Digital Production Printing with Dry Full Color UV Curable Toner

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Abstract

Digital printing will become more and more important in the packaging industry. The functional requirements of printed packaging materials such as heat sealibility, solvent and scratch resistance can only be met by UV curable toners.

This paper describes the design and the use of dry colored UV-curable toners in an online printing and curing system. Within the design of the toner, it is very important to choose those raw materials which result in a toner with a high curing efficiency, necessary to cover differences in color, layer thicknesses and printing speed, without affecting the toner properties in a negative way.

Combining the benefits of UV curable toner with the high productivity web based digital color Xeikon presses, result in a powerful technology to produce small print runs in a cost efficient way.

Introduction

During the last years, various studies were carried out to evaluate the potential of digital printing in the packaging industry. The advantages of digital printing are obvious : cost efficient printing of short runs, reduction of stocks, very short delivery times and the possibility of printing variable data without an additional cost. Also the fact that digital printing allows the possibility of including (variable) security features can be beneficial.

This paper will show that electrophotography based on dry UV curable toner is very well suited as digital printing technology to fulfil the requirement of the packaging industry.

General Background

The market potential of digital printing[1] in the flexible packaging industry is estimated at 80 billion euro corresponding to 42 billion m^2. The potential of digital printing in this field is approximately 5 to 7% within the next 5 years. The printed packaging material has to fulfil numerous specifications. The most important ones are summarized in table 1.

Depending on the specific packaging application, one or more of the above mentioned specifications are very important. Most of all flexible packaging is heat sealed. Therefore it is essential, that the toner can withstand this sealing process because almost every product is printed in the sealing area. Some products are retorted after they are packed, for these products retortability of the toners is essential. Some products are even cooked in the packaging! Every product needs abrasion resistance, it comes in moving contact with other surfaces during storage or transportation.

Table 1. Most Important Requirements for Toner for the Use in Packaging Printing[1]

property	description
Heat sealibility	The toner has to resist a temperature of 250°C at a pressure of 80N/cm^2 for 60sec
Wrinkle test	The toner should not peel off the substrate after 20x partial flex (so called Gelboflextest)
Legal rules for food packaging	The toner has to be approved for indirect food contact. An approval for direct food contact is desirable.
Retortability	The toner has to withstand a temperature of 121°C for 30 minutes in a 100% humidity or water environment
Light fastness	The light fastness should be suitable for partial outdoor use. A light fastness of above 6 is wanted.
Solvent resistance	The toner should resist the following solvents: a) 96% ethanol b) mixture of 30% ethyl acetate 60% ethanol and 10% methoxypropanol

Also for other applications where as a finishing step heat is required, such as heat lamination (ski's, snowboard,..) and letterheads, a temperature resistant toner is needed.

Conventional toners are based on thermoplastic resins meaning that those toners start to melt above a certain temperature and solidify again during cooling and this is a reversible process. This implies that the image will be disturbed during the after treatment such as heat sealing or retorting of the packaging material. Not only the temperature resistance of conventional toner is poor but also the mechanical and solvent resistance is very limited.

This means that there is a need for a toner system that should be changed after printing in such a way that the resin material becomes more resistant towards mechanical impact, temperature differences and should be able to withstand an organic solvent treatment. Make use of the crosslinking principle is the most efficient way to achieve the above requirements.

At this moment Xeikon International is developing a full color UV curable toner and developer set to run in an industrial environment on Xeikon engines. If the digital printer wants to apply UV curing in a production digital printing environment, then it is necessary that all colors are cured in the same extent, independent upon the layer thickness and the page coverage which is applied during image formation. This means that all colors must behave in the same manner, independent from the type of pigments and the pigment load which is used. This is the big challenge for making toner. On top of that the choice of pigments is limited because of the high level of light fastness and FDA-compatibility we are aiming for. The curing performance should also be quite independent on changes in printing conditions and curing speed.

UV Curable Toner

1. Toner

A UV curable toner comprises more or less the same ingredients as a conventional toner except that the standard resin is replaced by a special designed UV curable resin and also a photoinitiator is added. The photoinitiator forms radicals under the UV irradiation and starts the cross linking reaction.

To obtain a good curing efficiency one can adjust the curing power and/or increase the reactivity of the radiation curable toner. A MEK rub test is the most common used method to measure the curing efficiency.

Because increasing the UV power has some draw-backs towards the used substrates, such as shrinkage and wrinkling when heat sensitive substrates are used , the aim is to design a UV curable toner with an as high reactivity as possible in order to obtain an as broad processing window as possible. The reactivity of the toner composition can be improved by optimizing the type and concentration of the radiation curable resin and the photoinitiator.

