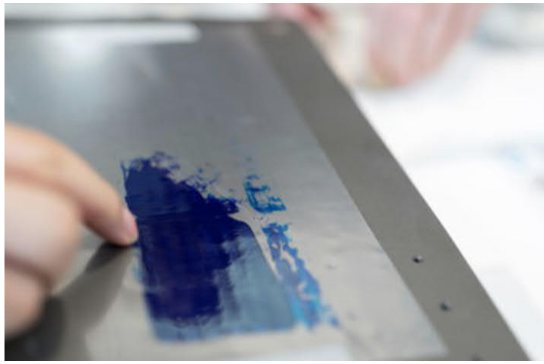

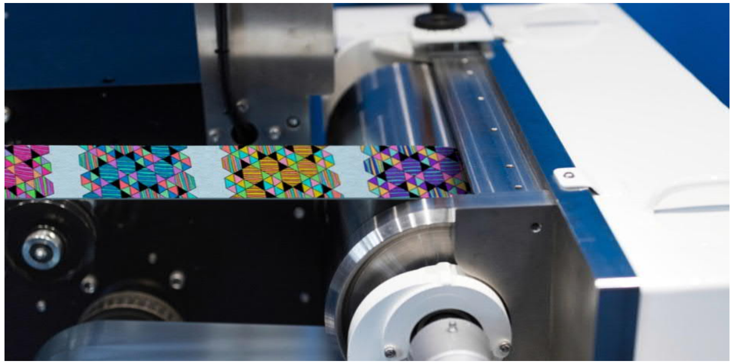

ebeam Technologies

Curing with Electron Beam

2-Week Training School for the CI programme on Accelerators for Security, Health and Environment (ASHE)

List of Contents

Disclaimer

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It is not intended to promote any specific company, brand, product or service

Some (personal) Definition

Curing is the polymerization of a (EB) reactive coating to a solid polymer film

EB Curing
Some history and applications

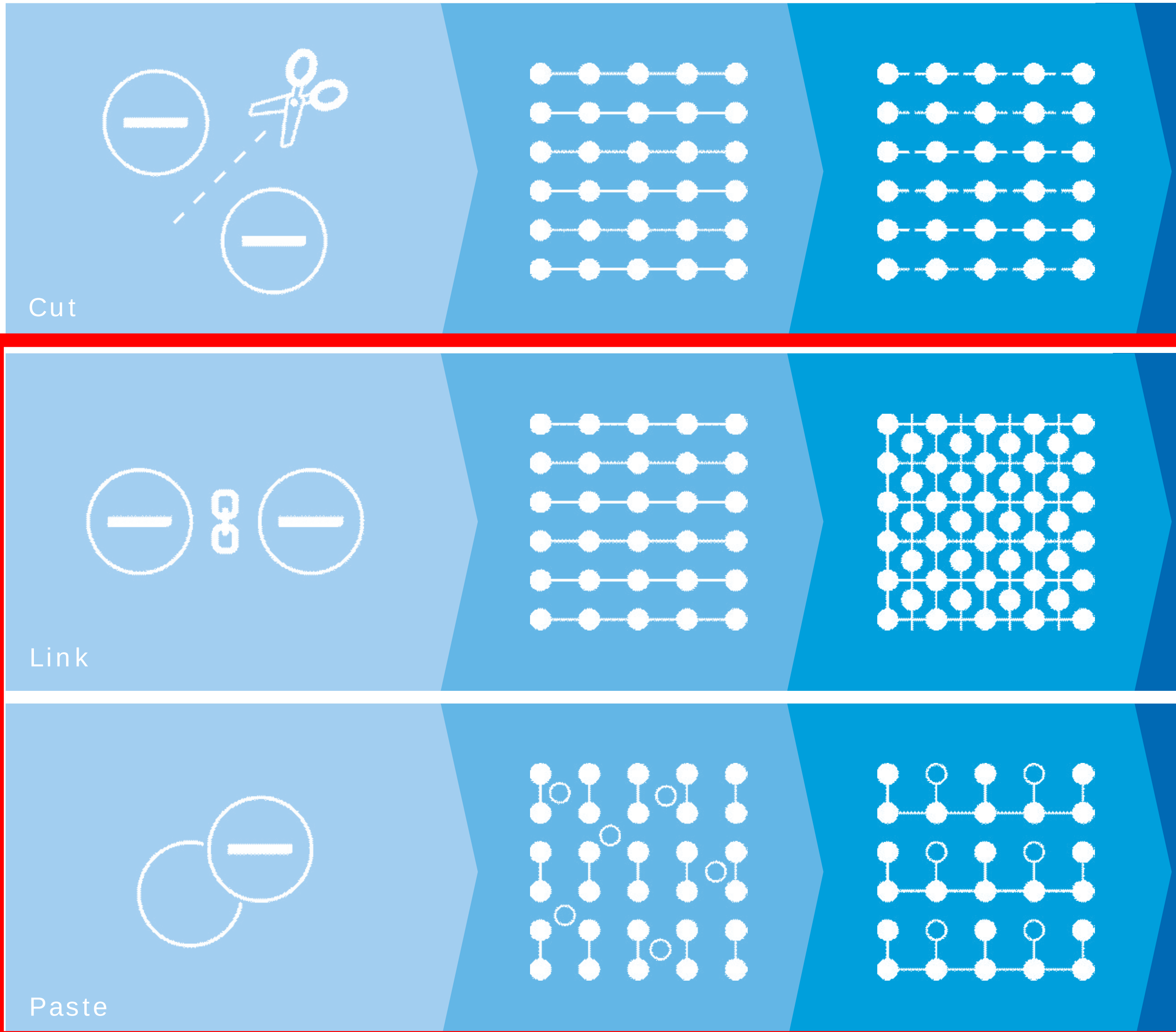
ebeam creates radicals

in any organic material

How ebeam works

The 3 effects
Get radical

Break a bond
and then ...



