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

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17
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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

Print Process	Drying processes	Principal applications
Sheetfed offset	Absorption/oxidation, UV	Wet Glue Labels, Cartons
Web offset (litho and waterless)	UV, EB, Heatset	PS, Shrink and Wet Glue Labels, Cartons, Flexible Packaging
Letterpress/dry offset	Absorption/oxidation, UV	Wet Glue Labels, PS Labels
Flexo	Air/evaporation, UV, EB	PS Labels, Flexible Packaging, Cartons
Gravure	Air/evaporation, UV	Flexible Packaging
Screen	Oxidation, Air, UV	PS labels, speciality packaging
Digital toner	Heat fusion	PS, Shrink and Wet Glue Labels, Cartons, Flexible packaging
Digital inkjet	UV, EB, Air/evaporation	PS, Shrink and Wet Glue Labels, Cartons, Flexible Packaging

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

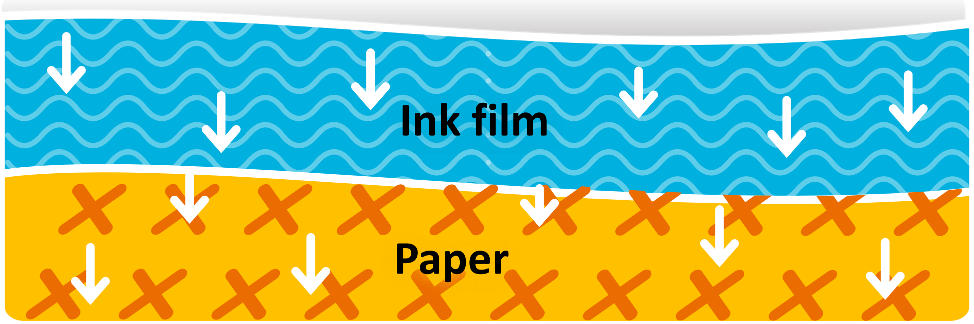
Initial setting by penetration (physical)

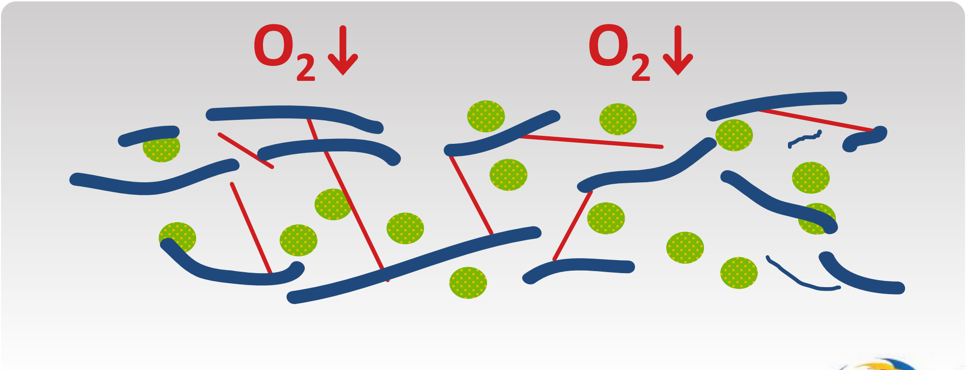
- Separation of liquid and solid ink components
- Film formation by "internal melting"
- Slight evaporation for 1 - 2 days after printing

Oxidation of ink vehicle (chemical)

