XEIKON

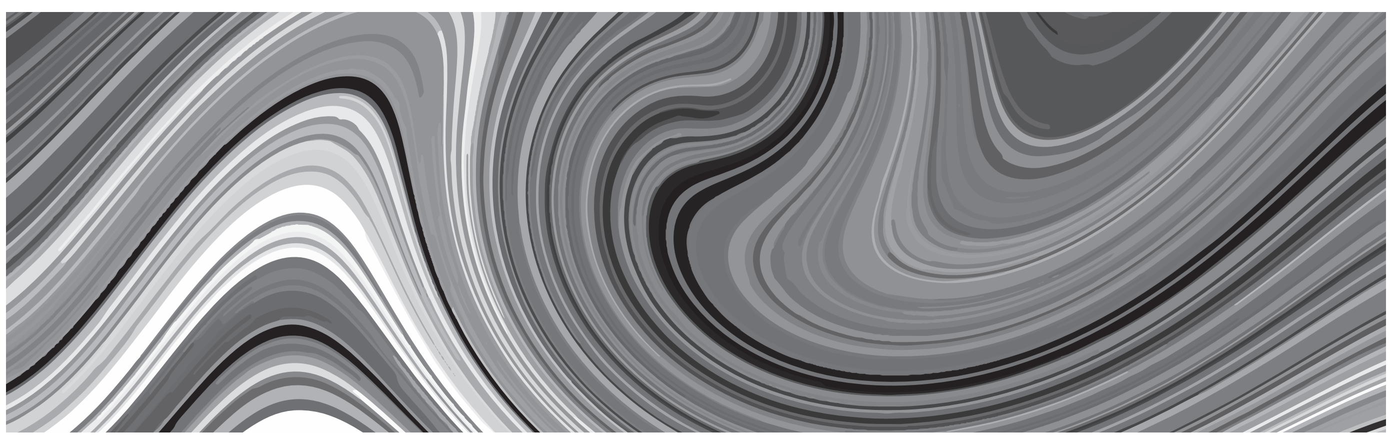
MIGRATION-OPTIMISED DIGITAL INK SYSTEMS FOR PACKAGING PRINTING

White paper

A division of FlintGroup

IN THIS PAPER

Section



Section 01

MIGRATION-OPTIMISED DIGITAL INK SYSTEMS FOR PACKAGING PRINTING

With the increasing acceptance of digital printing in the various application areas of packaging printing, the range of requirements for digital ink systems has expanded. The migration behaviour of ink systems is moving into the focus of the decision-making process of labels- and packaging printers and plays a decisive role in the selection of a digital printing press. The properties of the ink system determine to a large extent which application segments the printing system can cover - and to which segments it could be expanded to if necessary. This White Paper provides the answers and shows which criteria must be particularly considered.

There is no such thing as "one" ink system that suits all applications in digital packaging printing. Printed or labelled packaging must meet other requirements in addition to the demand for minimum migration behaviour and high food safety. These include criteria such as scuff and scratch resistance, wet strength, light fastness, but also heat and chemical resistance. This makes it clear that these complex requirements cannot be met by a single ink system. For this reason, the selection of the most suitable ink system - alongside the choice of the appropriate press technology and workflow - is central to a packaging printer's decisions. The ink system must cover the application segments of its customers whilst at the same time offering the highest level of process reliability. And it must comply with the existing legal requirements. It is equally important for a converter to opt for an ink system that causes the least amount of effort in the seamless documentation of the production process for labels and packaging and thus relieves them in their daily business.

A look back reveals the background as why food safety plays such a role in packaging printing. Since the beginning of the last decade, several incidents have been reported in the press, in which chemical substances were found in food. Consumers were alerted in newspaper reports about photo initiators in baby milk or mineral oil in recycled cardboard resulting in a transference to packaged food. Not only legislative bodies in Europe but also associations and the affected brand owners took action, on the one hand to protect consumers and on the other to avert damage to the company's image. This resulted in numerous sets of regulations and rules, three of them which are frequently cited are briefly outlined as an introduction of the current legal background.

"Sawing the branch off the tree you're sitting on is never a good way to move forward…."

