A novel, non-mechanical method for producing matte and dull papers with exceptional print gloss

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ABSTRACT: In the manufacture of low-gloss coated paper, it is very difficult to achieve both low sheet gloss and high print gloss. The reason is found in the technical approaches used for the production of low gloss coated papers. These include the use of fine pigments with little or no calendering, coarse pigments with calendering, a bimodal mixture pigment approach, the use of a shrinkable binder, and special calendering techniques. With most of the pigment and binder approaches, the effect is not limited to the surface but extends through the bulk of the coating. The micro-roughness that produces the low sheet gloss usually includes a high level of micro-porosity, making high ink gloss difficult to achieve. Special calendering techniques, such as those using sand blasted or etched roll surfaces, can make it difficult to achieve high levels of smoothness. The technique described in this paper involves the application of a very light weight, pigmented coating to a previously coated paper. The result is a partial layer or "less-than-mono-layer" of pigments bound to the surface, which suppresses sheet gloss. The associated surface micro-roughness, while coarse enough to suppress sheet gloss, is fine enough to be covered by the ink film. This provides for a low gloss, mark-resistant paper surface that produces good print gloss and exceptional delta gloss.

Application: The technology described here could result in a new grade of paper and add value to low gloss paper grades.

High print gloss and high print quality on low gloss papers provide eye-catching images and text on an easy-to-read, low glare background. Low gloss coated papers are classified as matte paper with a 75° TAPPI gloss of 0 to 20 units and dull paper with a gloss of 20 to 40 units. These low gloss grade papers form an important and growing segment of coated papers. However, it has been difficult to achieve an adequate balance between the low sheet gloss and high print gloss and high print quality.

Technical approaches in producing low gloss coated papers include fine pigments with little or no calendering, coarse pigments with calendering, bimodal mixture pigment approach (1), shrinkable binder approach through some level of carboxylation (2) and special finishing and calendering approach (3). Some potential disadvantages with these approaches are marking, print abrasion and especially limitation to achieve high delta between ink and sheet gloss (commonly known as snap). With the pigment approach and the shrinkable binder approach, it is difficult to control the surface roughness and the porosity independently. It is inherently difficult to totally decouple the low ink gloss and poor print quality from the low gloss paper.

Sheet gloss is affected by surface roughness. Ink gloss and print quality are affected by both the surface roughness and the porosity. The surface roughness affects the ink gloss and print quality because the sheet roughness can be telegraphed to the ink surface and the ink density may not be uniform if the surface roughness is similar or greater than the ink thickness. The porosity affects the ink gloss and print quality by controlling the ink holdout and setting rate. High ink holdout and low setting rate help the ink density and leveling and therefore produce high print gloss and quality. It needs to be balanced, however, because too low an ink setting rate generates setoff problems. The print ink thickness of a printed area is typically much greater than a micron. If we can control the surface roughness to less than a micron in the Z-direction, the roughness effect on the ink gloss should be minimal.

The approach taken in this study is to double-coat. The first coat (base coat) provides a reasonably smooth surface and porosity and the second coat (top coat) is a very lightweight, less-than-mono-layer coat. This second coat provides the controlled roughness to be within less than 1 μm relative to the smooth base coat. Such roughness is enough to yield less than 30 units of sheet gloss. The top coat also provides for increased ink hold out and thus good ink gloss development.

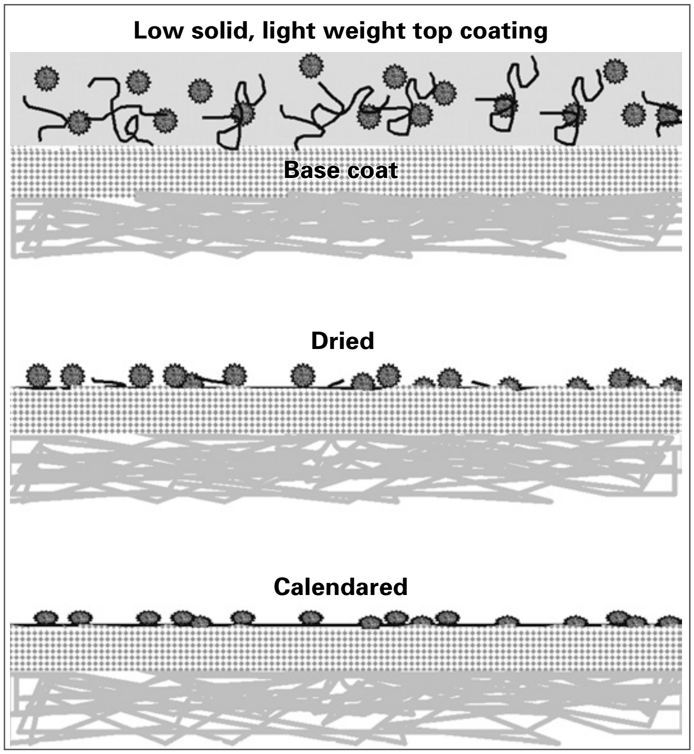
Both solution polymers and latex polymers in the lightweight top coat will inevitably size or seal the base coat to some degree, thus producing the improved ink holdout. The pigments used in the top coat are needed to suppress sheet gloss development and insure adequate porosity to promote ink setting.

