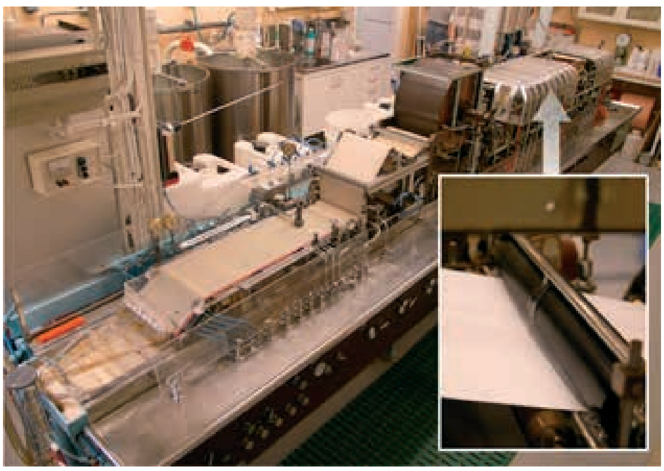


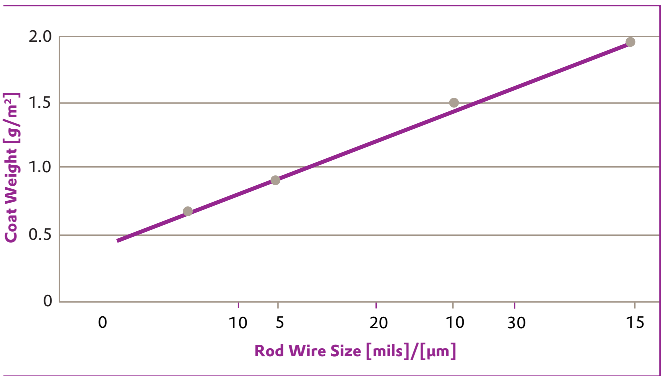
Figure 8
Kämmerer paper machine "XPM" used for online-sizing trials. The small picture shows the puddle-type size press.

The puddle size press is a common piece of equipment on many paper machines used to apply a functional treatment. The size press solution typically has a low solids content and viscosity. Detailed operations of the size press is beyond the scope of this paper, but in general, the press forces the size press solution into the voids between fibers via hydraulic pressure and leads to the sheet being satu-rated as opposed to the surface treatment obtained with metering size presses or coaters.

4.1 Paper Sizing Trials with PVA Based Formulations

To simulate the size press treatment in the lab environment, the coating formulation containing AERODISP® was formulated to 4% solids resulting in a Brookfield viscosity of less than 100 cPs. The coating was comprised of 100 dry parts of a cationized AEROSIL® fumed silica (AERODISP® WK 7330, Evonik), 10 dry parts of poly-vinyl alcohol (Celvol® 523, Celanese) and 15 dry parts of a cationic polymer (Induquat ECR 35L, Indulor Chemie GmbH). This coating was applied to a multi-purpose printing paper (20 lb Spectrum® DP, Georgia Pacific) with the appropriate wire-wound rod (see **Figure 7**), dried with a heated forced air gun and then dried under restraint using a Laboratory Sheet Dryer (Model S 100, Adirondack Machine Corporation). This approach allowed the treatment to saturate the sheet, minimize wrinkles and avoid curl, while obtaining low pickup weights. The correlation between rod size and coat weight was linear as seen in **Figure 9**.

Figure 9 Correlation between rod number and coat weight



In this technical information the results given for PVA containing formulations are mainly based on off-line laboratory trials. For the online-sizing trials the solids content of the different PVA based formulations was kept constantly at 11%.

4.2 Paper Sizing Trials with Starch Based Formulations

For both laboratory and online pilot plant trials the sizing solutions used were at 11 % solids. Either cationic starch or non-ionic starch were dissolved in a jet cooker and held at a constant temperature of 60 °C before use.

For the lab trials unsized inkjet base paper was used as substrate; the sizing formulation was applied using a wire-wound rod (**Figure 7**) with resulting coat weights of 1.0 g/m^2. For the online-sizing trials (Kämmerer machine at MoRe, Sweden, **Figure 8**) a standard chemical pulp consisting of birch and pine fibers was used (Hi-Cat starch, PCC filler, ASA sizing, Percol and Bentonite as microparticle retention aid, without optical brighteners). Fibers were beaten to a usual value of 25 °SR (Schopper-Riegler). Pulp stock conductivity and pH were adjusted to the same level for each of the trials.

The paper machine was run at constant speed (1.8 m/min) and drying conditions during all trials. The only variable was the composition of the sizing solution. The coat weight on the top side of the paper was about 0.5 – 0.7 g/m^2.

4.3 Image Quality Measurements

The treated papers were printed on various inkjet printers, such as Hewlett-Packard Photosmart 8250, Hewlett-Packard Deskjet 5652, Epson Stylus PHOTO R 200, Epson Stylus PHOTO R 240, and Canon PIXMA iP 6600 D. These printers were selected for their distinctly different ink sets and printing mechanisms employed. The Epson inks typically contain higher concentrations of organic solvents which make them more discriminating with respect to the paper used. Results on additional printers such as Epson Stylus PHOTO R 2400, Epson Stylus PHOTO R 285, Epson Stylus PHOTO R 800, HP Photosmart D 7360 and Kodak Easyshare 5300 are available on request.

Print patterns were created with CorelDRAW® software (**Figures 10a** and **10b**). They contain the various elements needed for quantifying print attributes such as optical density, color gamut area, print mottle and grain, inter-color bleeding and dot circularity.

All data in this study were obtained with both the "Personal Image Analysis System" (PIAS) (QEA Inc.) and the SpectroEye® Densitometer (GretagMacbeth Switzerland).