... leave it broken

Example: Sterilization

... let it bond to itself

Example: cross-linking of packaging material and cables

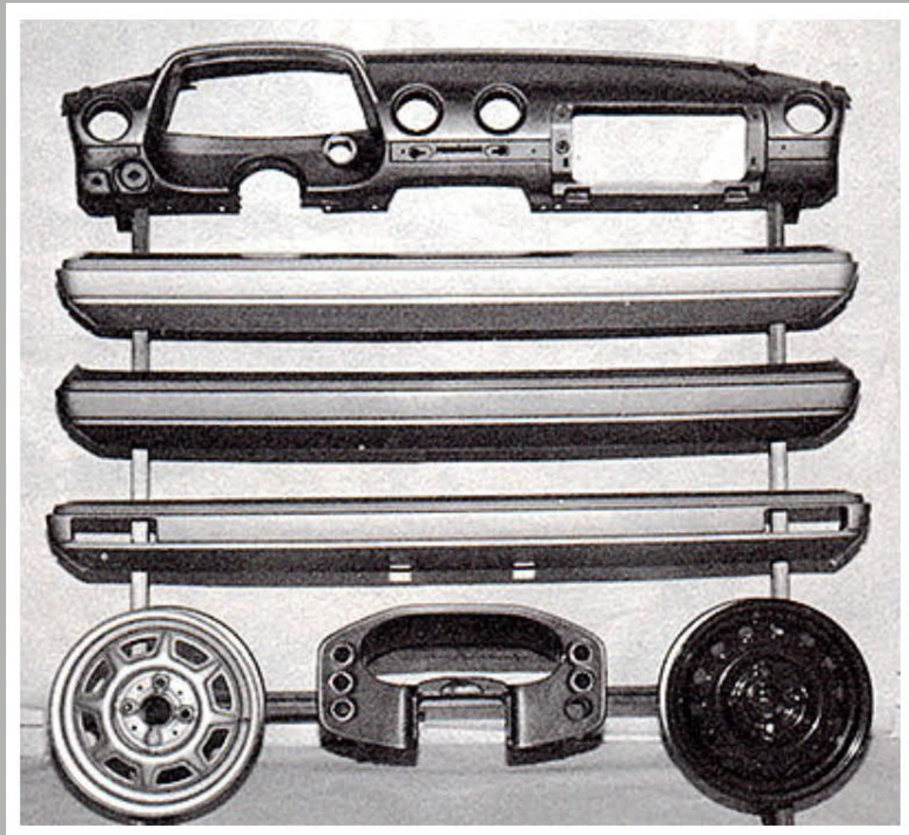
... let it bond to something else

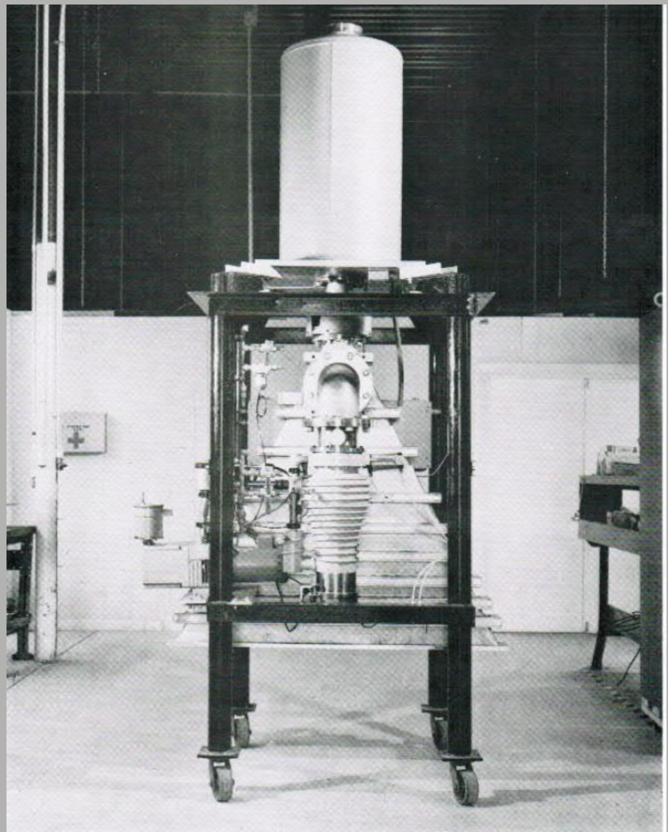
Example: Reactive compounding, grafting of biocompatible materials on membranes