The curing of the radiation curable toner can be improved by increasing the concentration of photo-initiator. This way introduces some drawbacks. Depending on the type of photoinitiator, a drop in Tg could be observed resulting in a toner with a too low Tg. Those low Tg toner has a bad storage stability and increased formation of agglomerates during development. Another drawback of a high photoinitiator concentration is the possibility that a higher amount of unused photoinitiator is still present in the cured image.

The two most popular types of photoinitiators are alpha hydroxy ketones (AHK) mainly used for surface cure and (bis)acylphosphines (BAPO) used for in depth cure.[2]

Due to the limitations of UV power and photo-initiator concentration a proper choice of UV curable resin is necessary to obtain a high curing performance. The most logical way is to increase the reactivity of the binder. The reactivity of the binder resin is expressed as the amount of double bounds per gram (meq/gr) of the radiation curable resin and can easily be determined by the use of NMR-techniques.

We have found that the number of double bounds can not be increased unlimited. The binder can become too reactive, resulting in a unstable viscosity behaviour during the preparation. On the other hand not only the total number of double bounds is important. Blends of different types of radiation curable binders can result in toners with a higher curing efficiency than what could be expected from the total reactivity as expressed by the number of double bounds. The reason for this is not completely clear but can possibly be related with the reactivity of each type of double bound on itself and in a copolymerization with other types of double bounds.

2. Inkjet-UV-Curable Inks

UV curable toner is not the only digital technology which can be used; UV curable inkjet is a possible alternative, especially on temperature sensitive substrates. Electrophotography however has some major advantages over inkjet. For the same printing speed, a much higher image quality can be obtained and the overall reliability of the toner printing systems is much better (e.g. nozzle clogging). Industrial presses like the Xeikon 5000 have repeatedly proven of being capable of printing up to 3 million A4 sizes per month.

Another important difference is that the raw materials contain no low molecular weight components and thus also no volatiles. Prints made with UV curable toner can be handled in the same manner as prints made by conventional toner. The amount of components that was extractable in acetonitrile was equal for curing at 100 W/cm and 200 W/cm. In the case of UV curable inkjet, the images can be wiped off when no curing has taken place. If the curing was not performed 100% some unreacted, volatile, low molecular weight material will be present in the image. This means also that the curing conditions i.e. lamp life, geometry, need a more adequate control.

Also the fact that less to no oxygen inhibition takes place implies that the curing conditions are less critical for UV toners.

By optimizing the current formulation we were also able to lower the photo initiator concentration to such a level that no risk marking is necessary indicating that working with UV curable toner is much safer than working with inkjet.

3. Experiments

Toners of 7-8 µm were prepared by melt kneading the raw materials followed by a milling and classifying step. In order to improve the flowability 0.5% of hydrophobized silica R972 was added.

With those toners images are printed and fused with a Xeikon engine followed by an online UV curing in a separate unit were the images were surface heated and subsequentely cured (figure 1). The standard settings of curing are: curing speed 12.5cm/s, UV power 200W/cm and an iron doped bulb.

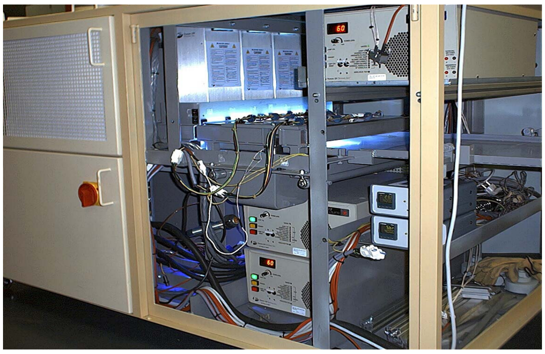

Figure 1. UV curing station

3.1. Test Methods

Solvent resistance test of fused and cured toner particles: using a cloth soaked with MEK (methylethylketone) the fused and cured toner images are rubbed softly. One count is equal to an up and down rub. The rubs are counted till the substrate becomes visible. The number of rubs is a measure for the solvent resistance of the toner images.

Temperature resistance test of fused and cured toner particles: the fused and cured samples are folded inside and put between 2 plates for 5 sec at a pressure of 6 bar. Only the upper plate is heated. The temperature at which the toner starts to stick together is determined for the uncured and corresponding cured toner sample. The temperature difference between both toner samples is a measure for the temperature resistance of the toner. The uncured toner starts sticking together between 110 and 120°C.

Tg of toner particles and resin: the glass transition temperature is preferably determined in accordance with ASTM D3418-82.

3.2. Effect of Photoinitiator and Binder

The test was performed on a cyan toner layer of 5µm, equivalent to 1 tonerlayer

From table 2 it is clear that an AHK photoinitiator is less favourable due to a somewhat lower curing performance and lowering in Tg of the toner in comparison with the BAPO initiator (testtoner 1 and 4).