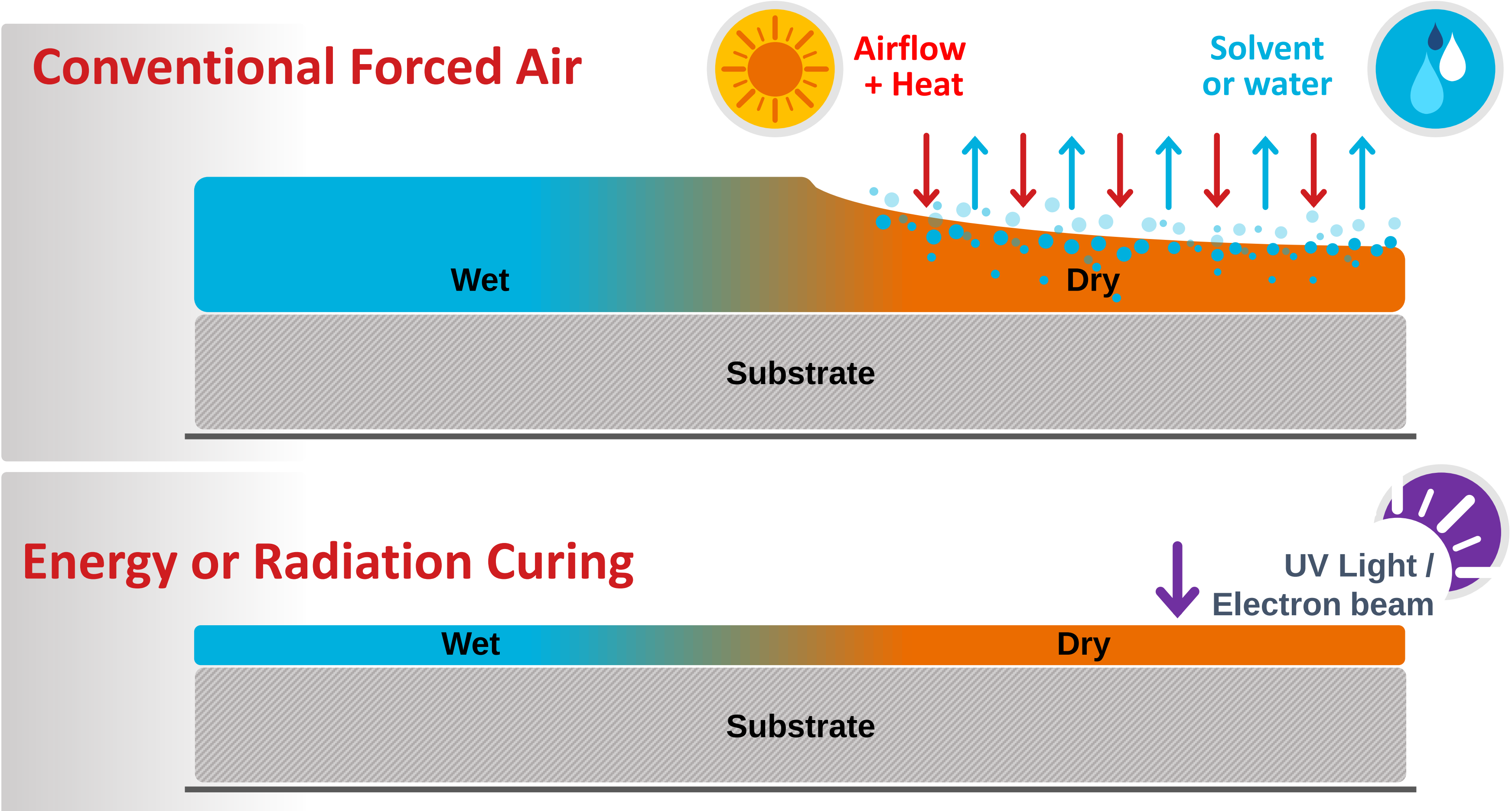
- Reaction of oxygen with double bonds
- Polymerization to a 3-dimensional network
- Uncontrolled break of reactive chains (odour !)

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





Reel to reel/web drying mechanisms



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

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

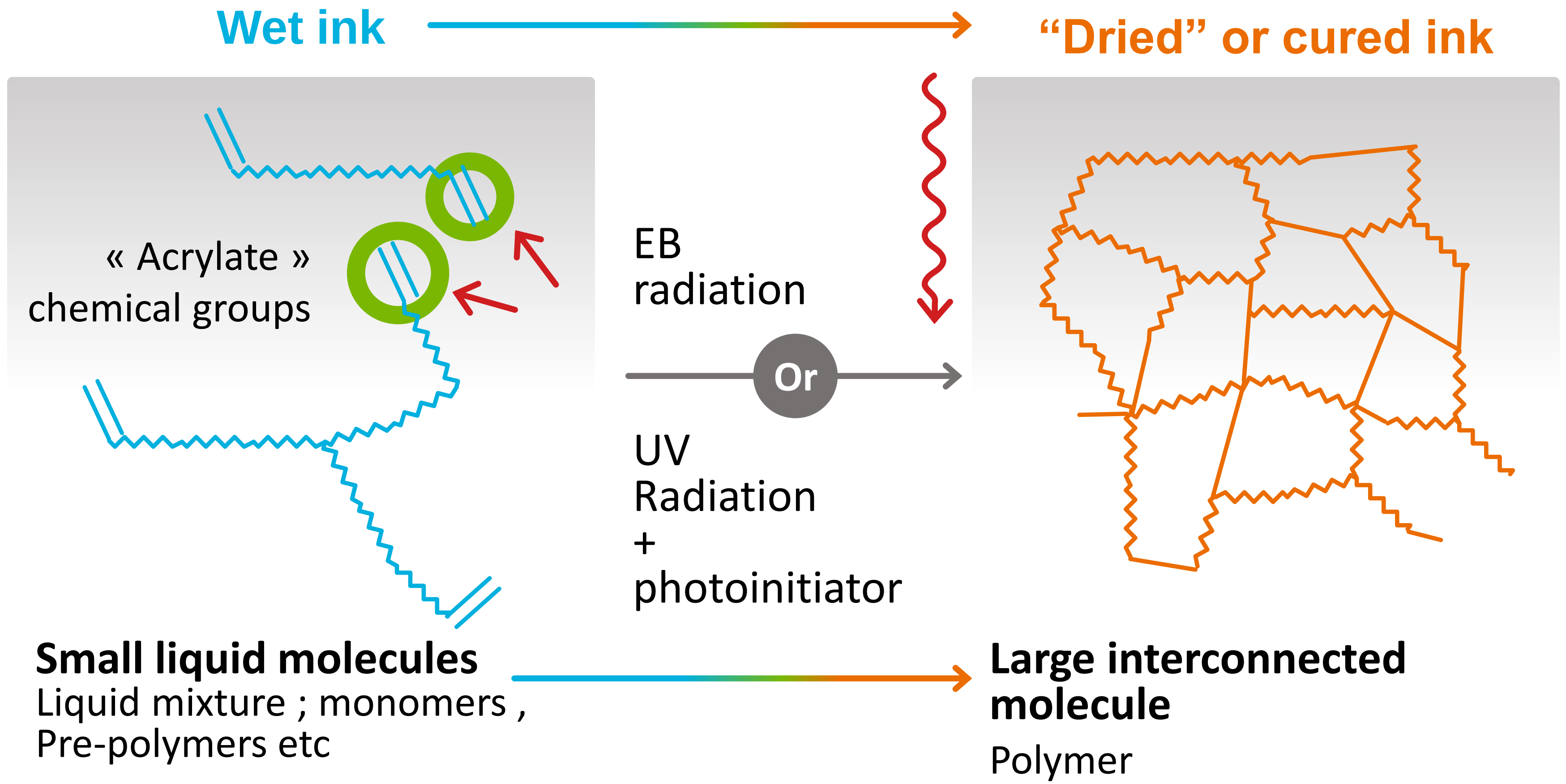
Intake air temperature	21ºC	21ºC	21ºC
RH of intake air	30%	50%	90%
Air temp required for same drying time	65ºC	74ºC	82ºC