For calculating the strike through the reflection at 460 nm of the backside (BS) of the printed area (black) and the unprinted paper is measured using the SpectroEye calculation for strike through: $\log (R_{B(Sunprinted)}/_{RB(Sprinted)})$ Values for graininess, mottling and resolution given in this technical information were determined by PIAS. Line width, blurriness and raggedness were measured on several lines of the print patterns A and/or B and the mean values were calculated.

Figure 10a Print **pattern A** for the evaluation of the print performance

Figure 10b Print **pattern B** for the evaluation of print performance, water fastness and surface strength

Color density and L*a*b* values were measured using both the SpectroEye and the PIAS device. The gamut area is calculated based on CIELAB a* and b* values for the different colored measuring areas.

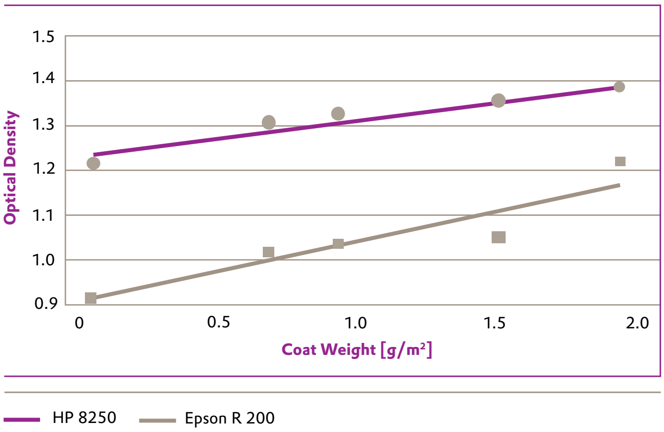
In order to graphically illustrate the changes in print performance versus the corresponding paper sized with 100 % polymer, the values measured for resolution, color density, gamut, mottling & graininess and strike through were converted into relative grades with the pigment-free reference at 1.0. Grades above 1.0 indicate a performance exceeding the performance of the reference. Differences of more than 0.05 are significant. It should be pointed out here that the values for each reference paper itself are always dependent on the printer used.

4.4 Results with PVA Based Sizing Formulations

4.4.1 Color Quality

Optical densities were averaged for the primary colors, Cyan (**C**), Magenta (**M**), Yellow (**Y**) and Black (**K**) and plotted against coat weight for the two inkjet printers.
As depicted in **Figure 11**, the density values increase in a linear relationship to coat weight.

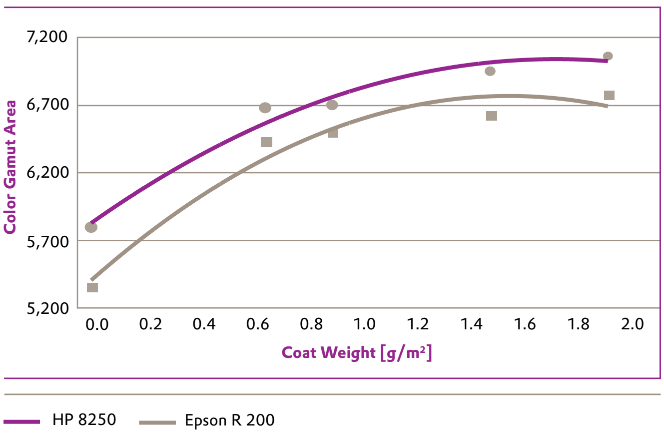
Figure 11 Effect of coat weight on optical density



The color gamut area was calculated from the CIELAB a* and b* values for the colors cyan, magenta, yellow, red, green and blue. Higher values indicate the possibility of making more color combinations and printing those more accurately.
In **Figure 12**, the color gamut area expands with increasing coat weights.

The increased performance in these color qualities is achieved when the ink resides at or near the surface of the sheet or if the coating is transparent. The unique structure of the fumed silica aids in immobilizing the colorant near the surface. Its small aggregate size helps to maintain transparency enabling vivid colors and bold images.

Figure 12 Effect of coat weight on color gamut area

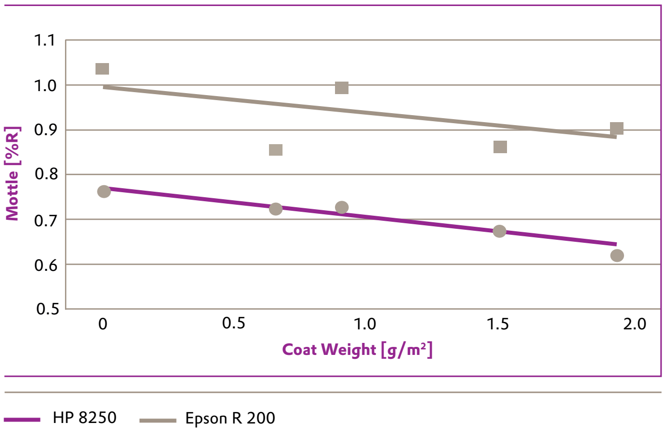


4.4.2 Print Uniformity

When ink is absorbed too slowly or unevenly by the coating, the image may appear "spotty" or mottled. In spite of high color values (e.g.; optical density, gamut) that might be obtained, the resulting print would be unacceptable.

Mottle is a measure of coarse scale color density nonuniformity (>250 µm), while grain is a measure of this non-uniformity at a finer scale (<250 µm). In **Figure 13**, print mottle and print grain are simultaneously reduced as treatment levels increase. In both cases the use of a fumed silica treatment improves the quality of the image.

