Ink drying and curing: the key to faster speeds, web handling and finishing

Jonathan Sexton
Sun Chemical
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a member of the DIC group

Color & Comfort

The world’s leading producer of inks, coatings and pigments

20,000+
Employees

176
Subsidiaries

63
Countries

Driving the future of innovation

17
R&D locations

2
average number of patents filed per month by Sun Chemical

$100M
per year invested in R&D
Contents

• How do inks dry?
• Modern drying systems
  • Conventional sheetfed drying
  • Conventional forced air drying
  • UV drying
  • EB drying
• Future – UV LED
• Assuring sufficient UV curing
• Summary drying system choices
Printing – how it was....

Good ink drying was not really critical!
## Modern drying for labels and packs

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Diverse print and drying possibilities for labels
Why do we need to dry ink?

• Avoid set off – degraded print quality, source of ink migration
• Mechanical resistance for rapid post print processing and handling
• Optimise adhesion
• Stabilise ink and coating film properties; gloss, slip etc
• Achieve the lowest print odour and ink component migration potential – legal requirement for food
Traditional sheetfed offset ink drying

**Initial setting by penetration** (physical)

- Separation of liquid and solid ink components
- Film formation by “internal melting”
- Slight evaporation for 1 - 2 days after printing

**Oxidation of ink vehicle** (chemical)

- Reaction of oxygen with double bonds
- Polymerization to a 3-dimensional network
- Uncontrolled break of reactive chains (odour !)

Setting rate influenced by:
- Absorbency of the paper
- Paper coating properties
- Ink viscosity and formulation

Ink film

Paper

O₂↓

O₂↓
Reel to reel/web drying mechanisms

Conventional Forced Air

Energy or Radiation Curing

Filmweight after drying = applied filmweight (some shrinkage..)
Ink filmweights – web printing

**Solvent based gravure ink**
- % solid in film = 25 %
- Wet filmweight = 3 - 4 g/m²
- Dry filmweight = 0,8 - 1 g/m²
- Viscosity = 0,05 - 0,2 Pas

**Water based flexo ink**
- % solid in film = 50 %
- Wet filmweight = 1-3 g/m²
- Dry filmweight = 0,8 - 1 g/m²
- Viscosity = 0,2 - 0,5 Pas

**EB/UV curing offset ink**
- % solid in film = 100 %
- Wet filmweight = 1 - 1,7 g/m²
- Dry filmweight = 1 - 1,7 g/m²
- Viscosity = 10 – 20 Pas

**EB curing flexo ink**
- % solid in film = 100 %
- Wet filmweight = 1 - 2,5 g/m²
- Dry filmweight = 1 - 2,5 g/m²
- Viscosity = 0,5 - 1,0 Pas

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EC inks 100% solids and higher viscosity
Solvent based printing, gravure and flexo

Long established and most widespread process for flexible packaging and labels

- **Cost effective** for long run lengths
- High print quality, particularly gravure
- Suitable for **multiple substrates/applications**
- Low ink cost/kg

But....

- They present a management control **risk** due to high volume of **flammable solvents**
- Regulatory and environmental pressure to reduce **VOC’s**
- Gravure uneconomic for short runs (repro cost)
- Need to control solvent retention
Water based printing

Widely used for label printing on paper, particularly in North America

**Problems**
- It is harder to evaporate water than solvent (2.5 slower than EtOH, 6 times slower than EtAc)
- Older dryers are not powerful enough
- Conflict between fast-drying and easy-cleaning

**Side-effects**
- Lower achievable press speed, especially if large superimposed solids
- Condensation on cold parts/corrosion

**Solutions**
- More concentrated inks allow less thickness
- Air flow optimisation / insulation of coolest parts of air piping

**To go further:**
- Set heat and air flow deck-by-deck
- Take humidity into account to maximize speed

<table>
<thead>
<tr>
<th>Intake air temperature</th>
<th>21°C</th>
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<tr>
<td>RH of intake air</td>
<td>30%</td>
<td>50%</td>
<td>90%</td>
</tr>
<tr>
<td>Air temp required for same drying time</td>
<td>65°C</td>
<td>74°C</td>
<td>82°C</td>
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High quality and productive printing possible with process optimisation
Energy curing - why?

