Non-leafing Aluminium for Metallic Offset Ink

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Keywords: Aluminium, Ink, Pigment, Offset

Abstract

For offset printing ink only "Leafing" metallic pigments are available when metallic effects are required. Unfortunately its optical advantage always diminishes when over-lacquered, inter-coat adhesion is weak, and after-press processing (e.g. lamination, foil-stamping, etc.) on "Leafing" metallic offset ink is always troublesome. Offset inks based on metallic pigments with "Non-leafing" properties are the best solution, offering both good inter-coat adhesion properties and retention of the metallic effect when over-lacquered. Until now, "Non-leafing" pigments with acceptable optical appearance were not available for offset printing.

The development of "Non-leafing" metallic pigments, which took place at ECKART, for offset printing applications took some time due to the manufacturing capability available. The first "Non-leafing" aluminium offset pigment with good optical appearance is presented to the printing industry along with its end product: Non-leafing Metallic Offset Ink. The study will include review of the production technology, starting with atomizing the aluminium, optimizing the milling parameters and the final formulation of the new ink. Technical advantages of this ink related to inter-coat adhesion and color blending will be included.

Introduction

With the intense competitiveness in the world economy, the demand for differentiation of one's products is escalated. Success often hinges on the use of special effects on the product designs and packaging, etc. Effect-enhanced products, such as metallic, iridescent (holographic) or polychromatic (thermo or radiation) are often desired to present instant sales-appeal and are guaranteed to get products noticed and differentiated from the competition.

In the Graphic Arts, different printing technologies are available to fulfil the requirements of the product designs, but each printing process has its own limitations in productivity and achievability of certain effects. Among others, the Offset printing process is the dominating printing technique, providing high quality prints in combination with acceptable printing speeds, and turn around time. Ironically, it stays behind in presenting special effects to other printing techniques such as; Gravure, Flexo or Screen, the processes where thicker films can be applied. For metallic effect, this thick ink-film allows the use of much coarser particles/pigments, consequently enhancing in reflectivity and special

effect. As fine pigments required in offset applications are much more complicated to produce, the product portfolio for special effect pigments usable in offset printing is very limited and new developments in this area are very rare.

This study presents a new development of “non-leafing” metallic pigment for Offset printing application in response to the demand of this enhancement, and also demonstrates advantages of its property to the application such as over-coat ability, color enhancement, and inter-coat adhesion.

Nature of Metallic Pigments

1) Leafing vs. Non-leafing

Metallic pigments used for offset printing ink are currently limited to so called "Leafing" pigments, a desirable characteristic for best reflectivity. Leafing pigments are poorly wetted by the ink binder system and therefore floating to the surface (Figure 1).

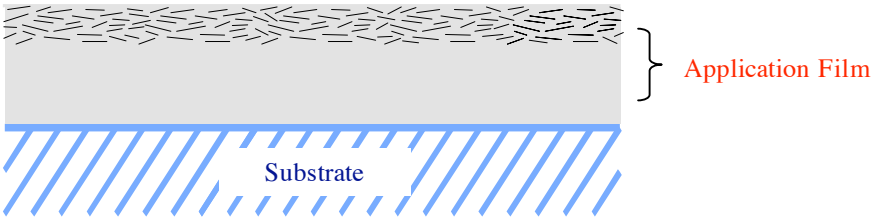


Figure 1: Schematic illustration of leafing pigments.

Although leafing metallic pigments provide the best metallic effect, they carry some drawbacks in loss of optical appeal as well as inter-coat adhesion when over coating is needed. Moreover, poor rub resistance properties and unstable color blends are evident.

Whenever a print product needs to be finished downstream (e.g. lamination, lacquering, hot foil stamping), inks based on metallic pigments with non-leafing properties are the best solution, because their random orientation allows good inter-coat adhesion properties (Fig. 2), while metallic effect remains.

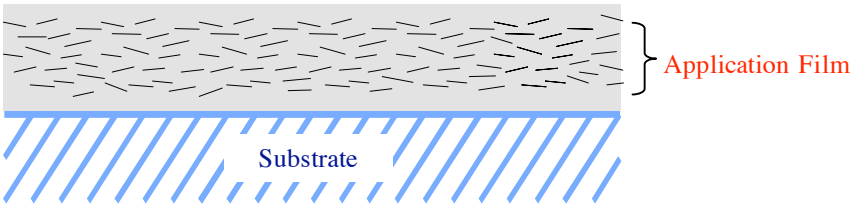


Figure 2: Schematic illustration of non-leafing pigments.

The disadvantages of non-leafing metallic pigments are poor coverage and less metallic appearance compared to results with leafing pigments. These disadvantages are mainly caused by an irregular pigment orientation within the application film, yielding less reflectivity.

2) <u>Particle Shape vs. Optical property</u>

General rule: the better the reflectivity, the higher the brilliance. The more the light scattering, the lesser the brightness.

Here the optical deficits can be nearly compensated by either using coarser pigments or so-called "silver dollar" pigments.