Dr. Lode Deprez, Xeikon

Section 02

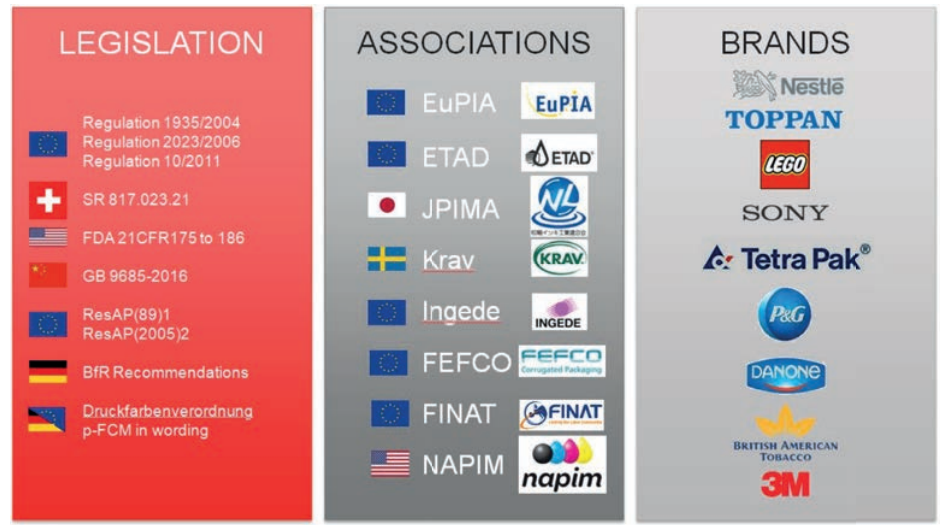
REGULATION (EU) 2023/2006

Regulation (EU) 2023 on Good manufacturing practice from 2006

It is known as the “Good Manufacturing Practice” Regulation for converters and describes in Article 3a “those aspects of quality assurance which ensure that materials and articles are manufactured in a consistent manner and are checked to ensure conformity with the rules applicable to them...”.

In concrete terms, this means not only for the converter but also for the supplier industry, such as ink manufacturers, to establish a quality assurance and quality control system in their production, in which all relevant raw and auxiliary materials for the manufacture of the product as well as all process steps influencing quality are completely documented.

European recycling 1991-2019



Overview of the large number of European and national regulations, rules of associations and requirements of brand manufacturers.

Regulation (EU) 10/2011 (plastic materials)

Known as the EU's Regulation on Plastic Materials, this regulation determines the total migration limit (OML) into a package, which is set at 10 mg / dm2 per food contact surface, regardless of the package size. With packaging modelled by a standard cube, where 1 kg of food is packaged in a cube of 10x10x-10cm, this corresponds to a migration of 60 mg / kg of food. For substances that are not evaluated in the regulation, the migration limit is 0.1 mg / kg (10 ppb) and may be used when there is a functional barrier.

For approximately 1,000 substances, specific migration limits (SML) are defined as the maximum permitted amount of a certain substance that can be transferred into food from a material (packaging material and / or printed layer).

Swiss Ordinance SR 817.023.21

The Swiss Ordinance contains a list of permitted substances for the production of inks which have been toxicologically assessed and for which a specific migration limit (SML) has been established. A second list (Part B) contains unevaluated substances for which the standard SML has been set at 10 ppb.

Curiously, due to the different requirements in the EU regulations and in the guidelines of the associations and the brand owners, the case may arise that an ink formulation complies with the EU regulations, which does not automatically mean that it is also compliant with Swiss Ordinance or the EuPIA list.

Conversely, an ink formulation can correspond to the EuPIA list, the Swiss Ordinance and the Nestlé standards, but is still not conform to the EU regulations.

Section 03

TYPES OF MIGRATION

Migration describes the transfer of substances from the packaging to the food. Migration is a diffusion-controlled process, which means it involves a net transport of molecules (migrants) from an area of higher concentration to an area of lower concentration. Two of the possible types of migration are described in the GMP Regulation (EU) 2023/2006, a third is gas phase migration.

PENETRATION MIGRATION

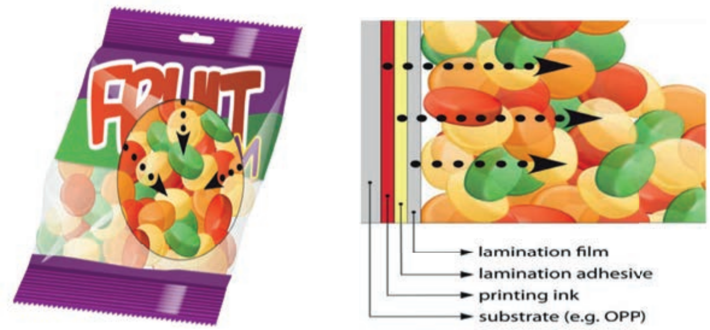
During this process, substances from the printed ink film migrate through the protective packaging film into the food which is in contact with the film.

SET-OFF MIGRATION

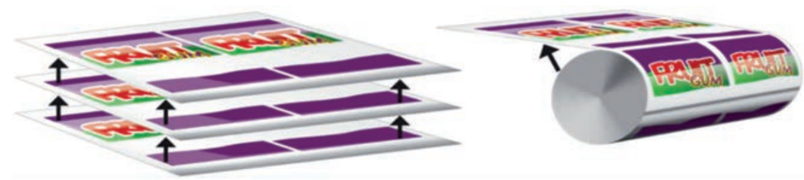
By this the regulation understands the set-off migration from the printed side to the reverse (unprinted) side in a pile or reel. Not only the ink but also the laminating adhesive and other substances from a laminated film can migrate from the printed film. This is not relevant for labels since the liner is removed before the labels are applied.