In order to balance these competing properties, the base coat and the top coat formulation need to be properly matched. **Figure 1** illustrates the basic idea of this approach. Such a structure would be very difficult to achieve by typical coatings through the pigment or binder variations because typical coatings can not control the porosity of the whole coating and the roughness on the surface within 1 μm independently. This lightweight top coat approach is similar to that of the special finishing and calendering approach (3), which generates the controlled roughness to the top surface by the roughness profiles on the surface of finishing roll.

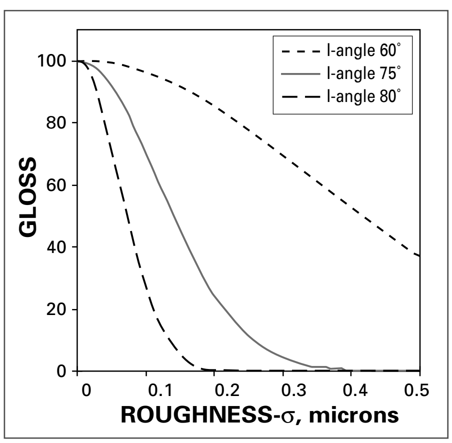
This paper presents the theoretical base and simulations for this approach, lab and trial results we have obtained to date, and conclusions and further work to make this approach practical.

THEORIES AND MECHANISM

Based on Fresnel theory (4) and the Chinmayanandam (5) equation for rough surfaces, Lee et al (2) have derived the TAPPI gloss expression as



1. This drawing illustrates the basic idea about how a low solid, lightweight top coating on a pre-coated paper can create a paper with controlled roughness to the surface and controlled porosity beneath the rough layer.



2. TAPPI gloss vs. surface roughness at 60°, 75°, and 85° incident angles. As indicated in the curve, 0.2 µm roughness is enough to produce a paper with a TAPPI 75° gloss of 35.

$$\text{TAPPI Gloss} = 100*[f(n, i)/f(1.540, i)] *\exp[-(4*\pi*\sigma*\cos(i)/0.550)^2]$$

where n is the refractive index of the coating surface, i is the angle of incident light, and σ is the standard deviation of surface roughness about the mean plane of surface while 1.540 is the refractive index of a 100 TAPPI gloss polished black glass surface and 0.550 µm is the effective wavelength of light used in TAPPI glossmeter. The gloss as a function of surface roughness is plotted in **Fig. 2** for three different incident angles: 60°, 75°, and 85°.

As Lee et al have pointed out and shown in Fig. 2, less than 0.2 µm roughness is enough to produce a paper with a TAPPI 75° gloss of 35. Our next question is if it is possible to create such roughness by depositing a less-than-mono-layer of pigment particles on a very smooth surface. To answer this question, we generated computer simulated micrographs by placing spherical particles on a smooth surfaces with one-third of the particle embedded beneath the surface at different coverage. **Figure 3** shows images of selected simulations.

Based on these simulated pictures, surface roughness as standard deviation of surface heights are calculated and plotted in **Fig. 4**, along with the calculated sheet gloss.

As indicated in Fig. 4, when a very smooth surface is covered 40% to 70% by particles with diameters equal to or greater than 0.5 µm, 0.2 µm or greater surface roughness can be achieved, thereby producing a matte or dull paper with a micro-rough, porous surface. The rough surface layer is limited to within the thickness of the pigment particle size. The porosity underneath this rough layer is controlled by the pre-coat of the base sheet and the sizing effect of the water soluble or latex binders from a top coat when this light coverage pigment layer is applied. Papers with such structures are indeed achieved by lab draw downs and pilot trials, as shown in scanning electron microscope (SEM) micrographs (**Fig. 5**).