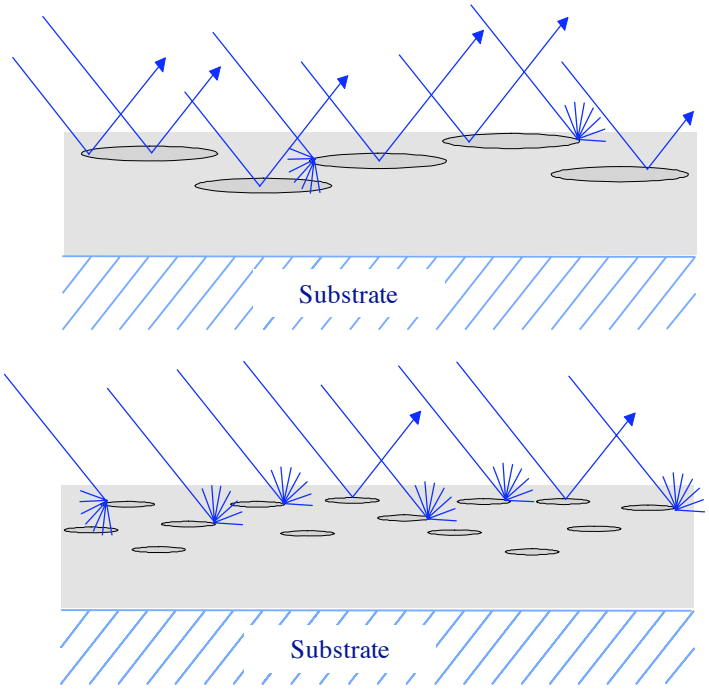


Figure 3: Impacts of pigment size and shape on the optical properties.

Coarser pigments and 'silver dollar' pigments (pigments which are ideally round shaped; see Figure 4) do have a good surface to edge ratio providing high reflection of the light versus low scattering at the edges. On the other hand, the more pigments become finer the more they are irregular shaped (Figure 5 and 6) as well as exhibiting a lower surface to edge ratio – as a consequence these pigments show a reduced metallic effect.

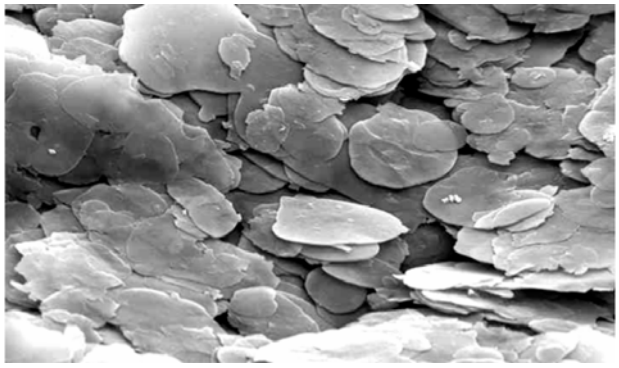


Figure 4: Light microscope photography of 'silver dollar' pigments.

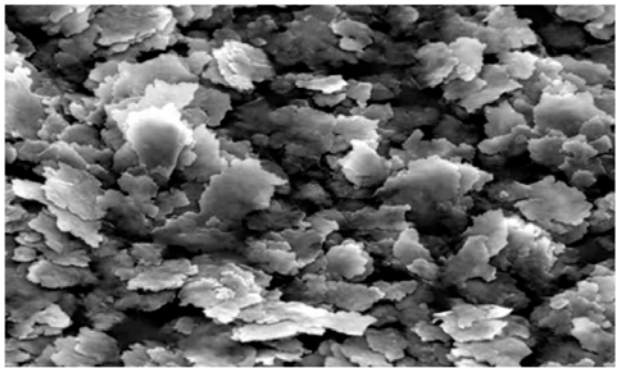


Figure 5: Light microscope photography of standard pigments (cornflake pigments) with $d_{50} = 7.5\ \mu m$ (typical use in liquid inks).

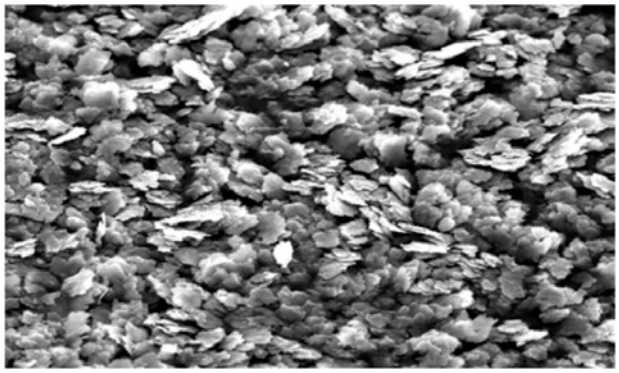


Figure 6: Light microscope photography of fine grade cornflake pigments, (typical use in offset inks) , $d_{50} = 3\ \mu m$.

The use of non-leafing metallic pigments in printing inks has increased over the years due to the fact that 70% of printed materials require downstream finishing, i.e. over-coating, lamination, and foil-stamping. It has been widely applied in other applications, except Offset ink because of the need of utilizing the finest metallic pigments. So far "non-leafing" pigments with acceptable optical appearance were not available for offset printing, which limits the offset process as the application of choice for many print products.

The new pigment technology for Offset application.

Targets and Production

"Silver dollar" technology, although it is new for printing inks, has been used for many years for the automotive paint industry. Several years ago, ECKART took the challenge to apply this technology of non-leafing 'silver dollar' aluminium to graphic arts, specifically the offset segment where good optical appearance and enhancement of downstream processes are needed.