ebeam

Industrial history of Electron Beam

History





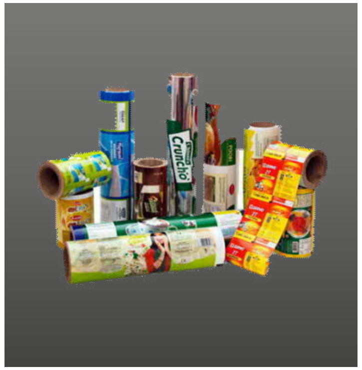
First Investigation : 60ies

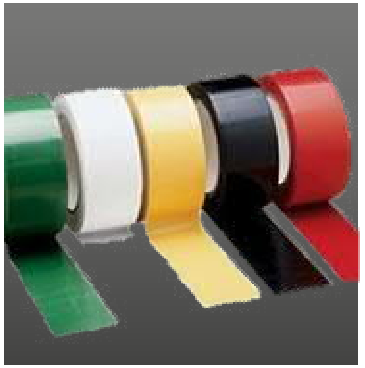
Inks Curing

Varnishing

Structure and Pattern Surfaces

Furniture Foil





Lamination

Hydrogels

Adhesives

(Past)
Magnetic Media

ebeam Applications

Hall of Fame

ebeam Printing

Printing Applications

Juice/milk

Detergent

In mold

Pouches

Shrink sleeve

Wrappers

Pet food

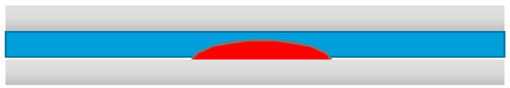
Other

Main Applications of Curing

Inks

Lamination Adhesives

Varnishes and Coatings



More than inks/coatings

The different modes of ebeam in Converting

Film Crosslinking

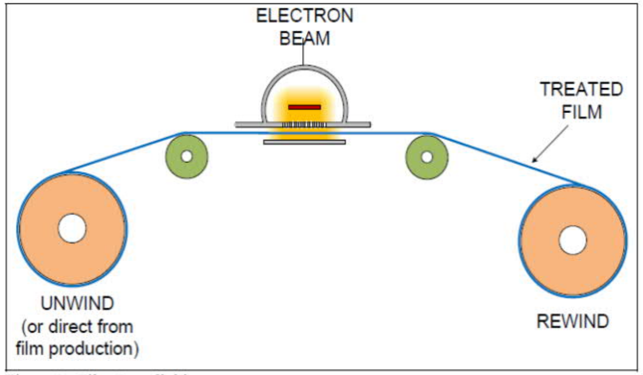


Figure 2. Film Crosslinking

Direct Coating/Printing

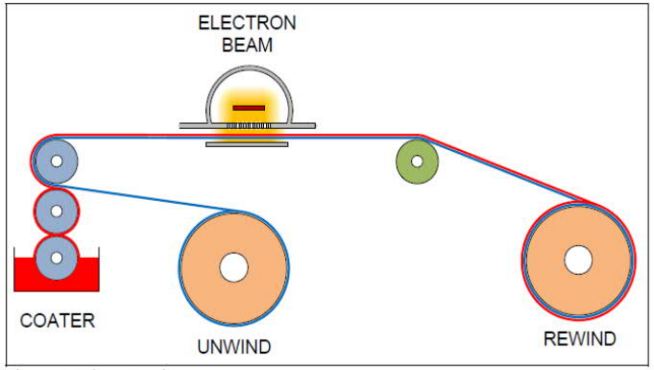


Figure 4. Direct Coating

Adhesives

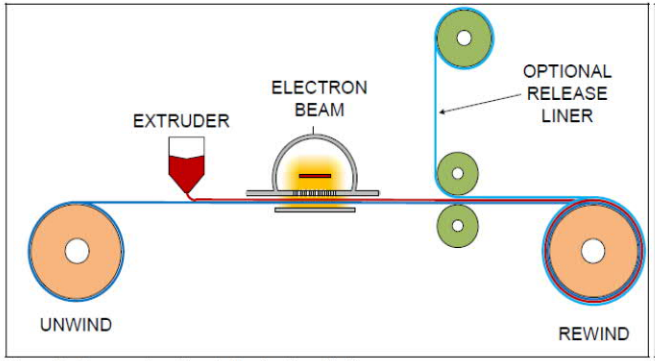


Figure 3. Pressure Sensitive Adhesive Crosslinking

Lamination

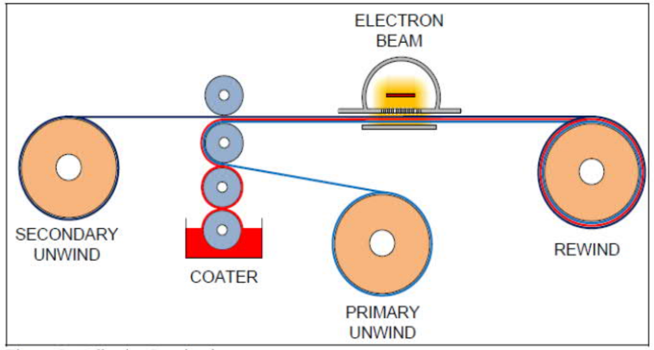


Figure 5. Adhesive Laminating

More than inks/coatings

The different modes of ebeam in Converting

Transfer Coating

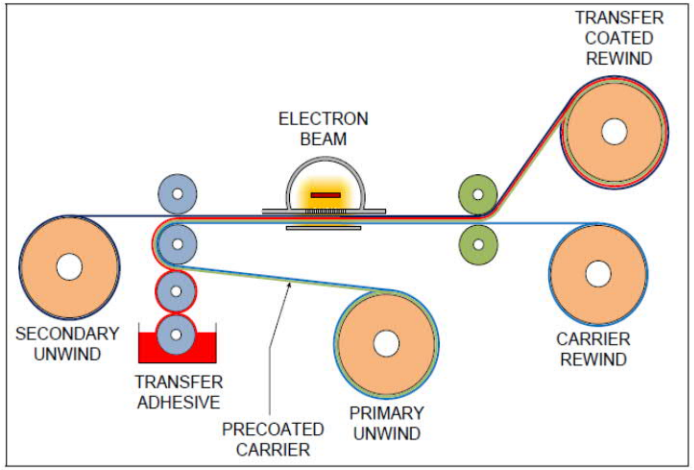


Figure 6. Transfer Coating

Backside Embossing / Pattern Transfer

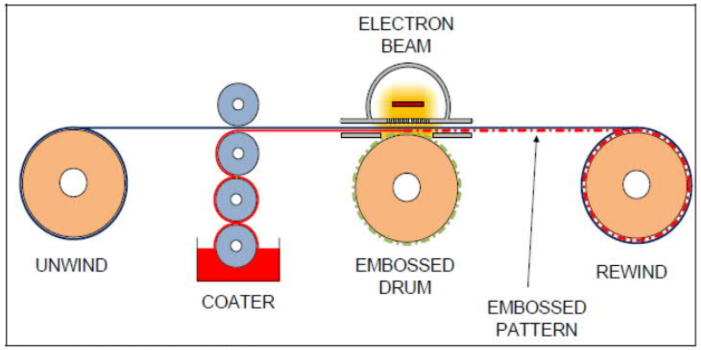
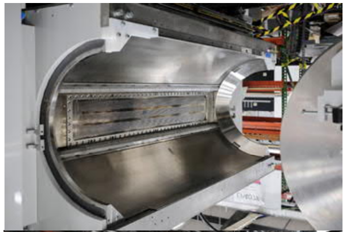


Figure 7. Backside Embossing

Linear Cathode «Curtain Type» Beam (<300kV)	Scanning Beam (mainly <500kV)



Linear Cathode «Curtain Type» Beam (<300kV)

- Widths from 0.25m to 3m
- Voltage from 80-300kV
  (Printing / Curing typical 80-125kV)
- Current from 20mA to 2000mA (typical ~800mA)
- Uniformity +-8% typical

Mainly used in high throughput

Scanning Beam (mainly <500kV)

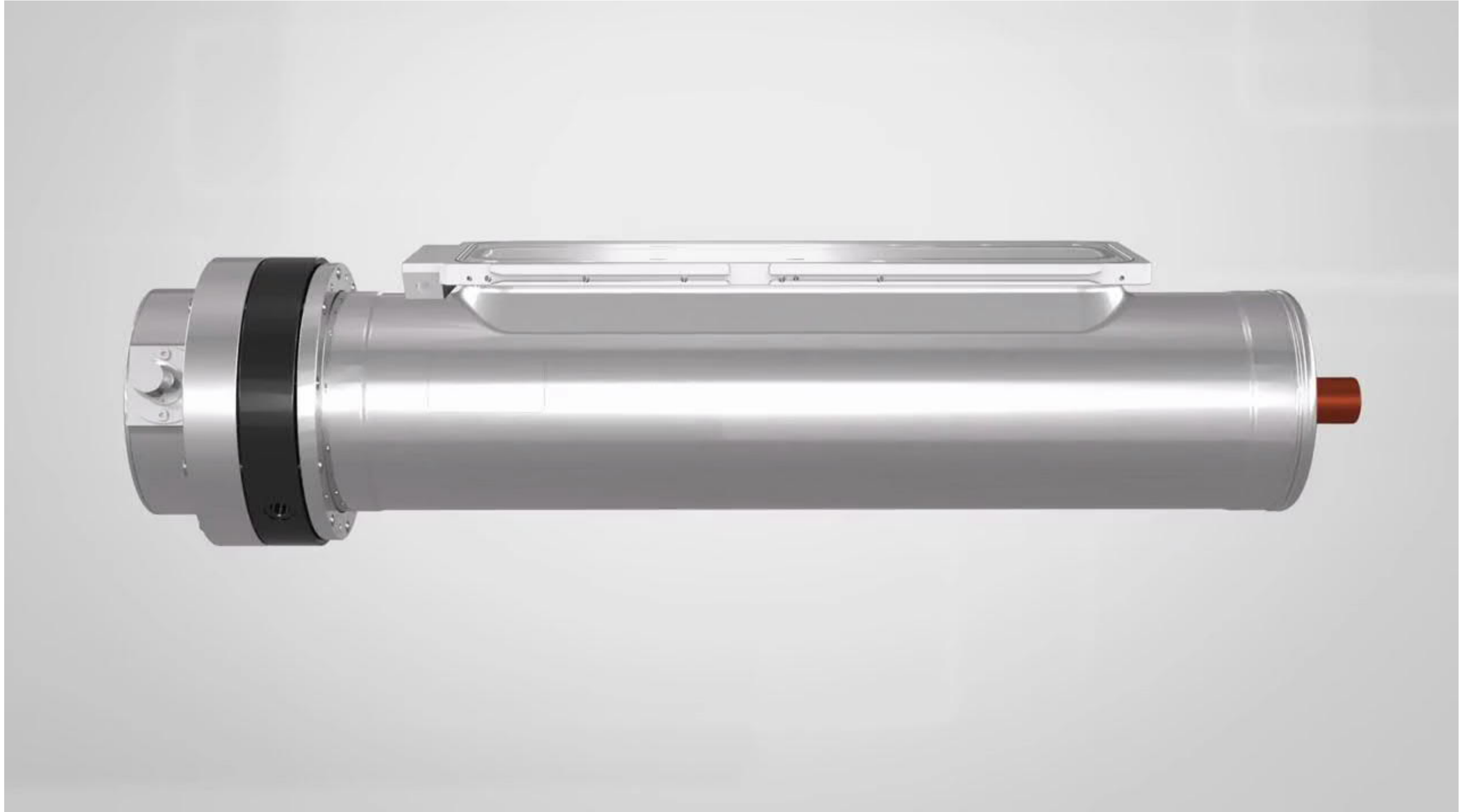
- Widths from 0.25m to 2 m
- Voltage from 80-300kV
  (Scanners not used in Printing)
- Current from 20mA to 200mA
- Uniformity better than 5% (better possible)

Mainly used in wood panels and high uniformity requirements (Adhesives)

Drying Methods and where EB stands in that landscape

Introduction

What is electron beam technology?