GAS PHASE MIGRATION

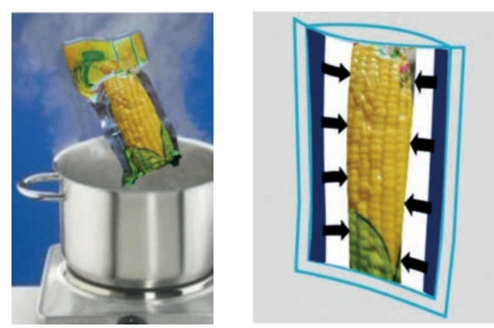
When cooking, baking or heating frozen or unfrozen food in its original packaging, evaporation or condensation migration of ink components from the packaging into the food can occur via the gas phase (so not in contact).



Migration through penetration of the packaging material



Migration through set-off from the printed to the reverse side



Gas Phase Migration through evaporation and condensation

Section 04

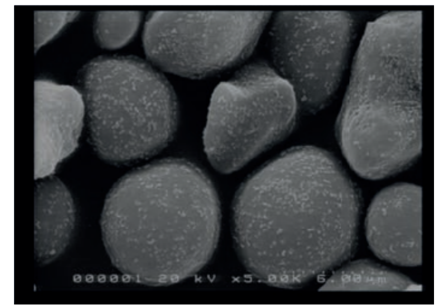
INK SYSTEMS IN DIGITAL PRINTING

Digital packaging printing involves two fundamentally different processes. Electrophotography, with the dry toner or liquid toner process, in which the image is transferred via toner through electrically charged imaging drums. And the inkjet process, in which the image is transferred via ink drops coming out of the print heads.

Xeikon dry toner

The base material of the Xeikon dry toner is a polyester resin, which has an average percentage of over 90% in the formulation (white has 60%). Other components are pigments, charge control agents and other additives. The toner particles are triboelectrically charged. They take part in the imaging process and after the powder image is transferred to the substrate in the impression zone, the toner particles are fixed to the substrate under the influence of heat at 110°-130°C. The relatively large toner particles melt during this process and coagulate to form a homogeneous, solid polyester film with a thickness of approx. 4 µm per toner layer.

An essential criterion for the migration behaviour of ink components from the ink layer is the molecular weight and the matrix they are embedded in. In the polyester layer of Xeikon dry toner, the other ingredients are also large sized molecules and virtually immobile and therefore have a migration risk that is considered negligible. One could consider the toner particles as functional barriers on their own. In addition to their excellent migration properties, dry toners also have a high light fastness due to the pigment choice.



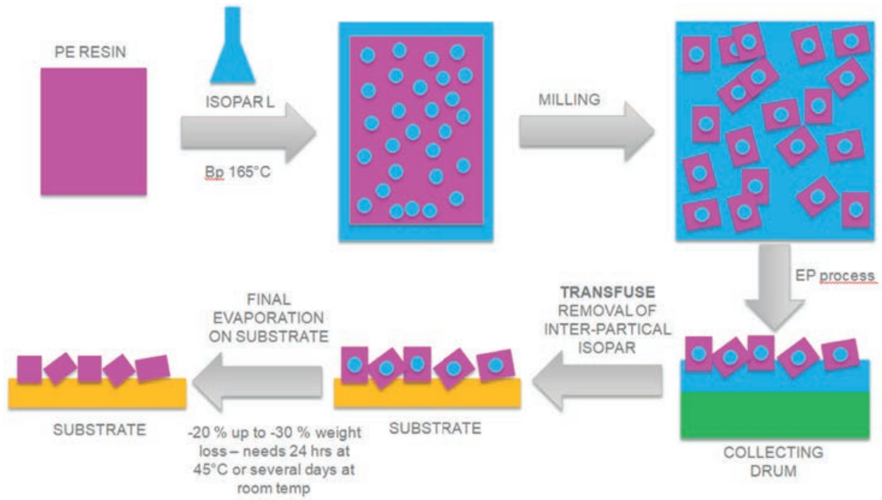
Shape modified Xeikon QB-toner with clearly visible flow and charge additives embedded on their surface.

Dry toner layer of 4 colours melted onto a paper label substrate showing the particle behaviour has completely disappeared.

Liquid toner

The resin material of a liquid toner is a polyethylene derivative, to which pigments, additives and a solvent are added. The amount of resin surrounding the pigment is much smaller than in dry toner and additionally the barrier properties of polyethylene are more than a million times less performant than those of polyester. The solvent used is Isopar L, a synthetic isoparaffinic oil. At the start of the liquid toner production process, the resin absorbs the solvent whereby some swelling occurs. In a subsequent size reduction process, the components of the previously obtained paste are ground to a particle size of about 2 µm. These particles then receive a charging agent at the surface so they can take part in the imaging process.

When fused to the substrate, the solvent evaporates from the spaces between the resin particles. Solvent which is in the polyethylene resin remains there at first. It takes a certain time for complete evaporation and a reduction of the layer thickness, the latter depending on the ambient conditions. For this reason, packaging material printed with liquid toner cannot be processed into packaging directly from the machine if no additional functional barrier is in place. After full evaporation, the final risk of migration of the synthetic oil into the food is low, but there is a disadvantage in the workflow compared to other ink systems due to the idle time.