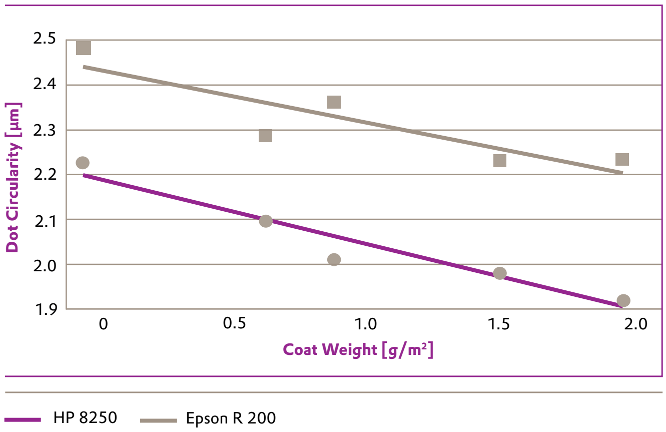
Figure 13 Effect of coat weight on print mottle



4.4.3 Print Resolution

In inkjet printing, the dot is the most fundamental element and is the basis for constructing higher level elements such as lines, text characters, graphics and images. The quality of the dot formed is a critical indicator of a print's final quality. The circularity of the dot is influenced by uniform ink absorption. For this element, dots with a nominal size of 100 µm were printed and evaluated for their circularity. In this metric, a value of 1.0 (aspect ratio) represents a perfectly round dot. As shown in **Figure 14**, the dot circularity improves as the fumed silica treatment level increases.

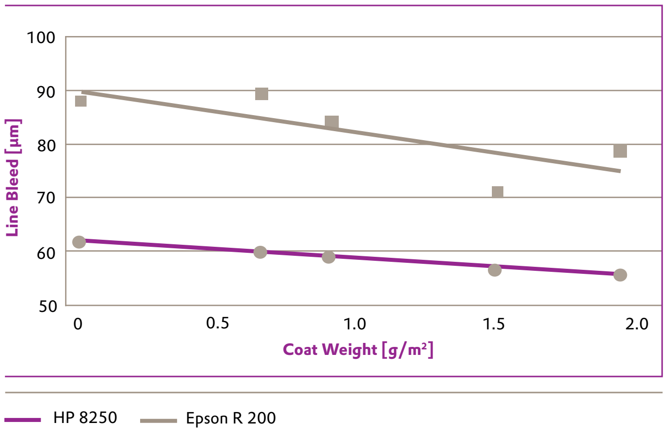
Figure 14 Effect of coat weight on dot circularity at 100 µm



Line quality is another important consideration for evaluating print quality, as it correlates strongly to text quality. The amount of line growth, particularly when the line can "bleed" into another adjacent color, reveals the ink-media interactions.

The deviation from a nominal line thickness of 280 µm is averaged for 12 combinations of primary line colors (K, C, M and Y) on blocks of the four primary colors. **Figure 15** shows how increased coat weights reduce line bleed.

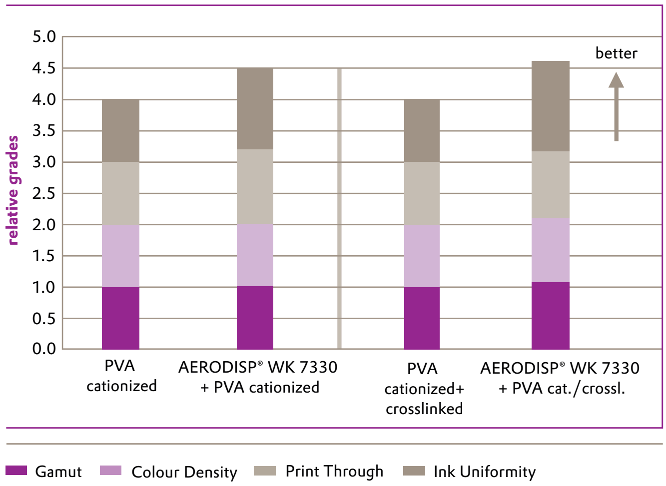
Figure 15 Effect of coat weight on line bleed



4.4.4 Overview Print Performance

The results obtained from the online-sizing trials were consistent with the laboratory results and particularly demonstrated that the addition of fumed silica to a PVA based sizing formulation has a very positive effect on print uniformity (**Figure 16**).

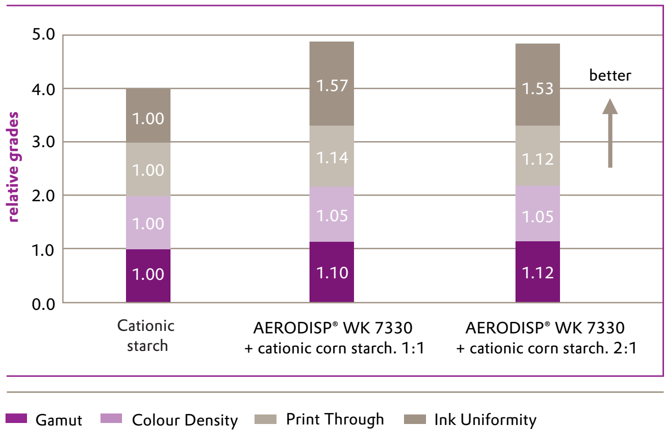
Figure 16 Print performance of PVA sized papers with and without fumed silica (AERODISP® WK 7330 at a pigment to binder ratio of 2 : 1. Mean values of three different printers.)



4.5 Results with Starch Based Sizing Formulations

Also the addition of AERODISP® to comparatively inexpensive starch based formulations leads to a significant improvement in print performance even at pigment to binder ratios between 2:1 and 1:1 (**Figure 17**).

Figure 17 Print performance of cationic starch sized papers with and without fumed silica (AERODISP® WK 7330 at a pigment to binder ratio of 1 : 1 and 2 : 1, respectively. Mean values of three different printers.)