- Dry prints off-press, immediate processing
  - Reduction in work in progress and space requirements
- No spray powder required in sheetfed
- No solvent emissions
  - Environmental benefit
- What you print is what you get
- Ink system remains open on press almost indefinitely
- Improved adhesion to some substrates
- High quality and resistant finish
- Small foot-print/space for drying equipment
How UV and EB Inks Cure

Wet ink

“Dried” or cured ink

EB radiation

Or

UV Radiation + photoinitiator

« Acrylate » chemical groups

Small liquid molecules

Liquid mixture; monomers, Pre-polymers etc

Large interconnected molecule

Polymer

Instant cure, solid and resistant ink film
What Is Ultra Violet (UV) Energy?

UV light is a type electromagnetic radiation emitted at shorter wavelengths than visible light. This carries energy and momentum, which may be imparted when it reacts with matter. The fundamental entity that carries this energy is called a photon.
UV Wave Length Output

UVC surface cure - lost first when lamps deteriorate

UVA through cure

UVC 200-280nm
UVB 280-315nm
UVA 315-400nm
How UV light is generated

Typical construction of medium pressure mercury lamp

- Metal or ceramic end-fitting
- Bead of mercury
- Fused silica quartz
REFLECTORS – the challenge

- 360° energy radiation
- 25% directly incident on web
- 75% potentially wasted
  - Reflector’s job to recover

Need to look after reflectors – critical to drying!

Courtesy GEW
What is Electron Beam curing?

- Vacuum Chamber
- Repeller (80–125 kV to >300kV)
- Filament
- Titanium Window
- Electron e- Strahl (Radiation dose 25 – 30+ kGy)
- Inert Atmosphere
- Coating / Ink
- Substrate
EB curing – key characteristics

• Fast Curing, up to 400m/min (usual limit of standard EB units)
• Robust process (GMP); automatically adjusts power to web speed
• “Cold” process but can effect films (odour, colour, seal temp.)
• Curing not affected by colour or print density
• Electrons can penetrate deep into printed structures, cure through substrates not an issue, adhesion can be improved
• Cure inhibited by oxygen; nitrogen inverting essential and reduces print odour
• Ideally suited to “wet on wet” web printing with curing at end of press
• Ink film low odour, low migration (no UV PI)
Light Emitting Diodes (LED’s)

How it works…..

- Uses silicon based semi-conductor technology.
- Two differently doped semiconductor materials are used, one that adds electrons (n-type) or one that has holes that attract electrons (p-type).
- When current is applied the holes and electrons migrate to the p-n region junction, combine and emit a photon.
- Photon wavelength is determined by the energy required for electrons to flow across the gap, which is affected by the dopants used.
“Low energy” UV curing – technology drivers

• Perceived environmental benefits
• Increasing regulatory pressure on Mercury lamps (RoHS)
• Energy saving
• Zero ozone generation by UV LED’s and doped mercury lamps removes need for air extraction
• Operational efficiency (on-off without warm up for LED)
• Advantages of UV over conventional inks in sheetfed, low investment cost in low energy Hg mercury lamps
  – Fast turn around
  – Lower work in progress
  – Spray powder elimination
UV lamp types

• High Pressure Mercury UV lamp
  • More powerful in shorter wavelength areas
  • Effective for surface cure
  • Effective for clears

• Metal halide type UV lamps (eg H-UV)
  • More powerful in longer wavelength areas
  • Effective for depth cure
  • Effective for colour inks and whites

• LED-UV Lamp
  • 365nm, 385nm, 395nm single peak
  • Long (close to visible) wavelength area
  • Strong UV intensity (vs. electric-discharge tube)

No ozone generation with Halide lamps or LED’s
LED Technology characteristics

• Light only produced at target wavelength – no wasted spectrum
• Limited choice of ink photo-initiators aligned with existing wavelengths
  • In particular for coatings and food compliant inks
  • Need to use more PI - inks more expensive
• No shortwave UV ; no ozone
• No infra red emission so no heat generation in front of the lamps
  • Low impact on sensitive substrates, but heat from Mercury UV lamps can help cure rate
• Peak intensity reducing with distance to the print ; focusing used in sheetfed
• Long lifetime (~20k hours +) ; Stable spectral output over time
• Instant on/off, modular capability
• Low maintenance ; no reflectors, only window to keep clean
Ink formulation status