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

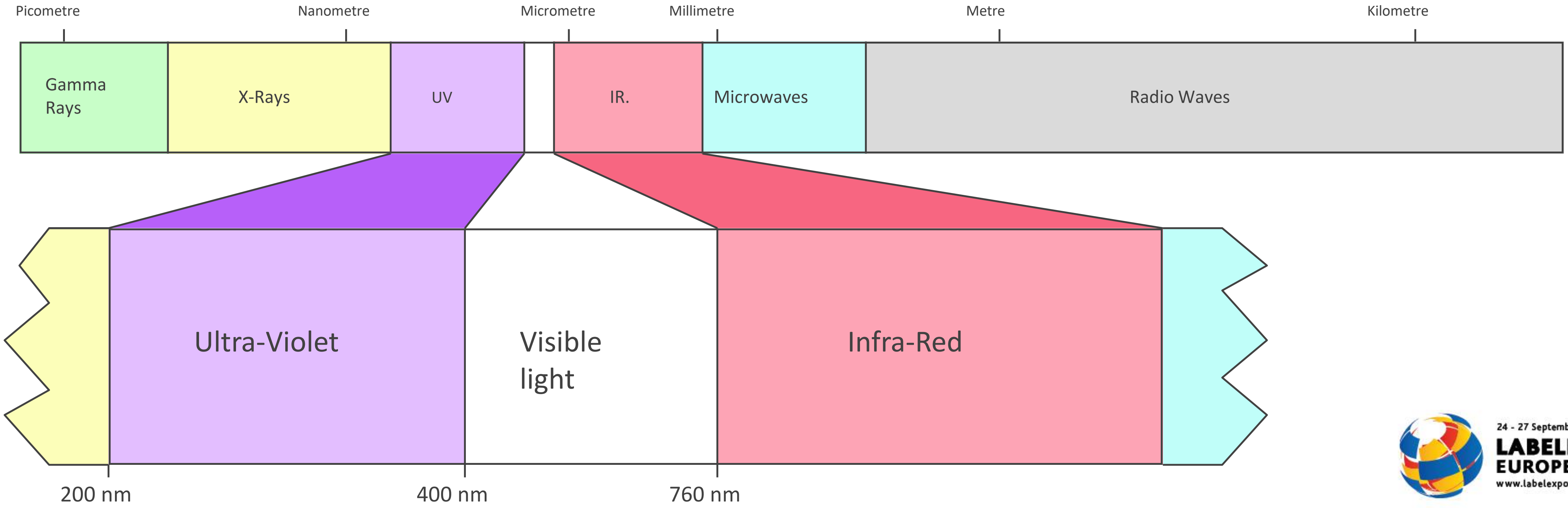
How UV and EB Inks Cure



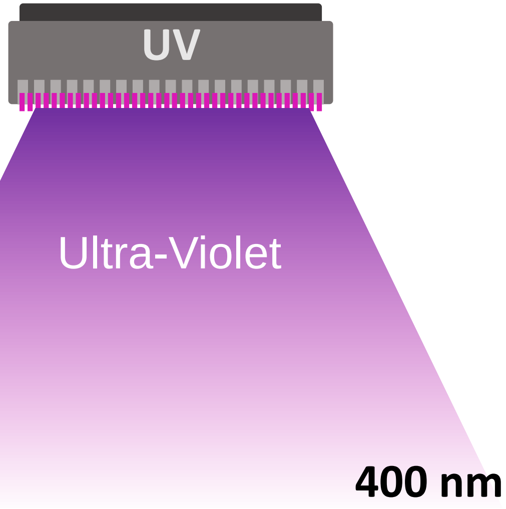
Instant cure, solid and resistant ink film