While print through, color density and color gamut increased between 5 and 15 %, print uniformity was enhanced by more than 50 % in comparison to the treatment with pure cationic starch (**Figure 18**). As for the trials with PVA based formulations discussed in the previous section, the findings from various offline-sizing experiments in the laboratory were confirmed by the online-sizing trials. The data contained in these graphs are based on prints from the Epson Stylus PHOTO R 240, HP Deskjet 5652 and Canon PIXMA iP 6600 D. Data obtained with other printers, using dye as well as pigment based inks, are available on request.

Along with evaluating the print performance of relatively "slow" office printers, we also looked at the penetration speed of water based liquids into the paper surface using dynamic liquid penetration.

As seen in **Figure 20**, fumed silica coated papers have a distinctly faster penetration behavior compared to a reference paper surface treated with pure starch. The capillary forces of the approx. 20 to 100 nm wide pores are an important feature of the fumed silica-based coating that can play a major role in addressing the needs of high speed commercial inkjet printers.

Figure 18 Relative improvement of various print properties resulting from the addition of AERODISP® WK 7330 to a cationic corn starch based sizing formulation

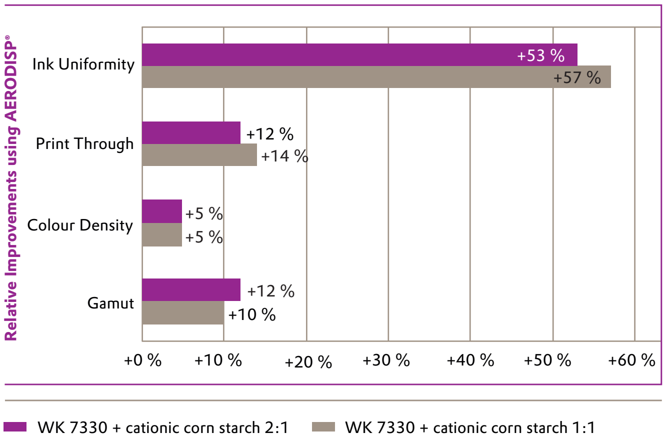
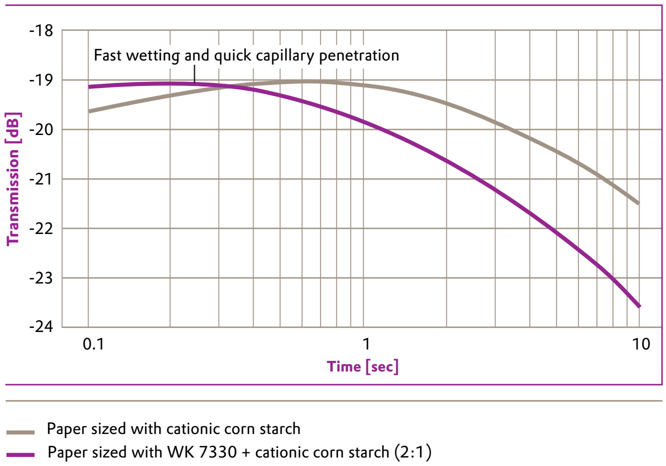
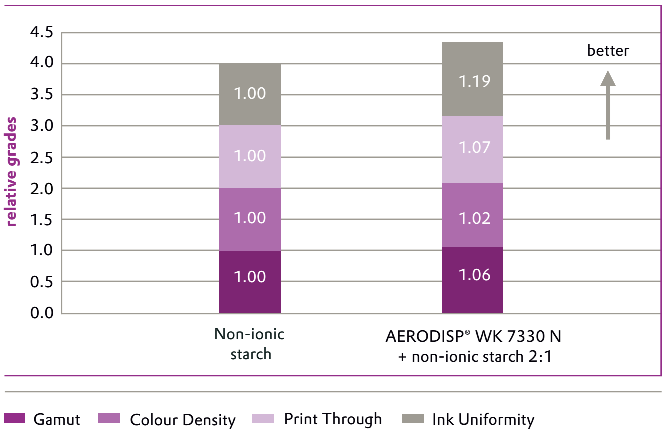


Figure 20 Dynamic liquid penetration into starch sized papers with and without AERODISP® WK 7330 (measured using an emco DPM-33, emco, Leipzig, Germany)



Similar results were found with non-ionic starch based formulations where AERODISP® had a positive impact on print performance and in particular ink uniformity (**Figure 19**).

Figure 19 Print performance of non-ionic starch sized papers with and without fumed silica (AERODISP® W 7330 N at a pigment to binder ratio of 2 : 1. Mean values of three different printers.)



4.6 Comparison to Colloidal Silica and Calcium Carbonate

Calcium carbonate and colloidal silica are both well known pigments in the paper industry and could be considered for paper sizing as well. We therefore compared one well established $CaCO_3$ grade used for paper coatings and two different types of colloidal silica with our AERODISP® fumed silica dispersions in typical paper sizing formulations.

As shown in **Figure 21**, the addition of colloidal silica to a non-ionic starch based sizing formulation did not result in any significant improvement of print performance versus the pure starch formulation. On the other hand, AERODISP® substantially enhanced color density, color gamut and in particular ink uniformity. Colloidal silica consists exclusively of discrete, isolated spherical particles and lacks a fractal or secondary structure. In contrast to fumed silica, it therefore provides only very limited additional porosity and adsorptivity.

Figure 21 Print performance of non-ionic starch sized paper with AERODISP® W 7330 N compared to colloidal silica (Pigment to binder ratio 2 : 1. Mean values of three printers.)