Pigment requirement

The offset process limits the average particle size of metallic flakes to a maximum of about 10 microns, ideally a range of 5 – 8 microns is required. A silver dollar type of pigment had been chosen for best optical properties achievable. The challenge is the manufacturing capability to mill this type pigment to the required fineness with minimum loss of optical property. After thorough experiments from atomising to finishing in the milling process, ECKART has successfully optimised the manufacturing process of the finest 'silver dollar' aluminium pigments. Reproducible milling conditions of this new pigment took numerous trials and are now under control for consistency.

The final product was indeed a silver dollar type aluminium pigment within the requested particle size distribution (see Figure 8).

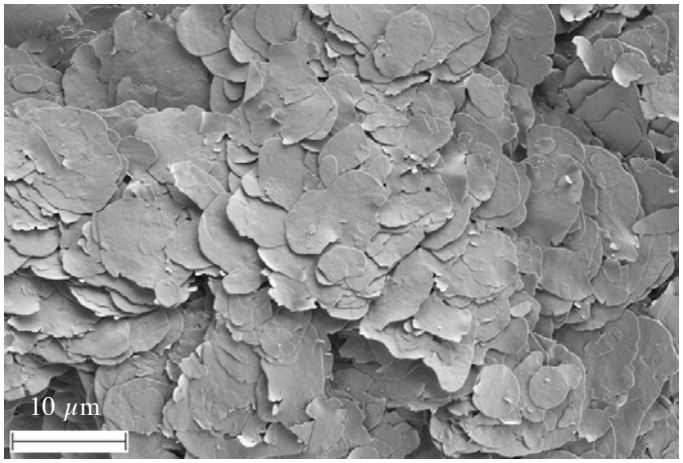


Figure 8: Light microscope photography of the non-leafing aluminium offset pigment showing the silver dollar type shape (d50 ≅ 8 µm)

Ink Requirement

The road for the development of the final ink was open. The formulation of a metallic ink based on leafing pigments is totally different to inks based on metal pigments with non-leafing properties. The binder system, surface chemistry and additives are carefully selected to suit the characteristic of this fine 'silver dollar' non-leafing pigment. The binder system for non-leafing ink should wet the metal pigment well without affecting the final orientation. The illustrations below (Figure 9 & 10) display the gloss and density that increase over time when incorporating the pigment in selected binder.

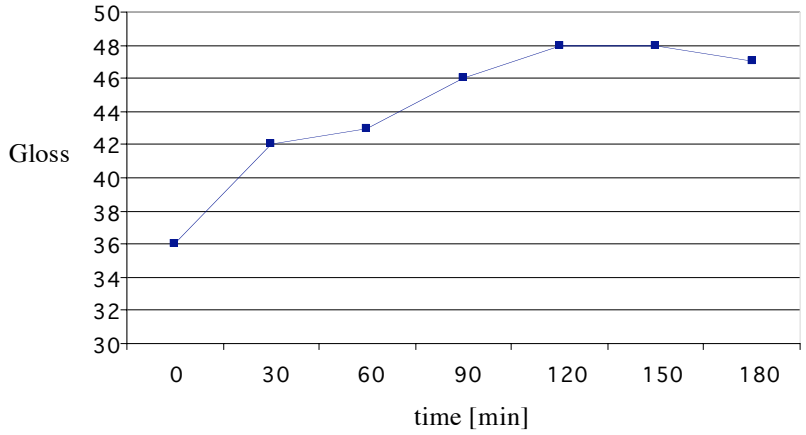


Figure 9: Increase of gloss values of the non-leafing silver dollar ink.

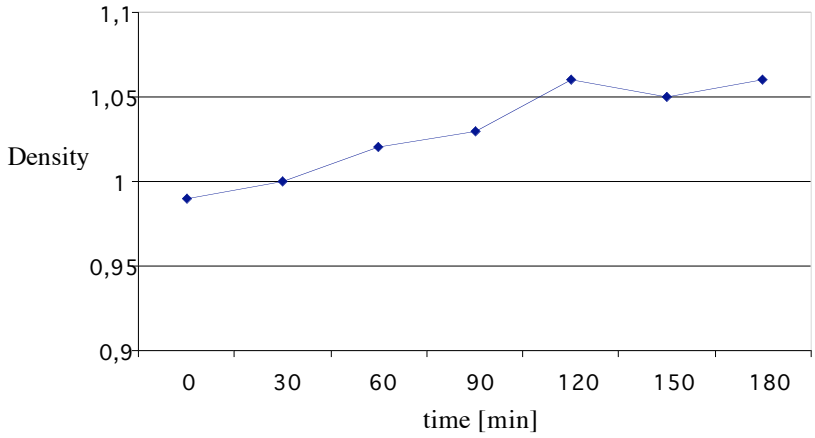


Figure 10: Increase of density values (measured with the cyan filter) of the non-leafing silver dollar ink.

Pigment & Ink properties

The final challenge is to combine pigment and ink technologies. The optical properties of the pigment and the physical properties of the final ink had to be investigated as these were only theoretically known. In fact, leafing and non-leafing properties is quite logical for coating applications or printing applications where high ink films are applied. It seems questionable for the pigment orientation phenomenon in offset application where an average ink film thickness is only about 2 microns[1]. The first unique formulation of offset metallic ink with non-leafing aluminium is developed from the integration of physical and chemical properties of selected binder system and advanced metallic pigment manufacturing, commercially called MetalStar® Sheetfed 06-7000 NL (non-leafing).