Weight loss of liquid toner during the drying process

Section 05

MIGRATION OPTIMISED UV INKJET INKS

In the market the term "low migration" UV inkjet ink is often used to express that an ink series has particularly low migration behaviour. Misleadingly, this may give the impression that these ink series would always comply with the conformity requirements for food applications due to their improved migration behaviour. This is not automatically the case.

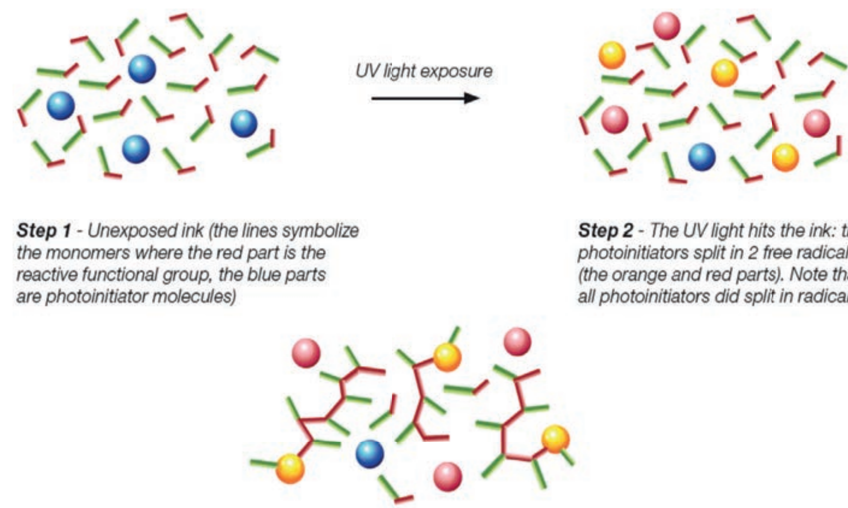
In this White Paper, the term "migration-optimised" is therefore used instead of "low migration". It is a better description of the issue, since with every UV inkjet ink system the user must ensure that the migration limits for the respective application are observed.

As far as the formulation of migration-optimised UV inkjet inks is concerned, they consist of a carrier liquid which is a solvent containing highly reactive monomers (e.g. acrylates) and diffusion-inhibited photo initiators. All the solid components of migration-optimised UV inkjet inks must be ground very finely, because the inkjet ink must pass through the fine nozzles of the print heads without clogging them. Additionally in order to guarantee the jetting at a very high frequency the viscosity of the inks must be low, preventing the use of very large and high concentrations of multi-site reactive molecules.

When curing under the influence of UV light, the photo initiators contained in the formulation form free radicals which react with the monomers, causing them to polymerize into a film.
To achieve a maximum degree of cross-linking, the cross-linking can be carried out under inert conditions with the aid of nitrogen. The nitrogen has the task of replacing the oxygen during the curing process, which would otherwise disturb the cross-linking reaction. Under optimum curing conditions (new lamps, right speed, right design, layer thickness, humidity, temperature,…), a degree of cross-linking of up to 99.9995% should be achieved to have only 1 unreacted molecule per 100.000 still able to migrate and this is the limit (in a coating of 100 % ink coverage which has a thickness of 6 micron thickness max 1 molecule on +/- 100,000 should not have reacted to be on the safe side of migration (10 ppb).

This degree of cross-linking is significantly higher than that of standard UV inkjet inks which react with an efficiency of 92 - 98%.

With such a high cross-linking reaction of migration-optimised UV Inkjet inks, the proportion of still reactive monomers in the dry ink film with a layer thickness of over 5 µm is very low and with certain substrates (PET or very thick PP) safe food packaging can be realised. Nonetheless, uncross-linked photo initiators or monomers can remain in the ink film and, because of their small particle size, are potential candidates for migration, even with migration-optimised UV inkjet inks.



Step 1 *- Unexposed ink (the lines symbolize the monomers where the red part is the reactive functional group, the blue parts are photoinitiator molecules)*

Step 2 *- The UV light hits the ink: the photoinitiators split in 2 free radical parts (the orange and red parts). Note that not all photoinitiators did split in radicals.*