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

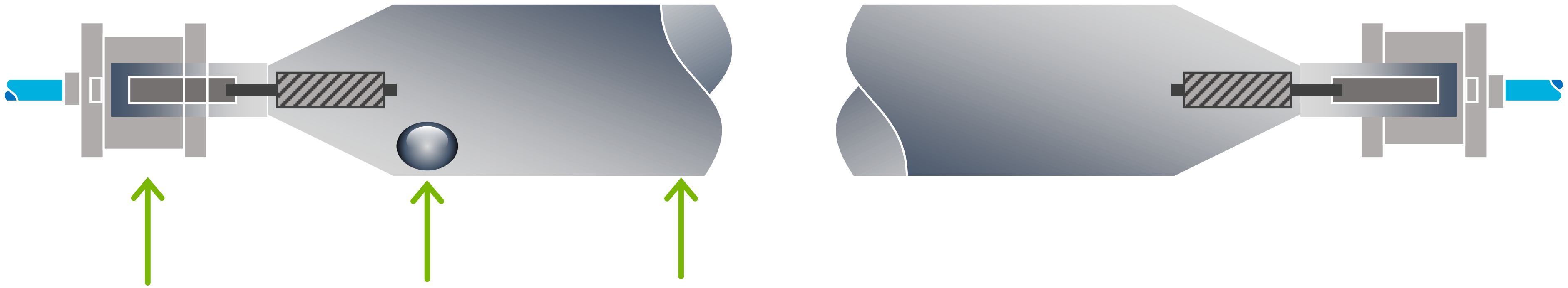
200 nm

400 nm

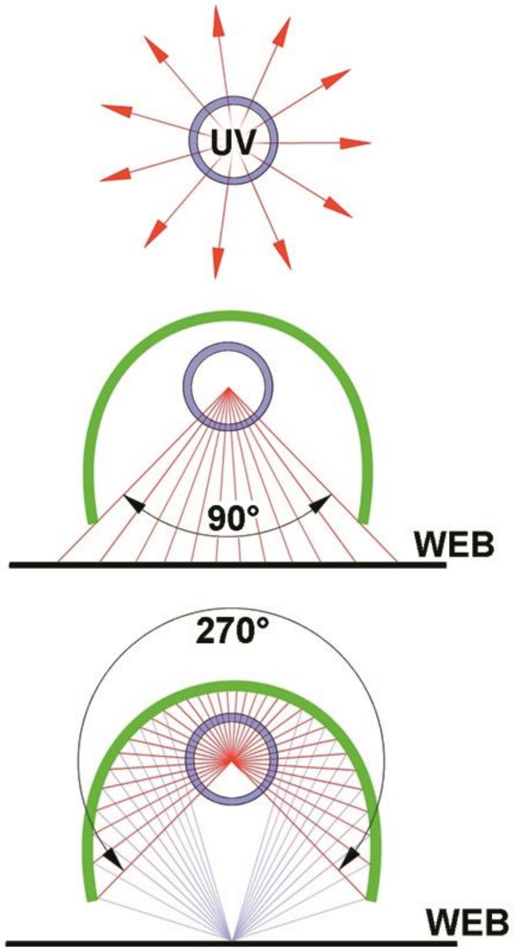
UVC **200-280nm**	**UVB** **280-315nm**	**UVA** **315-400nm**