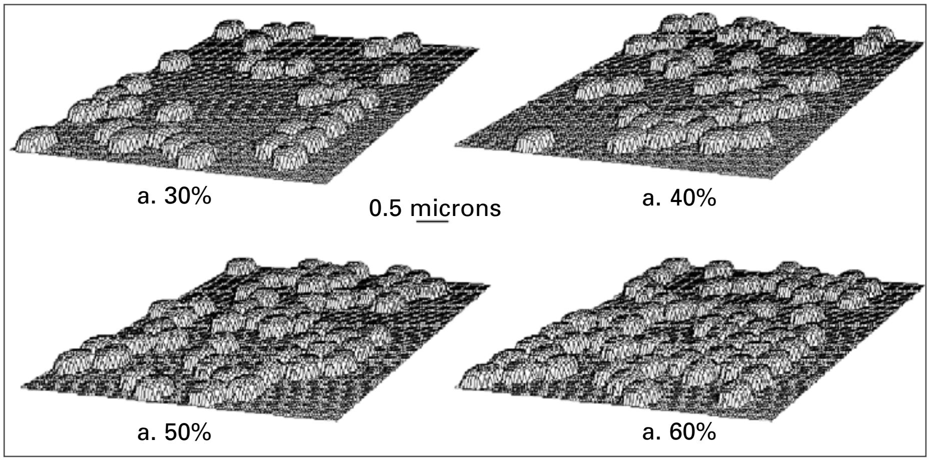
Figure 5a shows a SEM micrograph of a base sheet, a wood-free paper coated with ultra fine CaCO3/clay (90/10). This base sheet is then lab coated with a formulation containing about 1% alkali soluble emulsion (ASE) and about 2% 0.6 micron plastic pigments, using #6 Meyer wire wound rod. Figure 5c shows a SEM micrograph of this lightly coated paper. The surface is covered by the plastic pigment particles at about 40% to 50% coverage. In order to understand the effect of 1% ASE in the lightweight top coat, the 1% ASE solution is coated on the same type base sheet without any pigments (Fig. 5b). It appears to have smoothed and sealed the surface. The 75° gloss of the lightly top-coated paper of Fig. 5c is only about 5 to 10 units before calendering and about 25 to 30 units after 1 NIP, 130°F, 1030 pli, and 600 ft/min soft calendering. The micrograph of Fig. 5c was taken after calendering. Based on the micrograph, the calendering takes away the macro-roughness of the sheets and maintains most of the micro-roughness from the lightly coated, partially covered, top pigment layer.

FORMULATIONS AND TEST METHODS

A pre-dispersed pigment or organic particle latex was first diluted to the desired concentration with tap water, then the rheology modifier emulsion or solution and any other ingredients were added while stirring to form the coating composition. After mixing all of the ingredients, we adjusted the coating composition to a pH of 8.5 to 9 with aqueous ammonium hydroxide (28 weight percent).

We applied each coating composition to a number of pre-coated paper sheets (9 in by 12 in). The composition was drawn down by hand onto the paper sheet using a #4, #5, or #6 Meyer wire-wound rod. Due to the low solids content of the coating composition, the coat weight was too low for us to measure accurately. The estimated coat weights were usually less than $1.5 g/m^2$ and typically less than $1.0 g/m^2$. Each coated paper sheet was oven dried at 80°C for 1 min and then conditioned overnight at about 22°C and 50% humidity.

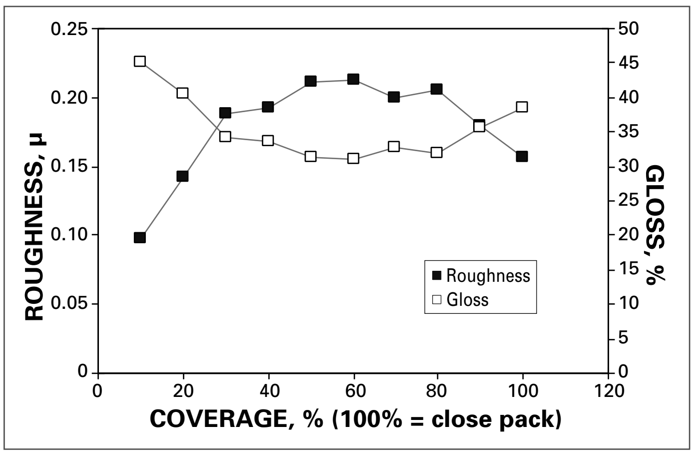
The sheets were calendered at equal and/or different conditions to produce a constant sheet gloss. Before and after cal-



