The use of silica additives in UV printing inks

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Introduction

Matte finish has become one of the very popular finishes for consumer products in the graphic art industry in recent years. Many different matting agents like silicas, waxes, organic materials, and fillers have been developed with different manufacturing processes, treatments, and particle sizes to achieve the desired matte effect. However, UV/EB curing system has its challenge since the amount of matting agent needed to achieve a certain gloss level would be significantly higher than waterborne or solvent-borne chemistry due to the lack of film shrinkage. With the high loading of the matting agent, it is even more important to choose the matting agent(s) with good gloss reduction while maintaining acceptable viscosity for printing presses.

Two principally different process technologies are used for the manufacture of silica, one is the thermal process which leads to pyrogenic silica while the other is the wet process yielding precipitated silica, silica gel, or silica sol. In general, silicas are hydrophilic after the formation and could be treated with different chemicals to turn the surface into a different level of hydrophobicity. The most common treating agents are organosilicon compounds.

The focus of the study is to compare a series of products from matting efficiency, storage stability, viscosity impact to rub resistance and show the benefit of a novel sphere shape silica particle will also be introduced to further improve the performance of the matte coating and increase the block resistance and scratch resistance without too much impact to viscosity.

Table 1 outlines the typical physical properties of the spherical particle included in the study. With the novel continuous recirculating reaction, the spherical particle type silicas have shown unique morphology compared to traditional fumed or precipitated silica matting agents. Other particles used in the study have been listed in the table. It could be seen that the Specific Surface Area and Oil absorption of these novel spherical particles are significantly lower than traditional matting agents which minimize the viscosity impact of particles within the ink and overprint varnish (OPV) formulation.

Silica particle	SP-1	SP-2	SP-3	TP-1	TP-2
Silica type	Spherical	Spherical	Spherical	Precipitated	Precipitated
Particle Size, d50 (um)	5.5	10	15	6.5	4.4
Surface Treatment	None	None	None	PE Wax	PE Wax
Specific surface area(N2), m2/g	<12	<12	<12	220	130
DOA absorption, ml/100g	40	50	45	295	245

Table 1:Physical properties of silica particles

The matting effect is achieved by the reflection and deflection of the light where particle size and surface roughness play a very important role. In general, a larger particle size matting agent could lead to a lower gloss unit compared to a smaller particle size product at the same loading. However, most of the flexographic and gravure printing with a rapid print speed produces the film thickness as low as 2-3 microns. This could lead to a very uneven surface for finished products if the particle size is too large. At the same time, the large particle could also stick at the doctor's blade which creates the streaking effect on the product in the long last printing process. This is one of the key reasons we choose SP-1 and TP-1 as the main testing products in this study.

Results and Discussion

Experiment

Matting agents and novel silica particles are all added at varying levels and matting efficiency, viscosity impact, rub resistance and stability had been evaluated. The formulation used in the study is noted in Table 2. The OPV film was printed with RK proofer with 9um wet film thickness at speed 5 onto coated black Leneta chart (initial gloss is 85 @60°), the drawdown was then cured by mercury lamp at speed of 7~8 meter/minutes.

	Percentage	Type
Epoxy base oligomer	40.0	Oligomer
DPGDA	29.9	Monomer
TMPTA	12.8	Monomer
Defoamer	0.4	Defoamer
Amine synergist	4.0	Amine synergist
Photo initiator	2.4	Photo initiator
Dispersant	0.5	Dispersant
Matting agent	vary	Matting agent
Total:	100.0	

Table 2: Formulation used for this study

One critical factor in formulating matte UV OPV is the viscosity buildup from the matting agent especially at a higher level, mainly due to the interaction between matting agent and oligomer/monomer in the system. Oil absorption is detrimental property to consider when choosing the matting agent and the high viscosity could hugely impact the application and overall appearance of the coating. Figure 1 to 4 review the viscosity impact of silica particles on the coatings. Figure 1 showed the viscosity change with the addition of SP-1 where the minimal impact could be observed even when the loading goes as high as 15%wt.