How UV light is generated

Typical construction of medium pressure mercury lamp



REFLECTORS – the challenge

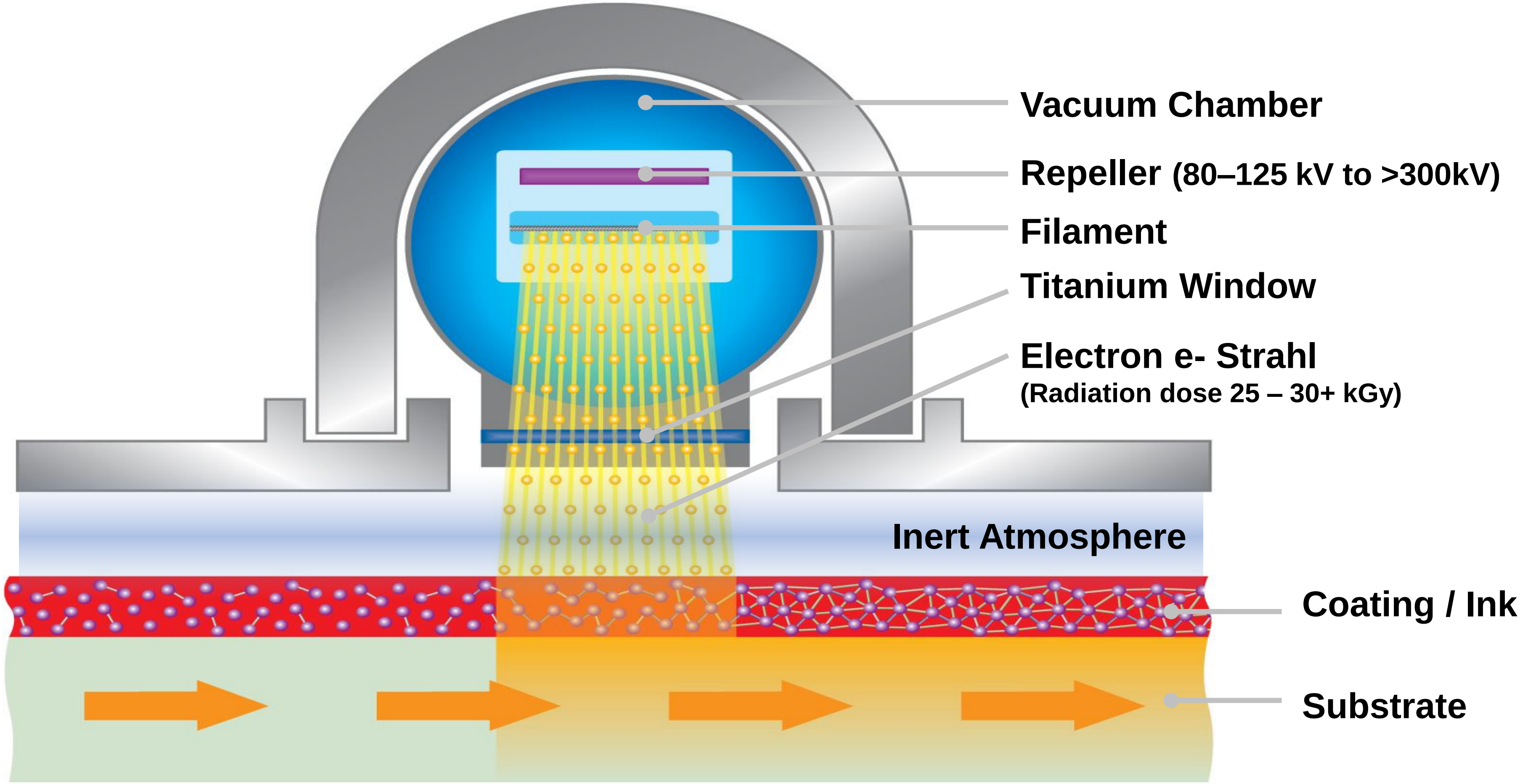


- 360°energy radiation
- 25% directly incident on web
- 75% potentially wasted
  - Reflector's job to recover

Courtesy GEW

Need to look after reflectors – critical to drying !

What is Electron Beam curing ?

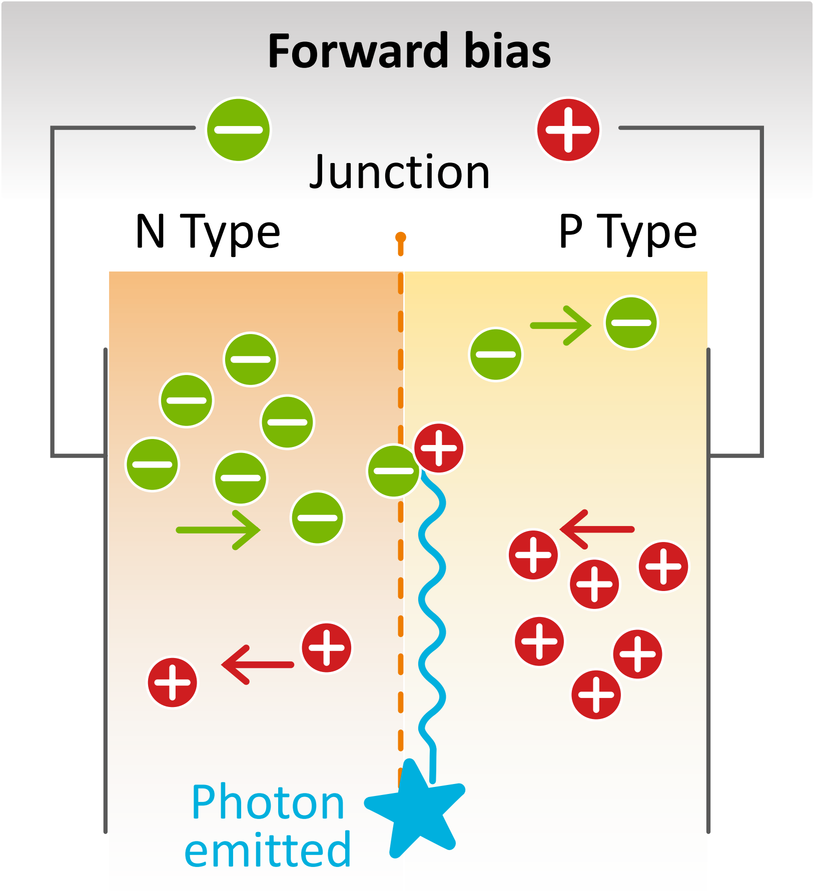


EB curing – key characteristics

- 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 inerting 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