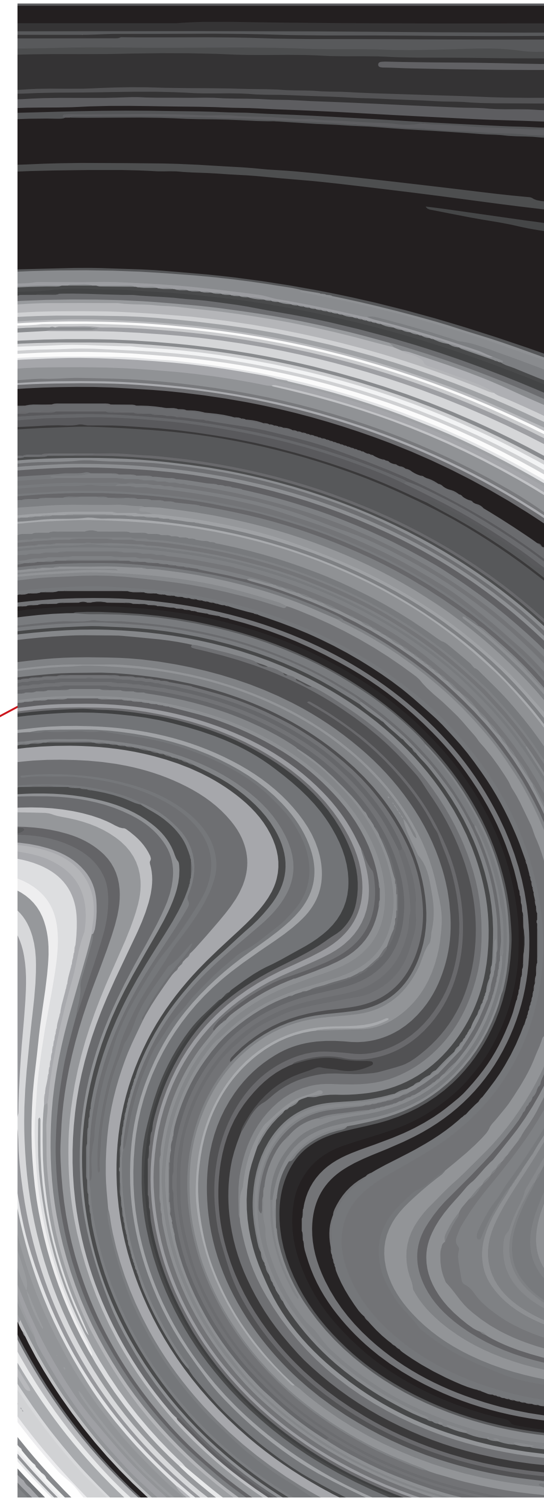
Step 3 *- After UV light exposure, one of the radical parts started a cross-link reaction with the monomers resulting in a polymer where the red parts of the monomers are linked to each other. Unused photoinitiator (blue part), unlinked photoinitiator residus (red parts) and unreacted monomers are all potential candidates for migration.*

Functional barriers with UV-Inkjet Applications

According to “Good Manufacturing Practice”, good cross-linking must be ensured and also documented by the converter so that it can be tracked later, if migration occurs and the reasons for this are questioned by the food producer. Since migration-proof curing can only be achieved under optimum curing conditions, there is a certain amount of scepticism among many brand owners of food products concerning migration-optimised UV inkjet inks.
As far as the odour of the inks is concerned, it is low with migration-optimised ink layers, which means that packaged foods also pass a Robinson*1 test.

Migration of ink components from the cross-linked ink film into the packaging can be prevented by a functional barrier. A functional barrier can be a plastic film bag in a printed folding box or the printed substrate itself. Whether a material constitutes a functional barrier or not depends on its defined conditions of use, the type and concentration of the migrating substance, the type of food in the packaging and the storage time and conditions (e.g. temperature). Solid substances such as glass or pure metal always act as a functional barrier. With plastic films, the barrier properties are determined by the type and thickness of the material. By printing on and laminating with PET films (high functional barrier), UV inkjet printed material can also cover migration-sensitive applications. This is not at all guaranteed with thin polypropylene or polyethylene films.

Printing on uncoated paper requires a primer which prevents the ink from sinking into the substrate and in turn poses a migration risk. But even with primer, some of the ink can always be absorbed by the paper without the UV light being able to reach and cure these fractions. As a result migration will never be OK!



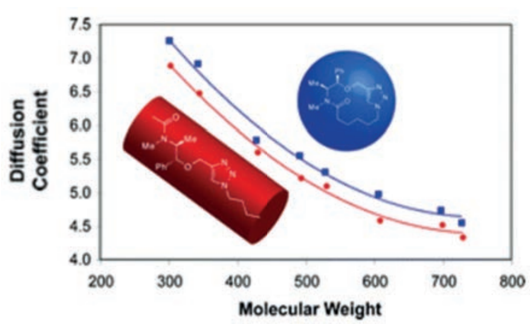
Section 06

INFLUENTIAL FACTORS ON MIGRATION BEHAVIOUR

Not only different ink components with their different molecular sizes have an influence on the migration behaviour. The mass transfer from printing inks depends on other factors such as storage time, storage temperature, the barrier properties of the packaging material and, ultimately, the packaged goods.

THE SIZE

The size of the ink components (mostly linked to the molecular weight) plays a crucial role in the migration behaviour. Small molecules with their small mass are more mobile and their tendency to migrate is higher than that of larger molecules. The shape of the particles also has an influence on the migration ability, although not to the same extent as the molecular size itself. In general, round particles diffuse slightly more than elongated particles, as they have a more compact shape for the same mass. Since the molecular mass increases with increasing particle size, the generally accepted limit for migrating particles is the atomic mass unit of 1,000 Daltons. For clarification and to be able to better estimate this unit, here are some atoms or molecules for comparison:



One hydrogen atom corresponds to approximately 1 Da, a water molecule has an atomic mass unit of 18 Da and a fat molecule about 800 Da, depending on the type. They are therefore all capable of migration in terms of their size.