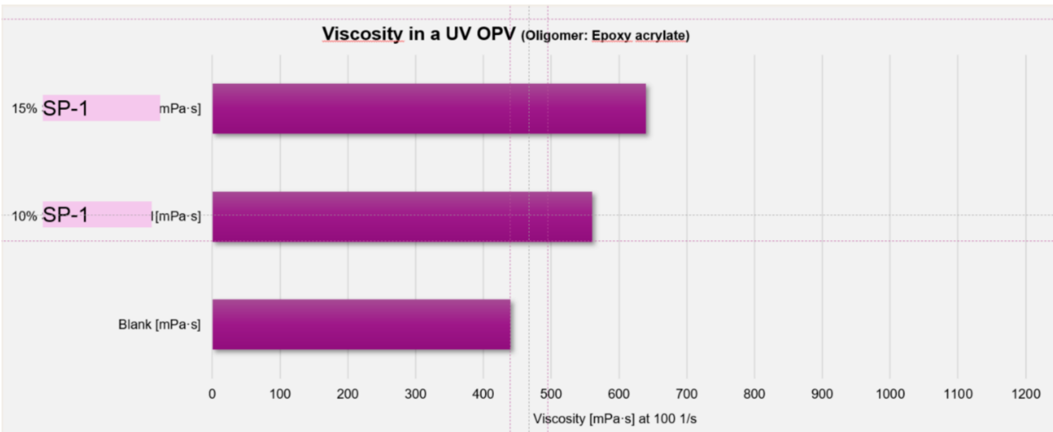

Figure 1: Viscosity impact of SP-1

The Comparison between SP-1 and TP-1 is reviewed in Figure 2 where the impact of viscosity with TP-1 is much higher at 1300 cps which makes the coating much harder to handle. With the whole industry leaning toward the deep matte effect, customers are not satisfied with the gloss unit at 20 anymore. It could be seen from Figure 3 that SP-1 is not able to create the same level of matte effect by itself with the same loading compared to traditional matting additives. Using it alone could be difficult despite minimal viscosity impact.

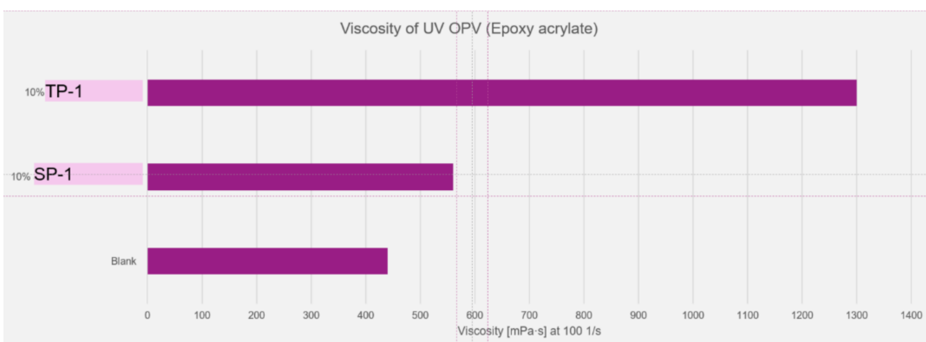

Figure 2: Viscosity impact comparison between TP-1 and SP-1

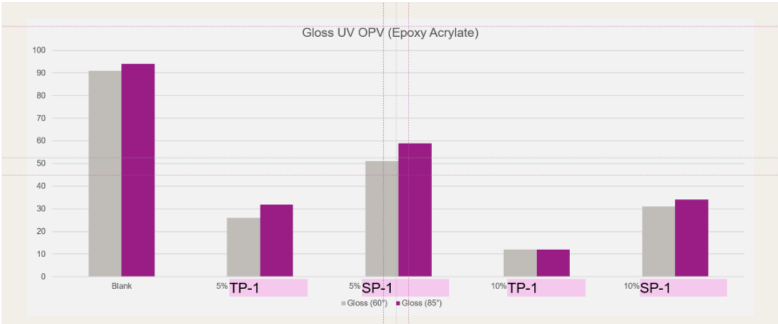

Figure 3: Gloss comparing (60°)

Gloss level and Viscosity result summarized in Figure 3 described the use of SP-1 as the matte booster together with TP-1. Even though the gloss unit achieved by 7% TP-1 and 5% SP-1 is only a little bit better than 10% TP-1 by itself, the viscosity is less than half of the single TP-1 which could be a huge benefit for operation.

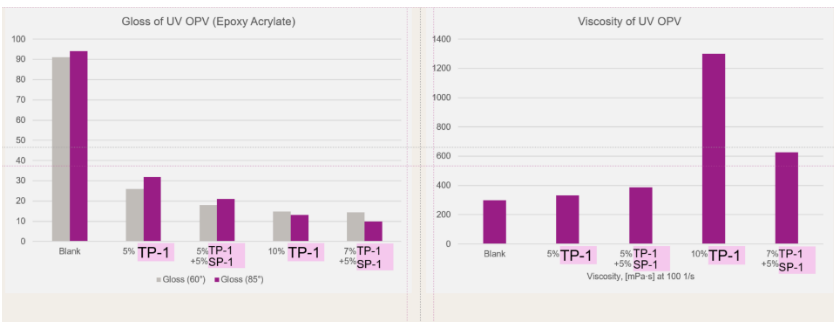

Figure 4: Combine gloss and viscosity

Figure 5 showed the morphology difference between novel silica particle technology and traditional precipitated silica. One of the main reasons for the poor rub resistance performance of matte OPV is that micro-roughening surface could easily be damaged during the surface interaction. The spherical shape particle could help protect the surface roughness from amorphous silicas which leads to better rub resistance or burnish resistance. It could be seen from Figure 6 that 7% TP-1 + 5% SP-1 showed better rub resistance with 15um grits polishing paper for 150 rub cycles despite comparable gloss unit.