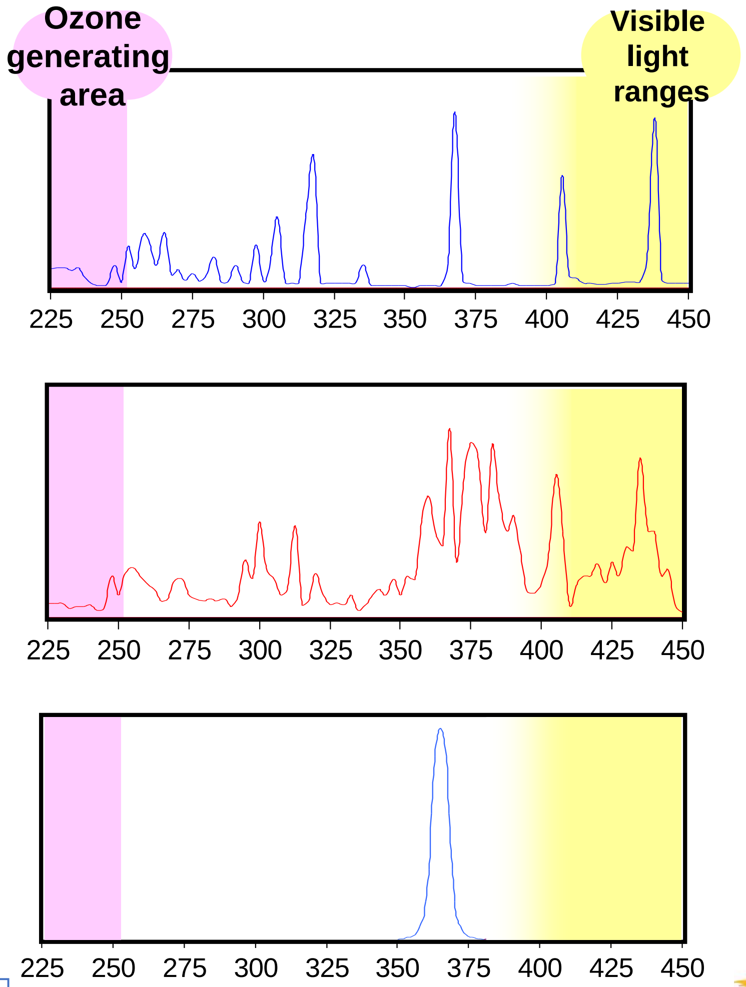
- Perceived environmental benefits
- Increasing regulatory pressure on Mercury lamps (RoHS)
- Energy saving
- Zero ozone generation by UV LED’s and doped mercury lamps removes need for air extraction
- Operational efficiency (on-off without warm up for LED)
- Advantages of UV over conventional inks in 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

Different types can be installed on the same press

- 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)



X-axis : Wavelength (nm) Y-axis : Relative Energy (%)