Metallic Appearance:

One great advantage of the non-leafing ink is its ability to maintain metallic appearance after over-lacquering, unlike its rival based on leafing pigment where significant loss of brilliance is always evident when top-coat is applied. Unfortunately, there is no quantitative measurement of "brilliancy" that is considered an industry standard procedure. The measurement of metallic apparance currently in place is a subjective measurement done by visual comparison only.

"Lustre Index" study[2] done by X-Rite presents an interesting concept of defining metallic appearance however is not known for industry uses and is not included in this study.

Physical Properties

The metallic effect retained of the non-leafing silver ink makes this product ideal for jobs where the prints have to be protected by a lacquer or laminate (e.g. packaging), but only if the adhesion properties are acceptable. Again a comparison test between leafing and non-leafing inks was made. Pre-printed sheets were overlacquered with a UV coating and adhesion tested after 24 hours (Figures 11).

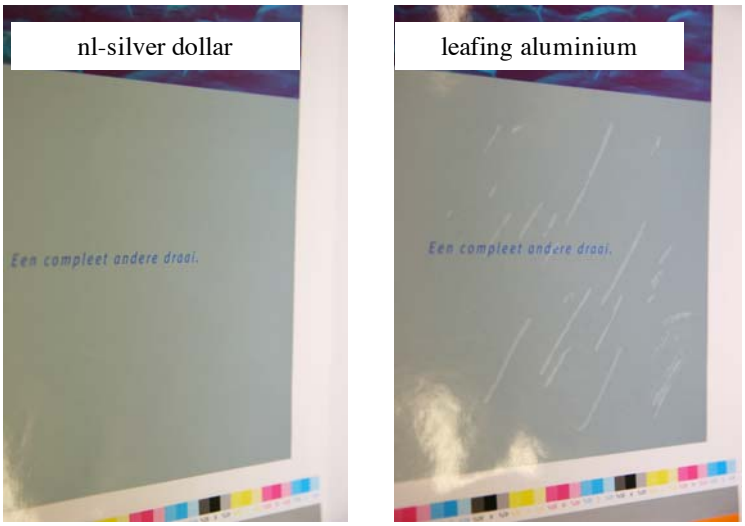


Figure 11: Scratch test on off-line UV coated prints of the NL silver dollar and conventional leafing aluminium pigment.

The fingernail scratch test shows clearly the poor adhesion of the UV lacquer on top of the leafing aluminium based ink, whereas none of UV lacquer could be scratched off from the non-leafing silver dollar based ink.

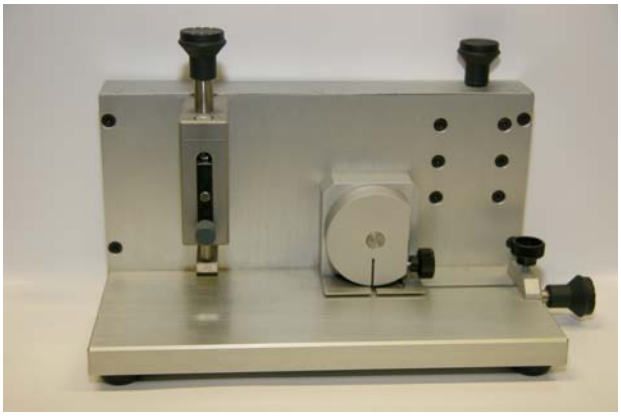


Figure 12: FOGRA tape adhesion tester.

For the test of the tape adhesion the FOGRA tester (Fig. 12) has been used in combination with three different tape types of different adhesive strength (3N, 5N and 7N). The non-leafing silver dollar ink shows very good adhesion properties, whereas the leafing aluminium ink has nearly none (Figure 13 and 14).

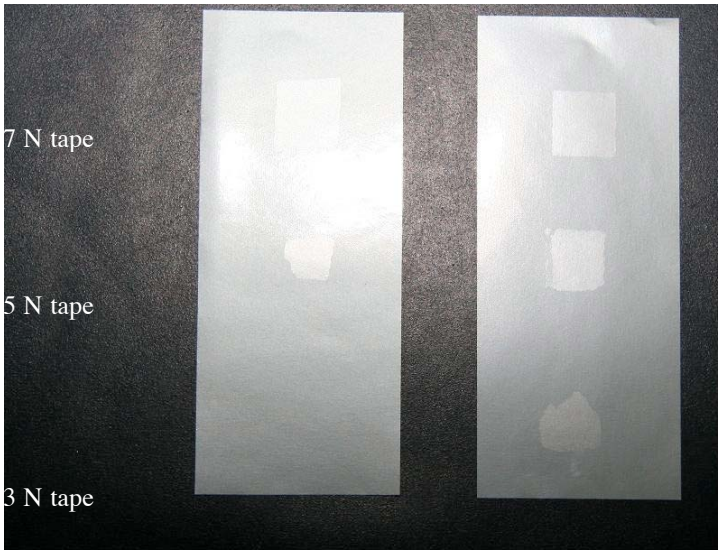


Figure 13: Photos of the tape adhesion tests.