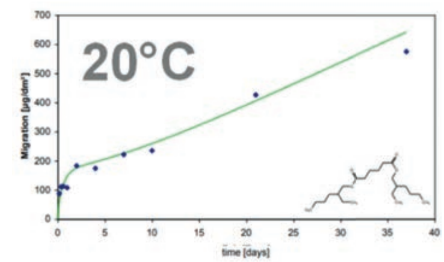
THE STORAGE TIME

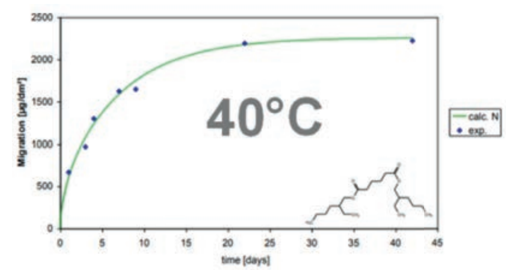
Due to the storage time at a temperature of 20°C, the migration behaviour in the test set-up, for example with a lamination film of 20 µm OPP/ink/30 µm OPP, increases exponentially in the first two days and continues almost linearly thereafter.

THE STORAGE TEMPERATURE

The storage temperature has a very decisive influence on the migration behaviour. As a rule of thumb, the diffusion rate increases by a factor of 3 in steps of 10°C when the temperature is increased. This means that when the storage temperature is increased from 20° to 40°C, for example, a progression in migration behaviour by a factor of 9 (=3x3). Such a situation can usually occur in summer during non-chilled transport by lorry or even exceed it.

During the simulation long-term tests, the storage temperature is increased to 60 °C. A test after 10 days of storage at this temperature corresponds approximately to a test period of 2 years at room temperature of 20°C.





THE PACKAGING MATERIAL

Different chemistry can have very different barrier properties against migration, like the difference mentioned earlier between PE resin in liquid toner versus polyester in Xeikon dry toner. This is also true for packaging films where it also depends on the molecular structure of the film, whereas polyester film generally has a very high barrier against penetration. Polyethylene and polypropylene on the other hand have a much lower barrier. In this example, the barrier properties of various plastic films are listed according to their diffusion barrier against the photo initiator benzophenone.

Polymer	Diffusion barrier
HDPE	1
LDPE	1
PVC	1
PP	10
PET	100.000.000
EVOH	100
PA	100

THE SURFACE/VOLUME RATIO

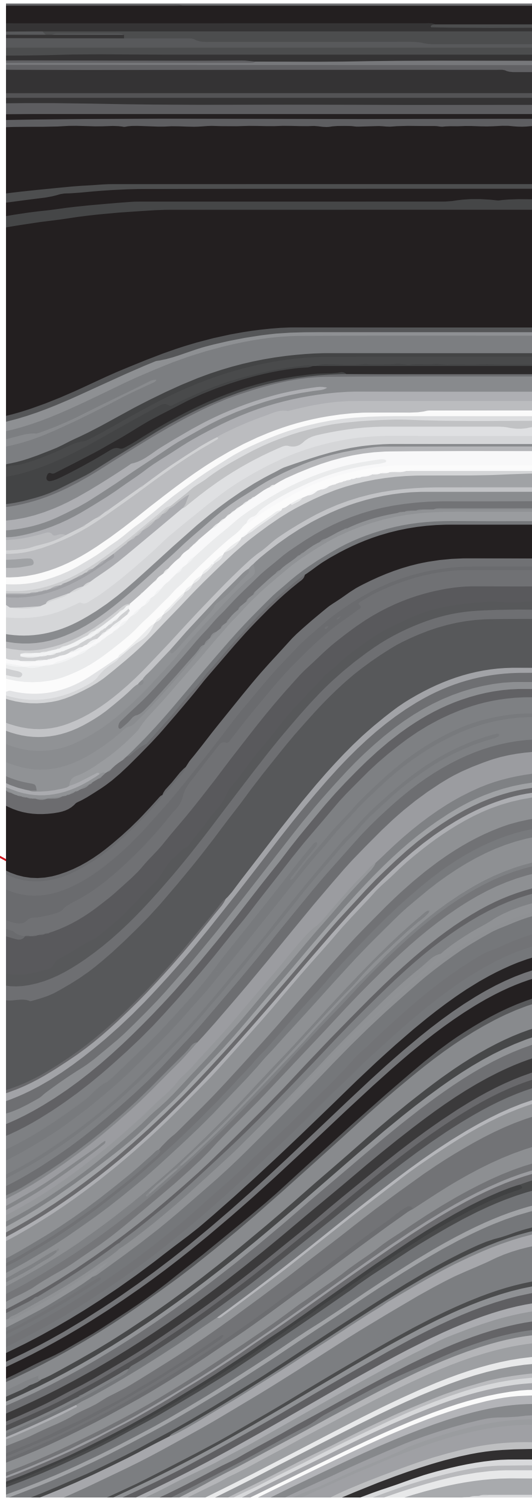
For packaging, the thickness of the film as well as the surface/volume ratio of the packaging also plays a role. Small packages printed over the entire surface always have the worst migration values, since the printed packaging proportion is very high compared to the contents and many components can migrate into the food.