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

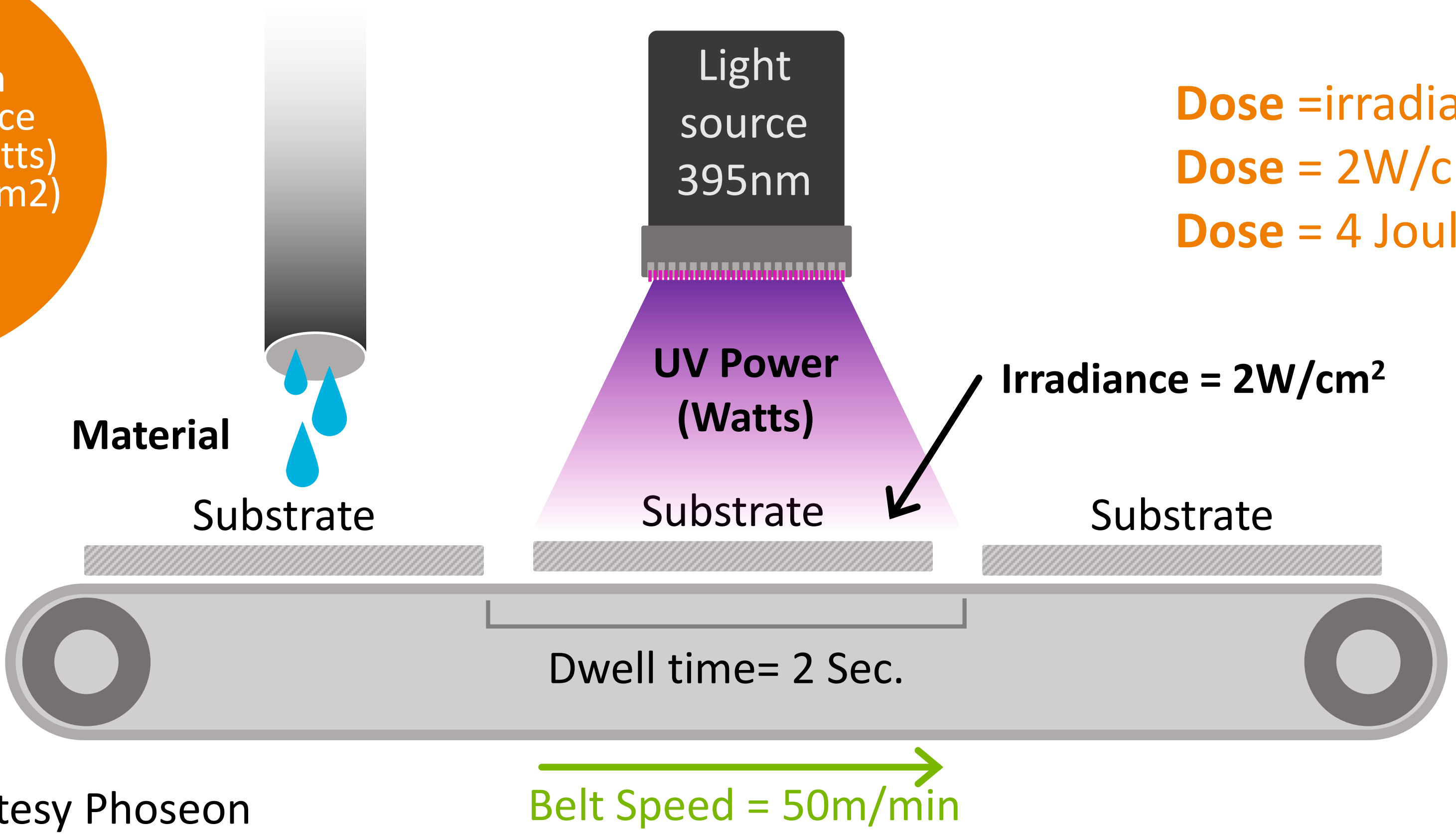
Ink formulation status

- 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/cm2)
Dwell time

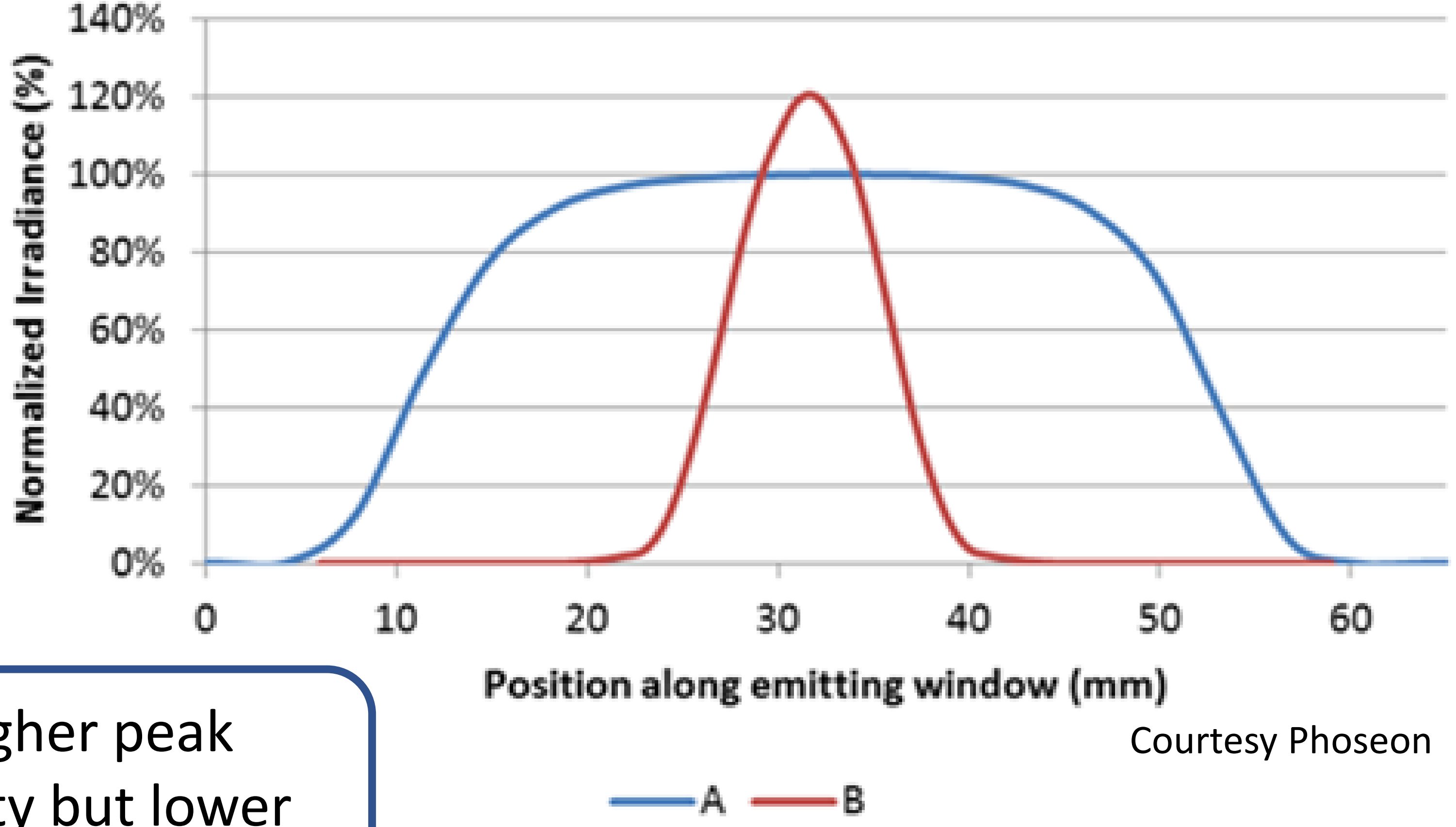


Dose =irradiance x dwell time
Dose = $2W/cm^2$ x 2 sec.
Dose = 4 Joules $/cm^2$

Courtesy Phoseon

Not just one parameter is important in system selection !

Peak Irradiance (intensity)



Courtesy Phoseon

B higher peak intensity but lower total power than A

UV curing performance

UV Intensity

Thermal Footprint

UV Dose

Ink Properties

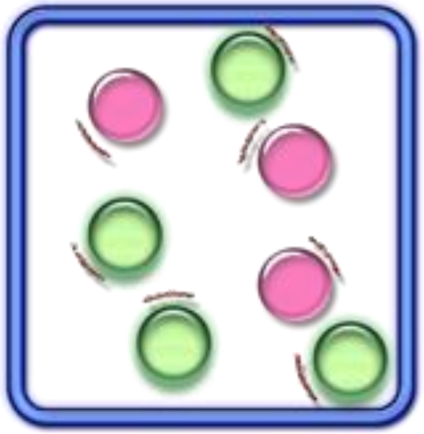
Curing Performance

Surface Cure
Adhesion
Gloss
Dot gain
Migration
etc.

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

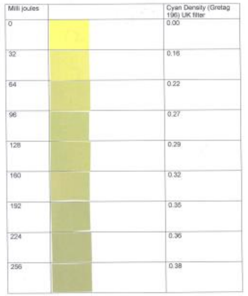