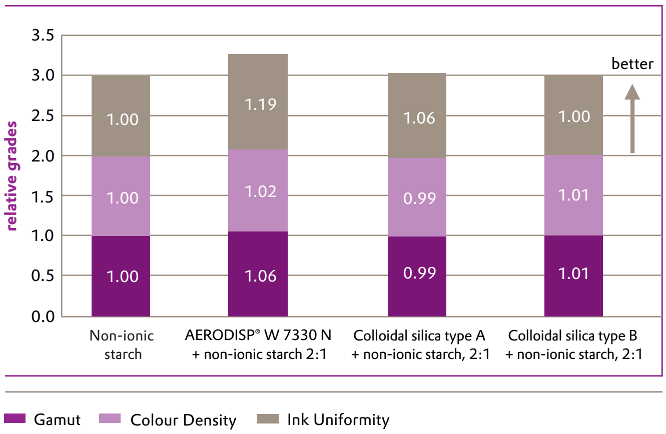
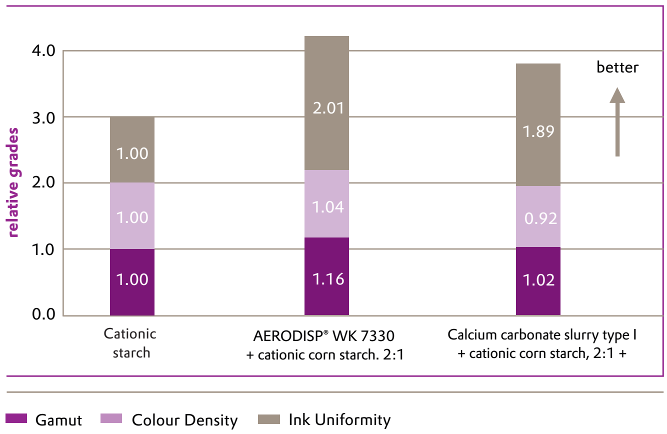


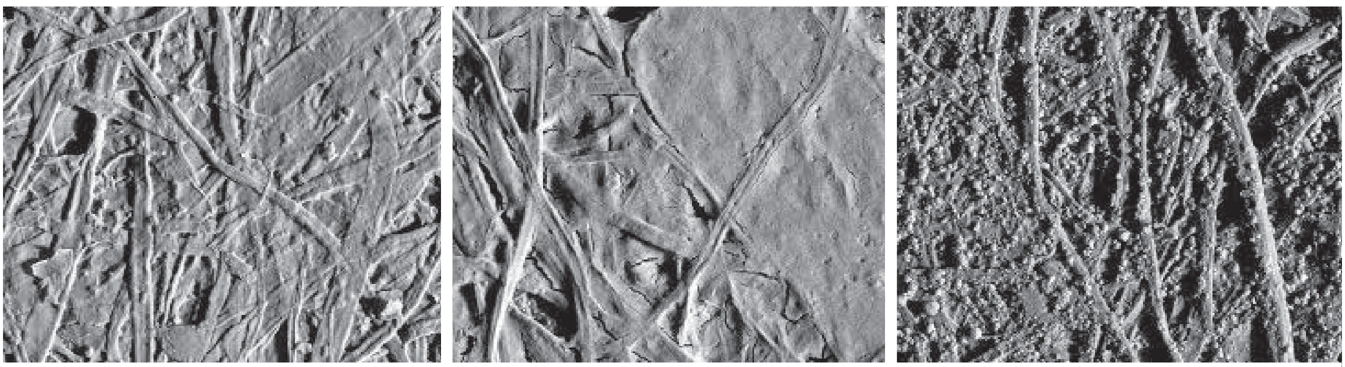
Figure 22 Print performance of cationic starch sized papers with AERODISP® WK 7330 compared to calcium carbonate (Pigment to binder ratio 2 : 1. Mean values of three printers.)



Different from colloidal silica, calcium carbonate can have a positive impact on print performance; however it is clearly inferior to AERODISP® in cationic sizing formulations (**Figure 22**).

Viewing the surface of paper sized with combinations of fumed silica and starch versus pure polymer and/or calcium carbonate under an electron microscope (**Figure 23**) provides an idea of the critical factors that account for the superior printing results obtained with AERODISP® products.

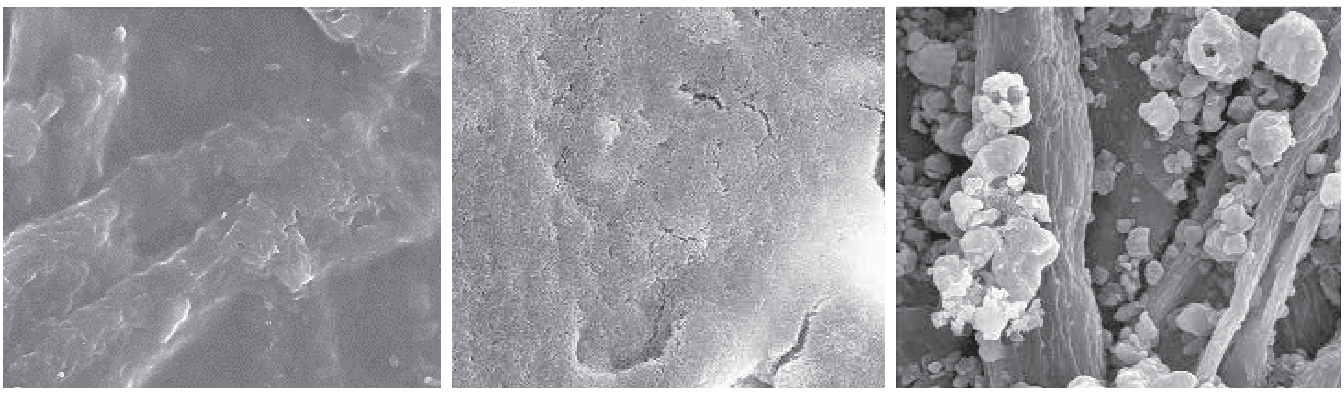
Figure 23 Scanning Electron Microscopic (SEM) images (two different magnifications) of paper surfaces sized with pure cationic corn starch (**left**), cationic corn starch combined with AERODISP® WK 7330 (**middle**), calcium carbonate (**right**), respectively.