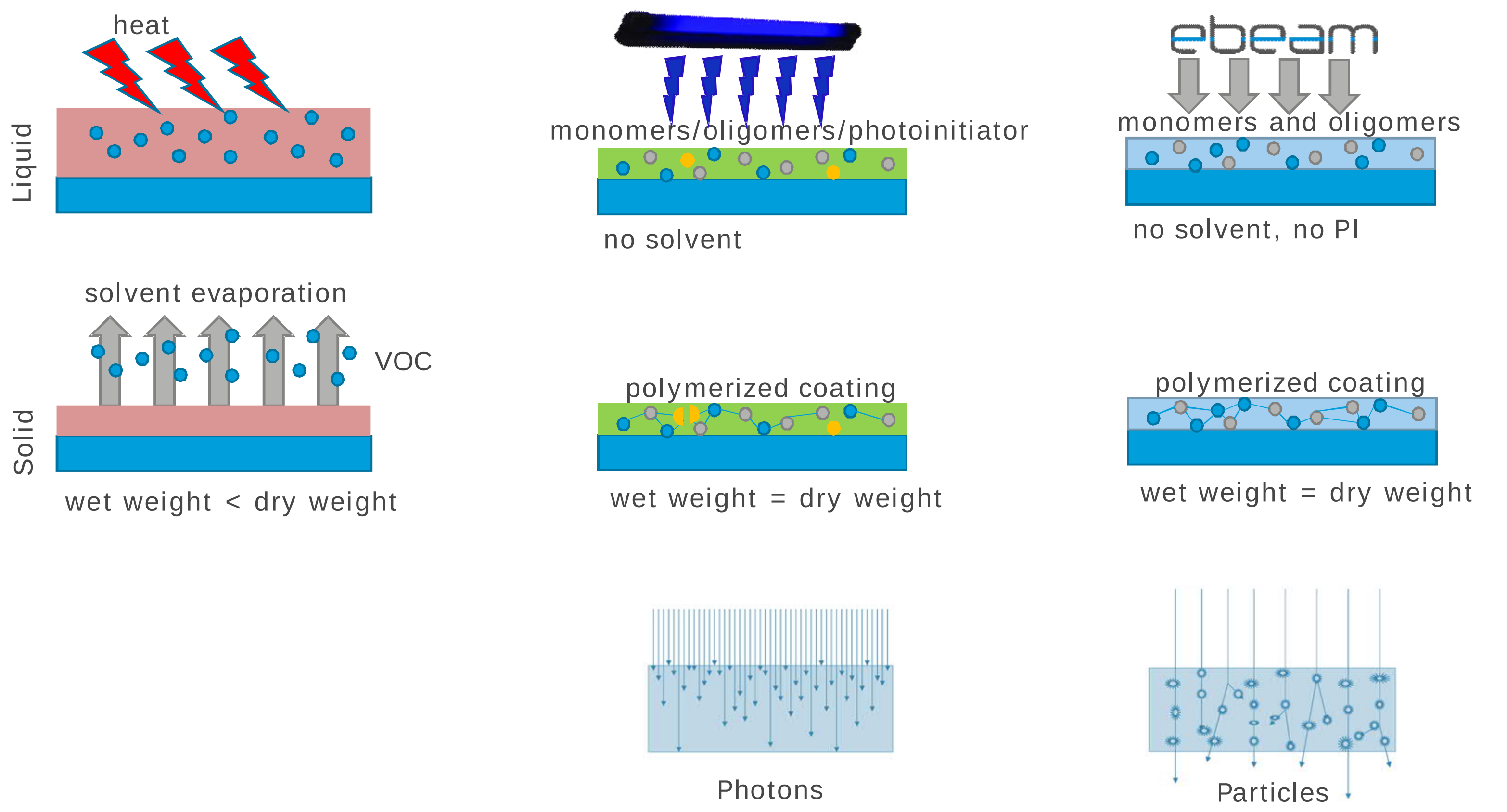


«Drying» Methods

Traditional Drying Methods	Energy Curing	
Thermal	UV / UV-LED	Electron Beam
Water Based	100% Solid	100% Solid
Solvent Based	Hybrid	Hybrid
Steam / Oxid. (Textiles)		

Drying Methods (2)

Thermal	UV / UV-LED	EB



Drying Methods (3)

UV vs. EB numbers

UV / UV-LED	EB

• Energy in the form of photons
• Wavelength determines energy; typically 250 to 450 nm
• Energy unit conversion; 350 nm photon = 3.5 eV
• Total applied energy typically 0.1 to 0.5 J/cm2
	• Energy in the form of accelerated electrons
	• Accelerating voltage determines energy; typically 80 to 180 kV
	• Typical electron energy at substrate; >70 keV
	• Total applied energy typically 20 to 40 kGy
	  • 1 kGy = 1 J/gram
	  • For 50 gram/meter^2 layer = 0.1 to 0.2 J/cm^2

ebeam

Drying Methods (3)

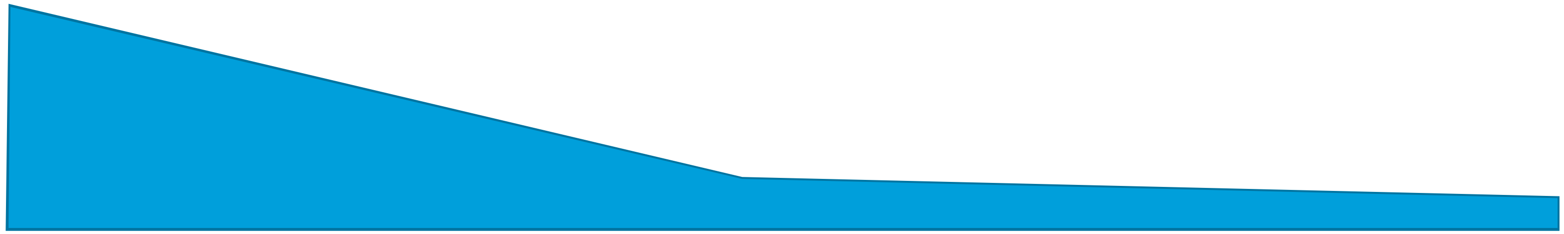
UV vs. EB Penetration

UV / UV-LED	EB
• Penetration depends on the optical density of the material	• Penetration depends on the mass density of the material
• Penetration is controlled by the peak irradiance (power and focus) of the UV source	• Penetration is controlled by acceleration potential (voltage) of the beam

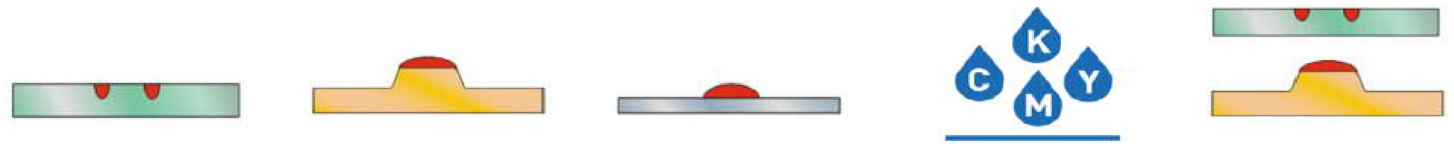
• Good penetration into clear materials	• Easily penetrates into clear, pigmented, filled, and opaque materials
	  • Can cure thick and/or heavily pigmented or filled inks and coatings
	  • Enables lamination of opaque materials

• Limited penetration into pigmented, filled, and opaque materials
  • Effective curing of thin ink films
  • Effective curing of thick coatings with low pigment loading
  • Lamination of clear materials	

Drying Methods (2)

	Thermal	UV / UV-LED	EB
Floor Space			
Energy Req.	20-100	5-10	1
Special Req.	Solvent EX-Proof & Insurance VOC & Incinerator Water-based Very long dryers and very high power requirements	Photoinitiator needed Special PI for UV-LED Limitations for high pigmentation End-of-line and Interstation drying	Inerting Limitiations in Shape of product high throughput preferrable End-of-line drying

Printing / Coating methods and what drying method can be applied (excl. Textile)



Rotogravure	Flexo	Offset		Digital		Finishing		
Web fed	Web fed	Sheet fed	Web fed	Web fed	Sheet fed	Sheet fed	Web fed	**Press Manufacturers**
Water	Water	Water	Water	Water	Water	Water	Water	**Ink Manufacturers**
Solvent	Solvent	Solvent	Solvent	~~Solvent~~	~~Solvent~~	Solvent	Solvent	
UV	UV	UV	UV	UV	UV	UV	UV	
~~ebeam~~	ebeam	~~ebeam~~	ebeam	ebeam	~~ebeam~~	~~ebeam~~	ebeam	

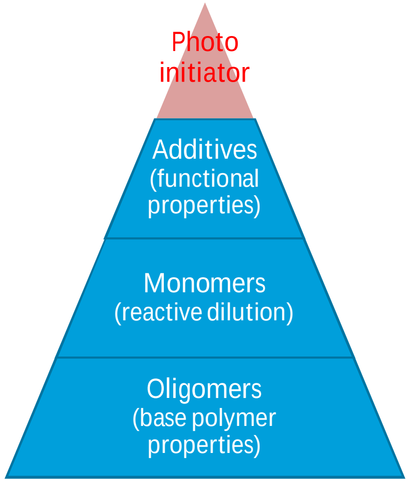
Thermal - UV - UV Led - ebeam | **Curing**

Printers - Converters | **Packaging Production**

EB Curing
Curing Chemistry and Process

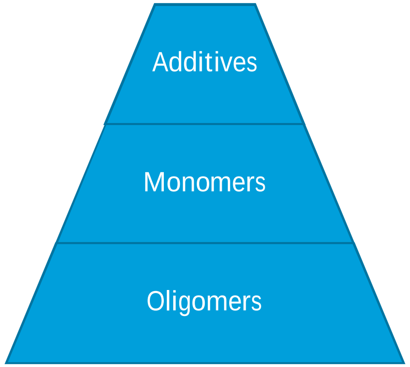
energy cureable chemistries

UV vs. EB basic formulation building blocks



UV

- Mostly free-radical curing chemistry
- Some cationic chemistry
- Curing in air or nitrogen atmosphere
- PI concentration ~5% (air), <1%(Nitrogen)
- PI is a mayor cost component
- PI are low molecular weight, PI migration is a concern in Food Packaging
- PI can cause yellowing over time