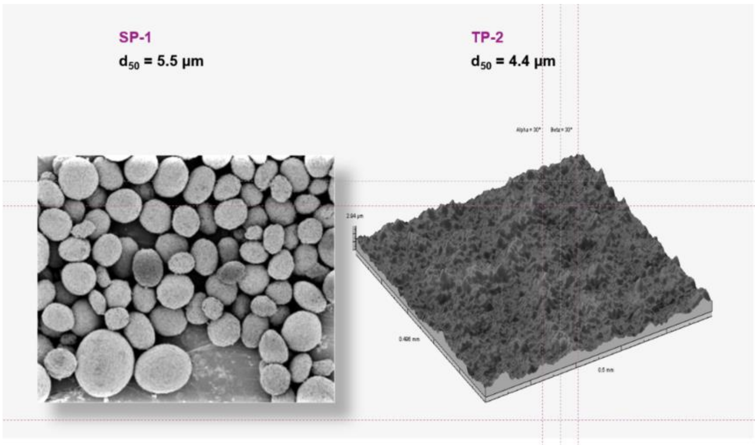

Figure 5: Morphology difference between SP-1 and TP-1

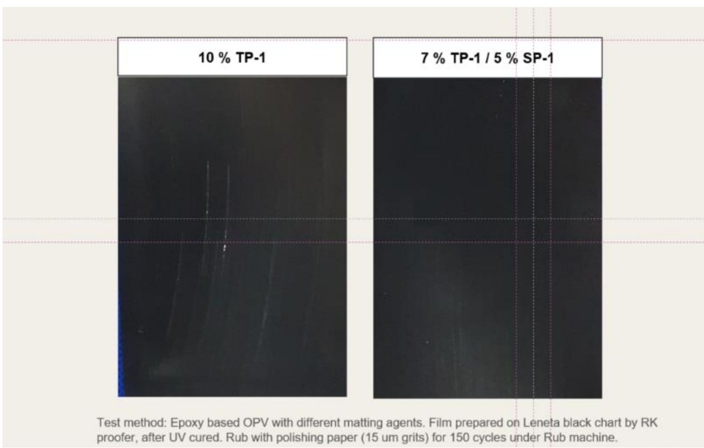

Figure 6: Rub resistance comparison

The low oil absorption offers great benefits like low viscosity impact and minimal binder absorption, it also impacts the shelf life of the silica suspension in the formulation. After storage 4 weeks under ambient temperature, it could be seen from Figure 7 that SP-1 showed the most noticeable phase separation while both TP-1 and TP-1 + SP-1 remain very uniform suspension. This could be explained that amorphous silicas provide enough interaction with oligomer/monomer to help spherical particles against flocculation and ensure the long-term usability of the coating.

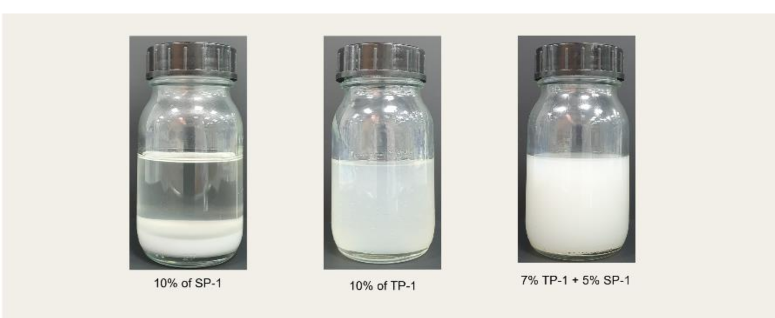

Figure 7: Storage ability comparison

With the globalization trend and rapid growth of market need for food packaging ink, global inventory registration and food contact regulation becomes more important in the current market. Novel spherical shape particle offers great food contact compliance listed in Figure 8 where they possess favorable status on most widely used regulation globally.

Broad global listing

Excellent regulatory status

- Swiss Ordinance A
- BfR Recommendation XIV, XXXVI (plus further chapters)
- FDA: 175.105,175.300, 176.170, 176.180 (plus further chapters)
- China: GB 9685-2016
- EU: Regulation 10/2011 (PIM)

Figure 8: Food contact status and global registration

Conclusions

Matting finish is a complicated process with many factors. The end-user result could be impacted by oligomer and monomer usage, initiators, matting agents, and other additives like defoamers/deaerators. The ideal matting agent should provide a good matting effect with acceptable particle size. In UV/EB curing formulation, the surface treated silica is the preferred product since outstanding stability could be easier to achieve while maintaining a good viscosity for printing application.

The work demonstrated in this article highlighted the novel spherical particle represented by SP-1, SP-2 and SP-3 showed great market potential. SP-1 with more attractive particle size and stability provided a new tool for graphic art UV/EB formulator to achieve deep matte finish together with outstanding burnish, scratch resistance.