Paper sized with cationic corn starch

Paper sized with AERODISP® WK 7330 + cationic corn starch

Paper sized with calcium carbonate + cationic corn starch

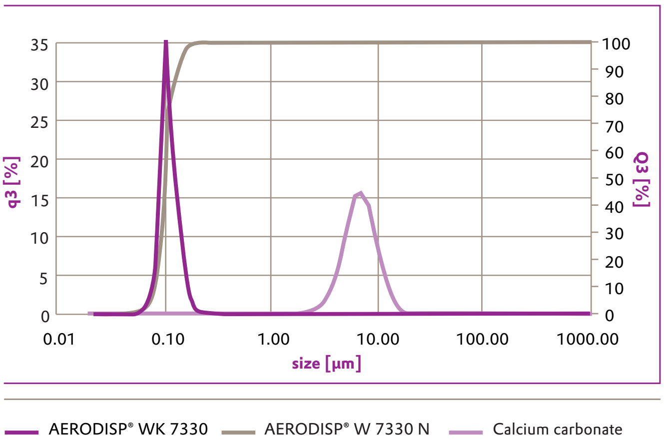


Nano-structured fumed silica creates a very thin yet smooth and porous coating that covers the paper fibers more or less completely. Dyes or color pigments are retained at the surface of the silica particles resulting in higher optical densities and an expanded color gamut area. As seen in the SEM micrographs, the paper surface is visibly more homogeneous, which in turn has a favorable effect on print resolution and ink uniformity.

In contrast, the much larger, micron sized calcium carbonate particles only provide some additional porosity for ink absorption; however, the surface coverage is inhomogeneous.

The particle size distribution curve of fumed silica in **Figure 24** in comparison to calcium carbonate makes it apparent why the paper sizing with an AERODISP® containing formulation give a smooth sponge-like surface.

Figure 24 Particle size distributions (volume) of two different AERODISP® fumed silica dispersions in comparison to calcium carbonate (Horiba LA-910)



4.7 The Performance of AERODISP® Sized Other Printing Technologies

The outstanding performance of AERODISP® sized press treated papers in inkjet printing has been proven for many sizing formulations and conditions as well as on numerous printers. But what about other printing technologies?

4.7.1 Xerography

AERODISP® sized papers, produced during our online-sizing trial, were printed on two different laser printing devices: a XEROX DC 12 using a conventional toner and a XEROX DC 3535 operating with a modern chemical toner. With both devices the papers could be printed without any major problems. Although significant improvements were not observed, there was no degradation in print performance and quality relative to the reference.

4.7.2 Flexography

Optical density and print uniformity are also important attributes on conventional printing platforms such as flexography. The online-sizing pilot trial samples were printed with black, water based flexographic ink using the FlexiProof 100 (RK Print Coat Instruments). In this preliminary evaluation, optical density and print uniformity were both improved by the addition of fumed silica to the sizing agents (PVA and starch).

Figure 25 Black optical density increases with the addition of AERODISP® fumed silica to the size press treatment

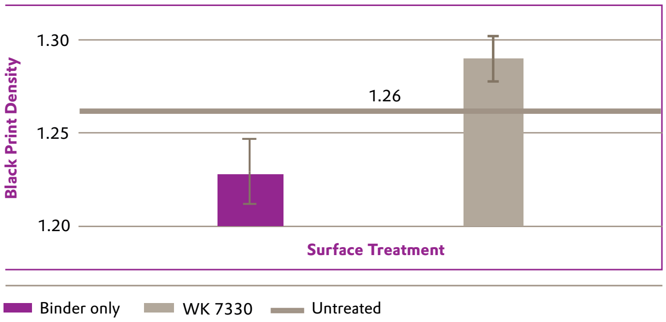


Figure 26 Print uniformity, on a fine scale improves when AERODISP® is added to the sizing agent(s), as seen by the reduction in print grain

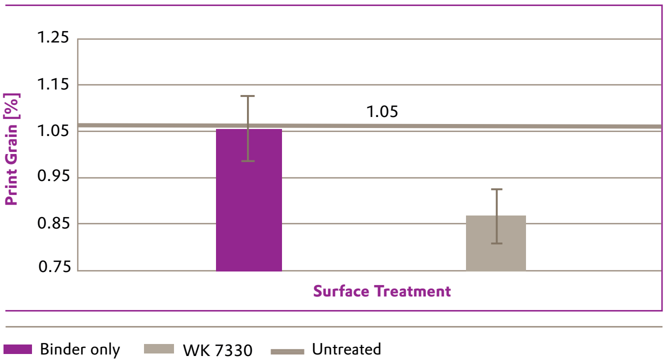
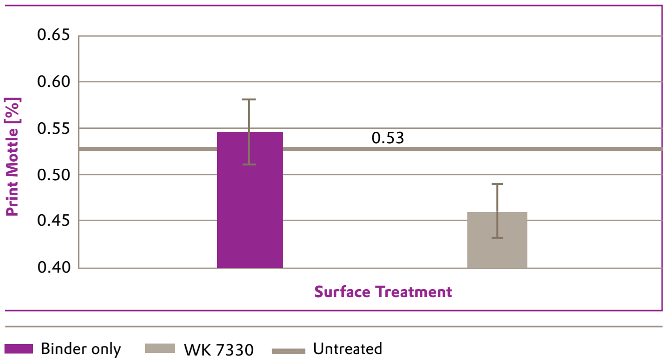


Figure 27 Print uniformity, on a coarse scale, also improves when AERODISP® is added to the sizing agent(s), as seen by the reduction in print mottle.