The influence of the migration from differences in the packaging material, e.g. through the presence of plasticizers or waxes in the films, is not considered in this white paper.

THE FOOD TYPE

The food type also plays an important role, determined by its particle size as well as its consistency. The migration of most organic molecules into fatty foods is more pronounced than into dry foods.

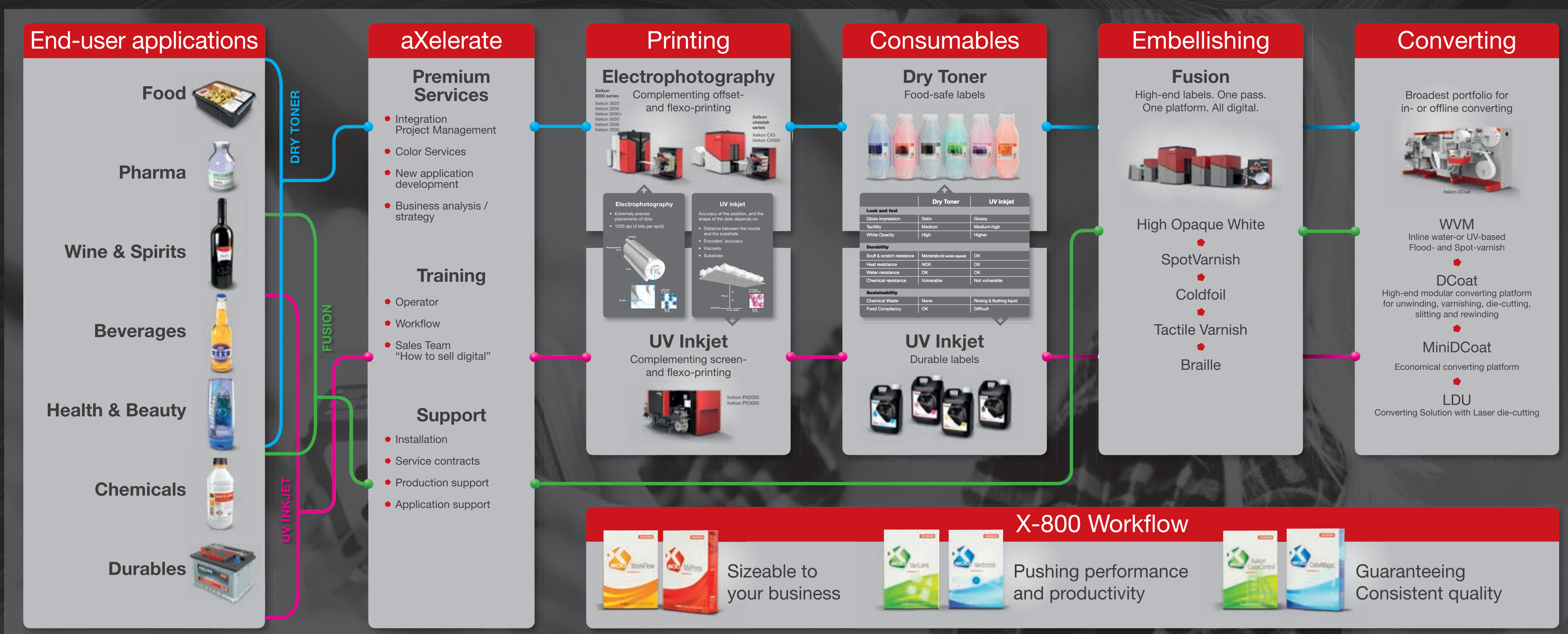
The surface of the foodstuff in a package also plays a decisive role. Smooth surfaces that lie close to the packaging have a larger contact surface to the packaging than foodstuff, with a structured surface. The latter absorb substances less well due to the smaller contact surface.



Section 07

XEIKON SOLUTIONS FOR LABEL- AND PACKAGING PRINTING

What conclusions can be drawn from the properties of dry toners and UV inkjet inks when deciding to purchase a digital printing system? This depends first of all on the composition of the segments of the end customer portfolio. It shows in which segments the existing customers are located. In addition, further target segments can be defined into which the portfolio is to be developed. Such a portfolio is divided into the classic segments of food, pharmaceuticals, wine & spirits, beverages, health & beauty, chemical labels and durable labels. The first five segments account for over 70% of the total market.



Section 08

END-USER APPLICATIONS

FOR DRY TONER

Especially in small to medium-sized companies, a machine must fit into the company's overall portfolio. If the analysis shows that the emphasis is predominantly on the food segment, as well as the other segments like pharmaceuticals, wine & spirits, beverages and health & beauty, the dry toner process becomes the focus of a decision. The dry toner process with its solid polyester resin layer has its strengths in food safety, avoids cross-contamination of listed substances and ensures product safety in the important food and health & beauty segments. In the pharmaceutical segment, with 1,200 dpi print resolution, it meets the requirements for finest details, smallest reverses, colour consistency as well as the demands for counterfeit protection. When printing on structured papers such as wine labels, the dry toner process is superior to inkjet in terms of print quality. With press widths of up to 516 mm, it offers a high print volume and with this print width is also competitive with UV inkjet narrow web presses.