With respect to the choice of polymer we clearly see that an increase in number of double bounds (test toner 1 to 3) is not resulting necessarily in a higher curing efficiency. Polymer 1 and 2 are acrylic functionalized polyester resins[3] and polymer 3 is a polyester based on fumaric acid. By blending polymer 1 and 4 (test toner 5 to 7), polymer 4 being an urethane acrylate adduct, very high curing efficiencies can be obtained. Polymer 4 alone can not be used due to its high reactivity: i.e. during melthomogenisation the crosslinking already starts resulting in a very high viscous toner material which can not be fused anymore in the print engine. The reactivity is even so high that it is possible to decrease the photo initiator concentration to 1%, a level that makes labeling with special warnings is no longer necessary.

Figure 2. Diary cups; left: printed with UV curable toner-right printed with conventional toner (no toner in sealing area)

3.3. Effect of Color and Layer Thickness

A magenta, yellow and black toner was prepared according the resin composition of testtoner 6.

Table 3 shows us that the curing level of all the colors is very high. The black toner shows the lowest curing efficiency but is still acceptable. A possible explanation can be that the carbon black pigment catches the radicals formed by the photo initiator.

Also for thicker toner layers an even higher MEK rubtest is found, indicating that the used BAPO photo initiator is very well suited for in depth cure, where the AHK initiator fails to cure thick toner layers.

Table 2. Effect of Photoinitiator and Binder

Test toner	binder	Reactivity	BAPO	AHK	MEK rubtest	Tg °C	Temp. resistance
1	Polymer 1	0.9	3	0	70	50	>130
2	Polymer 2	0.7	3	0	12		>100
3	Polymer 2	1.9	3	0	22		>120
4	Polymer 1	0.9	0	3	55	46	>130
5	polymer 2 polymer 4	1.26	3	0	80		>130
6	polymer 1 polymer 4	1.23	3	0	670		>130
7	polymer 1 polymer 4	1.23	3	0	500		>130

Table 3. Effect of Color and Layer Thickness

Test toner	color	Thickness (µm)	BAPO	AHK	MEK rubtest
8	Y	5	1		550
9	B	5	1		270
10	M	5	1		550
11	M	10	1		>2000
12	M	15	1		>2000
13	M	5		1	400
14	M	10		1	1630
15	M	15		1	450

Table 4. Effect of Curing Speed and Curing Power

Test toner	BAPO	UV Power (W/cm)	Speed (cm/s)	MEK rubtest
1	3	200	12	70
6	3	200	12	672
6	3	200	25	300
6	3	200	37.5	180
7	1	200	12	500
7	1	200	25	265
7	1	200	37.5	100
7	1	150	12	450
7	1	100	12	130

Figure 3. Blisterpacks printed with UV curable toner

3.4. Effect of Curing Speed and Curing Power

With testtoner 6 and 7 the effect of curing speed and curing power was studied.

The above data clearly shows that we were able to expand our curing window to such an extent that even at a speed of 37.5 cm/s a still higher MEK rubtest is found than that of reference testtoner 1. Also by lowering the UV power by a factor 2, the MEK rubtest was still higher than that of the reference testtoner 1.

Testtoner 1 refer to the latest status reported during NIP 19[4] conference. Knowing that we were able to pass the tests described in table 1 with testtoner 1, when printing on the packaging materials MIXPAP and aluminium foil, the above results show what a major step forwards we made in the design of our UV curable toner formulation.

3.5. Spot Colors

Initial tests reveal that the same curing could be obtained by replacing the standard pigments by white, green, red or blue colors. This implies that brand colors, often used in packaging printing, can be incorporated in a Xeikon 5000 engine which is equipped with a 5th printing station.

Conclusion

This paper clearly shows what progress has been made by changing a conventional toner to a UV curable toner system.[5,6,7] By choosing the right raw materials we were able to design a toner formulation with a very broad process window towards UV power, curing speed, colour and layer thickness.

We have set a major step in the development of these toners and combining this with the strengths of Xeikon print engines results in a total solution for high demanding applications such as flexible packaging, where the post finishing step is as important as the printing process itself. It is interesting to mention that also non packaging applications, are also under investigation (e.g. high durable books, solvent resistant labels,…).

References

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Biography

Werner Op de Beeck is Project Manager Toner and Developer at Xeikon International. He received his university degree in 1987.

After his studies he joined the central research group Electrophotography at Agfa as assistant project leader.

From 1998 he became a project leader within the same R&D group and after the move in 2000 of this R&D group to Xeikon International he took up his current function.