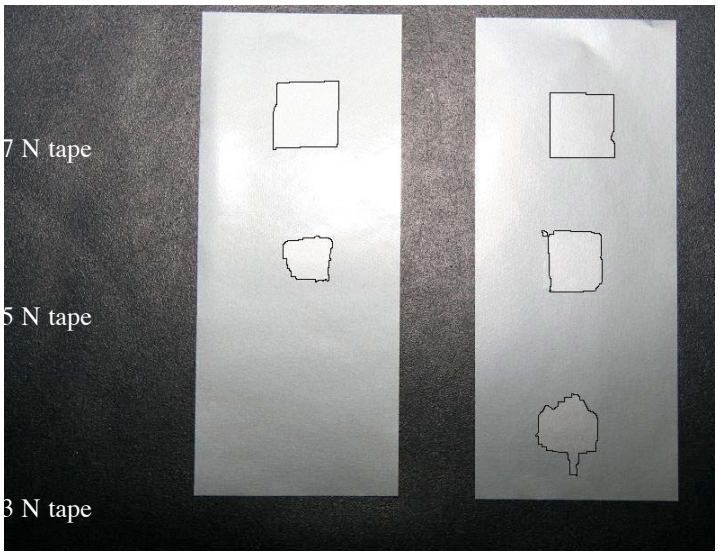


Figure 14: Photos of the tape adhesion tests with marked areas of the destroyed UV lacquer for better visualisation.

According to the test results, it can be concluded that non-leafing pigment yields a greater advantage in UV overcoat-ability, which has failed in all cases with leafing pigmented ink. The test has been carried on commercial presses in several occasions with success. However, there is variety of UV lacquers available, so one should not consider this non-leafing pigmented ink as a universal solution. Testing with required UV lacquer prior to going on press should be a common practice to guarantee success.

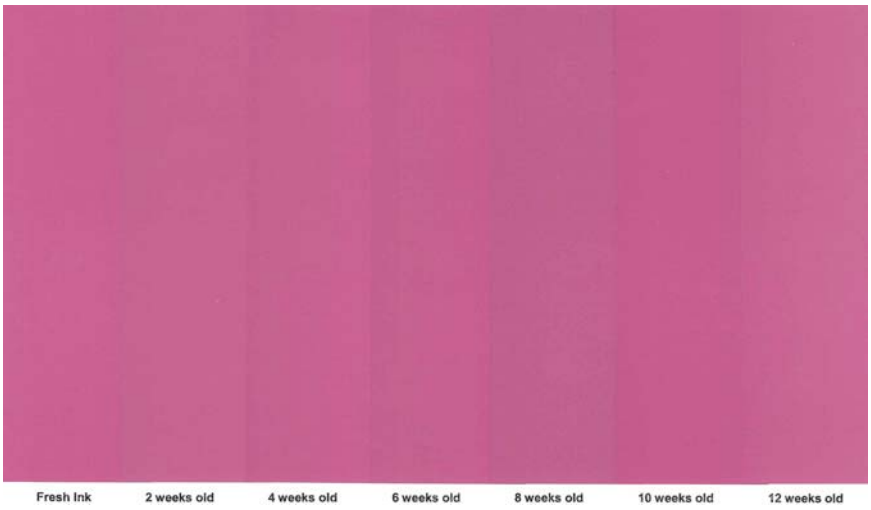
Similar tests for lamination properties are in the process, but results have not been completed at this report time.

Metallic Color Blends

The world of metallic effect can be amplified by mixing colored inks with metallic inks, such as Pantone® 8000 Series, or by overprinting metallic inks with process colors or special colours (Metal-FX Technology, MIPP Process). All these techniques are suffering from the leafing properties of existing offset silver inks, leading to weak colour strength and silvery effects. The new non-leafing silver ink is breaking these limitations.

The blends of non-leafing ink with colored inks offer a much more vibrant colors and do not change into grayish and dirty looking shades, even if varnished.(Figure 15) These blends, theoretically will be more color stable than actual mixtures with leafing pigmented ink which often change the metallic shade within short storage times. As an example various blends based on the non-leafing silver and conventional silver have been made and stored at 40°C to check the stability. Color and gloss readings were made frequently to see how the shade changes over time, displayed on Appendix A, B. This result at report time is still inconclusive. More colors and alternate mixing process are experimented, and will further reported.

Pantone® 8082C Blend with Non-Leafing 06-7000 Silver



Pantone® 8082C Blend with Leafing 07-2877 Silver"

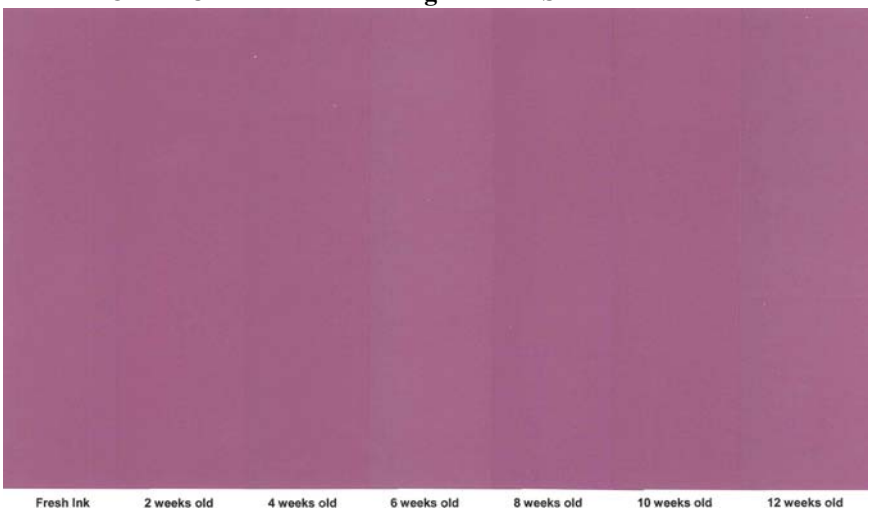


Figure 15: Scheme of color change of metallic blend over time compared between leafing and non-leafing silver ink

The color shift seen in the blend with the leafing silver ink is known to be caused by the degradation of the leafing effect overtime, which is possibly due to chemical and physical reactions occurring during the process. For example: the use of a three-roll mill in the mixing process can easily grind the metallic pigment further (Figure 16 A&B) causing it to degrade the leafing ability and impact the consistency of blended colors (Figure 16 C&D). This phenomenon is unlikely to

happen with non-leafing "silver dollar" aluminium. The following photographs demonstrate the impact of three-roll mill to metallic particles.