3. Computer simulated micrographs of perfect smooth surfaces covered with 0.500 µm size particles at 30%, 40%, 50%, and 60% coverage. Hexagonal close packing is defined as 100% coverage.

endering, sheets were evaluated for various properties.

Sheet gloss and print gloss were measured at a 75° angle using a Technidyne T480 Glossmeter (Technidyne, New Albany, Indiana, USA). The test method for measuring gloss was TAPPI Test Method T-480 published in "TAPPI Test Methods 1994-1995" by TAPPI PRESS (Atlanta, Georgia).

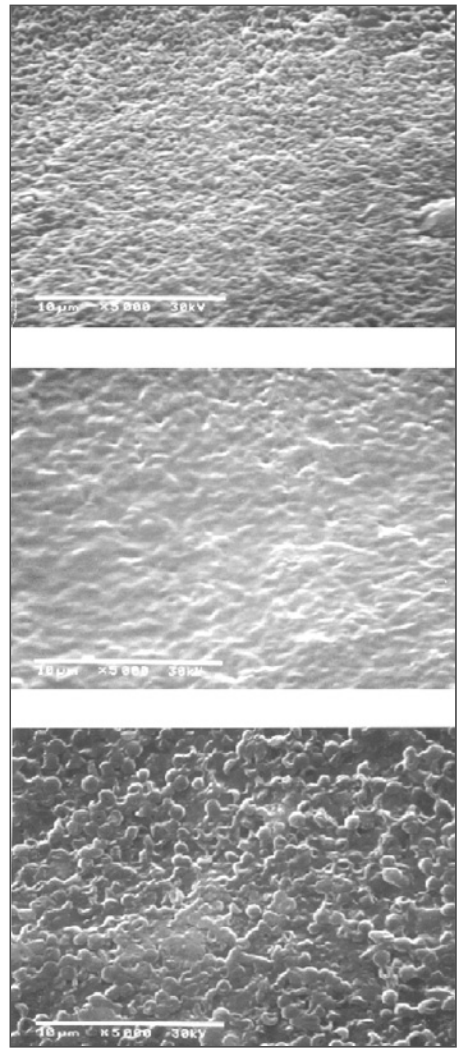


4. Calculated surface roughness as a function of coverage for a smooth surface covered by a less-than-mono-layer of 0.5 µm pigments.

Delta gloss—the difference in gloss between a printed and unprinted area of a substrate—was determined by first cutting coated, calendered sheets into 4.7 cm by 23 cm strips. We measured sheet gloss for each strip at five points along each strip. The entire surface of each strip was then printed with a black, heatset ink using a Prufbau Printer (Prufbau, Munich, Germany) at a print speed of 0.5 m/s. Pressure on the form roll was 800 N, ink volume was 0.15 mL, ink distribution time on the blanket roll was 45 s, and ink distribution time on the form roll was 15 s. After printing, the strips were dried for 2 min on a metal drum heated to about 50°C. We then conditioned the printed strips overnight at about 22°C and 50% humidity. The gloss for each printed strip was measured the same way as for the strip before printing. We calculated the delta gloss by subtracting the averaged sheet gloss of the strips before printing from the averaged print gloss of the printed strips.

We measured smoothness with a Parker Print-SURF Roughness Tester (Model No. ME-90) made by Messmer Instruments, Ltd. We selected five sheets and measured the surface roughness at four different points on each sheet. The averaged value of surface roughness for the 20 points was reported as the smoothness value.

The viscosity of the coating compositions was measured using a Brookfield LVF viscometer, Spindle 3, at 60 rpm. The viscosity of the compositions ranged from 700 to about 2000 cP.



5. Micrographs of coating surfaces (a). All mineral coated base sheet-sample 1 of Table I, (b) example (a) coated with 1% ASE emulsion-sample 2 of Table I, and (c) example (a) coated with 1% ASE emulsion and 2% 0.6 µm plastic pigment-sample 5 of Table I.