The results described in 4.7.1 and 4.7.2 demonstrate that paper sizing with AERODISP® not only improves the inkjet print performance but enables the manufacture of multi-functional papers which can be used on various printing platforms.

4.8 Guide Formulations

This section provides guide formulations for paper sizing with AERODISP® fumed silica dispersions. These formulations can be adjusted for your specific process and optimized to meet the desired product properties. Coat weights between 0.5 and 2.0 g/m² are recommended. The sizing formulation can be applied with all common size press types.

Table 1 Sizing formulation containing cationic corn starch for printing paper with enhanced print performance

Starting Materials		Content (dry parts)
AERODISP® WK 7330 (Evonik Industries)	Cationic fumed silica dispersion	100
C★Film starches (Cargill)	Cationic corn starch	30–100
Water	Water	Adjust to desired solids content

If a non-ionic starch is preferred, we recommend the use of our anionic fumed silica dispersion AERODISP® W 7330 N.

Table 2 Sizing formulation containing polyvinyl alcohol for high performance printing papers

Starting Materials		Content (dry parts)
AERODISP® WK 7330 (Evonik Industries)	Cationic fumed silica dispersion	100
MOWIOL® 5–88 (Kuraray Europe GmbH)	Polyvinyl alcohol (partially hydrolyzed, low molecular weight)	10–100
INDUQUAT® ECR 35 L (Indulor Chemie GmbH) or equivalent p-DADMAC grades	Cationic Polymer	5–30
CARTABOND® TSI (Clariant)	Glyoxal resin	0–5
DYNOL® 604 (Air Products)	Defoamer	0–0.5
Water	Water	Adjust to desired solids content

Table 3 Sizing formulation containing latex for printing paper with enhanced print performance

Starting Materials		Content (dry parts)
AERODISP® WK 7330 (Evonik Industries)	Cationic fumed silica dispersion	100
ACRONAL® type latex (BASF AG)	Styrene-acrylate dispersion	25–50
LUMITEN® PPR 8450	PVP	3
ACROSOL® C 50 L (BASF AG)	Co-binder/ thickening agent	2.5
CATIOFAST® CS (BASF) or equivalent p-DADMAC grades	Cationic agent	1
Water	Water	Adjust to desired solids content

5 Processing Advantages with AERODISP®

The water evaporation rate in the paper-making process is an important factor that governs machine speed which in turn affects the cost of manufacture. Using polymeric film forming components can inhibit water evaporation reducing productivity or driving energy costs upward.

The AERODISP® fumed silica particle creates a void and channel structure which disrupts film formation enabling water evaporation to proceed faster.

Another important parameter is the solids content of a paper sizing solution which is limited by the maximum viscosity processable on a size press. The addition of AERODISP® to many polymer based formulations – starch and polyvinyl alcohol included – is accompanied by a reduction in viscosity (**Figure 30**). For a given viscosity requirement, higher application solids can be achieved at the size press. The combination of high solids (less water to be evaporated) and a porous structure (more efficient evaporation) may reduce the energy required during the drying process.

Figure 28 Water evaporation rate (isothermal TGA scan) indicating faster water evaporation as a function of AERODISP® concentration in the polymeric system

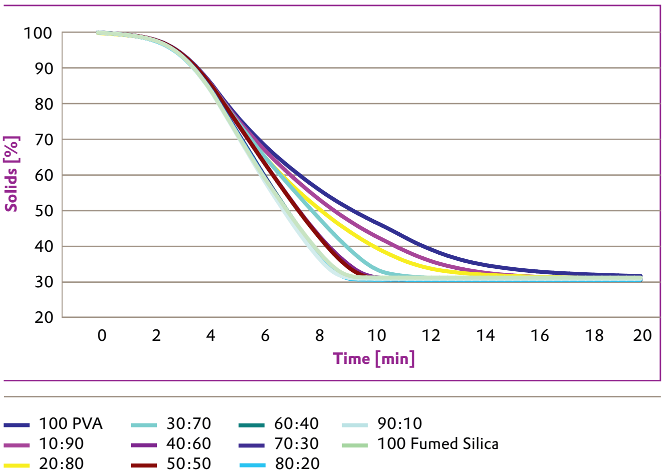


Figure 29 In this view of the TGA scan, we can see that at a loading of 10 parts pigment is sufficient to enhance evaporation while at 40 parts the evaporation rate is near an optimum