- Physical space in the press
- Determine the irradiance (intensity) threshold to achieve a minimum required curing level
- Test at various line speeds and thus dose to determine optimal curing dose
- Optimise the distance from source to print which may have an effect
- Talk to your ink and equipment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



Milli joules		Cyan Density (Gretag 196) UK filter
0		0.00
32		0.16
64		0.22
96		0.27
128		0.29
160		0.32
192		0.35
224		0.36
256		0.38

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 perform 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."

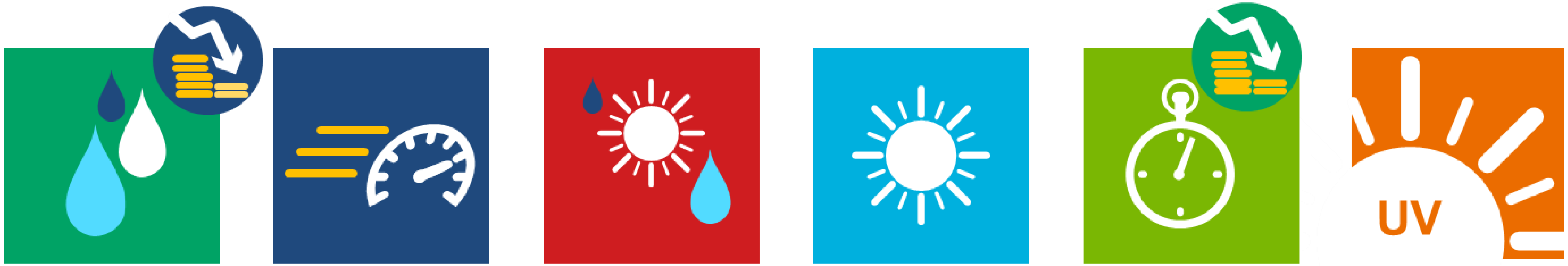
UVFoodSafe GROUP Powered by FINAT

FINAT Linking the Label Community

Summary – ink drying

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