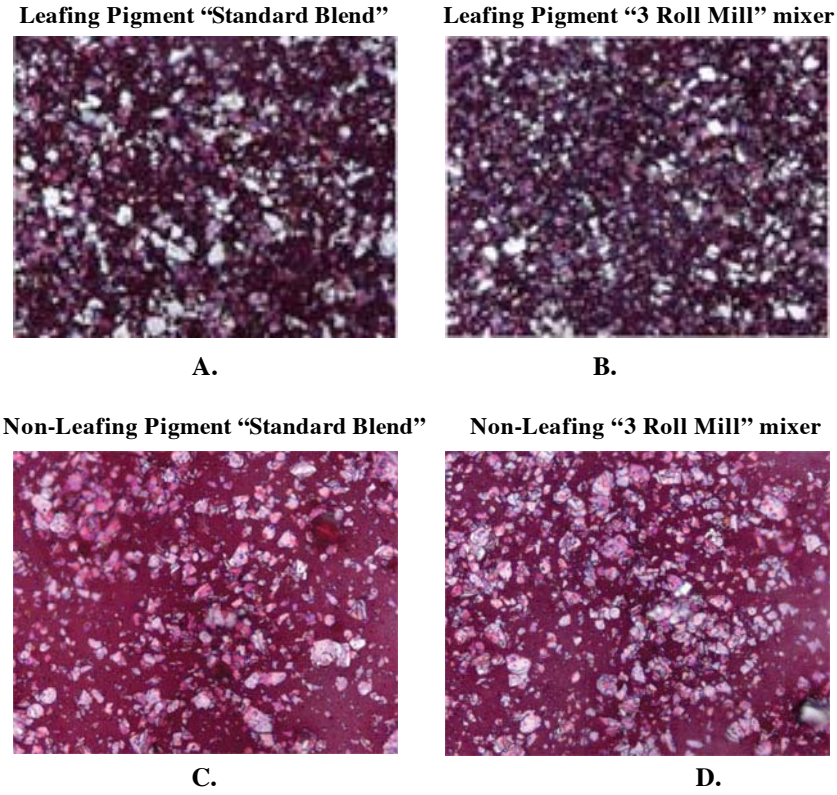


Figure 16: Leafing vs. Non-Leafing Comparison in Pantone® 8081c (100X Magnification.

Conclusions

The development of the first non-leafing pigment suitable for the offset application has been successful by applying "silver dollar" technology in the pigment-manufacturing step. The final, optimized ink formulation based on this new pigment grade meets all theoretical advantages of non-leafing pigments. This unique non-leafing offset ink is the first in the industry to unlock many difficulties in printing metallic, such as overcoat ability, inter-coat adhesion, lamination, and lastly consistency and vibrancy of metallic blends.

Acknowledgments

The author would like to acknowledge the following companies for their help in the project by providing press time, Heidelberg Druckmaschinen, KOMORI and MAN Roland.

References

1. R. H. Leach, "The Printing Ink Manual", Van Nostrand Reinhold (International) Co. Ltd., 1989.

2. A. Matthew, “Control of metallic inks using lustre index”, X-rite, August 2003

Appendix A
Color Readings of Metallic Color blended with Leafing and non-leafing inks

Complete Report

Customer: EIMC
Color: Pantone 8082c Leafing Silver
Description: Fresh Ink
Database: 5-Angle
Filter: All Samples
Report Date: 02/21/2006

STANDARD 02/21/2006 3:07 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	90.52	20.40	-16.85	26.46	320.45	0.00	0.00	0.00	0.00
Angle: 25°	D65/10°	68.10	26.06	-16.52	30.85	327.62	0.00	0.00	0.00	0.00
Angle: 45°	D65/10°	47.09	33.06	-17.01	37.18	332.78	0.00	0.00	0.00	0.00
Angle: 75°	D65/10°	38.06	38.15	-18.82	42.54	333.74	0.00	0.00	0.00	0.00
Angle: 110°	D65/10°	34.03	38.94	-18.50	43.12	334.59	0.00	0.00	0.00	0.00

Note:

Lot ID:

SAMPLE #1 02/21/2006 3:08 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	91.42	21.08	-16.62	26.84	321.75	1.15	0.60	3.27	0.55
Angle: 25°	D65/10°	68.39	26.88	-16.55	31.57	328.38	0.88	0.47	2.47	0.42
Angle: 45°	D65/10°	47.09	34.08	-17.21	38.18	333.20	1.04	0.48	2.73	0.41
Angle: 75°	D65/10°	38.11	39.38	-19.12	43.78	334.10	1.27	0.55	3.03	0.45
Angle: 110°	D65/10°	34.13	40.15	-18.78	44.33	334.93	1.24	0.53	2.84	0.43