RESULTS AND DISCUSSION

Using plastic pigments

Table I shows the coating compositions for the aqueous top coat compositions of samples 1-6. **Table II** lists properties before calendering for the coated sheets of samples 1-6.

All of the formulations have the same rheology modifier concentration (1%) and different levels of the organic particle pigment (from 0.5% to 4%). The total solids content ranges from 1% to 5%. The 1% of the ASE rheology modifier provides adequate viscosity for the composition during coating and adequate binding strength in the dry state. Compositions

SAMPLE ID	PIGMENT[1], Parts	MODIFIER[2] RHEOLOGY, Parts per 100 pigment	TOTAL SOLIDS, % by wt.
1*	N/A	N/A	N/A
2	N/A	Note[3]	1.00
3	100	200	1.50
4	100	100	2.00
5	100	50	3.00
6	100	25	5.00

* Control without any top coat; [1] Plastic pigment.; [2] Alkali soluble emulsion (ASE).; [3] No pigment in this formulation.

I. Coating formulations for the aqueous top coat compositions of samples 1 to 6 using plastic pigments. Formulation 1 is just tap water as a control. Formulations 2 to 6 are compositions with 0 to 4% pigment loading, but fixed amount of rheology modifier.

EXAMPLE	BRIGHTNESS, %	OPACITY, %	SHEET GLOSS, %	SMOOTHNESS, µm
1*	84.0	92.3	15.7	4.10
2	83.0	92.4	19.9	4.33
3	83.3	92.3	6.5	4.24
4	83.6	92.5	5.2	4.09
5	83.7	92.5	4.7	4.06
6	83.7	92.6	4.2	4.04

*Control without any top coat.

II. Properties before calendering for the coated sheets of Samples 1 - 6. As shown in the table, the aqueous top coat compositions with proper amount of pigment and rheology modifier reduce the sheet gloss significantly without increasing the surface roughness for printing or altering other properties such as brightness and opacity.

SAMPLE ID	SHEET GLOSS[1], %	PRINT GLOSS, %	DELTA GLOSS	CHANGE IN DELTA GLOSS[2]
1*	30.74	58.0	27.2	—
2	31.72	57.5	25.8	-1.4
3	29.34	67.6	38.2	11.0
4	29.88	69.6	39.7	12.5
5	29.96	70.1	40.1	12.9
6	30.10	74.6	44.5	17.3

* Control without any top coat; [1] Sample 1 was calendered at 30 psi, 130°F, and 600 ft/min, one nip; sample 2 was calendered at 10 psi, 130°F, and 600 ft/min, one nip; and samples 3-6 were calendered at 30 psi, 130°F, and 600 ft/min, four nips; [2] Change in delta gloss = (delta gloss of sample n (n = 2, 3, 4, 5, or 6)) minus (delta gloss of sample 1).

III. Properties after calendering to a targeted gloss of 30% for the coated sheets of Samples 1 - 6. Sheets coated with formulations 3- 6 are extremely resistant to sheet gloss development. They require more severe calender conditions to achieve the targeted gloss and provide a low gloss but nonetheless smooth surface for printing. Therefore, the print gloss and the snap are improved significantly.

coated in that way reduce the sheet gloss significantly without increasing the surface roughness for printing or altering other properties such as brightness and opacity. At the 0.5% pigment level, the gloss reduction is already significant and it is only slightly better at higher levels.

Table III lists the properties after calendering for the coated sheets of samples 1-6. The sheets were calendared to a targeted gloss of 30%.

Compared to the control without any top coat (sample 1) and the control coated only with the rheology modifier ASE (sample 2), the sheets of samples 3-6 require more severe calender conditions to achieve the targeted gloss. Therefore, they provide a low gloss, but nonetheless smooth surface for printing. The delta gloss for the sheets of samples 3-6 is improved by about 11 to 17 units over the control without any top coat (sample 1).

Table IV lists the properties for the coated sheets of samples 1-6 calendered under the same conditions (20 psi, 130°F, and 600 ft/min).

Under the same calender conditions noted for Table IV, the delta gloss for the sheets of samples 3-6 is improved by about 14 to 18 units over the control without any top coat.

The extreme resistance to glossing of such papers on calendering is well-illustrated by both Table III through different calendering conditions for the same targeted gloss and by Table IV through different gloss results under the same calendering condition.