EB

- (Almost) exclusively free-radical curing chemistry
- Exclusively in inerted atmosphere
- No PI needed, direct initiation of polymerization
- High conversion rates typical, high gloss, high hardness, high chemical resistance

Reactice Oligomer Types

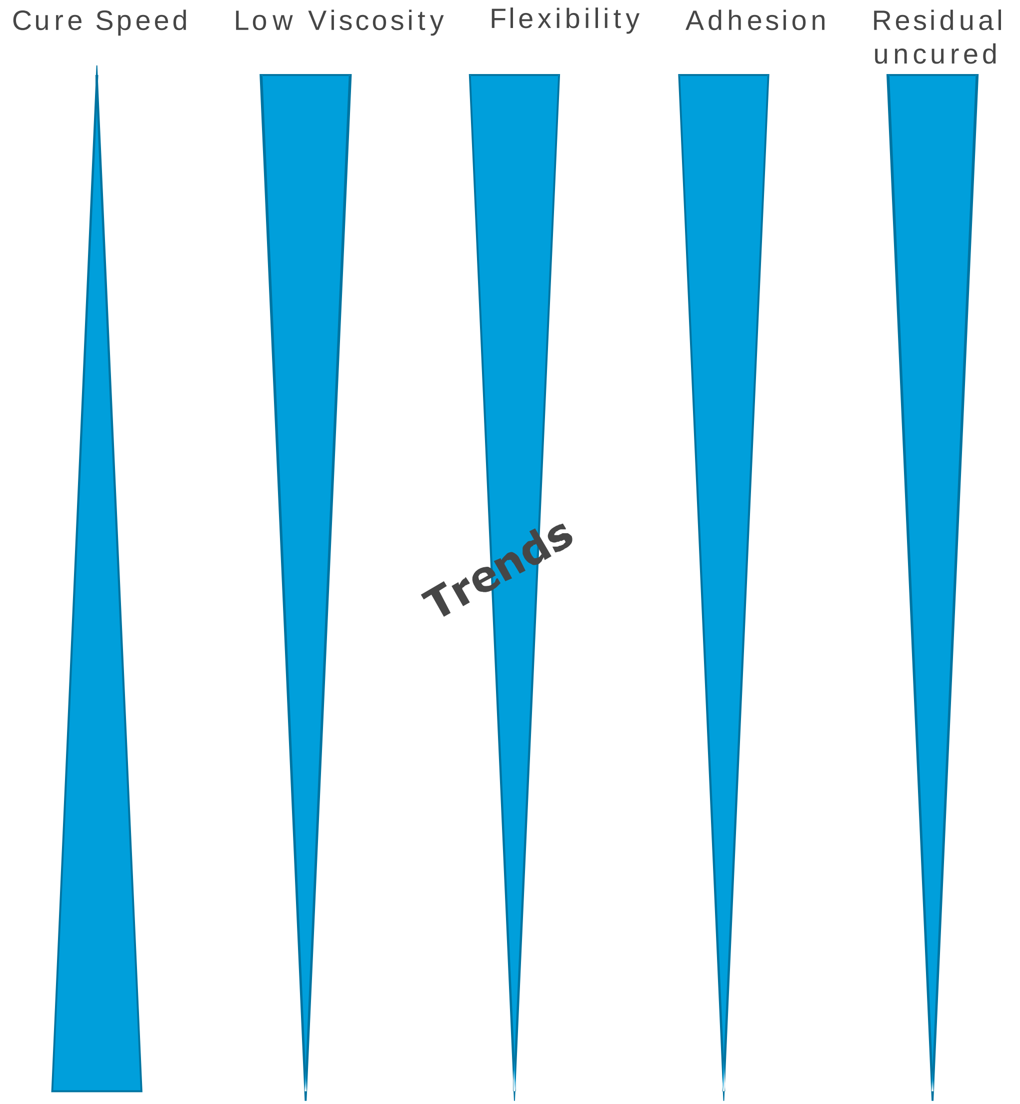
Acrylated Type	Characteristics
Epoxies	fast curing, hard, solvent resistant, low cost
Aliphatic Urethanes	flexibility, tough, non-yellowing, resist to weather
Aromatic Urethanes	flexible, tough, lower cost than aliphatic
Polyesters	low viscosity, good wetting properties
Acrylics	good weathering properties, low Tg
Speciality Resins	adhesion, special applications

Reactive Monomer selectrion

Monofunctional

Di-functional

Tri-functional and higher



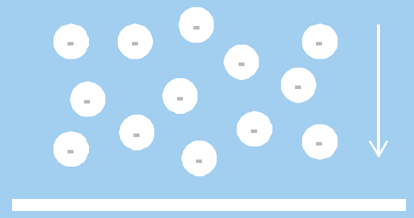
Non-Reactice Additives

- Pigments
- Fillers
- Deformers
- Flatting Agents
- Wetting Agents
- Foaming inhibitors
- Slip Aids

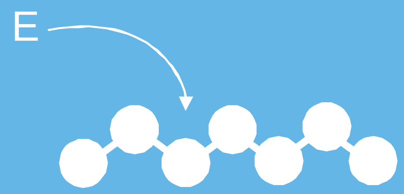
How does it work?

How does electron beam technology cure inks and coatings?

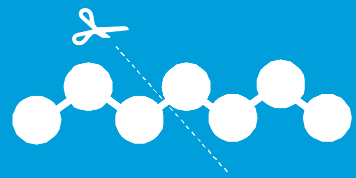
electrons are accelerated towards the print/coating



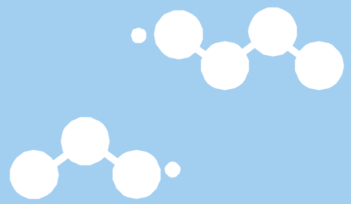
Electrons transfer their energy to the monomers/ oligomers/ polymers



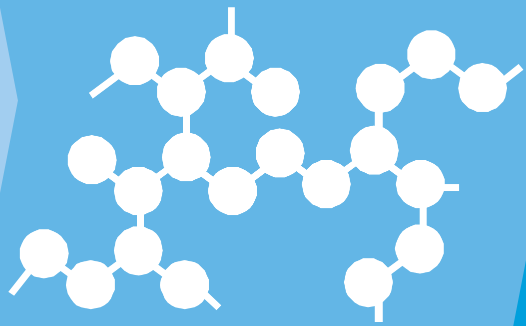
This energy transfer causes bonds to break in these molecules (acrylate functionality)



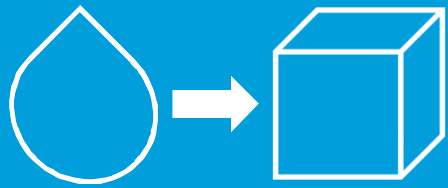
Reactive free radicals are generated



Polymerization occur between different molecules



The result: a liquid to solid film within milliseconds

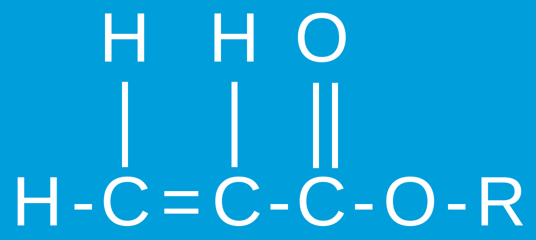


ebeam

How does it work?

What is the chemistry behind this?

Acrylate chemistry is proven to work



However the mechanism/propagation/film morphology is less well studied than in UV

???
???

Typical Conditions for Curing with EB

Dose Dose Rate Speed	Dose 20-60kGy (25-45kGy typical) Dose Rate up to 12'000kGy m/min Speed 25-400m/min (100-300m/min typical)
Inerting	Residual oxygen < 200ppm typical <50ppm for special applications (Siliconization)

Why choose ebeam?