If further fastness properties are required in these segments, e.g. high scuff and scratch resistance, heat resistance or chemical resistance, these properties can be achieved by UV coating or film lamination. This also applies to the important criterion gloss. For this purpose the dry toner press can be supplemented with an inline or offline (UV) varnishing unit, otherwise inline or offline film lamination would have to be performed in a separate operation.

FOR UV-INKJET

If the focus of the portfolio is on durable labels, chemical labels, health & beauty or beverages, UV inkjet printing, with its process specific benefits, is the focus of a decision. Its strengths lie in its scuff and scratch resistance, heat and water resistance, resistance to chemicals, higher printing speeds (narrow web) and good light fastness properties. It is characterized by its high ink film thickness and high gloss, which largely eliminates the need for additional over coating.

Of course, UV inkjet printing can also be applied to print food applications and achieve conformity with the above-mentioned regulations or requirements of associations and brand owners. However, this entails a higher outlay, e.g. investment in inert conditions for curing the ink film, ongoing costs for nitrogen consumption and the need to document all printing parameters in the production process.

Another possibility is the use of a barrier film, which is laminated in a separate process step and prevents the migration of ink components into food. In this way, market segments that are not among the key markets can be covered.

COMPLEMENTARY SOLUTIONS

All this shows the complementary solutions offered by dry toner and UV inkjet printing in migration-optimised packaging printing. Both ink systems have their distinct strengths and clear application segments, but can also be used in an extended range of applications if required, and together they offer a robust portfolio of solutions that meets the needs of demanding end-user markets.

Certificates and declarations

Nestlé Standards on materials in contact with food (4.0.19/2016)
All monomers on Swiss Ordinance SR 817.023.21, Annex 10 part A list
Rest of the ingredients are also listed on the Swiss Ordinance SR 817.023.21 Annex 10
Compliant with Chinese National Food Safety Standard GB 4806.1-2016
Compliant with Chinese National Standard on Printing Inks GB 9685-2016
Nestlé Guidance Note on Packaging Inks (10/2018)
RoHS 3 compliant (Restriction of the use of certain Hazardous Substances)
Completely tin and Organo tin free
EuPIA Exclusion Policy compliant
FDA approved for direct food contact at room temperature with dry, non-fatty food
Sony Green List
REACH compliant
CONEG (Coalition of Northeastern Governors) compliant
Compliant with California Proposition 65
CPSIA (Consumer Product Safety Improvement Act) compliant
EPEA Cradle2Cradle compliant
Compliant with Directive 2009/48/EC on the Safety of Toys and the implementing standard EN 71-3
Compliant with Council of Europe Resolution AP(89)1
Compliant with ILFI Red List
Compliant with Packaging and Packaging Waste Directive 94/62/EC
Compliant with TSCA
Compliant with Decorative Wallcoverings standard EN15102

Free of
- Mineral oils
- PAH (Polycyclic Aromatic Hydrocarbons)
- Photo initiators
- Conflict Minerals
- Latex
- PAA (Polyacrylic acid)
- Allergens
- PFOA/PFOS (Perfluorooctance acid/Perfluoroctane sulfonic acid)
- Palm Oil
- Phthalates
- VoC

All statements are available on request. Just send an email to: xeikon.regulatory.affairs@flintgrp.com

**1 Sensory test in accordance with EN 1230-2 based on the assessment of a possible transfer of taste from paper and cartonboard intended for food packaging to a food or test medium via the gas phase.*
**2 from German AiF project no. 13040 N, operated by Fraunhofer IVV & FABES*
**3 After A. Feigenbaum et al., 'Functional barriers: properties and evaluation',Food Additives and Contaminants, Volume 22, Issue 10 (2005): 956-967*

ABOUT XEIKON

Xeikon is an innovator in digital printing technology. The company designs, develops and delivers web-fed digital color presses for label and packaging applications, document printing, as well as commercial printing. These presses utilize LED-array-based dry toner electrophotography, open workflow software and application-specific toners. Xeikon also manufactures basysPrint computer-to-plate (CtP) solutions for the commercial printing market. These proven CtP systems combine the latest exposure techniques with costefficient UV plate technology, high imaging quality and flexibility. For the flexographic market, Xeikon offers digital platemaking systems under the ThermoFlexX brand name. ThermoFlexX systems provide high resolution plate exposure including screening, color management, as well as workflow management.All the Xeikon solutions are designed with the overarching principles of profitability, quality, flexibility and sustainability in mind. With these guiding principles and a deep, intimate knowledge of its customers, Xeikon continues to be one of the industry's leading innovators of products and solutions.

For more information,
visit www.xeikon.com

Xeikon
Dr. Lode Deprez
VP Digital inks and Imaging Processes,
RA and IP, Xeikon
lode.deprez@flintgrp.com

XEIKON MANUFACTURING N.V.
T. +32 (0)3 443 13 11
Duwijckstraat 17 - 2500 Lier - Belgium
www.xeikon.com - info@xeikon.com

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