Using mineral pigments

This lightweight top coat approach not only works with special plastic pigments, but also with mineral pigments.

Table V gives the coating compositions for the aqueous top coat compositions of samples 1-7 using mineral pigments. The high level of mineral pigments used, relative to the plastic pigments shown, is mainly due to the density difference. In this set of experiments, control 1 serves as the "dull" control. The lightweight coating is applied to control 2, a 60 gloss grade of paper.

Table VI shows various properties after calendering under the same condition as Table IV for the coated sheets of samples 1-7. Note the dramatic decrease in sheet gloss brought about by the light coating. The delta gloss for the sheets of samples 3-7 is improved by about 15 to 25 units over the control without any top coat.

One interesting difference we noted for this approach is that the plastic pigments are deposited on the base sheet as discrete particles while the mineral pigments are deposited as clusters of particles. This is clearly seen in the SEM micrograph of **Fig. 6**. Due to the cluster formation, the particle size requirement to generate a low gloss surface for mineral pigments is less important than for plastic pigments. Otherwise, we observed no other difference between mineral and plastic pigments.

SURFACE STRENGTH AND BURNISH RESISTANCE

We conducted a pilot trial with this approach. **Table VII** lists the base coat and the top coat formulations and the corresponding results are listed in **Tables VIII and IX**.

Samples 1 and 2 in Tables VIII and IX are the controls with only a single conventional coat. The low solids top coat was applied to the control 2 paper with three different blade loadings. Sample 3 was coated with the lowest blade pressure and

SAMPLE ID	SMOOTHNESS, microns	SHEET GLOSS, %	PRINT GLOSS, %	DELTA GLOSS	CHANGE IN DELTA GLOSS[1]
1*	2.19	29.4	57.2	27.8	---
2	2.06	35.1	62.2	27.0	-0.8
3	2.04	21.8	63.7	41.9	14.1
4	1.92	19.5	63.8	44.3	16.5
5	1.89	19.5	64.5	45.0	17.2
6	1.86	19.9	66.1	46.2	18.4

* Control without any top coat. [1] Change in delta gloss = (delta gloss of example n (n = 2, 3, 4, 5, or 6)) minus (delta gloss of example 1).

IV. Properties for the coated sheets of Samples 1-6 calendered under the constant conditions (20psi, 1300F and 600fpm).

SAMPLE ID	PIGMENT***, % by wt.	RHEOLOGY MODIFIER 1, % by wt.	RHEOLOGY MODIFIER 2, % by wt.	TOTAL SOLIDS % by wt.
1*	N/A	N/A	N/A	N/A
2**	N/A	N/A	N/A	N/A
3	100	20	24	8.00
4	100	10	12	16.00
5	100	5	6	24.00
6	100	20	24	12.00
7	100	20	24	10.00

* Control 1 without any top coat; ** Control 2 without any top coat; *** Ultrafine calcium carbonate.

V. Coating formulations for the aqueous top coat compositions of samples 1 to 7 using mineral pigments. Formulations 1 and 2 are controls without top coats. Formulations 3 to 7 are compositions with different pigment and rheology modifier loading.

SAMPLE ID	SMOOTH-NESS, µm.	SHEET GLOSS,%	PRINT GLOSS, %	DELTA GLOSS	CHANGE IN DELTA GLOSS***
1*	2.24	37.8	72.9	35.1	—
2**	1.64	60.0	85.8	25.8	—
3	1.75	31.3	87.5	56.2	21.1
4	1.72	26.0	86.2	60.2	25.2
5	1.67	31.1	82.2	51.1	16.0
6	1.69	30.2	86.3	56.1	21.0
7	1.57	30.5	86.9	56.5	21.4

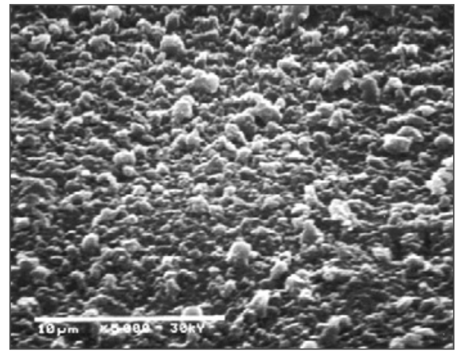
* Control 1 without any top coat; ** Control without any top coat; *** Change in delta gloss = (delta gloss of sample n (n = 3, 4, 5, 6, or 7)) minus (delta gloss of sample 1).