Benefits of ebeam in printing and food packaging

No Photoinitiators + No PI Odour	High Performance + Constant in Time	Colour Blind + Better Adhesion	Energy Efficiency + No Heat
No PI Migration + No Taint/Yellowing	Thorough Curing + Consistent Curing	Consistent Depth of Cure + High Performance	Heat-Sensitive Substrates

EB Curing
Printing Methods

ebeam for printing applications

Printing Technologies

- Analog
  - Offset
  - Flexo
- Digital
  - Electrophotography
  - Inkjet

ebeam Printing

Drying processes used in printing

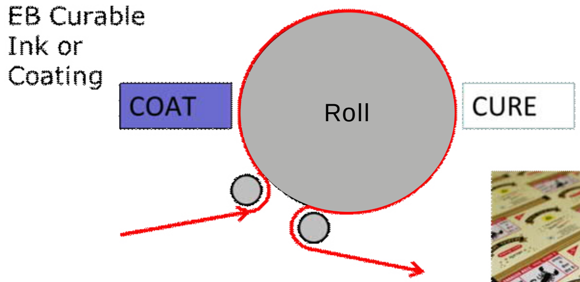
	EB	UV	Oxyd./IR	H_2O Heat	Solvent Heat
Sheet-Offset					
Web-Offset					
CI-Offset					
In-Line Flexo					
CI-Flexo					
Gravure					
Inkjet					

EB is always End-of-line drying, hence not well suited if Interstation drying is needed. Printing is wet-on-wet

More than inks/coatings

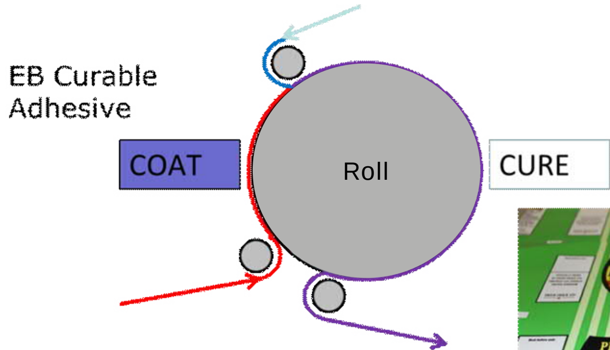
4 in 1 using ebeam technology enables further brand-building and custom designs

Printing / Coating



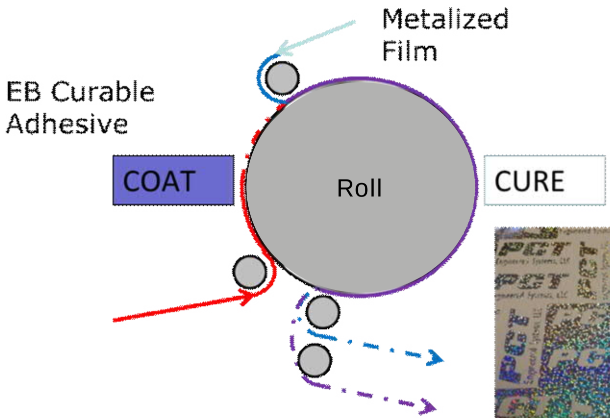
Instant Cure of Thick, Opaque, Metallic, and Textured Coatings

Lamination

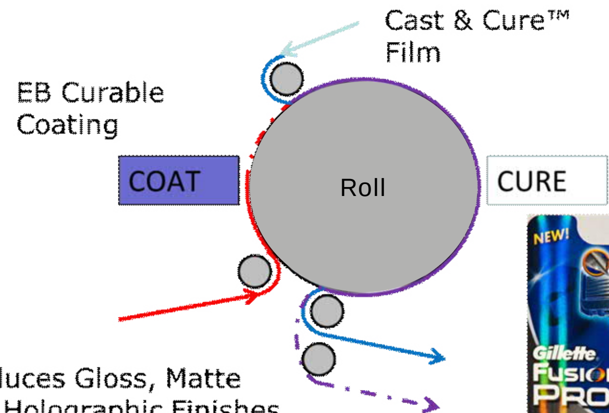


Fully Cured Structure Can be **Die Cut**, **Slit** or **Shipped** Immediately

Foil Transfer



Cast & Cure™



Produces Gloss, Matte and Holographic Finishes

Film is Rewound and Reused

Printing technologies

Offset printing with ebeam

Innovation:

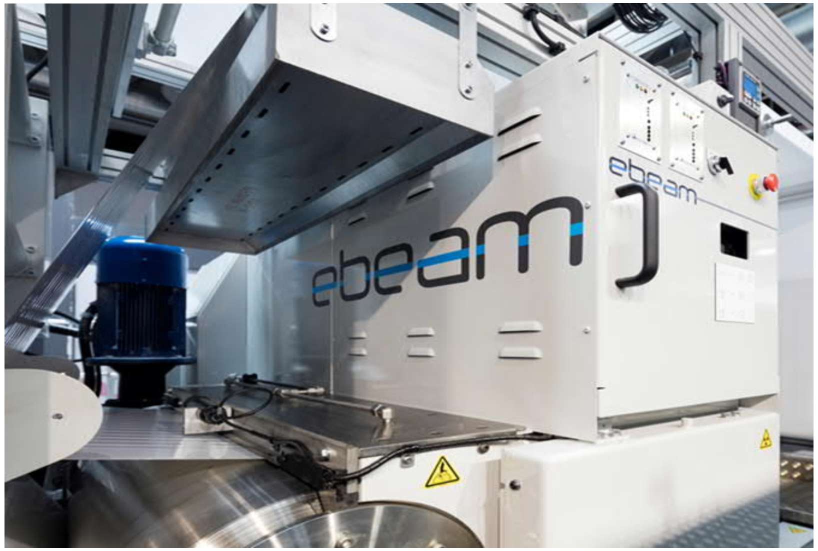
- EB curing – ebeam Core
- easy-to-change rolls
- substrates as thin as 12 µm

Printing technologies

Flexo printing with ebeam

4-in-1 concept:

- EB curing – ebeam Core
- EB lamination in-line
- slitting
- automatic unloading system



Printing technologies

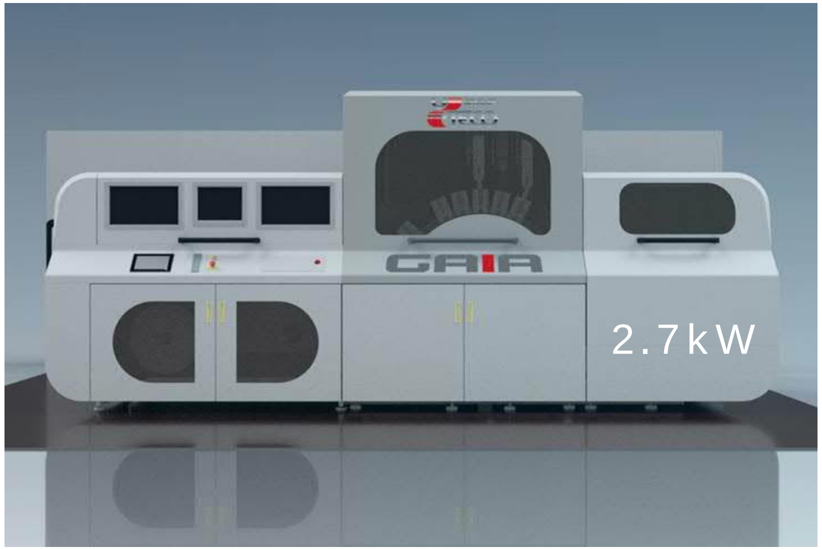
Digital printing with ebeam

ebeam Compact:

the world’s most compact ebeam

Printing technologies

Digital technology for custom printing: GAIA



- 25m/min (XAAR 1003)
- Aluminium, paper, plastic films
- Food-packaging grade EB CMYK inks
- Xaar 1003 / Samba printheads
- Variable data
- 350 mm cure width

HP Indigo Finishing Effects

HP Indigo

HP Indigo

- Electrophotographic printing
- Used in a variety of applications including food packaging