• Very specific wavelengths – not many photo-initiators absorbing well
  – High level of initiator required due to weaker and mis-aligned light source
• Commercial and non-food packaging applications most common today but availability of inks for food packaging improving rapidly
• Sufficient curing requires a very reactive vehicle
  – Can lead to brittle ink film which can effect adhesion of plastics
• Difficult to obtain a tack free surface (no short wavelengths)
• LED Inks and varnishes are more susceptible to cure by ambient light
  – Need to shield ink ducts, keep containers closed
• Challenge to formulate coatings – yellowing

Challenges for ink makers!
Understanding UV and LED curing

Wavelength
Peak irradiance
UV power (Watts)
Dose (Joules/cm$^2$)
Dwell time

Dose \(=\) irradiance \(\times\) dwell time

Dose \(=\) 2 W/cm$^2 \times 2\) sec.
Dose \(=\) 4 Joules /cm$^2$

Not just one parameter is important in system selection!
Peak Irradiance (intensity)

B higher peak intensity but lower total power than A

Courtesy Phoseon
UV curing performance

Curing Performance

- UV Intensity
- Thermal Footprint
- Ink Properties

UV Dose

All aspects of the curing equation must be balanced and well understood to optimise curing performance

Courtesy GEW
Thermal Footprint is also critical for effective curing

Low Temperature
Less Collisions
Slow Curing

High Temperature
More Collisions
Faster Curing

But…
Too high substrate temperature can result in wrinkling, warping and other issues

Thermal Footprint must be optimised for each application

Quartz windows used to control heat can affect UV cure
LEDs with lower frontal heat output can affect UV cure

Courtesy GEW
Key factors in LED system selection

• Physical space in the press
• Determine the irradiance (intensity) threshold to achieve a minimum required curing level
• Test at various line speeds and thus dose to determine optimal curing dose
• Optimise the distance from source to print which may have an effect
• Talk to your ink and equipment supplier!

LED has advantages but must be carefully specified and will not be the best choice in every case
Controlling UV cure

• Correct drying and curing is vital in all drying processes and particularly UV
• Ensures press productivity and final label quality
• Appropriate specification of drying and curing equipment is critical
• All drying systems need regular maintenance and monitoring; for UV:
  • Regular cleaning of reflectors
  • Verification of UV energy level at the print surface
  • Replacement of lamps at prescribed intervals and before degradations affects print quality or productivity
UV dose monitoring

Test strips – simple and practical to attach to a web for approximate dose

Dose measuring « pucks » ; for horizontal curing conveyers
Not suitable for web presses

UV lamp dose monitors, ideally installed in front of the lamp, temporary or permanent installation
Press-side UV cure assessment

Cure level can be determined by analytical techniques, but a variety of simple tests can be performed by the press;

Through cure

- Solvent rubs
  - MEK or Acetone for EB & UV coatings
  - IPA for EB & UV Inks
  - Comparative number of rubs

- Thumb twist test

- Rub test against substrate (FINAT test FTM 27)

Surface cure

- Scratch (also check gloss and slip....)

- EB & UV coatings and whites - KMnO4 stain (FINAT test FTM 30)

- Adhesion Test- Tape test (FINAT test FTM21/22)
FINAT project on UV curing for food packaging

- **UVFoodSafe** is a cross industry group of businesses and industry stakeholders managed by FINAT (the European association for the self-adhesive label industry)

- **UVFoodSafe** is investigating the important parameters in controlling UV cure and their relationship to final migration performance as well as developing best practice guidance

- Practical experimentation and best practice guidance development is underway and final conclusions and content will be presented in early 2020

**Vision Statement**

"To create confidence within end user and converter communities in the use of UV printing in food packaging and labels through education and the provision of application specific best practice, enabling the consistent delivery of compliant print to the market.”
Drying system choice is influenced by many factors and must satisfy multiple criteria to meet market needs.
Drying system choices

Water-based flexo / gravure inks are a good low cost option for lamination and can be printed on existing presses.

WetFlex EB Flexo specifically offers gravure quality high speed printing and is an “Ultra Press friendly” solution.

Electron Beam water-based versions are required for surface print with good resolubility.

UV flexo offers the widest flexibility in press format, ink products, and applications.

Electron Beam offset is the best option for fast turnaround / short run with low cost plates based on the extended gamut concept.

UV offset is the longest established process for solvent free printing and with low cost plates.

Not forgetting digital......UV, EB Injet, Toner,

Multitude of process choices today for label and packaging printing ; talk to your suppliers !
Thank you for your attention

Questions

With thanks to GEW and Phoseon for kindly contributing content