VI. Properties for the coated sheets of Samples 1 - 7 after calendering. The delta gloss for the sheets of Samples 3 - 7 is improved significantly, comparing to the control without any top coat.

INGREDIENTS	BASECOAT Wt. % 100 based on parts of pigment	TOPCOAT Wt. % 100 based based on parts of pigment
Ultra fine $CaCO_3$	90	100
#1 clay	10	—
CMC	0.5	—
Latex binder	12	—
ASE type rheology modifier	—	44
pH	8.5	8.5
solids content, %	67.0	8.0

VII. Base coat and top coat formulations for a pilot trial.VII.

therefore has the highest coat weight Sample 4 was coated with medium blade pressure and has medium coat weight. Sample 5 was coated with the highest blade pressure and has the lowest coat weight. We estimated the coat weight of



6. Micrograph of a coating surface-sample 3 of Table V, which is double-coated with a typical base coat and a special low solid, light weight top coat. The top coat formulation has 2.44% ASE type rheology modifiers and 5.56% ultra fine calcium carbonate pigments.

the topcoat for all three samples to be between 0.5 and 1.5 g/m^2.

The results in Table VIII show that the lightweight top coat has significantly suppressed the sheet gloss and it did not increase the print roughness. Instead, it made the sheet smoother for print and increased the print gloss. As the coverage of the lightweight top coat increased, the delta gloss improvement also increased compared with the control. The depression of sheet gloss and elevation of print gloss both contributed to delta gloss improvement.

Table IX lists the IGT dry-pick strength and the 60 s setoff measured by brightness. The pick strength with the lightweight top coat is higher than the controls and it increases as the blade pressure decreases, or presumably the coat weight increases. This less-than-mono-layer, lightweight top coat seems well adhered to the base coat. A simple fingernail-burnishing test of these samples also revealed that the lightweight top coat layer has equal or better burnish resistance compared to the controls. The resistance to gloss development on calendering, the resistance to burnishing, and the good pick strength are all consistent with each other.

We measured setoff by brightness—high brightness is better, indicating less setoff. The sizing effect of the solution polymer in the top coat on the base coat reduces the porosity and therefore, as the blade pressure decreases or the coat weight increases, the setoff gets worse. Close examination of the top coated sheet also revealed some mottling caused

SAMPLE ID	DESCRIPTION	SMOOTHNESS, µm	SHEET GLOSS, %	PRINT GLOSS, %	DELTA GLOSS	CHANGE IN DELTA GLOSS*
1	Control 1	2.80	37.61	70.33	32.72	—
2	Control 2	2.11	50.66	78.16	27.50	—
3	Lightweight top coated low blade pressure	1.93	27.11	79.87	52.77	20.05
4	Lightweight top coated medium blade pressure	1.92	38.55	81.09	42.54	9.82
5	Lightweight top coated high blade pressure	1.84	41.45	81.07	39.62	6.90

* Change in delta gloss = (delta gloss of sample n (n = 3, 4, and 5) minus (delta gloss of sample 1).

VIII. Sheet and print properties for the trial samples using the formulations given in table 7. Samples 1 and 2 are the controls with only the base coat. Sample 1 was not calendered while sample 2 is calendered. Samples 3 to 5 are double coated with a conventional base coat and a low solid light weight topcoat. The difference among samples 3 to 5 is the top coating blade pressure.

SAMPLE ID	DESCRIPTION	IGT DRY-PICK	SETOFF BY BRIGHTNESS, 60 s
1	Control 1	166	87.68
2	Control 2	163	86.44
3	Lightweight top coated low blade pressure	201	50.94
4	Lightweight top coate medium blade pressure	170	70.18
5	Lightweight top coate high blade pressure	169	75.42

IX. Pick strength and ink setoff properties for the trial samples using the formulations given in table 7. The Pick strength with the light weight top coat is higher than the controls and also gets higher as the blade pressure decreases or presumably the coat weight increases. This light weight top coat seems well adhere to the base coat. The sizing effect of the solution polymer in the topcoat to the base coat reduced the porosity and therefore, as the blade pressure decreases or the coat weight increases, the setoff gets worse.

by the top coat. Setoff and mottling need to be improved to make the approach practical. Nonetheless, this work offers a base for a brand new approach to making coated matte and dull paper.