HP Indigo ElectroInk

- Polyethylene-based
- Dried ink is soft and susceptible to abrasion
- Heat sensitive → melts when heat-sealing even when laminated

HP Indigo Finishing Effects

HP Indigo with EB OPV and EB Lamination

Solventless / WB / SB Lamination

- Takes time for adhesive to dry
  → heat-sealing and slitting delayed
- Reduced depth of image

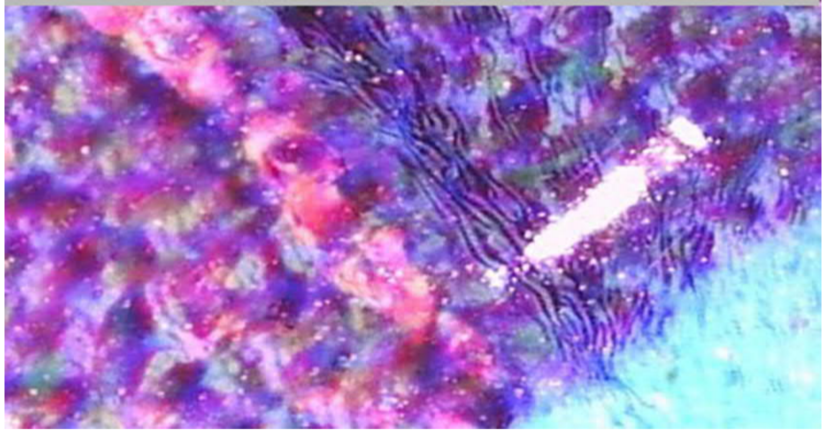
EB OPV & Lamination

- Instantaneous drying
  → immediate heat-sealing & slitting

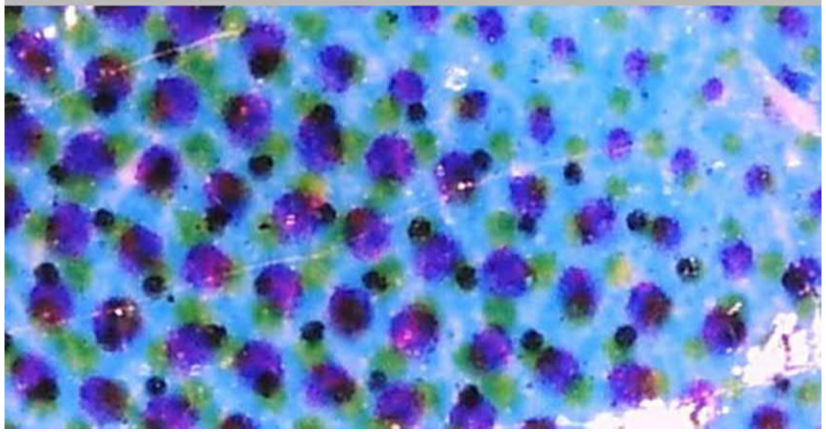
EB OPV

- Maintained depth of image
- Effects: gloss, matte, soft touch
- Scratch resistance
- Demonstrated food compliance