Note: 2 weeks old

Lot ID: LEAFING SILVER 2 WEEKS OLD

SAMPLE #2 02/21/2006 3:09 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	91.53	20.07	-16.80	26.17	320.06	1.07	0.41	2.86	0.37
Angle: 25°	D65/10°	68.53	25.84	-16.44	30.63	327.53	0.49	0.21	1.36	0.20
Angle: 45°	D65/10°	47.06	32.77	-16.91	36.87	332.71	0.31	0.14	0.68	0.12
Angle: 75°	D65/10°	37.81	37.83	-18.67	42.18	333.73	0.43	0.20	0.64	0.16
Angle: 110°	D65/10°	33.75	38.62	-18.36	42.76	334.57	0.45	0.22	0.64	0.17

Note: 4 weeks old

Lot ID: LEAFING SILVER 4 WEEKS OLD

SAMPLE #3 02/21/2006 3:09 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	93.26	19.82	-16.85	26.02	319.64	2.80	1.03	7.60	0.91
Angle: 25°	D65/10°	69.99	25.36	-16.37	30.18	327.16	2.03	0.84	5.77	0.81
Angle: 45°	D65/10°	48.08	32.22	-16.75	36.31	332.53	1.32	0.62	3.97	0.59
Angle: 75°	D65/10°	38.76	37.16	-18.55	41.53	333.48	1.24	0.58	3.74	0.47
Angle: 110°	D65/10°	34.68	38.02	-18.34	42.21	334.25	1.14	0.55	3.65	0.43

Note: 6 weeks old

Lot ID: LEAFING SILVER 6 WEEKS OLD

SAMPLE #4 02/21/2006 3:10 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	91.97	20.16	-17.14	26.46	319.63	1.50	0.59	4.10	0.52
Angle: 25°	D65/10°	68.91	25.97	-16.66	30.85	327.32	0.83	0.34	2.29	0.34
Angle: 45°	D65/10°	47.61	32.91	-17.07	37.07	332.59	0.54	0.26	1.65	0.27

Angle: 75°	D65/10°	38.57	37.86	-18.84	42.28	333.54	0.58	0.30	1.92	0.25
Angle: 110°	D65/10°	34.61	38.77	-18.63	43.01	334.34	0.62	0.35	2.00	0.26

Note: 8 weeks old

Lot ID: LEAFING SILVER 8 WEEKS OLD

SAMPLE #5 **02/21/2006** **3:10 PM**

L*a*b* Data:	**Ill/Obs**	**L***	**a***	**b***	**C***	**h°**	**DE***	**DEcmc**	**DEfmc2**	**DE2000**
Angle: 15°	D65/10°	92.74	19.90	-16.75	26.01	319.91	2.28	0.83	6.11	0.74
Angle: 25°	D65/10°	69.20	25.73	-16.36	30.49	327.56	1.16	0.47	3.15	0.46
Angle: 45°	D65/10°	47.39	32.90	-16.92	37.00	332.79	0.35	0.16	0.96	0.16
Angle: 75°	D65/10°	38.14	38.05	-18.77	42.43	333.75	0.14	0.06	0.35	0.05
Angle: 110°	D65/10°	34.14	38.94	-18.52	43.12	334.57	0.11	0.06	0.31	0.05

Note: 10 weeks old

Lot ID: LEAFING SILVER 10 WEEKS OLD

SAMPLE #6 **02/21/2006** **3:11 PM**

L*a*b* Data:	**Ill/Obs**	**L***	**a***	**b***	**C***	**h°**	**DE***	**DEcmc**	**DEfmc2**	**DE2000**
Angle: 15°	D65/10°	91.06	20.21	-16.85	26.31	320.18	0.57	0.23	1.56	0.20
Angle: 25°	D65/10°	68.45	25.79	-16.34	30.53	327.63	0.48	0.21	1.17	0.20
Angle: 45°	D65/10°	47.46	32.73	-16.90	36.83	332.70	0.51	0.23	1.47	0.22
Angle: 75°	D65/10°	38.68	37.76	-18.77	42.17	333.57	0.73	0.37	2.34	0.30
Angle: 110°	D65/10°	34.61	38.56	-18.51	42.77	334.35	0.70	0.38	2.36	0.28

Note: 12 weeks old

Lot ID: LEAFING SILVER 12 WEEKS OLD

Complete Report

Customer: EIMC
Color: Pantone 8082c NonLeafing Silver
Description: Fresh Ink
Database: 5-Angle
Filter: All Samples
Report Date: 02/21/2006

STANDARD 02/21/2006 2:59 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	84.18	40.05	-25.16	47.29	327.86	0.00	0.00	0.00	0.00
Angle: 25°	D65/10°	67.64	43.50	-22.64	49.04	332.50	0.00	0.00	0.00	0.00
Angle: 45°	D65/10°	51.12	47.53	-20.14	51.62	337.04	0.00	0.00	0.00	0.00
Angle: 75°	D65/10°	44.13	52.02	-21.36	56.24	337.68	0.00	0.00	0.00	0.00
Angle: 110°	D65/10°	40.52	52.84	-20.93	56.84	338.39	0.00	0.00	0.00	0.00

Note:

Lot ID:

SAMPLE #1 02/21/2006 3:00 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	88.09	38.62	-25.60	46.34	326.46	4.19	1.60	13.29	1.45
Angle: 25°	D65/10°	70.07	41.51	-22.53	47.23	331.51	3.15	1.29	10.90	1.19
Angle: 45°	D65/10°	51.38	45.22	-19.58	49.28	336.58	2.39	0.93	6.29	0.75
Angle: 75°	D65/10°	43.30	49.87	-20.79	54.03	337.37	2.38	0.93	3.95	0.76
Angle: 110°	D65/10°	39.66	50.92	-20.53	54.90	338.04	2.15	0.86	3.37	0.69

Note: 2 weeks old

Lot ID: NONLEAFING SILVER 2 WEEKS OLD

SAMPLE #2 02/21/2006 3:01 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	87.74	40.87	-26.32	48.61	327.22	3.83	1.42	9.55	1.26
Angle: 25°	D65/10°	69.56	42.87	-22.78	48.55	332.02	2.03	0.82	6.54	0.80
Angle: 45°	D65/10°	50.73	45.84	-19.36	49.76	337.10	1.90	0.74	3.27	0.60
Angle: 75°	D65/10°	42.68	50.39	-20.49	54.40	337.87	2.35	0.99	3.11	0.86
Angle: 110°	D65/10°	39.07	51.36	-20.11	55.16	338.62	2.23	0.98	2.89	0.80

Note: 4 weeks old

Lot ID: NONLEAFING SILVER 4 WEEKS OLD

SAMPLE #3 02/21/2006 3:01 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	87.21	40.77	-26.33	48.53	327.14	3.33	1.25	8.21	1.11
Angle: 25°	D65/10°	69.07	43.42	-23.18	49.22	331.90	1.54	0.64	4.61	0.63
Angle: 45°	D65/10°	50.18	46.37	-19.59	50.34	337.09	1.59	0.65	2.42	0.61
Angle: 75°	D65/10°	42.00	50.73	-20.52	54.72	337.98	2.63	1.20	4.55	1.08
Angle: 110°	D65/10°	38.40	51.62	-20.09	55.39	338.73	2.59	1.23	4.48	1.02

Note: 6 weeks old

Lot ID: NONLEAFING SILVER 6 WEEKS OLD

SAMPLE #4 02/21/2006 3:02 PM

L*a*b* Data:	Ill/Obs	L*	a*	b*	C*	h°	DE*	DEcmc	DEfmc2	DE2000
Angle: 15°	D65/10°	88.93	41.47	-27.73	49.88	326.23	5.59	2.15	13.48	1.90
Angle: 25°	D65/10°	70.60	42.60	-23.64	48.72	330.98	3.26	1.38	11.23	1.34
Angle: 45°	D65/10°	50.15	43.70	-18.73	47.54	336.80	4.20	1.63	7.63	1.36

Angle: 75°	D65/10°	40.47	47.65	-19.08	51.32	338.18	6.15	2.57	7.66	2.21
Angle: 110°	D65/10°	36.60	48.55	-18.63	52.00	339.01	6.25	2.71	7.52	2.21

Note: 8 weeks old

Lot ID: NONLEAFING SILVER 8 WEEKS OLD

SAMPLE #5 **02/21/2006 3:02 PM**

L*a*b* Data:	**Ill/Obs**	**L***	**a***	**b***	**C***	**h°**	**DE***	**DEcmc**	**DEfmc2**	**DE2000**
Angle: 15°	D65/10°	84.43	42.02	-26.52	49.69	327.75	2.41	0.96	3.95	0.76
Angle: 25°	D65/10°	67.59	44.65	-23.36	50.39	332.38	1.35	0.53	2.50	0.42
Angle: 45°	D65/10°	50.23	47.68	-19.97	51.69	337.27	0.93	0.42	2.83	0.46
Angle: 75°	D65/10°	42.79	52.08	-21.03	56.17	338.02	1.39	0.68	4.01	0.64
Angle: 110°	D65/10°	39.24	52.88	-20.56	56.74	338.75	1.34	0.69	3.83	0.59

Note: 10 weeks old

Lot ID: NONLEAFING SILVER 10 WEEKS OLD

SAMPLE #6 **02/21/2006 3:03 PM**

L*a*b* Data:	**Ill/Obs**	**L***	**a***	**b***	**C***	**h°**	**DE***	**DEcmc**	**DEfmc2**	**DE2000**
Angle: 15°	D65/10°	87.47	40.13	-25.54	47.57	327.52	3.31	1.20	9.01	1.09
Angle: 25°	D65/10°	69.06	42.20	-22.02	47.60	332.44	2.03	0.80	5.88	0.72
Angle: 45°	D65/10°	50.69	45.38	-18.89	49.16	337.40	2.52	0.98	3.91	0.80
Angle: 75°	D65/10°	43.32	49.80	-20.08	53.70	338.04	2.69	1.04	3.34	0.84
Angle: 110°	D65/10°	39.61	50.57	-19.66	54.26	338.75	2.76	1.08	3.19	0.86

Note: 12 weeks old

Lot ID: NONLEAFING SILVER 12 WEEKS OLD

Appendix B

Pantone® 8082 C Leafing vs. Non-Leafing Silver "Gloss Comparison"

Gloss Readings @ 60°

Ink Age	MetalStar® 06-7000 Non-Leafing Silver	MetalStar® 07-2877 Leafing Silver
Fresh Ink (Standard)	57	71
2 weeks old	52	65
4 weeks old	50	67
6 weeks old	51	64
*8 weeks old**	47	67
10 weeks old	53	63
12 weeks old	50	63