CONCLUSIONS AND RECOMMENDATIONS

We have demonstrated that when a controlled layer of certain size pigment particles or particle clusters is deposited on a well pre-coated paper via a low solids, lightweight top coat, a low gloss paper with high print delta gloss is produced. The porosity and surface roughness of such papers are controlled by the selection of pigments used in the lightweight top coat as well as the amount of lightweight top coat applied. The porosity and smoothness underneath this thin layer is controlled by the conventional coating of the base sheet and any sizing effect the lightweight top coat may generate. The papers with this structure are very resistance to gloss development on calendering and exhibit significantly improved smoothness for printing.

This study has only demonstrated the basic principles of a totally new approach to produce matte and dull papers with high print gloss and quality. The balance of different print properties and printability still needs to be improved via the refinement of the base sheet character and the components and solids level of the lightweight top coat formulation. **TJ**

ACKNOWLEDGMENT

The authors thank Barrett Bobsein and Dave Gleeson for helping with pilot trials and Reiner Martens, Dave Sheasley, and Stuart Gentry for their support and stimulating discussions. We also thank Nick Triantafillopoulos for his encouragement and suggestion to publish this paper.

LITERATURE CITED

1. Drage, P. G., Hiorns, A. G., Parsons, D. J. and Coggon, L., *Tappi J* 80(11):175(1998).
2. Lee, D. I., and Hendershot, R. E., "Development of Low Glossing Paper Coating Latexes: Theories and Concepts." Tappi Coating Conference, p31 (1986).
3. Becher, J., Berghausen, F. J., Fröhlich, H. P., Grosser, T., Heckes, U., Papier, G., Baran, R. G., Benda, H. "Dull Cast-Coated Paper And Method For Manufacturing Thereof " International Patent Application No. WO 9931320.
4. Moor, D., O., and Hunter, R. S., *J. Am. Ceramic Soc.* Vol. 24, p167(1941).
5. Chinmayanandam, T. K., *Phys. Rev.* Vol. 13, p96(1919).

APPENDIX

List of materials

The pigments, binders, and rheology modifiers presented in this paper are described below.

Pigments:

Plastic pigments—polymer particles with a morphology (particles comprising at least one polymer core phase containing at least one void, at least one polymer shell phase at least partially surrounding the core, and at least one channel connecting the void in the core to the exterior of the particle) and composition defined in U.S. Patent No. 5,510,422 and European Published Patent Application No. 0 842 992 A2.

Mineral pigments—Hydrocarb® HG Slurry with 75% solids, 92 brightness, 0.35 microns median particle size, and 99% particle size smaller than 2 microns from OMYA, Inc.

Binders:

RHOPLEX® B-15—acrylic emulsion, 46% solids and -4°C glass transition temperature from Rohm and Haas Company.

CP 620NA—modified styrene butadiene latex, 50% solid, 15°C minimum film formation temperature, and 0.175 microns particle size from Dow Chemical Company.

Rheology modifiers:

Acrysol® ASE-60—crosslinked alkali swellable acrylic emulsion copolymer with 28% solids. When the emulsion is diluted with water and neutralized with a base, each latex particle swells and/or dissolves. The emulsion clarifies under these conditions, becomes highly viscous, and provides rheological properties.

Acrysol® ASE-75—Non-crosslinked alkali soluble acrylic emulsion copolymer with 40% solids. When the emulsion is diluted with water and neutralized with a base, each latex particle swells and/or dissolves. The emulsion clarifies under these conditions, becomes highly viscous, and provides rheological properties.

Received: March 9, 2001
Revised: October 23, 2001
Accepted: November 16, 2001

This paper is also published on TAPPI's web site <www.tappi.org> and summarized in the May *Solutions! for People, Processes and Paper* magazine (Vol. 86 No. 5)

INSIGHTS FROM THE AUTHORS

We chose this topic for our research because we felt that it targeted an unmet market need. There has been ongoing work for decades to achieve high print gloss on matte and dull papers. This technology takes a large step towards meeting that need. A patent is pending for the techniques described in our paper, so it is a novel approach.

We feel that this technology could result in a new grade of paper—one which meets an unmet market need and adds value to low gloss grades of paper. This technology is in the early stages of commercial development and the next step will involve full scale mill trials, followed by marketing introduction.

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