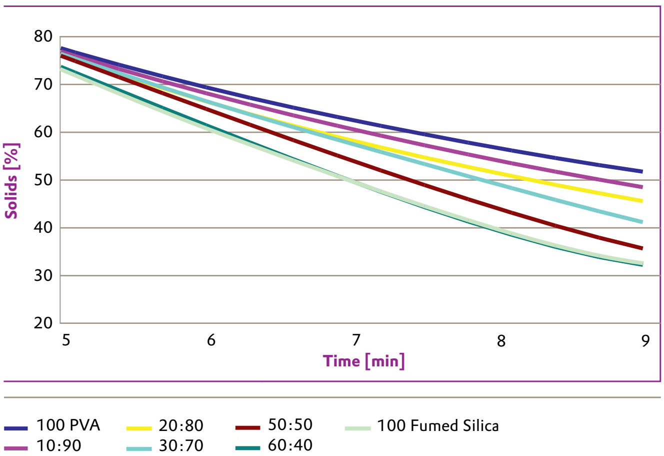
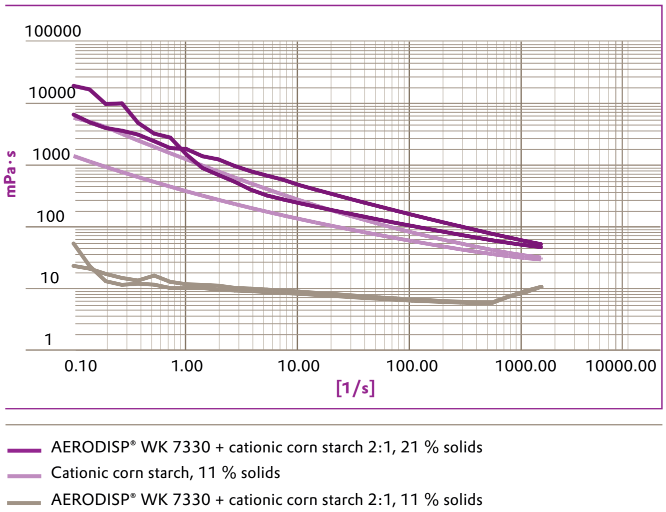


Figure 30 Viscosity curves of cationic corn starch solutions with and without AERODISP® WK 7330 (measured with a Physica MCR-300 rheometer). The addition of fumed silica results in a significant reduction of the viscosity and allows increasing the solids content



6 Packaging, Delivery and Storage

Evonik's AERODISP® dispersions are available in 220 kg (485 lbs) drums and 1,000 kg (2,205 lbs) recyclable intermediate bulk containers (IBCs). Samples are supplied in either 1 quart and 1 gallon (North America) or 1 liter and 5 liter containers (Rest of World).

Figure 31
1 m³ (257 Gallon) intermediate bulk container (IBC) containing 1,000 kg (2,205 lbs) AERODISP®

AERODISP® products are normally stable in terms of sedimentation, creaming out or demixing because of their fine particle size. Depending on the product, they should be used within 6 or 12 months from the date of manufacture.

There are several factors that need to be considered with respect to the storage conditions:

- Storage at room temperature is recommended. Frost and excessive heat must be avoided because it could cause the solid particles to aggregate and sediment.
- The viscosity of AERODISP® dispersions with high solid contents may increase further, especially at high temperatures or as a result of fluctuations. In isolated cases, also some slight sedimentation may occur. These processes are easily reversed by agitation or shearing.
- To prevent biological contamination, Evonik uses sterile-filtered, deionized water during production and add small amounts of a suitable preservative to some products.

6.1 Handling

AERODISP® dispersions are simple to handle. They can be pumped, transported and dosed with most equipment suitable for liquids. Special precautions are only required in a few cases.

Please refer to Evonik´s Technical Information No. 1278 "Handling of AERODISP® Fumed Silica and Fumed Metal Oxide Dispersions" for more detailed information. Also our specialists will gladly advise you on handling matters at any time.

6.2 Material Safety Data Sheets

You will receive a material safety data sheet (MSDS) with every sample or initial delivery of our products. Before working with any product, read its Safety Data Sheet carefully. Material Safety Data Sheets may also be obtained from your local Evonik' sales representative or from our website (**www.aerosil.com**), after registration.

6.3 Additional Information

Besides this Technical Information, other publications are available upon request or through our website **www.aerosil.com**. From the navigation point "Service Center", you may request or download additional literature. Product Information sheets for individual products are available through the "Product Finder" under "Solutions and Products".

7 Product Overview

We especially recommend the following products for paper sizing. Additional products are available on request. Please contact our technical experts at any time for a detailed discussion of your formulation needs.

Product Name	Core Particle	Solids Content (wt. %)[1]	Surface Charge	pH Value[2]	Viscosity (mPas)[3]	Density (g/ml)	Additive
AEROSDISP® W 7330 N	Fumed Silica	30	Anionic	9.5–10.5	≤ 1,000	1.20	Sodium Hydroxide
AERODISP® WK 7330	Fumed Silica	30	Cationic	2.5–4.0	≤ 1,000	1.20	Cationic Polymer

The data represents typical values, not production parameters

[1] Solid contents may vary +/- 1 %.
[2] Measured according to EN ISO 787-9 method.
[3] Measured according to DIN EN ISO 3219 at a shear rate of 100 s^{-1}.

Authors:
Leo Nelli, Astrid Müller, Steffen Hasenzahl,
Christoph Batz-Sohn

8 References

1 C. Batz-Sohn, "Tailor-made Silica and Alumina for Inkjet Media Coatings", Proceedings NIP 20, 805, Salt Lake City, UT, 2004.

2 Industry Brochure "AERODISP® Fumed Silica and Metal Oxide Dispersions", Company Publication, Evonik Industries, Essen.

3 Industry Brochure "Inkjet Media Coatings", Company Publication, Evonik Industries, Essen.

4 A. Storeck, *et al*; "Novel Inkjet Coating Alumina", Proceedings NIP 22, Denver, CO, 2006.

6 United States Patent No. 6,808,769 (Evonik Industries)

7 United States Patent No. 7,015,270 (Evonik Industries)

8 Technical Information No. 1331 "AEROSIL® Fumed Silica and AEROXIDE® Fumed Alumina for Glossy Photo Inkjet Media", Evonik Industries, Essen.

9 C. Batz-Sohn, "New approach to improving inkjet print performance of plain sized paper with nanostructured pigments", ipw – The magazine for the International pulp & paper industry 7-8 / 2008.

10 Technical Information No. 1357 "AERODISP® Fumed Silica Dispersions as an Anti-Slip Agent for Paper Bags", Evonik Industries, Essen.

11 Industry Information No. 2243 "Products for the Paper and Film Industry", Evonik Industries, Essen.

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