Heat Seal Area
Solventless lamination



Heat Seal Area
ebeam cured OPV



HP Indigo Finishing Effects

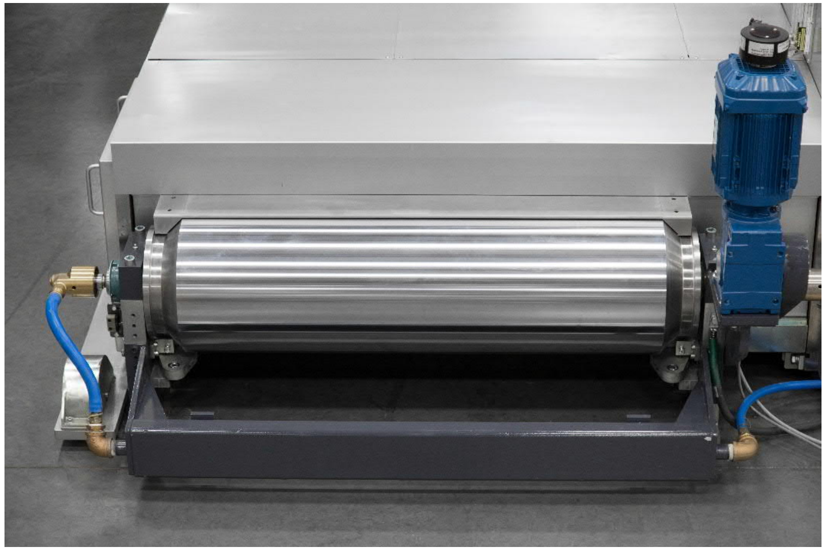
HP Indigo with EB Spot Embellish-ment

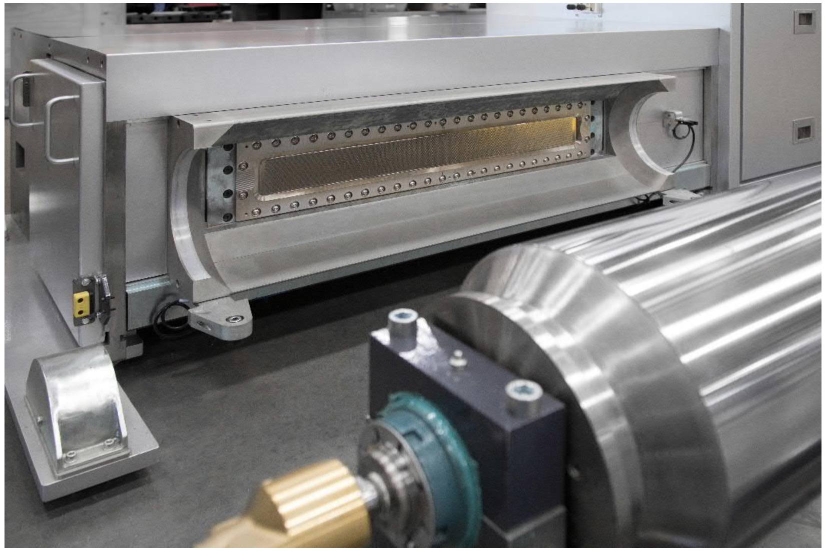
Printed varnish on spot areas

- Wet-look and other effects
- Luxury branding

CORE 100

Build for Indigo Finishing





EB Lamination

The natural fit for digital printing

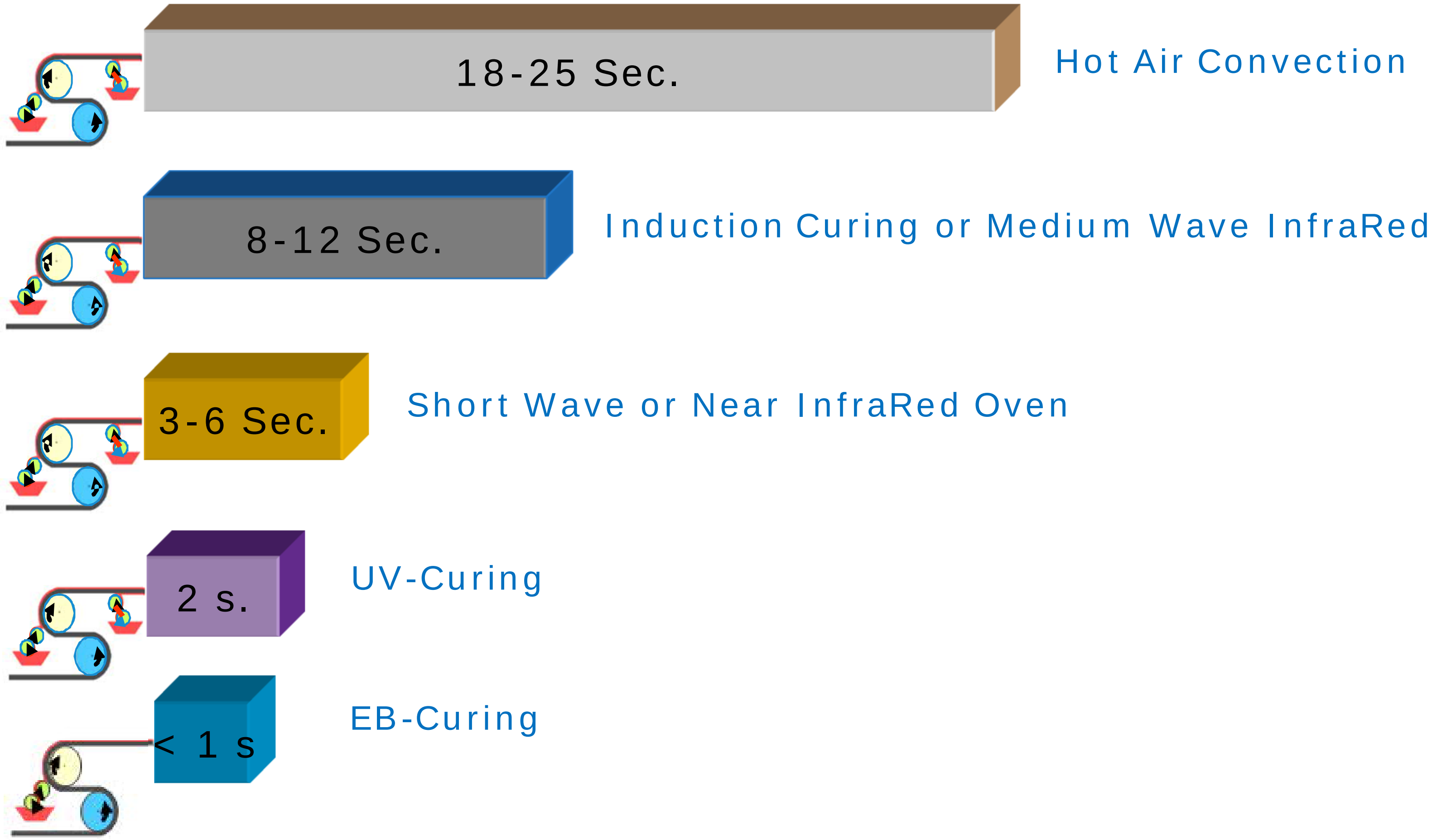
Solvent Lamination Solvent-less lamination	EB Lamination
• From hours to days between lamination and shipment • Large warehouses needed for printed product • Pouching and/or slitting need a high level of cure before the process	• EB Laminating adhesives cure instantly • Slitting can be performed ON THE PRESS right after printing • Pouching can be performed immediately after lamination • No warehousing of goods – ships directly off the press • Laminating adhesives are stable. No unnecessary cleaning of coaters
Not ideal for digital workflow	Ideal for digital workflow

Walking on Electrons: Pattern transfer and high resistance flooring

Cleveland Steel Case

Example:

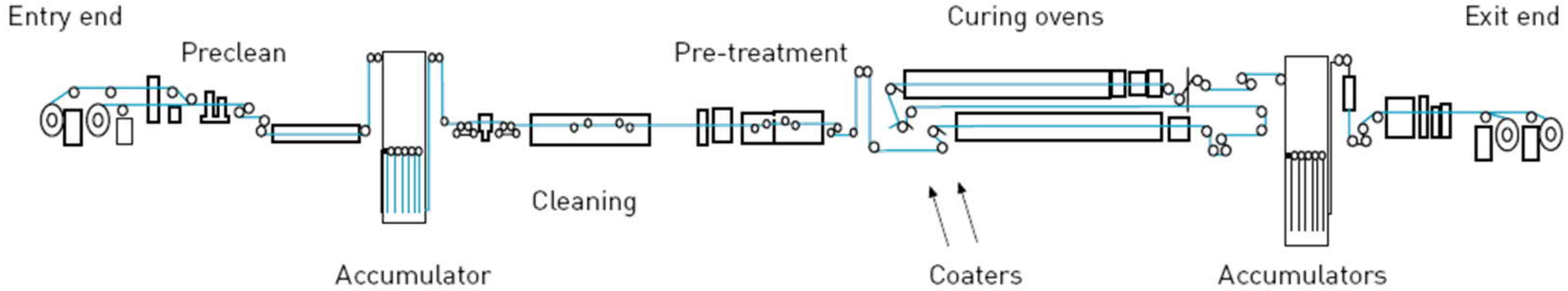
EB / UV Hybrid Coil Coating vs Solvent based Coil Coating



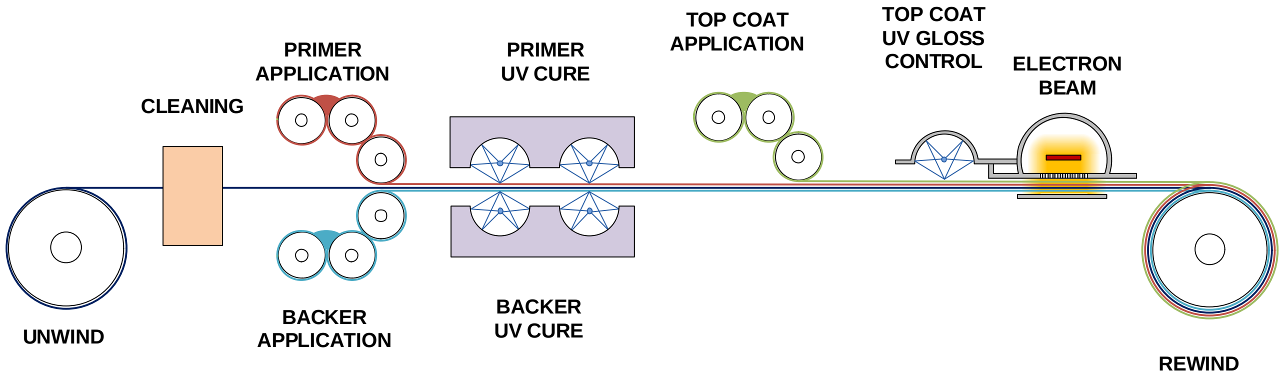
Cleveland Steel Case

Example: EB / UV Hybrid Coil Coating vs Solvent based Coil Coating

Before



After



Cleveland Steel Case

Example: EB / UV Hybrid Coil Coating vs Solvent based Coil Coating

Energy Consumption

	Power [MW]	Rel. Consumption	Energy Cost [$/year]
Convection (Gas)	15.6	100%	2.5M
IR	9.2	59%	2.5M
EB + UV	0.59	< 4%	< 0.2M

EB 0.15
UV 0.44

..but functional chemistry has higher baseline cost

Business case is a mix from Energy, Raw Materials, floor space, Insurance cost, Environmental cost

Patent WO2016164220A1

The next step in ebeam digital printing:

Water-based EB-curable inkjet ink

Patent WO2016164220A1

The formulation

An electron beam curable water based inkjet ink comprising:

a) Acrylate functional
- monomer
- oligomer
- or polymer

b) Soluble dyes and/or dispersed pigments

c) optional additives

d) optional non-reactive water-soluble or dispersible polymers

e) 20-90% water

ebeam

Patent WO2016164220A1

What is the advantage of using water-based EB-curable inkjet inks?

< 1cP at 25°C

More scope for formulating to a jettable viscosity

ebeam

Patent WO2016164220A1

What is the advantage of using water-based EB-curable inkjet inks?

< 1cP at 25ºC

Reduce potential migration:

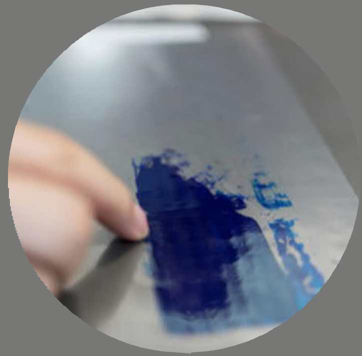
- Higher molecular weight monomers
- Oligomers
- Polymers

Run your tests at our trial sites

Conclusions

EB provides many benefits:

- high performance inks/coatings
- environmental advantages



Proven curing option for safe food packaging

Digital printing + EB curing enables brand-building and customization:

- printing/curing
- 4 in 1 technology

Water-based EB-curable inkjet inks:

- dry/cure without heat
- reduce migration potential

Get in touch

Contacts

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